

## MP104 Dual Power Amplifier

### FEATURES

- Low Cost Integrated Solution
- Peak Output Current >10A within SOA
- Internal Power Dissipation 100 W Per Channel
- 50V/ $\mu$ s Slew Rate

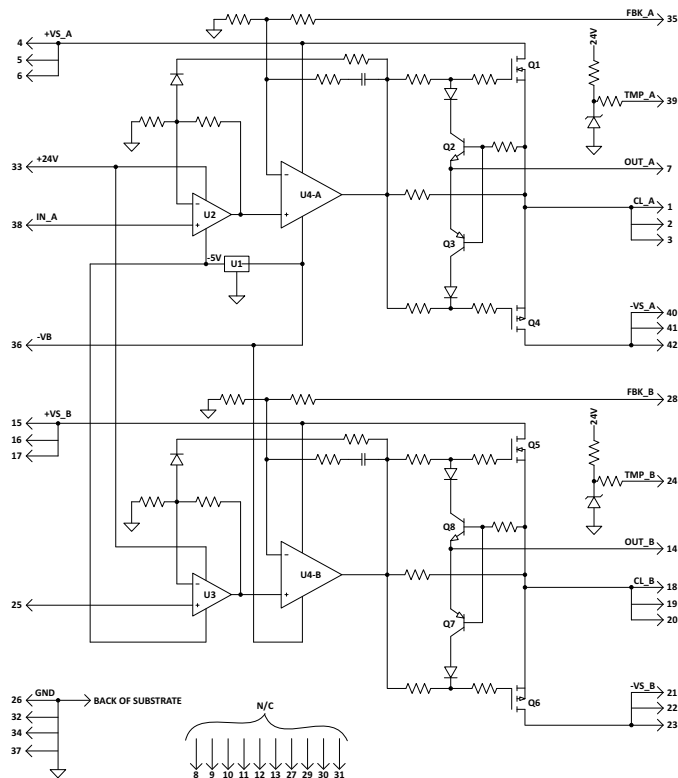
### APPLICATIONS

- Piezoelectric Actuation For Ink Jet Printer Nozzles

### DESCRIPTION

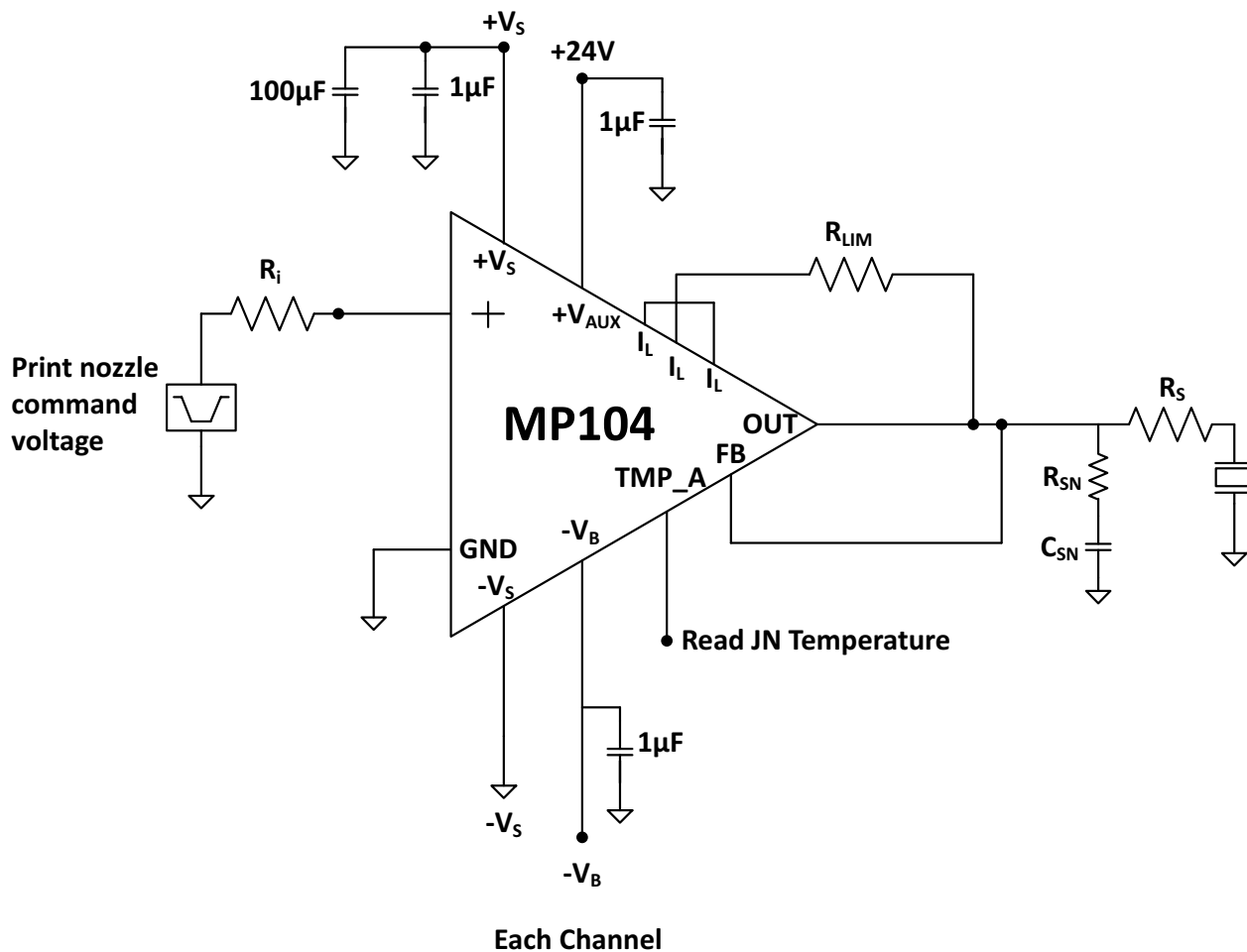
The MP104 is a high voltage, high output current dual channel power amplifier for driving capacitive loads such as piezo devices used in ink jet printing applications. The MP104 utilizes proprietary IC's combined with discrete semiconductor and passive elements on a thermally conductive insulated metal substrate, delivering very high power from a compact module. The amplifier gain is fixed at 64 V/V when the feedback pin is connected to the  $V_{OUT}$  pin. Internal compensation provides optimum slew rate and ensures stability. The only external components required are the current limit resistors  $R_{LIM}$ , a series isolation resistor  $R_S$  and the power supply bypass capacitors.

