Precautions for connecting APA outputs to other devices

By Stephen Crump
Applications Engineer, Audio Power Amplifiers, Audio and Imaging Products

Multiple audio power amplifiers (APAs) may be connected to one output circuit by design, to multiplex different sources or to connect an external amplifier to save battery life. Also, one amplifier output may be connected to another or to a power supply by mistake. Any of these connections can force APA outputs to abnormal voltages, and this can damage an APA. This article explains limits that must be observed to avoid such damage.

Damage can occur whether an APA is active or shut down. The output of most APAs is protected with short-circuit protection (SCP) or overcurrent protection (OCP) when the APA is active, but the range of voltages the APA can tolerate is still the same. Generally, voltage forced into an APA output must be limited as follows to avoid APA damage:

- An APA output should not be forced more than 0.3 V above the APA’s positive power-supply voltage (VDD or VCC), or more than –0.3 V below its negative power-supply voltage (ground or VSS).
- An APA output must never be forced beyond the Absolute Maximum Ratings for supply voltages given in the APAs data sheet.

How APAs respond to voltages forced into their outputs

When shut down, APAs have different resistances at their outputs, ranging from a few ohms to several kilohms to high impedance. If an external audio source connected to an APA output can drive the resistance there, it will force its voltage at the APA output.

When active, most class-AB devices have continuous-current limiting for SCP. This kind of APA holds its output at its intended output voltage until it is forced into SCP or OCP by the other source. Then it continues to draw its limit current, but its output voltage is controlled by the other source. If the APA continues to draw its limit current, it may overheat and go into thermal shutdown. Then its output voltage is controlled entirely by the other source. When the APA cools down enough, it will turn on again, and this cycle will continue as long as the external source is connected.

A typical Class-D APA holds its output at its intended output voltage until it is forced into SCP or OCP. Then it shuts down and its output voltage is controlled by the other source, without drawing significant current, as long as proper voltage limits are observed. A class-D APA with cycle-by-cycle OCP generally behaves like a continuous-current limiter until it shuts down.

How damage occurs

If another source is connected to an APA output when it is shut down, it will force the APA output to follow its voltage. If the APA is active and the other source can supply enough current to force the APA into SCP or OCP, the other source will then force the APA output to follow its voltage. There are several different ways in which damage can be done.

Forward-biased body diode

Single-supply APAs operate between a positive power supply, usually called VDD or VCC, and ground. Output devices are FETs with body diodes that are reverse-biased in normal operation. Body diodes that are reverse-biased in normal operation (see Figure 1) can be damaged if one of the diodes becomes forward-biased and conducts excessive current. This can happen if an output of a single-supply APA is forced more than 0.3 V above VDD (or VCC) or more than –0.3 V below ground.
Texas Instruments (TI) DirectPath™ APAs operate between a positive power supply, usually called VDD, and a negative rail, usually called VSS, often generated from VDD with a switching circuit. The magnitude of VSS is generally less than the magnitude of VDD. Some DirectPath APAs regulate primary VDD to a lower level for their outputs, HPVDD, and generate a negative rail, HPVSS, from HPVDD, to control maximum output power. If an output of a DirectPath APA is forced more than 0.3 V above VDD/HPVDD or more than –0.3 V below VSS/HPVSS, one of the body diodes may become forward-biased and conduct excessive current, which can damage the diode.

**Power-supply overvoltage**

Even if external source currents do not damage a body diode, they may flow to VDD/HPVDD or VSS/HPVSS (see Figure 2). VDD/HPVDD and VSS/HPVSS typically only source current, so the diode currents may charge the supply voltages beyond their absolute maximum ratings and in turn may damage the APA and/or the supply components.

Table 1 may be helpful in understanding the different supplies for various DirectPath APAs. Supplies for devices not included here can be determined by comparing their data-sheet information to this table. Supply labels may be different from the labels shown in the table.

