# TCA2002

## STEREO CLASS-T™ AUDIO CONTROLLER USING DIGITAL POWER PROCESSING (DPP™) TECHNOLOGY

PRELIMINARY INFORMATION Revision 0.95 – April 2006

### GENERAL DESCRIPTION

The TCA2002 is a two channel audio controller that uses Tripath's proprietary Digital Power Processing (DPP™) technology. When combined with switching power output stages, the TCA2002 allows the implementation of a complete Class-T audio amplifier. Class-T amplifiers offer both the audio fidelity of Class-AB and the power efficiency of Class-D amplifiers.

The TCA2002 is pin compatible with the Tripath's previous stereo controllers, the TC2000 and TC2001. The basis for Tripath controllers is a proprietary, fully scalable, feedback structure. The TCA2002 is capable of single ended or bridged operation, with single or split power supplies. When mated with the appropriate power stage, amplifiers with output powers of 25W to 1000W, or more, are possible. Both Tripath power stages as well as third party power stages, whether integrated, or discrete, can be used to make a complete, high-performance switching amplifier.

Many features on the TCA2002 have been improved including increased supply range, elimination of turn-on pop, and automatic recovery from an overcurrent fault.

### APPLICATIONS

- High End Amplifiers
- Professional Audio Amplifiers
- 5.1-Channel DVD
- Mini/Micro Component Systems

### BENEFITS

- High fidelity, high efficiency Class-T controller
- Feedback structure allows usage of unregulated power supply
- Analog inputs
- Improved Click and Pop performance
- Wider power supply range

### FEATURES

- Class-T Architecture
- Audiophile Quality performance when mated with appropriate power circuitry
- Supply range configurable via external resistors
- Wide Dynamic Range >100dB
- Compatible with unregulated and regulated power supplies
- Break Before Make (BBM) circuitry
- Over voltage and Under voltage circuitry with wider supply range
- Fully deglitched comparators for overcurrent detection
- Automatic recovery from fault conditions
- Pin compatible with TC2000 and TC2001

## ABSOLUTE MAXIMUM RATINGS (Note 1)

| SYMBOL | PARAMETER | Value | UNITS |
|---|---|---|---|
| V5 | 5V Power Supply | 6 | V |
| Vlogic | Input Logic Level | -0.3 to V5 +0.3 | V |
| TA | Operating Free-air Temperature Range | -40 to 85 | °C |
| $T_{STORE}$ | Storage Temperature Range | -55 to 150 | °C |
| $T_{JMAX}$ | Maximum Junction Temperature | 150 | °C |
| $ESD_{HB}$ | ESD Susceptibility – Human Body Model (Note 2) | 2000 | V |
| $ESD_{MM}$ | ESD Susceptibility – Machine Model (Note 3) | 200 | V |

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. See the table below for Operating Conditions.
Note 2: Human body model, 100pF discharged through a 1.5kΩ resistor.
Note 3: Machine model, 220pF – 240pF discharged through all pins.

## OPERATING CONDITIONS (Note 4)

| SYMBOL | PARAMETER | MIN. | TYP. | MAX. | UNITS |
|---|---|---|---|---|---|
| V5 | Supply Voltage | 4.5 | 5 | 5.5 | V |
| $T_A$ | Operating Temperature Range | -40 | 25 | 85 | °C |

Note 4: Recommended Operating Conditions indicate conditions for which the device is functional. See Electrical Characteristics for guaranteed specific performance limits.

## THERMAL CHARACTERISTICS

| SYMBOL | PARAMETER | Value | UNITS |
|---|---|---|---|
| $\theta_{JA}$ | Junction-to-ambient Thermal Resistance (still air) | 80 | °C/W |

## ELECTRICAL CHARACTERISTICS (Note 5)

$T_A$ = 25 °C. See Application/Test Circuit.

| SYMBOL | PARAMETER | CONDITIONS | MIN. | TYP. | MAX. | UNITS |
|---|---|---|---|---|---|---|
| $I_q$ | Quiescent Current (Mute = 0V) | V5 = 5V | | 45 | 60 | mA |
| $I_{MUTE}$ | Mute Supply Current (Mute = 5V) | V5 = 5V | | TBD | TBD | mA |
| $V_{IH}$ | High-level input voltage (MUTE) | | 3.5 | | | V |
| $V_{IL}$ | Low-level input voltage (MUTE) | | | | 1.0 | V |
| $V_{OH}$ | High-level output voltage (HMUTE) | $I_{OH}$ = XmA | TBD | | | V |
| $V_{OL}$ | Low-level output voltage (HMUTE) | $I_{OL}$ = XmA | | | TBD | V |
| $V_{OH}$ | High-level output voltage (Yx, YxB) | $I_{OH}$ = XmA | TBD | | | V |
| $V_{OL}$ | Low-level output voltage (Yx, YxB) | $I_{OL}$ = XmA | | | TBD | V |
| $V_{TOC}$ | Over Current Comparator Voltage Threshold (OCD1 and OCD2) | | 0.85 | 0.97 | 1.09 | V |
| $I_{VPPSENSE}$ | VPPSENSE Threshold Currents | Over-voltage turn on (muted)<br>Over-voltage turn off (mute off)<br>Under-voltage turn off (mute off)<br>Under-voltage turn on (muted) | <br>121.6<br><br>45.6 | | 151.4<br><br>61.2<br> | μA<br>μA<br>μA<br>μA |
| $V_{VPPSENSE}$ | Threshold Voltages with $R_{VPP1} = R_{VPP2}$ = 383KΩ (Note 6) | Over-voltage turn on (muted)<br>Over-voltage turn off (mute off)<br>Under-voltage turn off (mute off)<br>Under-voltage turn on (muted) | <br>46.6<br><br>17.5 | | 58.0<br><br>23.4<br> | V<br>V<br>V<br>V |
| $I_{VNNSENSE}$ | VNNSENSE Threshold Currents | Over-voltage turn on (muted)<br>Over-voltage turn off (mute off)<br>Under-voltage turn off (mute off)<br>Under-voltage turn on (muted) | <br>118.7<br><br>41.0 | | 153.4<br><br>58.3<br> | μA<br>μA<br>μA<br>μA |
| $V_{VNNSENSE}$ | Threshold Voltages with $R_{VNN1}$ = 392KΩ $R_{VNN2}$ = 1.2MΩ (Note 6) | Over-voltage turn on (muted)<br>Over-voltage turn off (mute off)<br>Under-voltage turn off (mute off)<br>Under-voltage turn on (muted) | <br>46.5<br><br>16.1 | | 60.1<br><br>22.9<br> | V<br>V<br>V<br>V |