**Figure 1: Equivalent Schematic**



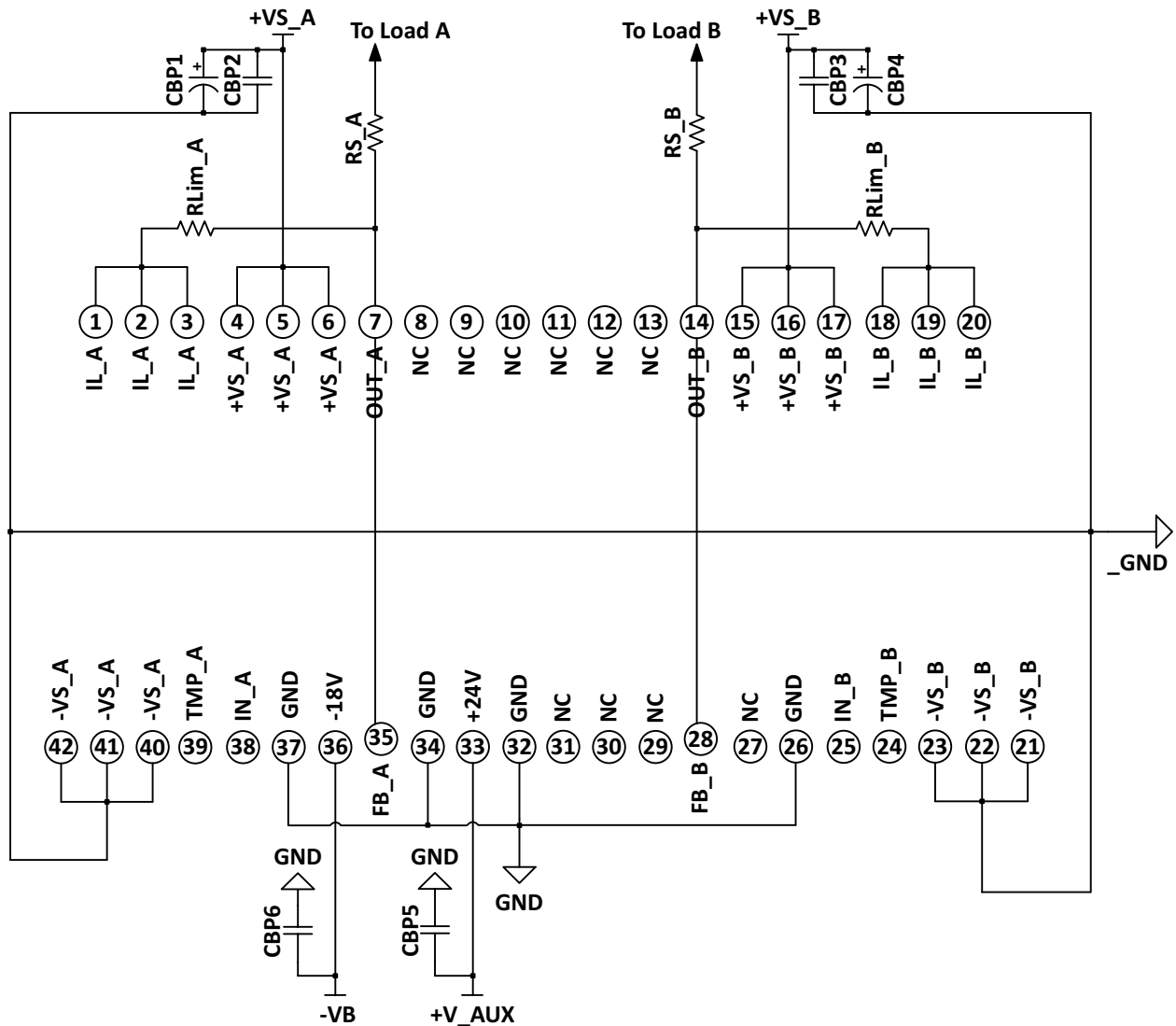
## TYPICAL CONNECTION

Figure 2: Typical Connection



## PINOUT AND DESCRIPTION TABLE

Figure 3: External Connections



| Pin Number     | Name               | Description                                                                                                                                                                                                                                                                   |
|----------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1,2,3          | I <sub>L</sub> _A  | High current output pins for channel A. A current limit resistor must be placed between these pins and the output pin 8.                                                                                                                                                      |
| 4,5,6          | +V <sub>S</sub> _A | Positive high voltage power supply pins for channel A.                                                                                                                                                                                                                        |
| 7              | Out_A              | Output pin for channel A.                                                                                                                                                                                                                                                     |
| 14             | Out_B              | Output pin for channel B.                                                                                                                                                                                                                                                     |
| 15, 16, 17     | +V <sub>S</sub> _B | Positive high voltage power supply pins for channel B.                                                                                                                                                                                                                        |
| 18,19,20       | I <sub>L</sub> _B  | High current output pins for channel B. A current limit resistor must be placed between these pins and the output pin 15.                                                                                                                                                     |
| 21, 22, 23     | -V <sub>S</sub> _B | Negative power supply pins for channel B.                                                                                                                                                                                                                                     |
| 24             | TMP_B              | Temperature sense pin for channel B.                                                                                                                                                                                                                                          |
| 25             | IN_B               | Input pin for channel B.                                                                                                                                                                                                                                                      |
| 28             | Feedback_B         | Feed back pin for channel B. This pin must be connected to output B pin 14 to close the feedback loop. When connected directly to pin 14 the closed loop voltage gain of channel B is 65 V/V. The gain can be increased by inserting a 1/4 W resistor between pins 28 and 14. |
| 26, 32, 34, 37 | GND                | Ground                                                                                                                                                                                                                                                                        |
| 33             | +V <sub>AUX</sub>  | +24V voltage power supply pin. A 24 V power supply is required for operation of front end small signal circuitry of each channel.                                                                                                                                             |
| 35             | Feedback_A         | Feedback pin for channel A. This pin must be connected to output A pin 7 to close the feedback loop. When connected directly to pin 7 the closed loop voltage gain of channel A is 65 V/V. The gain can be increased by inserting a 1/4 W resistor between pins 35 and 7      |
| 36             | -VB                | -18V voltage power supply pin for operation of front end small signal circuitry of each channel                                                                                                                                                                               |
| 38             | IN_A               | Input pin for channel A.                                                                                                                                                                                                                                                      |
| 39             | TMP_A              | Temperature sense pin for channel A.                                                                                                                                                                                                                                          |
| 40, 41, 42     | -V <sub>S</sub> _A | Negative power supply pins for channel A.                                                                                                                                                                                                                                     |

## SPECIFICATIONS

- Notes:** a) All Min/Max characteristics and specifications are guaranteed over the Specified Operating Conditions. Typical performance characteristics and specifications are derived from measurements taken at typical supply voltages and  $T_C = 25^\circ\text{C}$ .
- b)  $+V_S$  and  $-V_S$  denote the positive and negative supply voltages to the output stages.  $+V_{AUX}$  denotes the positive supply voltage to the input stages.

