Application Note | February 25, 2009 | AN1438.0

Intelligent Digital Amplifier Design Platform for OEM and Aftermarket Automotive Audio Amplifiers

Features

- Complete OEM/Aftermarket Automotive Class-D Amplifier Solution
- Integrated 12V Input DC/DC Converter Generates all System Voltages and Power-supply Sequencing
- Class-D Efficiency Reduces Heat and Size
- Small Form fit Factor Enables a *true* 100W x 8 Channels High-fidelity
- Flexible Audio Flow Configuration
- 8 Independent Channels of Audio Processing
- Powerful Digital Audio Management
- Reduced Audio System Complexity and Cost
- Audio Processing Features Enable Optimized Speaker Performance
- Minimum Development Cost/Risk/Time-to-Market
- Complete Reference Design Platform (RDP) Package offers Schematics, Layout Files, BOM, Firmware, Application Notes, and Development GUIs

Incredible Power and Performance

- 70W/Channel CEA-2006[1] Compliant Power Rating, <0.07% THD+N, 4Ω
- 100W/Channel <1.0% THD+N, 1kHz, 2Ω
- >103 dB SNR/>103 dB Dynamic Range (Unweighted, 20Hz to 20kHz)

Overview

The D2Audio™ VA100-8 is a self-contained, 100W per channel digital amplifier for manufacturers of state-of-the-art automotive electronics, where audio performance, size, heat, power, and digital interface are critical selling points.

The VA100-8 reference design amplifier platform contains D2Audio's DAE-2™ product, an intelligent, high-performance digital switching controller IC which supports both Digital Feedback as well as Digital Power Supply Correction, in conjunction with MOSFET output stages, high-quality output filter stages, Analog and Digital Audio inputs, and remote control turn-on.

The VA100-8 is capable of driving 1-Channel continuously at over 100W into an 2Ω load, while maintaining excellent audio quality across the audio band.

The VA100-8 Reference Design Platform (RDP) Package includes D2Audio Canvas™, a Windows™ application with an intuitive graphical user interface (GUI) which simplifies audio configuration and avoids complex programming during initial evaluation.

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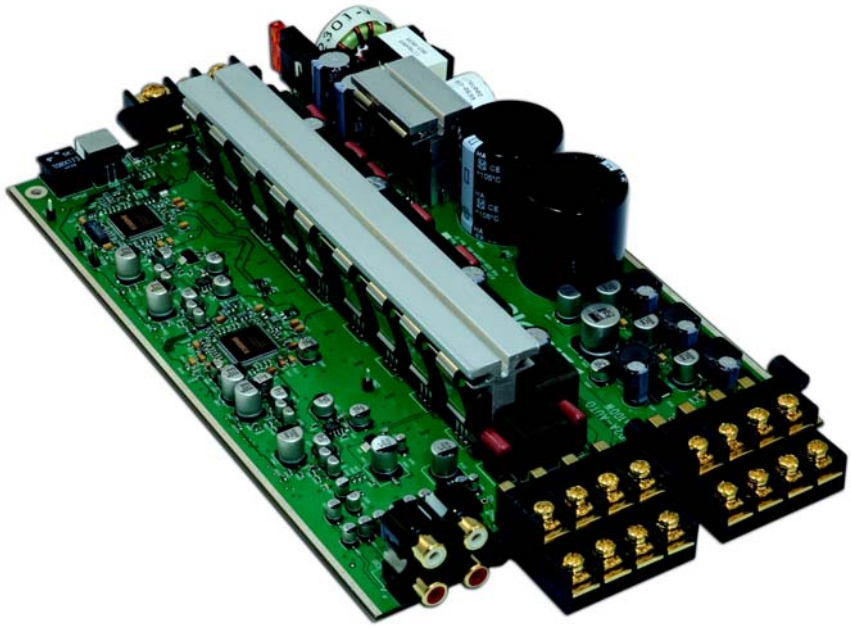

Introduction

The D2Audio™ VA100-8 is a self-contained, 100W per-channel digital amplifier designed for manufacturers of state-of-the-art automotive electronics. This amplifier provides an excellent solution where premium audio performance, small size, low heat dissipation, high amplifier power, and its digital interface, are critical features for competitive selling points.