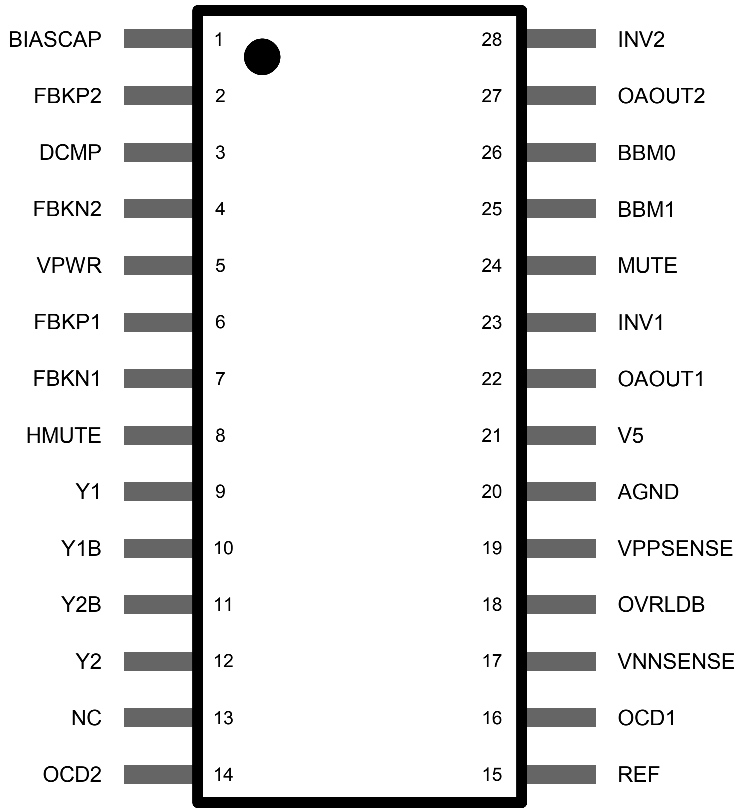
Note 5: Minimum and maximum limits are guaranteed but may not be 100% tested.

Note 6: These supply voltages are calculated using the $I_{VPPSENSE}$ and $I_{VNNSENSE}$ values shown in the Electrical Characteristics table. They are shown for example only and are based on a +/-45V typical supply voltage. The voltage values shown are calculated using $R_{VPP}$ and $R_{VNN}$ values without any tolerance variation. Tripath recommends 1% tolerance (or better) sense resistors for all applications. Please refer to the Application Information section for a more detailed description of how to calculate the over and under voltage trip voltages for a given resistor value.

## TCA2002 PIN DESCRIPTION

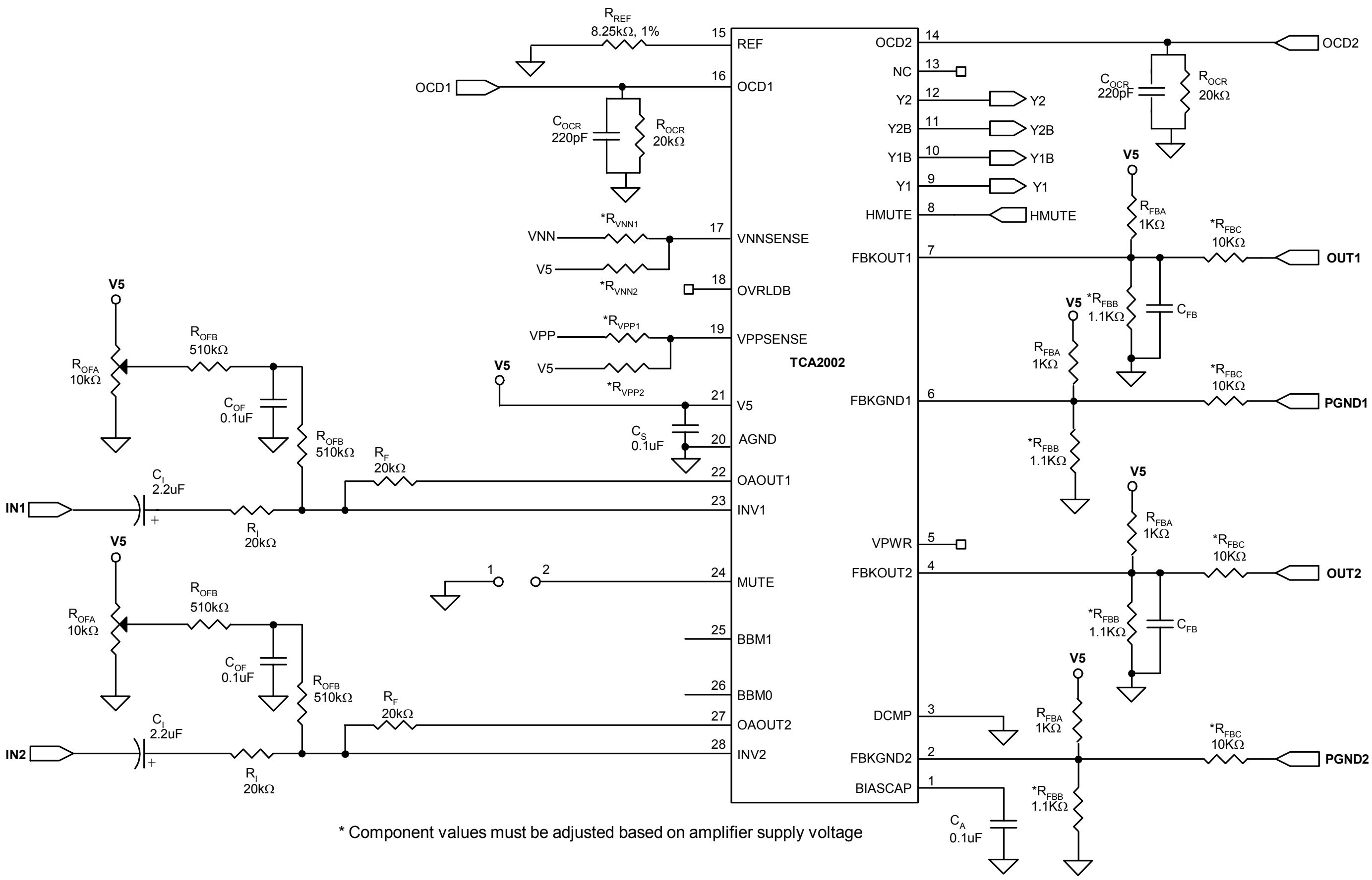
| Pin | Function | Description |
|---|---|---|
| 1 | BIASCAP | Bandgap reference times two (typically 2.5VDC). Used to set the common mode voltage for the input op amps. This pin is not capable of driving external circuitry. |
| 2<br>6 | FBKP2<br>FBKP1 | Positive switching feedback (Channels 2 & 1) |
| 3 | DCMP | Internal mode selection. Grounding this pin enables 16-pulses during startup. Connecting this pin to V5 disables 16-pulses during startup, which minimizes turn-on pop. DCMP must be grounded when connected to fet drivers or power stages using bootstrapped high-side supplies. |
| 4<br>7 | FBKN2<br>FBKN1 | Negative switching feedback (Channels 2 & 1) |
| 5 | VPWR | Test pin. Must be left floating. |
| 8 | HMUTE | Logic output. A logic high indicates both amplifiers are muted, due to the mute pin state, or a “fault”. |
| 9, 12 | Y1, Y2 | Non-inverted switching modulator outputs. (Channels 1 & 2) |
| 10, 11 | Y1B, Y2B | Inverted switching modulator outputs. (Channels 1 & 2) |
| 13 | NC | No connect |
| 14,16 | OCD2, OCD1 | Over Current Detect inputs. If either pin exceeds $V_{TOC}$, both amplifiers are muted. Ground if not used. The TCA2002 will try to automatically recover from an over current fault with an approximately 950mS repetition rate. |
| 15 | REF | Internal reference voltage; approximately 1.0 VDC. Connect and 8.25kΩ, 1% to AGND. |
| 17 | VNNSENSE | Negative supply voltage sense input. This pin is used for both over and under voltage sensing for the VNN supply. |
| 18 | OVRLDB | A logic low output indicates the input signal has overloaded the amplifier. |
| 19 | VPPSENSE | Positive supply voltage sense input. This pin is used for both over and under voltage sensing for the VPP supply. |
| 20 | AGND | Ground |
| 21 | V5 | 5 Volt power supply input. |
| 22<br>27 | OAOUT1<br>OAOUT2 | Input stage output pins. (Channels 1 and 2) |
| 23, 28 | INV1, INV2 | Single-ended inputs. Inputs are a “virtual” ground of an inverting opamp with approximately 2.5VDC bias. The bias at INV1 and INV2 is active, even if the MUTE pin is high. |
| 24 | MUTE | When set to logic high, both amplifiers are muted and in idle mode. When low (grounded), both amplifiers are fully operational. If left floating, the device stays in the mute mode. Ground if not used. |
| 25, 26 | BBM1, BBM0 | Break-before-make timing control to prevent shoot-through in the output MOSFETs. Please refer to the Application Information section additional information. |