## ABSOLUTE MAXIMUM RATINGS

| Parameter                                    | Symbol           | Min   | Max       | Units            |
|----------------------------------------------|------------------|-------|-----------|------------------|
| Supply Voltage, total                        | $+V_S$ to $-V_S$ |       | 160       | V                |
| Supply Voltage, $-V_S$ ( $+V_S$ return path) | $-V_S$           | 0/GND |           | V                |
| Supply Voltage, $-V_B$                       | $-V_B$           | -15   | -20       | V                |
| Supply Voltage, $+V_{AUX}$                   | $+V_{AUX}$       |       | 27        | V                |
| Output Current, pk, per channel (within SOA) | $I_O$ (pk)       |       | 12        | A                |
| Power Dissipation, internal, each channel    | $P_D$            |       | 100       | W                |
| Input Voltage                                | $V_{IN}$         | -5    | $V_{AUX}$ | V                |
| Temperature, pin solder, 10s max.            |                  |       | 225       | $^\circ\text{C}$ |
| Temperature, junction <sup>1</sup>           | $T_J$            |       | 150       | $^\circ\text{C}$ |
| Temperature Range, storage                   | $T_S$            | -40   | 105       | $^\circ\text{C}$ |

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

## INPUT

| Parameter                          | Test Conditions | MP104 |         |                | MP104A |     |     | Units                        |
|------------------------------------|-----------------|-------|---------|----------------|--------|-----|-----|------------------------------|
|                                    |                 | Min   | Typ     | Max            | Min    | Typ | Max |                              |
| Offset Voltage, initial            |                 | -14   | $\pm 5$ | +14            | *      | *   | *   | mV                           |
| Offset Voltage vs. Temperature     | Full temp range |       | $\pm 2$ |                |        | *   |     | $\mu\text{V}/^\circ\text{C}$ |
| Bias Current, initial <sup>1</sup> |                 |       | 2.5     | 12             |        | *   | *   | $\mu\text{A}$                |
| Input Voltage Range                |                 | -3    |         | $+V_{AUX} - 2$ | *      |     | *   | V                            |
| Input Resistance, DC               |                 |       | 1       |                |        | *   |     | M $\Omega$                   |
| Input Capacitance                  |                 |       | 1.5     |                |        | *   |     | pF                           |
| Noise                              |                 |       | 500     |                |        | *   |     | nV/ $\sqrt{\text{Hz}}$       |
| $V_{OS}$ vs. $V_S$                 |                 | +5    |         | -5             |        |     |     | $\mu\text{V}/\text{V}$       |

1. Doubles for every  $10^\circ\text{C}$  of case temperature increase.

## GAIN

| Parameter                            | Test Conditions                 | MP104 |     |      | MP104A |     |     | Units |
|--------------------------------------|---------------------------------|-------|-----|------|--------|-----|-----|-------|
|                                      |                                 | Min   | Typ | Max  | Min    | Typ | Max |       |
| Fixed Gain                           | Feedback connected to $V_{OUT}$ | 62.5  | 64  | 66.5 | *      | *   | *   | V/V   |
| Gain Bandwidth Product, 1 MHz        |                                 |       | 30  |      |        | *   |     | MHz   |
| Power Bandwidth, 130V <sub>p-p</sub> |                                 | 100   | 114 |      | *      | *   |     | kHz   |

## OUTPUT

| Parameter               | Test Conditions                  | MP104 |              |     | MP104A       |     |     | Units      |
|-------------------------|----------------------------------|-------|--------------|-----|--------------|-----|-----|------------|
|                         |                                  | Min   | Typ          | Max | Min          | Typ | Max |            |
| Voltage Swing           | Source $I_O = 10A$               |       | $+V_S - 8$   |     | $+V_S - 15$  | *   |     | V          |
| Voltage Swing           | Sink $I_O = 5A$                  |       | $-V_S + 2.5$ |     | $-V_S + 7.5$ | *   |     | V          |
| Current, peak, source   |                                  | 10    |              |     | 12           |     |     | A          |
| Current, continuous     |                                  |       | 10           |     |              | *   |     | A          |
| Slew Rate, rising edge  | $R_S = 1.5 \Omega$ , $CL = 80nF$ | 45    | 50           |     | *            | *   |     | V/ $\mu s$ |
| Slew Rate, falling edge | $R_S = 1.5 \Omega$ , $CL = 80nF$ | 45    | 50           |     | *            | *   |     | V/ $\mu s$ |

## POWER SUPPLY

| Parameter                      | Test Conditions | MP104       |      |     | MP104A |     |     | Units |
|--------------------------------|-----------------|-------------|------|-----|--------|-----|-----|-------|
|                                |                 | Min         | Typ  | Max | Min    | Typ | Max |       |
| Voltage, $-V_B$                |                 | -18         | -19  | -20 | *      | *   | *   | V     |
| Voltage, $-V_S$                |                 |             |      | GND |        |     | *   | V     |
| Voltage, $+V_{AUX}$            |                 | 21          | 24   | 25  | *      | *   | *   | V     |
| Voltage, $+V_S$                |                 | $-V_S + 20$ | 120  | 150 | *      | *   | *   | V     |
| Current, quiescent, $-V_B$     |                 |             |      | 26  |        |     | *   | mA    |
| Current, quiescent, $+V_{AUX}$ |                 |             | 13.5 | 21  |        | *   | *   | mA    |
| Current, quiescent, $+V_S$     |                 |             | 3    | 8   |        | *   | *   | mA    |