The VA100-8 amplifier platform is based around D2Audio's DAE-2™ product, an intelligent, high-performance digital switching controller IC which supports both Digital Feedback as well as Digital Power Supply Correction. The complete amplifier solution includes MOSFET output stages, high-quality output filter stages, Analog and Digital Audio inputs, and remote control turn-on.

Power and Performance

- 70W/Channel CEA-2006[1] Compliant Power Rating <0.07%, THD+N, 4Ω
- 75W/Channel <0.1% THD+N, 4Ω, >103dB SNR/DNR
- 100W/Channel <1.0% THD+N, 1kHz, 2Ω
- >103 dB SNR/>103 dB Dynamic Range (Unweighted, 20Hz to 20kHz)
- ±0.5 dB Frequency Response (20Hz to 20kHz, 2Ω)

Distinguishing Features

- A Complete OEM/Aftermarket Automotive Class-D Amplifier Solution
- D2Audio™ Intelligent Digital Controller IC (DAE-2) with Digital Feedback and Digital Power Supply Correction
- Designed for compliance with RoHS/Pb-Free manufacturing
- Integrated 12V input DC/DC converter generates all system voltages (±30V, +12V, +5V, +3.3V, and +1.8V) as well as handling power-supply sequencing
- Small form fit factor enables a *true* 100W x 8 channels high-fidelity, no compromise, CEA-2006 test compliant digital audio amplification into the thinnest of aftermarket or OEM audio amplifier enclosures
- Powerful Digital Audio Management Including SRC, Routing, Mixing, Multiple Digital Audio I/O, Tone Control, Parametric EQ, Compression
- Reduced Audio System Complexity and Cost for today's most advanced automotive audio systems (OEM and Aftermarket)
- Audio Processing features enable optimized speaker performance and delivers dramatically improved sound quality
- Minimum Development Cost/Risk/Time-to-Market
- Class-D Efficiency Reduces Heat and Product Size
- Complete Reference Design Platform (RDP) Package offers Schematics, Layout Files, BOM, Firmware, Application Notes, and Development GUIs

The VA100-8's Flexible Audio Configuration

- 8 Independent Channels of Audio Processing enables separate control over each of the Speaker Outputs
- Input Signal Processing: Input Selection, 8x8 Matrix Mixing
- Output Signal Processing: Tone Control, Crossovers, 8-Band Parametric EQ, Time Delay, Master Volume Control, Loudness Contour, Compressor, and Independent Channel Level Control

Evaluation Tools for Effective and Easy Use

- D2Audio Canvas™ GUI, an intuitive point-and-click audio configuration utility for OEMs, ODMs, and system designers
- D2Audio GUI enables firmware upgrade ability

Notes Regarding Testing Methods

[1]On May 28, 2003, the Consumer Electronics Association published standard CEA-2006, "Testing & Measurement Methods for Mobile Audio Amplifiers." This "voluntary" standard advocates a uniform method for determining an amplifier's RMS power and signal-to-noise ratio. Using 14.4V, RMS watts are measured into a 4Ω impedance load at 1 percent Total Harmonic Distortion plus Noise (THD+N), at a frequency range (for general purpose amplifiers) of 20Hz to 20,000Hz. Signal-to-Noise ratio is measured in weighted absolute decibels (dBA) at a reference of 1W into 4Ω. This applies to both external amplifiers and the amplifiers within in-dash receivers.