## TCA2002 PINOUT



# APPLICATION / TEST DIAGRAM

## TCA2002 Typical Application Circuit




* Component values must be adjusted based on amplifier supply voltage

## EXTERNAL COMPONENTS DESCRIPTION (Refer to the Application/Test Circuits)

| Component | Description |
|---|---|
| $R_I$ | Inverting input resistance to provide AC gain in conjunction with $R_F$. This input is biased at the BIASCAP voltage (approximately 2.5VDC). |
| $R_F$ | Feedback resistor to set AC gain in conjunction with $R_I$. Please refer to the Amplifier Gain paragraph, in the Application Information section. |
| $C_A$ | BIASCAP decoupling capacitor. Should be located close to pin 1 and grounded at pin 20. |
| $C_I$ | AC input coupling capacitor, which, in conjunction with $R_I$, forms a high pass filter at $f_C = 1/(2\pi R_I C_I)$. |
| $R_{FBA}$ | Feedback resistor divider connected to 5V. This resistor is normally set to 1kΩ. |
| $R_{FBB}$ | Feedback divider resistor connected to AGND. The value of this resistor depends on the supply voltage setting and helps set gain in conjunction with $R_I$, $R_F$, $R_{FBA}$, $R_{FBB}$, and $R_{FBC}$. |
| $R_{FBC}$ | Feedback resistor connected from either the OUT1A/OUT2A to FBKOUT1/FBKOUT2 or OUT1B/OUT2B to FBKGND1/FBKGND2. The value of this resistor depends on the supply voltage setting and helps set gain in conjunction with $R_I$, $R_F$, $R_{FBBA}$, $R_{FBB}$, and $R_{FBC}$. It should be noted that the resistor from OUT1/OUT2 to FBKOUT1/FBKOUT2 must have a power rating of greater than $P_{DISS} = VPP^2/(2R_{FBC})$. |
| $C_{FB}$ | Feedback delay capacitor that both lowers the idle switching frequency and filters very high frequency noise from the feedback signal, which improves amplifier performance. The value of $C_{FB}$ should be offset between channel 1 and channel 2 so that the idle switching difference is greater than 40kHz. |
| $R_{OFA}$ | Potentiometer used to manually trim the DC offset on the speaker output. |
| $R_{OFB}$ | Resistors that limit the manual DC offset trim range and allows for more precise adjustment. |
| $C_{OF}$ | Supply decoupling for the offset trim circuit. |
| $R_{REF}$ | Bias resistor. Locate close to pin 15 and ground at pin 20. |
| $C_S$ | Supply decoupling for the power supply pins. For optimum performance, these components should be located close to the TCA2002 and returned to their respective ground as shown in the Application/Test Circuit. |
| $R_{VNN1}$ | Main over-voltage and under-voltage sense resistor for the negative supply (VNN). |
| $R_{VNN2}$ | Secondary over-voltage and under-voltage sense resistor for the negative supply (VNN). This resistor accounts for the internal VNNSENSE bias of 1.25V. Nominal resistor value should be three times that of RVNN1. |
| $R_{VPP1}$ | Main over-voltage and under-voltage sense resistor for the positive supply (VPP). |
| $R_{VPP2}$ | Secondary over-voltage and under-voltage sense resistor for the positive supply (VNN). This resistor accounts for the internal VPPSENSE bias of 2.5V. Nominal resistor value should be equal to that of RVPP1. |

# APPLICATION INFORMATION

## TCA2002 Basic Operation

The TCA2002 is a 5V CMOS stereo signal processor that amplifies the audio input signal and converts the audio signal to a 1-bt complementary, Class-T™, switching pattern. This switching pattern is spread spectrum with a typical idle switching frequency of about 650kHz, externally adjustable by the output stage propagation delay and $C_{FB}$. The switching patterns for the two channels are not synchronized and the idle switching frequencies should differ by at least 40kHz to avoid increasing the audio band noise floor. The idle frequency difference can be accomplished by offsetting the value of $C_{FB}$ for each channel.