## THERMAL

| Parameter                                     | Test Conditions                 | MP104 |     |      | MP104A |     |     | Units |
|-----------------------------------------------|---------------------------------|-------|-----|------|--------|-----|-----|-------|
|                                               |                                 | Min   | Typ | Max  | Min    | Typ | Max |       |
| Resistance, AC, junction to case <sup>1</sup> | Full temp range, $f \geq 60$ Hz |       |     | 1    |        |     | *   | °C/W  |
| Resistance, DC, junction to case              | Full temp range, $f < 60$ Hz    |       |     | 1.25 |        |     | *   | °C/W  |
| Resistance, junction to air                   | Full temp range                 |       |     | 13   |        |     | *   | °C/W  |
| Temperature Range, case                       |                                 | -40   |     | +85  | *      |     | *   | °C    |

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

## TEMPERATURE SENSOR

| Parameter                             | Test Conditions                                 | MP104 |      |         | MP104A |     |     | Units |
|---------------------------------------|-------------------------------------------------|-------|------|---------|--------|-----|-----|-------|
|                                       |                                                 | Min   | Typ  | Max     | Min    | Typ | Max |       |
| Temperature sensor output, $V_{TEMP}$ | $T_C = 25^\circ\text{C}$                        |       | 2.98 |         |        | *   |     | V     |
| Temperature sensor gain               |                                                 |       | 10   |         |        | *   |     | mV/°C |
| Temperature accuracy                  | $T_C = -40^\circ\text{C}$ to $85^\circ\text{C}$ |       |      | $\pm 1$ |        |     | *   | °C    |

## TYPICAL PERFORMANCE GRAPHS

Figure 4: Power Derating

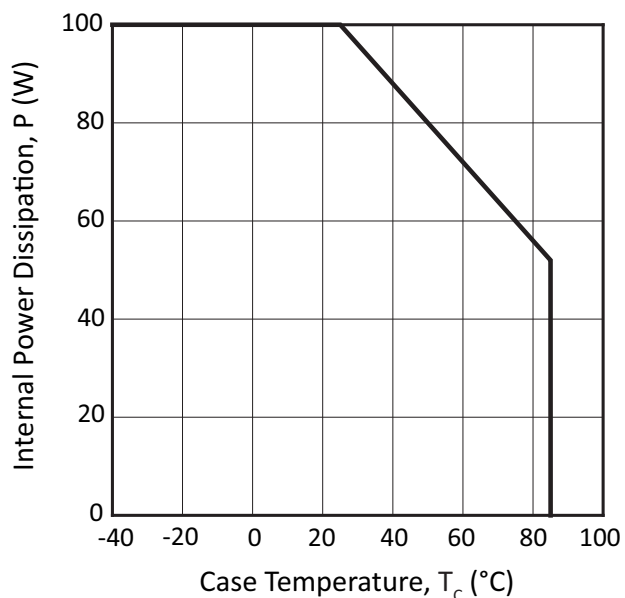


Figure 5: Large Signal Pulse Response (Full Load)

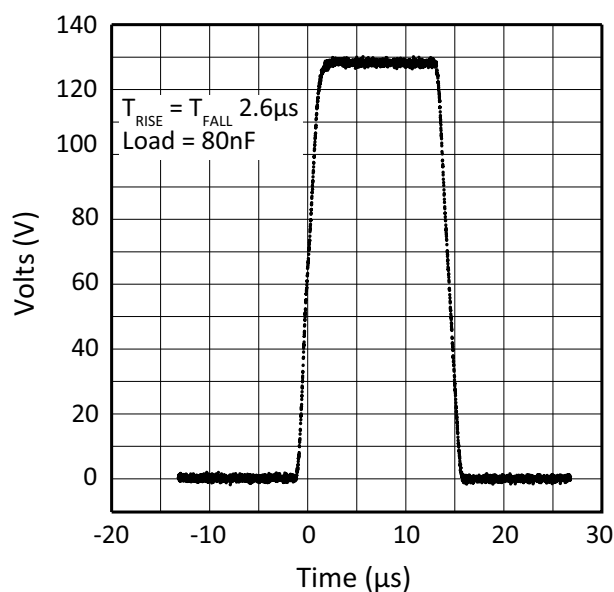


Figure 6: Small Signal Pulse Response (No Load)

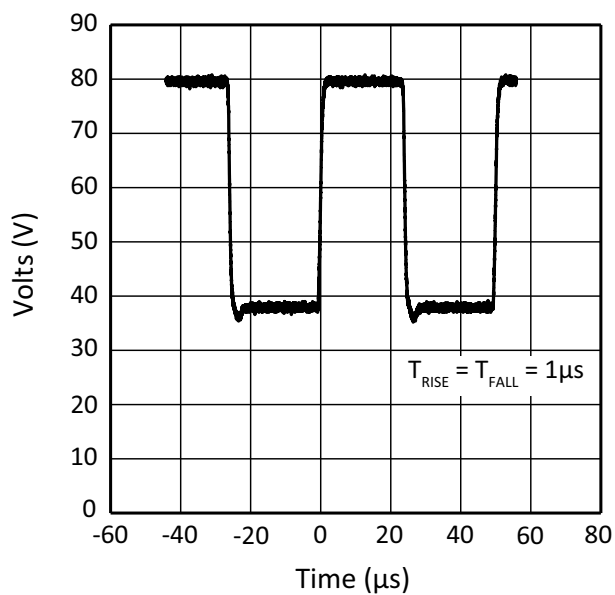
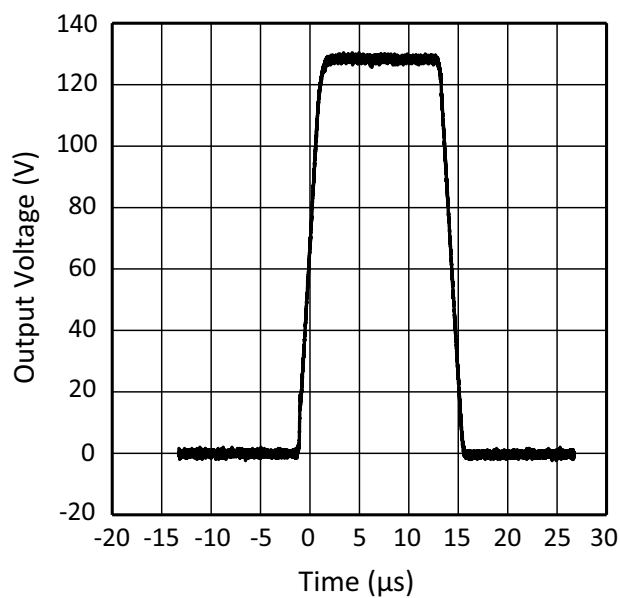
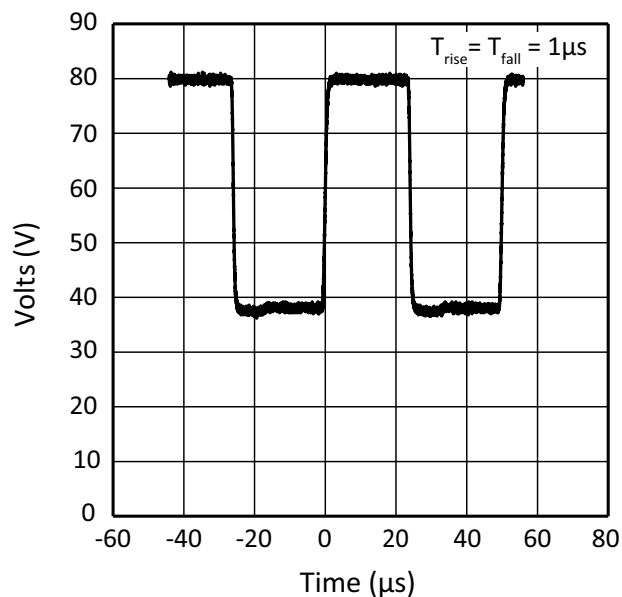


