Application Report
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APA Outputs Connected to Other Devices

Stephen Crump *Audio Products*

ABSTRACT

Audio power amplifier (APA) outputs are sometimes connected to other voltage sources, by design or mistake. If the connected source can force enough voltage at an APA output, it may damage the APA. This paper explains limits that must be observed to avoid damage and describes how it can happen, so it can be avoided by design.

Description

Multiple APAs may be connected to one output circuit by design, to multiplex different sources or to connect an external amplifier to save battery life; or, 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 cause damage to an APA. This paper provides information needed to resolve this issue during circuit design, to avoid damage.

Damage can occur if an APA is active or shut down. When they are active, most APAs protect their outputs with short-circuit protection (SCP) or over-current protection (OCP), but the range of voltages they can tolerate is still the same.

Generally voltages forced at APA outputs must be limited as follows to avoid damage.

1. APA outputs should not be forced more than 0.3V above their positive power supply voltage, VDD (or VCC), or more than –0.3V below their negative power supply voltage, Ground or VSS.
   - Single-supply APAs operate between a positive power supply, VDD (or VCC) and Ground.
   - DirectPath™ APAs operate between a positive power supply, usually called VDD, and a negative rail, usually called VSS, generated from VDD with a switching circuit. VSS is generally lower than the negative 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. Their outputs must not be forced more than 0.3V above HPVDD or more than –0.3V below HPVSS.
   - TPA6130A2 regulates its negative rail, CPVSS, to –2.8V, as long as its VDD is above 2.8V. When VDD is below 2.8V, CPVSS falls as VDD falls.
   - This table may be helpful in understanding the different supplies in various DirectPath™ APAs. Supplies for devices not included here can be determined by comparing to this list. Supply labels may be different from the labels shown in the table.

Device	TPA4411	TPA6130A2	TPA6132A2	TPA6136A2
Supply +	SVDD	VDD	HPVDD	HPVDD
Voltage	1.8–4.5	2.5–5.5	1.8	1.8
Supply –	SVSS	CPVSS	HPVSS	HPVSS
Voltage	~ (–SVDD)	~ (–VDD), VDD < 2.8V; ~ –2.8V, VDD ≥ 2.8V	–1.8	–1.8

2. 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.
   - In some cases no Absolute Maximum Rating is given for VSS/HPVSS. In these cases use the negative of the maximum Recommended Operating voltage for VDD/HPVDD.

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How APAs Respond to Voltages Forced at Their Outputs

When shut down, APAs have different resistances at their outputs, ranging from a few ohms to several kilohms to high impedance. If another source is connected to an APA output and it 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 forced by the other source.

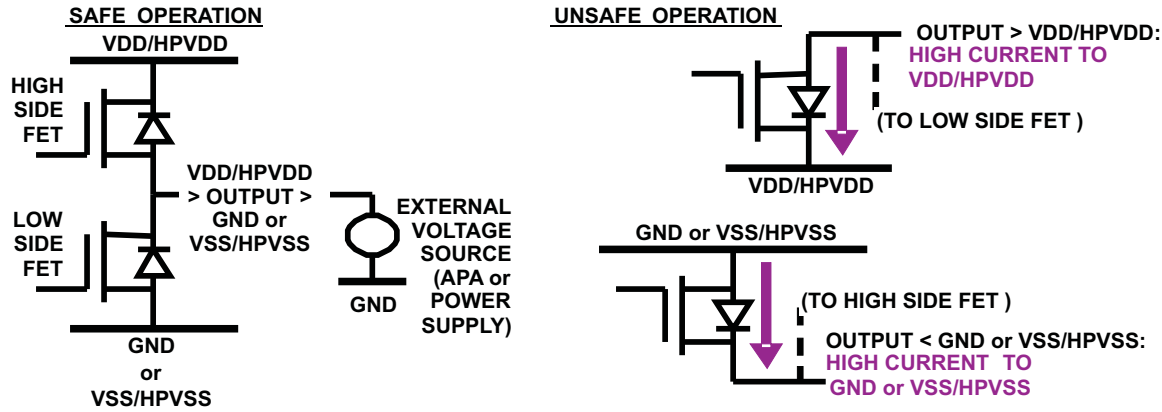
If an APA continues to draw its limit current, it may overheat and go into thermal shutdown. Then its output voltage is forced entirely by the other source. When the APA cools down enough, it will turn on again, and this cycle will continue as long as the other source is connected.

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 forced by the other source, without drawing significant current, as long as proper voltage limits are observed. Class-D APAs with cycle-by-cycle OCP generally behave like continuous current limiters until they shut down.

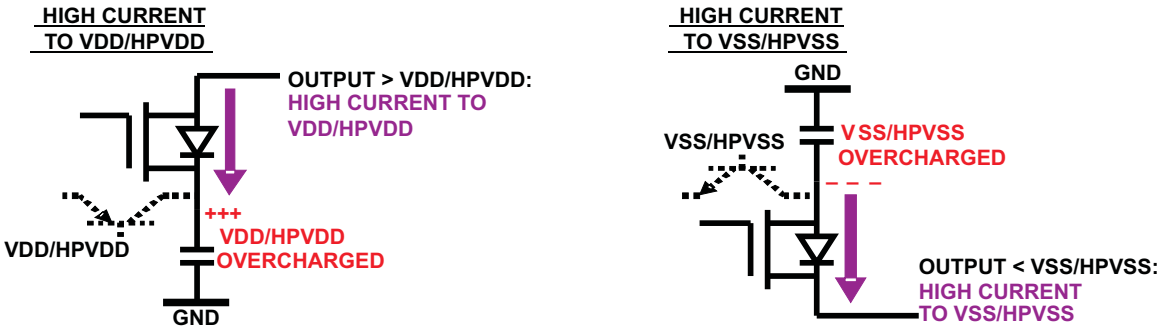
How Damage Occurs

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.

1. Damage to output device body diodes. (Output devices are FETs with body diodes that are reverse biased in normal operation.)
   - If an output of a single-supply APA is forced more than 0.3V above VDD (or VCC) or more than –0.3V below ground, one of the body diodes may become forward biased and conduct current, and this current may damage the diode.
   - If an output of a DirectPath™ APA is forced more than 0.3V above VDD/HPVDD or more than –0.3V below VSS/HPVSS, one of the body diodes may become forward biased and conduct current, and this current may damage the diode.



2. Overvoltage at power supplies.
   - Even if these currents do not damage a body diode, they may flow to VDD/HPVDD or VSS/HPVSS. VDD/HPVDD and VSS/HPVSS typically only source current, so the diode currents may charge them beyond their absolute maximum voltages, and this may damage the APA.



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