Complementary copies of the switching pattern are output through the Y1 and Y1B pins, and the Y2 and Y2B pins. These signals are used to drive the inputs of a MOSFET driver or integrated power stage. Additionally, “break-before-make” or dead-time can be added between the Yx and YxB transitions to minimize shoot-through currents in the output stage. This is adjusted by the BBM1 and BBM0 pins.

The TCA2002 can be used over a wide range of supply voltages. The supply range is determined by the values of the feedback resistors in conjunction with the over-voltage / under-voltage sense resistors.

The TCA2002 has over-voltage and under-voltage detection as well as overcurrent detection. These external inputs cause both channels of the amplifier to mute during the fault condition.

## Class T Amplifier Architecture

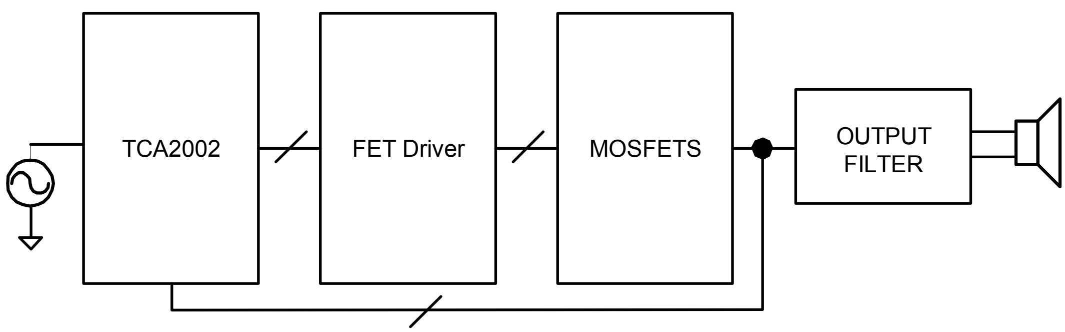



**Figure 1: Amplifier Architecture (One Channel)**

A basic Class T Amplifier Architecture is shown in Figure 1. There are three main blocks in the signal chain, though in some applications the FET Driver and MOSFETs may be integrated into a single package.

The TCA2002 accepts an analog input signal. It processes this analog signal and converts it into a complementary bitstream. This bitstream serves as the input to the FET Driver. The FET Driver completes the appropriate level shifting and signal buffering to drive the gates of the Mosfet output stage. Differential feedback is taken at the output and is used by the TCA2002 to ensure high signal fidelity. The output filter recovers the amplified signal and connects to the loudspeaker.

Figure 1 is a very simplified architecture diagram. Please refer to the more detailed block diagrams for the various amplifier configurations in the subsequent pages.

## Amplifier Gain

The gain of an amplifier based on the TCA2002 is the product of the input stage gain and the modulator gain. Please refer to the sections, Input Stage Design, and Modulator Feedback Design, for a complete explanation of how to determine the external component values for the various amplifier configurations.

$$A_{VTK2150} = A_{VINPUTSTAGE} * A_{V\ MODULATOR}$$

For example, using a TCA2002 with the following external components, in a Single Ended, Split Supply Application

$R_I = 20k\Omega$
$R_F = 30.1k\Omega$
$R_{FBA} = 1k\Omega$
$R_{FBB} = 1.1k\Omega$
$R_{FBC} = 10.0k\Omega$

$$A_{VTCA2002} \approx -\frac{20k\,\Omega}{30.1k\,\Omega}\left(\frac{10.0k\,\Omega * (1.0k\,\Omega + 1.1k\,\Omega)}{1.0k\,\Omega * 1.1k\,\Omega} + 1\right) = -13.35\ \frac{V}{V}$$

## Input Stage Design

The TCA2002 input stage is configured as an inverting amplifier, allowing the system designer flexibility in setting the input stage gain and frequency response. Figure 2 shows a typical application where the input stage is a constant gain inverting amplifier. The input stage gain should be set so that the maximum input signal level will drive the input stage output to 4Vpp.

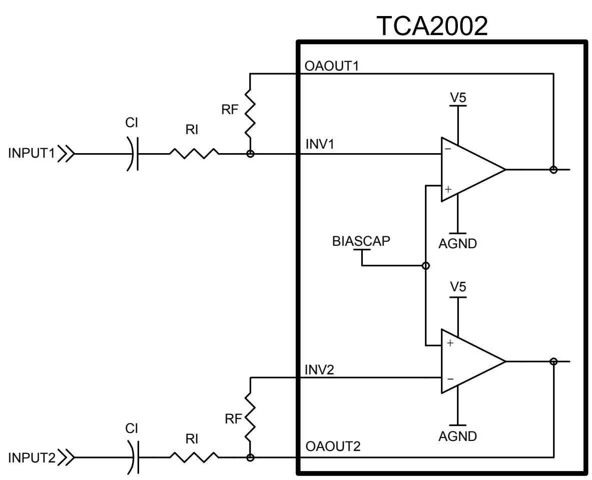



**Figure 2: Input Stage**

The gain of the input stage, above the low frequency high pass filter point, is that of a simple inverting amplifier: It should be noted that the input amplifiers are biased at approximately 2.5VDC. Thus, the polarity of $C_I$ must be followed as shown in Figure 2 for a standard ground referenced input signal

$$A_{V\ INPUT\ STAGE} = -\frac{R_F}{R_I}$$

### Input Capacitor Selection

$C_I$ can be calculated once a value for $R_I$ has been determined. $C_I$ and $R_I$ determine the input low frequency pole. Typically this pole is set below 10Hz. $C_I$ is calculated according to:

$$C_I = \frac{1}{2\pi f_P R_I}$$

where:

$R_I$ = Input resistor value in ohms.
$f_P$ = Input low frequency pole (typically 10Hz or below)

### Modulator Feedback Design

The modulator feedback converts the high-voltage output-switching signal to voltage levels that the TCA2002 can process. The optimum gain of the modulator is determined from the maximum allowable feedback level for the modulator and maximum supply voltage for the power stage. Depending on the maximum supply voltage, the feedback ratio will need to be adjusted for proper operation and to maximize performance. The values of $R_{FBA}$, $R_{FBB}$ and $R_{FBC}$ (see explanation below) define the gain of the modulator. In addition, the amplifier architecture affects the value of the feedback resistor values. Once these values are chosen, based on the maximum supply voltage, the gain of the modulator will be fixed even as the supply voltage changes. Thus, an amplifier based on TCA2002 has inherent PSRR unlike many other commercially available switching amplifiers.