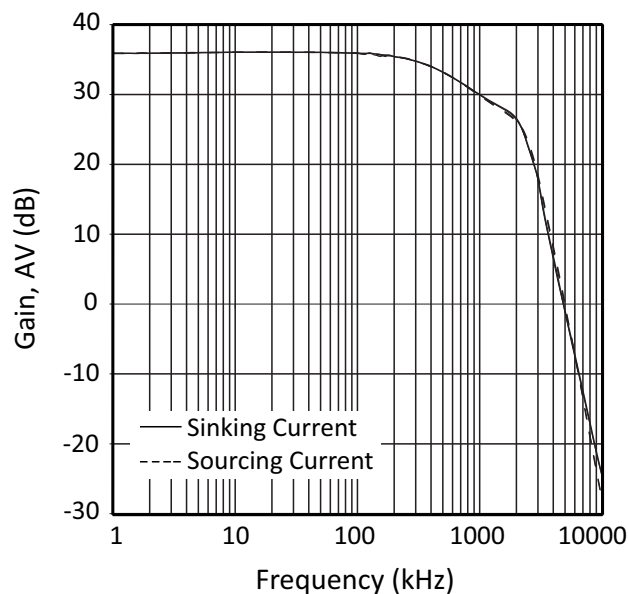
Figure 7: Large Signal Pulse Response (No Load)



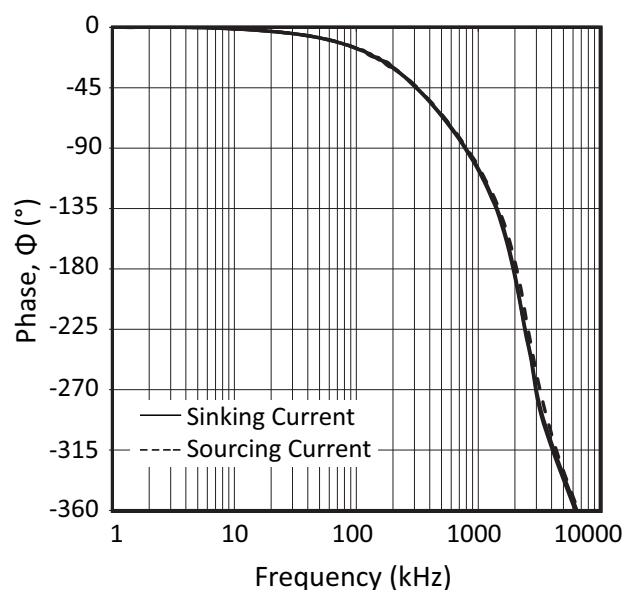
**Figure 8: Small Signal Response  
(Full Load)**



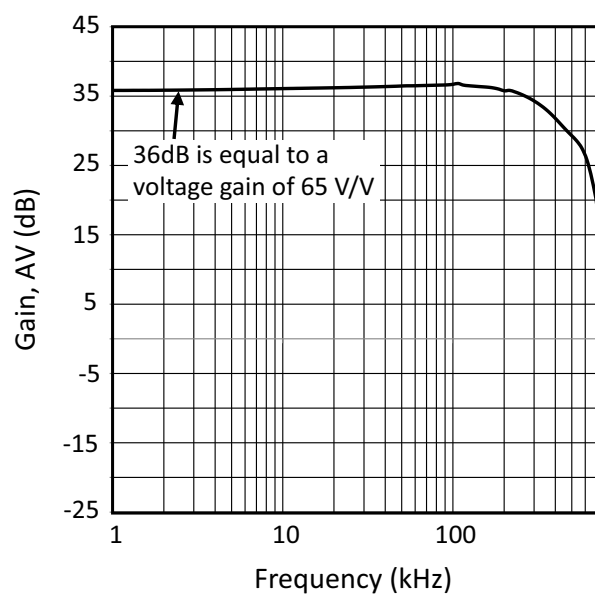
**Figure 9: Closed Loop Gain vs.  
Frequency Plot (Resistive Load)**