**Related Web sites**

- www.ti.com/audio
- www.ti.com/sc/device/partnumber

Replace partnumber with TPA4411, TPA6130A2, TPA6132A2, or TPA6136A2

---

**Table 1. Comparison of supply-voltage limits for APA devices**

<table>
<thead>
<tr>
<th>DEVICE</th>
<th>TPA4411</th>
<th>TPA6130A2</th>
<th>TPA6132A2</th>
<th>TPA6136A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Supply Voltage</td>
<td>SVDD = 1.8 to 4.5</td>
<td>VDD = 2.5 to 5.5</td>
<td>HPVDD = 1.8</td>
<td>HPVDD = 1.8</td>
</tr>
<tr>
<td>Negative Supply Voltage</td>
<td>SVSS ≈ –SVDD</td>
<td>CPVSS = –VDD when VDD &lt; 2.8 V**</td>
<td>CPVSS = –2.8 V when VDD ≥ 2.8 V**</td>
<td>HPVSS = –1.8</td>
</tr>
</tbody>
</table>

* APA outputs must never be forced beyond absolute maximum ratings for supply voltages.
  - For single-supply APAs, this includes VDD (or VCC).
  - For DirectPath APAs like TPA4411, this includes SVDD and SVSS.
  - For DirectPath APAs like TPA6132A2, this includes HPVDD and HPVSS.
  - Sometimes no absolute maximum rating is given for VSS/HPVSS. In these cases, the negative of the maximum recommended operating voltage for VDD/HPVDD should be used.

**When VDD < 2.8 V, CPVSS falls as VDD falls.
TI Worldwide Technical Support

Internet
TI Semiconductor Product Information Center
Home Page
support.ti.com

TI E2E™ Community Home Page
e2e.ti.com

Product Information Centers

America s Phone +1(972) 644-5580
Brazil Phone 0800-891-2616
Mexico Phone 0800-670-7544
Fax +1(972) 927-6377
Internet/Email support.ti.com/sc/pic/americas.htm

Europe, Middle East, and Africa
Phone
European Free Call 00800-ASK-TEXAS (00800 275 83927)
International +49 (0) 8161 80 2121
Russian Support +7 (4) 95 98 10 701
Fax +(49) (0) 8161 80 2045
Internet support.ti.com/sc/pic/euro.htm

Note: The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Asia
Phone
International +91-80-41381665
Domestic Toll-Free Number
Australia 1-800-999-084
China 800-820-8682
Hong Kong 800-96-5941
India 1-800-425-7888
Indonesia 001-803-8861-1006
Korea 080-551-2804
Malaysia 1-800-80-3973
New Zealand 0800-446-934
Philippines 1-800-765-7404
Singapore 800-886-1028
Taiwan 0800-006800
Thailand 001-800-886-0010
Fax +886-2-2378-6808
Email tiasia@ti.com or ti-china@ti.com
Internet support.ti.com/sc/pic/asia.htm

Important Notice: The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

© 2010 Texas Instruments Incorporated

DirectPath and E2E are trademarks of Texas Instruments. All other trademarks are the property of their respective owners.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that TI is neither designed nor intended for use in automotive applications or environments unless the specific TI products are specifically designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that any use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are not authorized for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>Audio</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Automotive</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Communications and Telecom</td>
</tr>
<tr>
<td>DSP</td>
<td>Computers and Peripherals</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Consumer Electronics</td>
</tr>
<tr>
<td>Interface</td>
<td>Energy</td>
</tr>
<tr>
<td>Logic</td>
<td>Industrial</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Medical</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Security</td>
</tr>
<tr>
<td>RFID</td>
<td>Space, Avionics &amp; Defense</td>
</tr>
<tr>
<td>RF/IF and ZigBee® Solutions</td>
<td>Video and Imaging</td>
</tr>
<tr>
<td></td>
<td>Wireless</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2010, Texas Instruments Incorporated