For the best signal-to-noise ratio and lowest distortion, the maximum differential modulator feedback voltage should be approximately 4Vpp. This will keep the gain of the modulator as low as possible and still allow headroom so that the feedback signal does not clip the modulator feedback stage.

### Modulator Feedback Design

For **SPLIT-SUPPLY, SINGLE ENDED** operation:

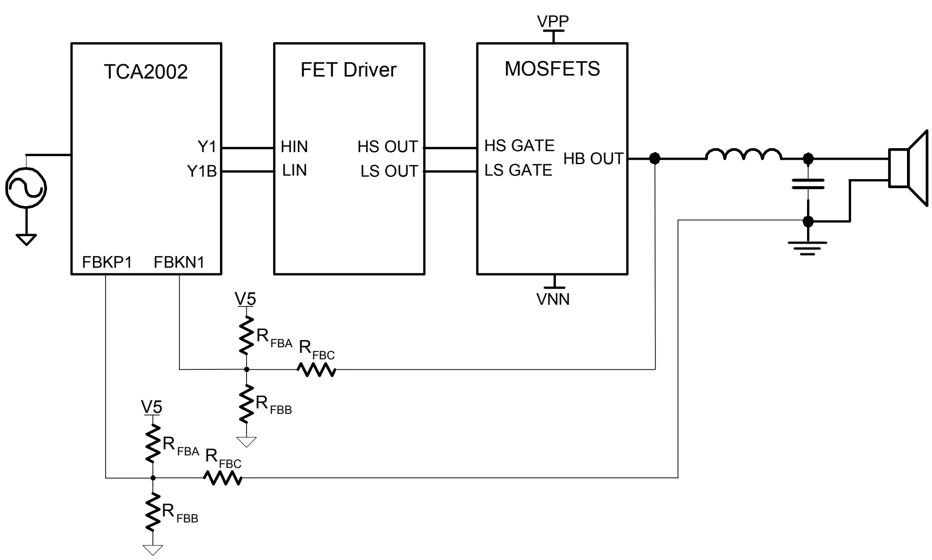



**Figure 3: Split Supply, Single Ended Circuit (One Channel)**

Figure 3 shows the basic split supply, single ended amplifier using a TCA2002. The MOSFET output stage operates from two power supplies, VPP and VNN, that are equal magnitude, but opposite polarity (for instance +/-60VDC). One terminal of the load is driven by the half-bridge MOSFET output stage. The other load terminal is ground referenced. Differential feedback is taken from the half-bridge output and load ground. The resistor divider networks at the TCA2002 scale the feedback signals. The resistor values are determined based on the supply voltage, as explained below.

The modulator feedback resistors are:

$$R_{FBA} = \text{User specified, typically } 1K\Omega$$

$$R_{FBB} = \frac{R_{FBA} * VPP}{(VPP - 4)}$$

$$R_{FBC} = \frac{R_{FBA} * VPP}{4}$$

$$A_{V\text{ - MODULATOR}} \approx \frac{R_{FBC} * (R_{FBA} + R_{FBB})}{R_{FBA} * R_{FBB}} + 1$$

The above equations assume that VPP=|VNN|.

For example, in a system with a **SPLIT-SUPPLY, SINGLE ENDED** amplifier of $VPP_{MAX}$=60V and $VNN_{MAX}$=-60V,

$R_{FBA}$ = 1k$\Omega$, 1%
$R_{FBB}$ = 1.071k$\Omega$, use 1.07k$\Omega$, 1%
$R_{FBC}$ = 15.0k$\Omega$, use 15.0k$\Omega$, 1%

The resultant modulator gain is:

$$AV\text{ - MODULATOR} \approx \frac{15.0k\,\Omega * (1.0k\,\Omega + 1.07k\,\Omega)}{1.0k\,\Omega * 1.07k\,\Omega} + 1 = 30.02V/V$$

For **SPLIT-SUPPLY, BRIDGED OUTPUT** operation:

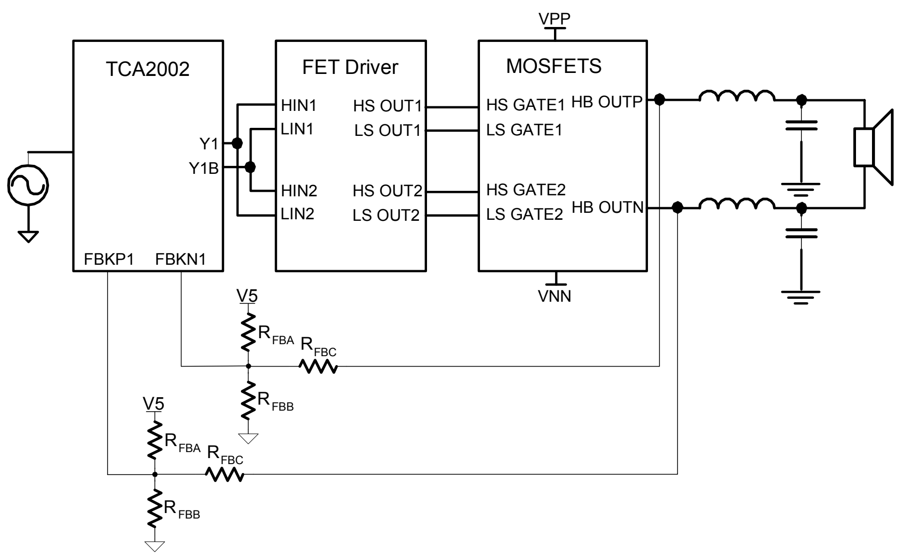



**Figure 4: Split Supply, Bridged Output (One Channel)**

Figure 4 shows the basic split supply, bridged output amplifier using a TCA2002. The MOSFET output stage operates from two power supplies, VPP and VNN, that are equal magnitude, but opposite polarity (for instance +/-60VDC). Both terminals of the speaker are actively driven. Differential feedback is taken from each half-bridge output. The resistor divider networks at the TCA2002 scale the feedback signals. The resistor values are determined based on the supply voltage, as explained below.