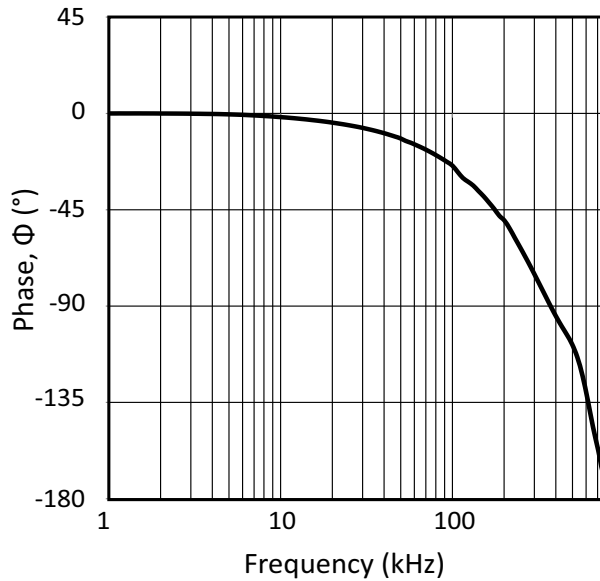
**Figure 10: Closed Loop Phase vs.  
Frequency Plot (Resistive Load)**



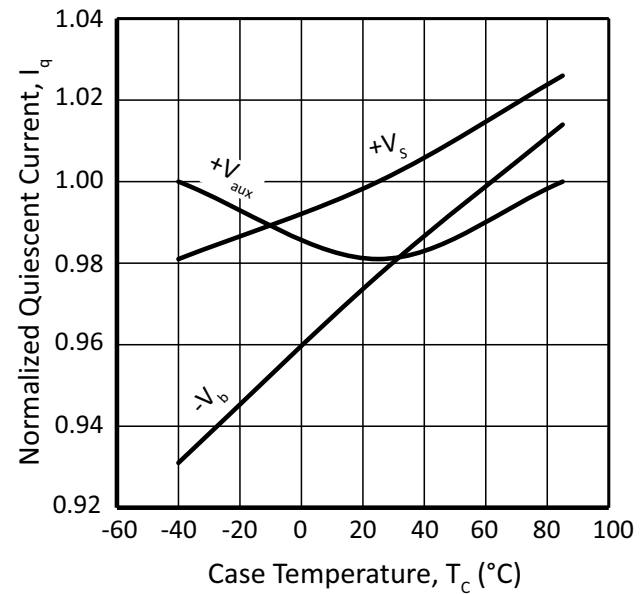
**Figure 11: Closed Loop Gain vs.  
Frequency (Capacitive Load 80nF)**



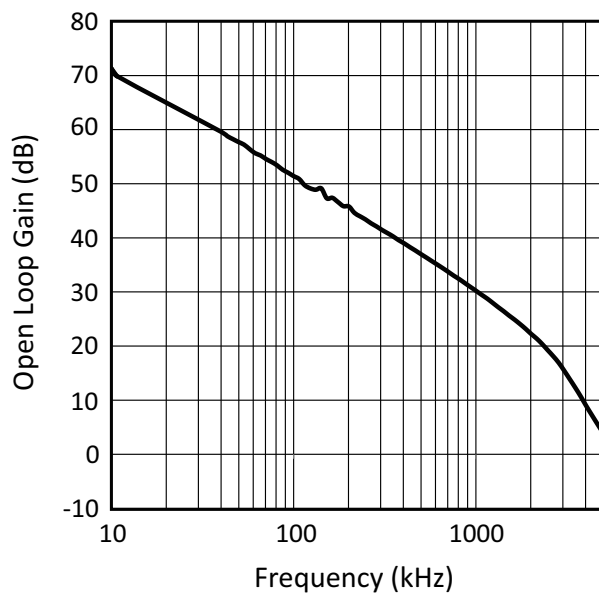
**Figure 12: Closed Loop Phase vs. Frequency Plot (Capacitive Load 80nF)**



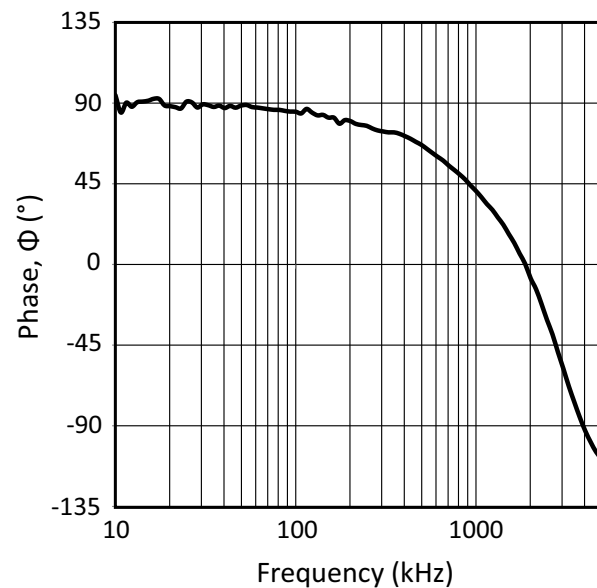
**Figure 13: Quiescent Current**



**Figure 14: Open Loop Gain Response (No Load)**



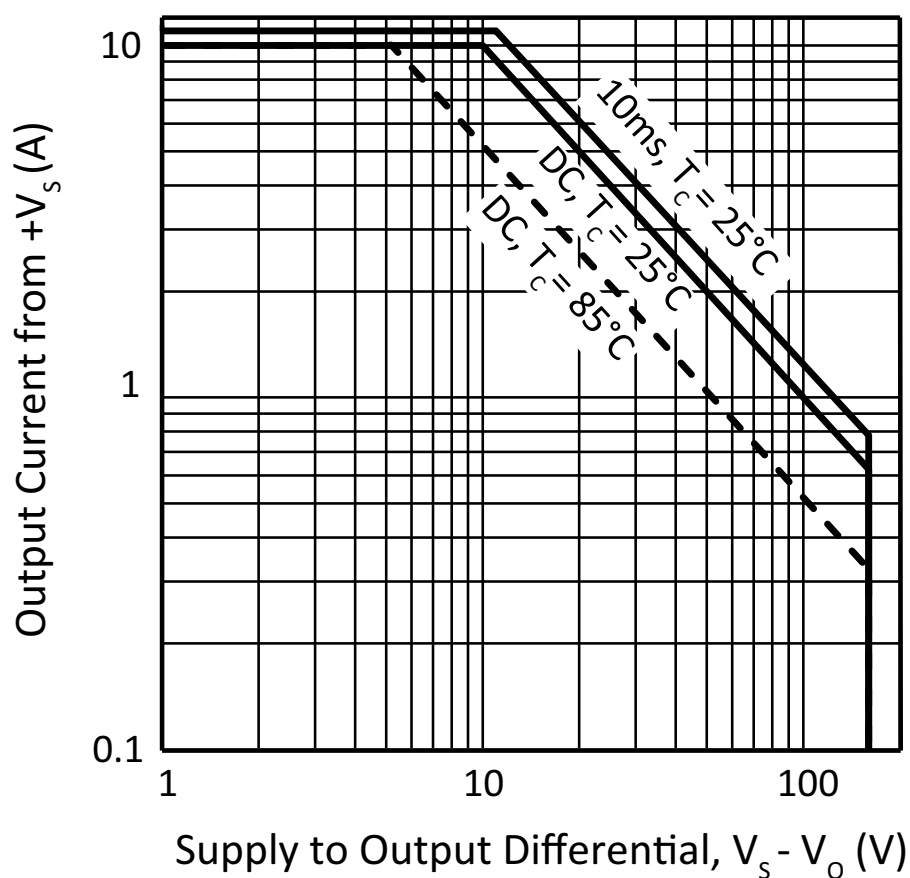
**Figure 15: Open Loop Phase Response (No Load)**