It should be noted that only one channel of the modulator is required to create a bridged amplifier. This is done by reversing the Y1 and Y1B connections to the second FET driver. This creates an out of phase signal at HB OUTN with respect to HB OUTP.

A bridged amplifier has the advantage of potentially 4 times the output power for a given supply rail. But the disadvantage is that the required number of FET drivers and MOSFETs per channel increases by a factor of two.

The modulator feedback resistors are:

$$R_{FBA} = \text{User specified, typically } 1K\Omega$$

$$R_{FBB} = \frac{R_{FBA} * VPP}{(VPP - 2)}$$

$$R_{FBC} = \frac{R_{FBA} * VPP}{2}$$

$$A_{V\text{ - MODULATOR}} \approx \frac{R_{FBC} * (R_{FBA} + R_{FBB})}{R_{FBA} * R_{FBB}} + 1$$

The above equations assume that VPP=|VNN|.

For example, in a system with a **SPLIT-SUPPLY, BRIDGED OUTPUT** amplifier of $VPP_{MAX}$=60V and $VNN_{MAX}$=-60V,

$R_{FBA}$ = 1kΩ, 1%
$R_{FBB}$ = 1.071kΩ, use 1.07kΩ, 1%
$R_{FBC}$ = 15.0kΩ, use 15.0kΩ, 1%

The resultant modulator gain is:

$$AV\text{ - MODULATOR} \approx \frac{15.0k\,\Omega * (1.0k\,\Omega + 1.07k\,\Omega)}{1.0k\,\Omega * 1.07k\,\Omega} + 1 = 30.02V/V$$

For **SINGLE-SUPPLY, BRIDGED OUTPUT** operation:

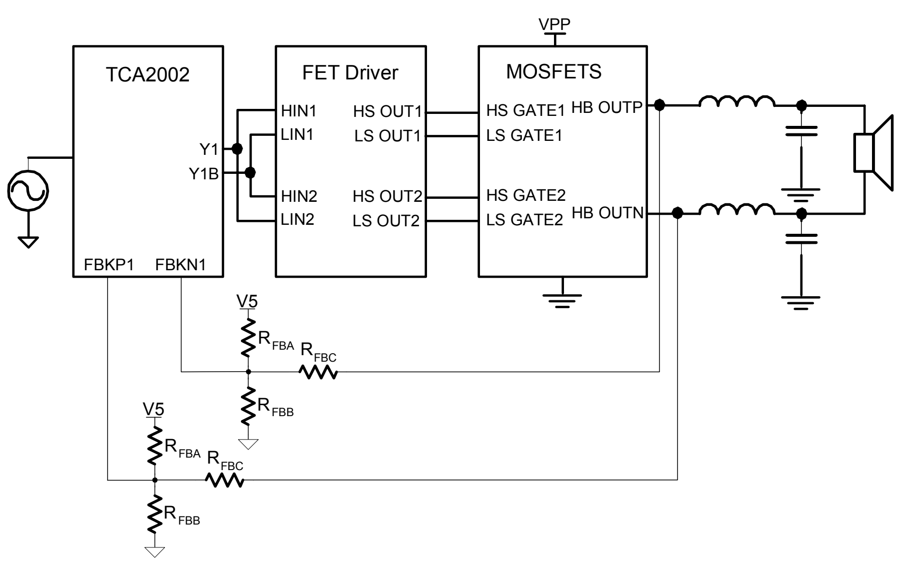



**Figure 5: Single Supply, Bridged Output (One Channel)**

Figure 5 shows the basic single supply, bridged output amplifier using a TCA2002. The MOSFET output stage operates from a single power supply, VPP (for instance 60VDC). Both terminals of the speaker are actively driven. Differential feedback is taken from each half-bridge output. The resistor divider networks at the TCA2002 scale the feedback signals. The resistor values are determined based on the supply voltage, as explained below.

It should be noted that only one channel of the modulator is required to create a bridged amplifier. This is done by reversing the Y1 and Y1B connections to the second FET driver. This creates an out of phase signal at HB OUTN with respect to HB OUTP.

A bridged amplifier has the advantage of potentially 4 times the output power for a given supply rail. But the disadvantage is that the required number of FET drivers and MOSFETs per channel increases by a factor of two.

The modulator feedback resistors are:

$$R_{FBB} = \text{User specified, typically } 1K\Omega$$

$$R_{FBC} = 350 * VPP - 1000$$

$$R_{FBB} = \frac{2333.33 * R_{FBC}}{(1000 + R_{FBC})}$$

$$A_{V\text{ - MODULATOR}} \approx \frac{R_{FBC} * (R_{FBA} + R_{FBB})}{R_{FBA} * R_{FBB}} + 1$$

For example, in a system with a **SINGLE-SUPPLY, BRIDGED OUTPUT** amplifier of $VPP_{MAX}$ = 60V,

$R_{FBA}$ = 2.22kΩ, use 2.21kΩ, 1%
$R_{FBB}$ = 1kΩ, 1%
$R_{FBC}$ = 20kΩ, 1%

The resultant modulator gain is:

$$A_{V\text{ - MODULATOR}} \approx \frac{20.0k\,\Omega * (1.0k\,\Omega + 2.21k\,\Omega)}{1.0k\,\Omega * 2.21k\,\Omega} + 1 = 30.05V/V$$

## Mute Control

When a logic high signal is supplied to MUTE, both amplifier channels are muted (both high- and low-side transistors are turned off). When a logic level low is supplied to MUTE, both amplifiers are fully operational. Please note, that unlike previous Tripath controllers such as TC2000 and TC2001, the state of MUTE does not effect the input stage biasing. Thus, even if MUTE is high, the bias at INV1 will be active. This will keep the input capacitor, $C_I$, charged via $R_I$, thus, minimizing turn-on pops.

Please note that the TCA2002 requires about 250mS to become active, after the de-assertion of MUTE (MUTE logic high → MUTE logic low). Also, the TCA2002 requires about 350uS to go into mute, after the assertion of MUTE (MUTE logic low → logic high).