## SAFE OPERATING AREA (SOA)

The MOSFET output stage of the MP104 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 flyback by the parasitic body diodes of the output stage MOSFET structure. However, for protection against sustained high energy flyback external fast-recovery diodes must be used.

**Figure 16: 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.

## CIRCUIT TOPOLOGY

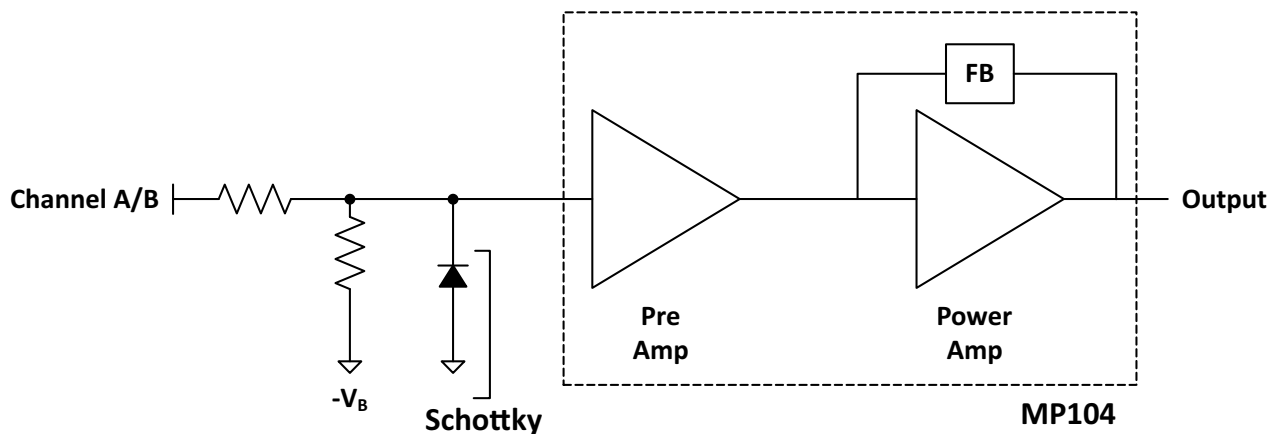
The MP104 consists of two identical amplifiers designated as Channel A and Channel B. Each amplifier consists of a fixed gain input preamplifier followed by a fixed gain power amplifier. The preamplifier section voltage gain is set to approximately 19dB. The power amplifier section is set to a voltage gain of approximately 17dB and its input is connected in cascade to the preamplifier output. The total closed loop gain is approximately 36dB.

The Open Loop Gain graph indicates the overall open loop voltage gain of the composite amplifier. However, for AC analysis and stability purposes, the preamplifier gain contribution must be subtracted from the overall gain since the feedback applies only to the power amplifier stage. The plot shows a voltage gain of 70dB at a frequency of 10 kHz. For feedback and stability analysis, the gain is effectively 51dB at 10 kHz. The second pole occurs at approximately at 2 MHz indicating a gain of approximately 5dB.

## INPUT CONSIDERATIONS

The output stage operates in non-linear mode when the output voltage is at the low level and effectively acts as a switch. The output stage low-side device must be sufficiently driven so that it is able to sink the specified current level. This requires the addition of a small negative offset voltage applied to the input. A value of from -150mV to -250mV should be sufficient. The amplifier will respond in its normal linear operating mode with an input voltage of zero to approximately 2.3V. Figure 12 shows a suggested circuit for providing a -250mV input offset voltage.

Figure 17: Recommended Circuit for Input Offset



## AMPLIFIER GAIN

When the feedback pin for each channel is connected to the corresponding OUT pin, the gain of the amplifier is internally set to 65 V/V. The amplifier gain can be increased by connecting a resistor between the feedback and OUT pin. The amplifier gain will be increased approximately 1 V/V for each additional 49.9  $\Omega$  added between the feedback and OUT pin.

## POWER SUPPLY BYPASSING

Bypass capacitors to power supply terminals +V<sub>S</sub> and -V<sub>S</sub> must be connected physically close to the pins to prevent local parasitic oscillation in the output stage of the MP104. Use electrolytic capacitors at least 10 $\mu$ F per output amp required. Bypass the electrolytic capacitors with high quality ceramic capacitors (X7R) 0.1 $\mu$ F or greater. Duplicate the supply bypass for the supply terminals of each amplifier channel. A bypass capacitor of 0.1 $\mu$ F or greater is recommended for the +V<sub>AUX</sub> terminal.

## CURRENT LIMIT

For proper operation, the current limit resistor ( $R_{LIM}$ ) must be connected as shown in the external connection diagram. For optimum reliability the resistor value should be set as high as possible. The value is calculated as shown below, with the maximum practical value of 30  $\Omega$ . The current limit function can be disabled by shorting the I<sub>L</sub> pin to the OUT pin.

$$R_{LIM} = \frac{0.7V}{I_{LIM}}$$

## POWER SUPPLY PROTECTION

Unidirectional zener diode transient suppressors are recommended as protection on the supply pins. The zeners clamp transients to voltages within the power supply rating and also clamp power supply reversals to ground. Whether the zeners 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 is 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.

## SERIES ISOLATION RESISTOR, R<sub>S</sub>

To insure stability with all capacitive loads a series isolation resistor should be included between the output and the load as shown in the external connections drawing. A 1.5  $\Omega$  resistor works well for capacitive loads between 40 and 80 nF. The resistor will affect the rise and fall time of the output pulse at the capacitive load. This can be compensated for on the input signal.