## Break-Before-Make (BBM) Timing Control

The TCA2002 can also insert a delay between the Yx and YxB output signals. This dead time will minimize shoot thru currents, in the case that the output driver or power stage does not have built in BBM circuitry. BBM0 and BBM1 are logic inputs (connected to logic high or pulled down to logic low) that control the break-before-make timing of the output transistors according to the following table.

| BBM1 | BBM0 | Delay |
|---|---|---|
| 0 | 0 | 120 ns |
| 0 | 1 | 80 ns |
| 1 | 0 | 40 ns |
| 1 | 1 | 0 ns |

**Table 1: BBM Delay**

The tradeoff involved in making this setting is that as the delay is reduced, distortion levels improve but shoot-through and power dissipation increase. The actual amount of BBM required is dependent upon components such as MOSFET type and gate resistor value as well as circuit board layout. The BBM value selected should be verified in the actual application circuit board. It should also be verified under maximum temperature and power conditions since shoot-through in the output MOSFETs can increase under these conditions, possibly requiring a higher BBM setting than at room temperature.

The voltage at the BBM pins is sampled at the falling edge of mute. Thus, the BBM cannot be dynamically adjusted based on the output level of the amplifier.

### Output Voltage Offset

The TCA2002 does not have internal compensation for DC offset. The circuit shown in the Typical Application circuit is a simple passive circuit that covers the range of expected offset voltage. Tripath has had success with both active and passive circuits for this purpose; please consult with the Tripath Applications team for further information.

### HMUTE

The HMUTE pin is a 5V logic output that indicates various fault conditions within the device. Also, HMUTE will be high if the MUTE input is connected to a logic high level.

### OVRLDB

The OVRLDB pin is a 5V logic output that is asserted just at the onset of clipping. When low, it indicates that the level of the input signal has overloaded the amplifier resulting in increased distortion at the output. The OVRLDB signal can be used to control a distortion indicator light or LED through a simple buffer circuit, as the OVRLDB cannot drive an LED directly. There is a 20K resistor on chip in series with the OVRLDB output.

If only 1 channel of the TCA2002 is used, the OVERLDB pin will be permanently low, since one modulator will not be switching. This can be alleviated if the unused (not connected to a power stage) modulator is run in self-feedback mode, via a few external resistors. Please contact your local sales office for more information.

### Over-current Protection

The TCA2002 has two over-current protection comparator inputs, located at OCD1 and OCD2. These inputs can be connected to an external power stage, over current circuit output, such as that of TP2150B or similar.

When the voltage across $R_{OCR}$ becomes greater than $V_{TOC}$ (approximately 0.97V) the TCA2002 will mute. Please note that the voltage at a given OCDx pin will need to exceed $V_{TOC}$ for 3uS for the fault to register. The low pass filter formed by ROCR and COCR further enhances this time-based deglitching. Upon an over-current fault, the HMUTE signal will be pulled high and both Yx and YxB will be low. Please note that both channels are muted if an over-current condition occurs.

The reaction to an over-current fault is different than previous Tripath controllers. Unlike previous controllers that latched an over-current fault, the TCA2002 will automatically try to recover. Once an over current fault has occurred, the HMUTE will be pulled high for approximately 700mS. At this point, HMUTE will go low, and the TCA2002 will begin its normal un-muting sequence for 250mS. Thus, the typical retry time from an over-current fault is 950mS

If over-current detection is not needed, for example in the cases where the power stage has built in over-current protection, simply connect OCD0 and OCD1 to AGND. This will disable the over-current detection comparators in the TCA2002.

### Over- and Under-Voltage Protection

The TCA2002 senses the power rails through external resistor networks connected to VNNSENSE and VPPSENSE. The over- and under-voltage limits are determined by the values of the resistors in the networks (see APPLICATION / TEST DIAGRAM). If the supply voltage falls outside the upper and lower limits determined by the resistor networks, the TCA2002 will mute. The HMUTE pin will be pulled high and the Yx and YxB pins will be low. The removal of the over-voltage, or under-voltage condition, returns the amplifier to normal operation. Please note that trip points specified in the Electrical Characteristics table are at 25°C and may change over temperature.

For applications where the TCA2002 is mated with a power stage that has built-in over and undervoltage protection, this protection feature can be disabled by connecting a 30kohm resistor from VPPSENSE (pin 19) to V5, and a 15k resistor from VNNSENSE (pin 17) to AGND. Please note that the MUTE pin must be held high until all power supplies are stable to eliminate any possible power supply sequencing problems.

The TCA2002 has built-in over and under voltage protection for both the VPP and VNN supply rails. The nominal operating voltage will typically be chosen as the supply “center point.” This allows the supply voltage to fluctuate, both above and below, the nominal supply voltage.

VPPSENSE (pin 19) performs the over and undervoltage sensing for the positive supply, VPP. VNNSENSE (pin 17) performs the same function for the negative rail, VNN. When the current through $R_{VPPSENSE}$ (or $R_{VNNSENSE}$) goes below or above the values shown in the ELECTRICAL CHARACTERISTICS section (caused by changing the power supply voltage), the amplifier will be muted. VPPSENSE is internally biased at 2.5V and VNNSENSE is biased at 1.25V.

Once the supply comes back into the supply voltage operating range (as defined by the supply sense resistors), the amplifier will automatically be un-muted and will begin to amplify. There is a hysteresis range on both the VPPSENSE and VNNSENSE pins. If the amplifier is powered up in the hysteresis band the amplifier will be muted. Thus, the usable supply range is the difference between the over-voltage turn-off and under-voltage turn-off for both the VPP and VNN supplies. It should be noted that there is a timer of approximately 200mS with respect to the over and under voltage sensing circuit. Thus, the supply voltage must be outside of the user defined supply range for greater than 200mS for the amplifier to be muted.

Figure 6 shows the proper connection for the Over / Under voltage sense circuit for both the VPPSENSE and VNNSENSE pins.

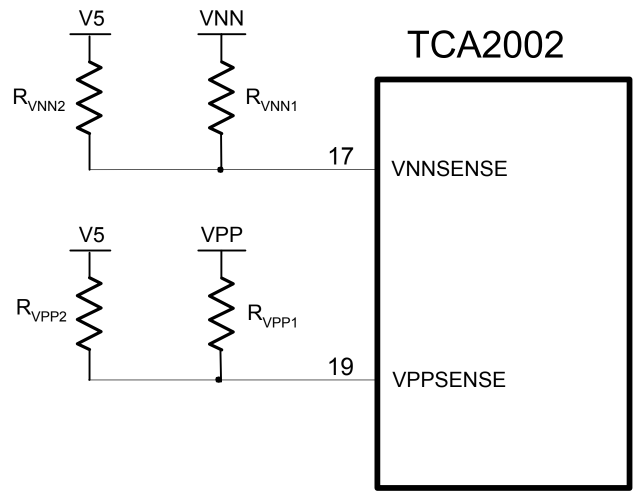



**Figure 6: Over / Under voltage sense circuit**

The equation for calculating $R_{VPP1}$ is as follows:

$$R_{VPP1} = \frac{VPP}{I_{VPPSENSE}}$$

Set $R_{VPP2} = R_{VPP1}$ .