## BACKPLATE GROUNDING

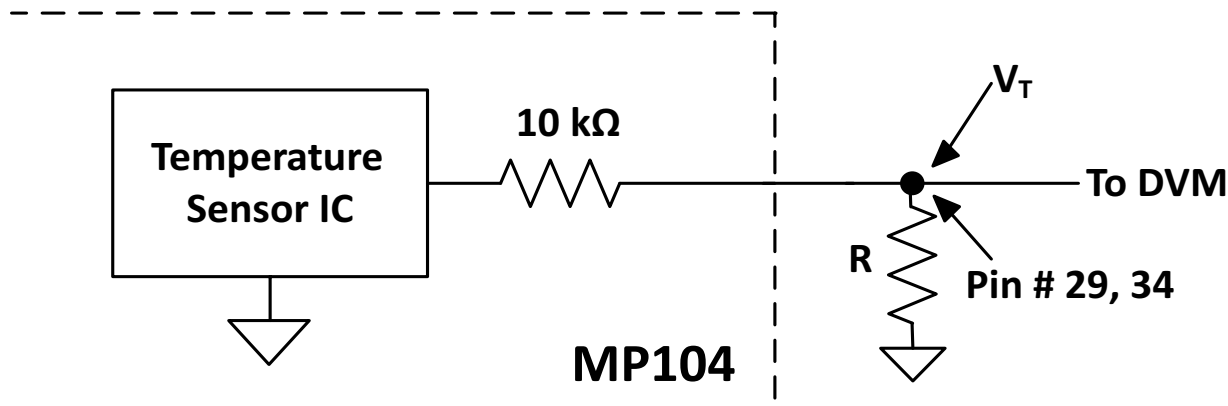
The substrate of the MP104 is an insulated metal substrate. It is required that it be connected to signal ground. This is accomplished when the ground pin (Pin 32) is properly connected signal ground.

## TEMPERATURE SENSING

The MP104 consists of two IC temperature sensors, located near the output MOSFETs of each channel. The scale factor of the sensor is  $10\text{mV}/^{\circ}\text{C}$ . The output voltage of the sensor is equal to approximately 2.98 V at room temperature ( $T_c = 25^{\circ}\text{C}$ ). The sensor has an uncalibrated temperature error of  $\pm 1^{\circ}\text{C}$ . The scale factor of the sensor can be adjusted by connecting an optional resistor “R” (refer Fig 18) to TMP\_A / TMP\_B pins using the following equation, where T is case temperature in  $^{\circ}\text{C}$ .

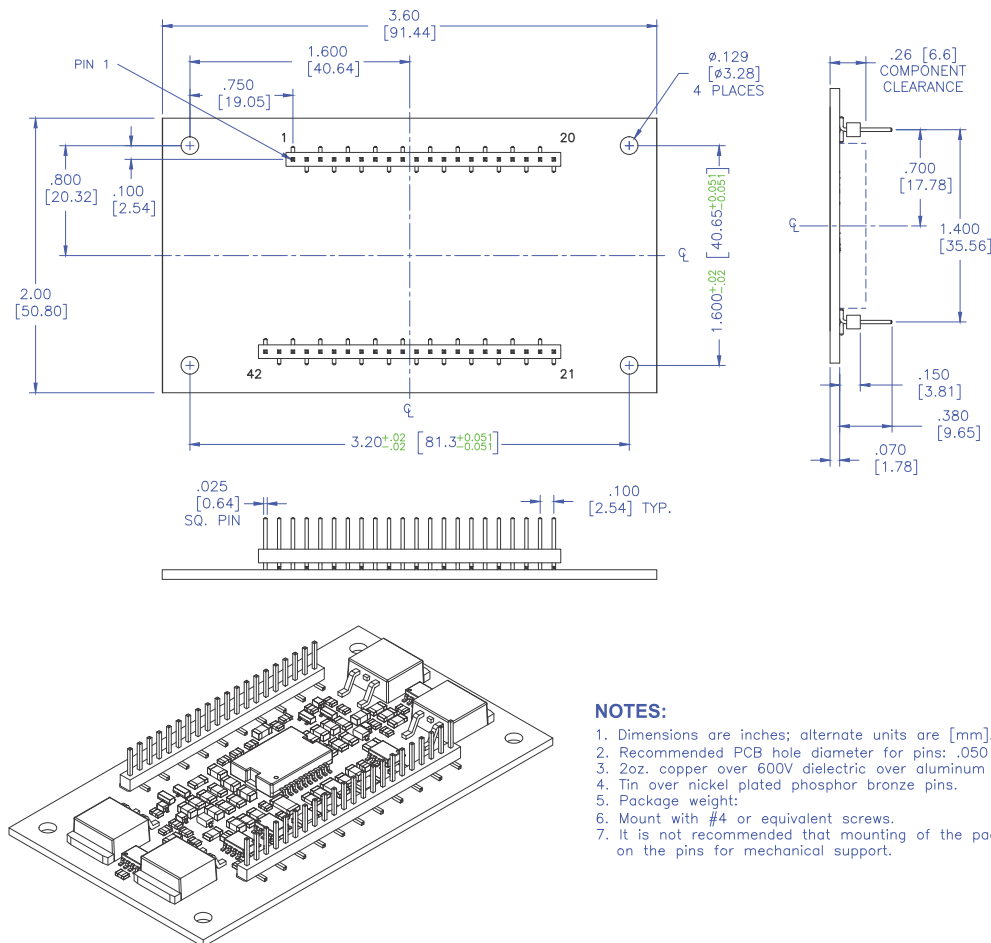
$$V_T = \frac{R}{10000 + R}(0.01T + 2.73)$$

Figure 18:



## PACKAGE OPTIONS

### PACKAGE STYLE KF



#### NOTES:

1. Dimensions are inches; alternate units are [mm].
2. Recommended PCB hole diameter for pins: .050 [1.27].
3. 2oz. copper over 600V dielectric over aluminum substrate.
4. Tin over nickel plated phosphor bronze pins.
5. Package weight:
6. Mount with #4 or equivalent screws.
7. It is not recommended that mounting of the package rely on the pins for mechanical support.

## NEED TECHNICAL HELP? CONTACT APEX SUPPORT!

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