The equation for calculating $R_{VNNSENSE}$ is as follows:

$$R_{VNN1} = \frac{VNN}{I_{VNNSENSE}}$$

Set $R_{VNN2} = 3 \times R_{VNN1}$ .

$I_{VPPSENSE}$ or $I_{VNNSENSE}$ can be any of the currents shown in the Electrical Characteristics table for VPPSENSE and VNNSENSE, respectively.

The two resistors, $R_{VPP2}$ and $R_{VNN2}$ compensate for the internal bias points. Thus, $R_{VPP1}$ and $R_{VNN1}$ can be used for the direct calculation of the actual VPP and VNN trip voltages without considering the effect of $R_{VPP2}$ and $R_{VNN2}$.

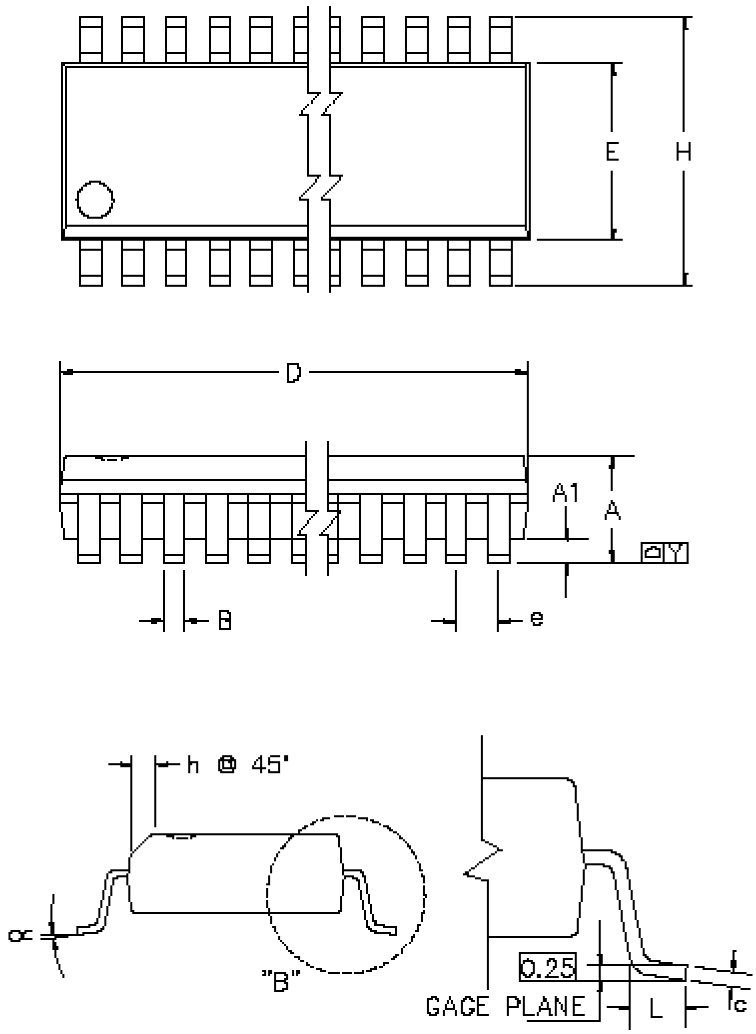
Using the resistor values from above, the actual minimum over voltage turn off points will be:

$$VPP_{MIN\_OV\_TURN\_OFF} = R_{VPP1} \times I_{VPPSENSE\ (MIN\_OV\_TURN\_OFF)}$$
$$VNN_{MIN\_OV\_TURN\_OFF} = -(R_{VNN1} \times I_{VNNSENSE\ (MIN\_OV\_TURN\_OFF)})$$

The other three trip points can be calculated using the same formula but inserting the appropriate $I_{VPPSENSE}$ (or $I_{VNNSENSE}$) current value. As stated earlier, the usable supply range is the difference between the minimum overvoltage turn off and maximum under voltage turn-off for both the VPP and VNN supplies.

$$VPP_{RANGE} = VPP_{MIN\_OV\_TURN\_OFF} - VPP_{MAX\_UV\_TURN\_OFF}$$
$$VNN_{RANGE} = VNN_{MIN\_OV\_TURN\_OFF} - VNN_{MAX\_UV\_TURN\_OFF}$$

## Package Information – TCA2002




| SYMBOL | MILLIMETER MIN | MILLIMETER NOM | MILLIMETER MAX | INCH MIN | INCH NOM | INCH MAX |
|---|---|---|---|---|---|---|
| | CONTROL DIMENSIONS ARE IN MM | | | | | |
| A | 2.35 | 2.54 | 2.65 | 0.092 | 0.100 | 0.104 |
| A1 | 0.10 | 0.17 | 0.30 | 0.004 | 0.006 | 0.012 |
| B | 0.33 | 0.42 | 0.51 | 0.013 | 0.016 | 0.020 |
| C | 0.23 | 0.25 | 0.32 | 0.009 | 0.010 | 0.012 |
| E | 7.40 | 7.50 | 7.60 | 0.291 | 0.295 | 0.299 |
| e | | 1.27 | | | 0.050 | |
| H | 10.00 | 10.30 | 10.65 | 0.394 | 0.406 | 0.419 |
| h | 0.25 | 0.50 | 0.75 | 0.009 | 0.020 | 0.029 |
| L | 0.40 | 0.70 | 1.27 | 0.015 | 0.028 | 0.050 |
| $\alpha$ | 0° | | 8° | 0° | | 8° |
| Y | 0 | | 0.10 | 0 | | 0.004 |
| D | 17.70 | 17.90 | 18.10 | 0.697 | 0.705 | 0.712 |

**PRELIMINARY INFORMATION** – The above specification is for a device that is currently in development. All specifications and device descriptions are subject to change based on product analysis and characterization. Please contact Tripath Technology for additional information not included or covered in this advanced document.



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