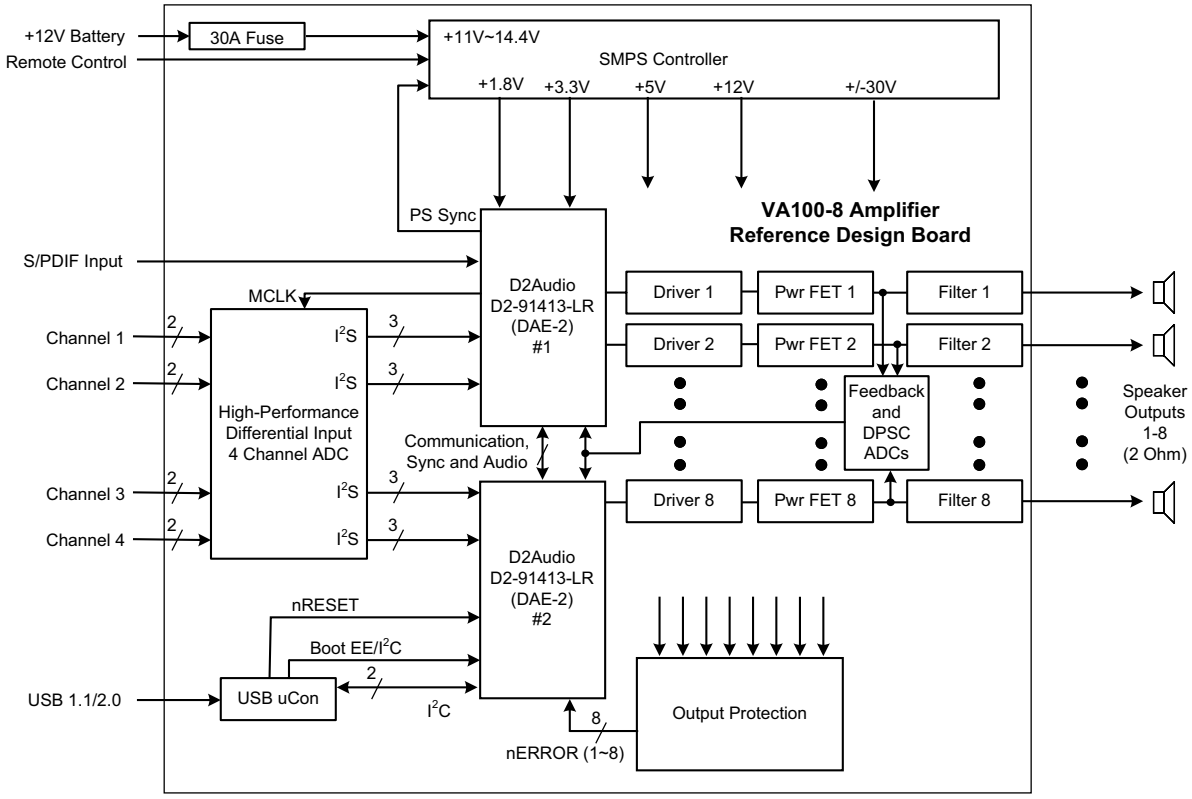

FIGURE 1. VA100-8 DIGITAL POWER AMPLIFIER MODULE INTERFACE BLOCK DIAGRAM

Using the VA100-8

Board Overview

The VA100-8 platform provides a complete system for evaluating the VA100-8 Digital Amplifier module. The system provides various audio input connections and a USB interface. Refer to Figure 2 for general layout and arrangement of the VA100-8 board.

Input Audio Source Options

The VA100-8 Evaluation Kit supports 4 pairs of analog stereo input channels as well as a S/PDIF digital input. The RCA jacks provide the interface for the analog inputs of the evaluation kit. An optical TOS-LINK connection is provided for the S/PDIF digital input.

USB Interface

The VA100-8 Evaluation Kit includes a USB interface for connection to a PC. This interface supports the D2Audio Canvas software. The USB interface supports a full-speed USB connection and is compatible with the USB1.1 and USB2.0 specifications.

Step-By-Step Setup

1. Set up in an ESD-approved work area.
2. Connect speakers (2Ω or 4Ω) to the loudspeaker connectors (see “VA100-8 Loudspeaker Connections” on page 7).
3. Connect an audio source to the appropriate S/PDIF or analog input jacks
4. Connect supply GND to VA100-8 GND terminal (see “VA100-8 Power Connections” on page 7).
5. Connect supply +12V source to VA100-8 +12V terminal (see “VA100-8 Power Connections” on page 7).
6. Connect power supply remote to VA100-8 REM terminal (see “VA100-8 Power Connections” on page 7).
7. Connect USB cable to VA100-8.
8. Connect USB Cable to PC.
9. Turn on external power supply.
10. Turn on VA100-8 with power supply remote, connected in STEP 6.
11. Install D2Audio Driver and the D2Audio Canvas™ software.
12. Launch D2Audio Canvas application, and refer to additional D2Audio Canvas instructions in its User’s Guide.
13. VA100-8 control, including volume settings, tone controls, and audio path selection is now controlled through the D2Audio Canvas interface.

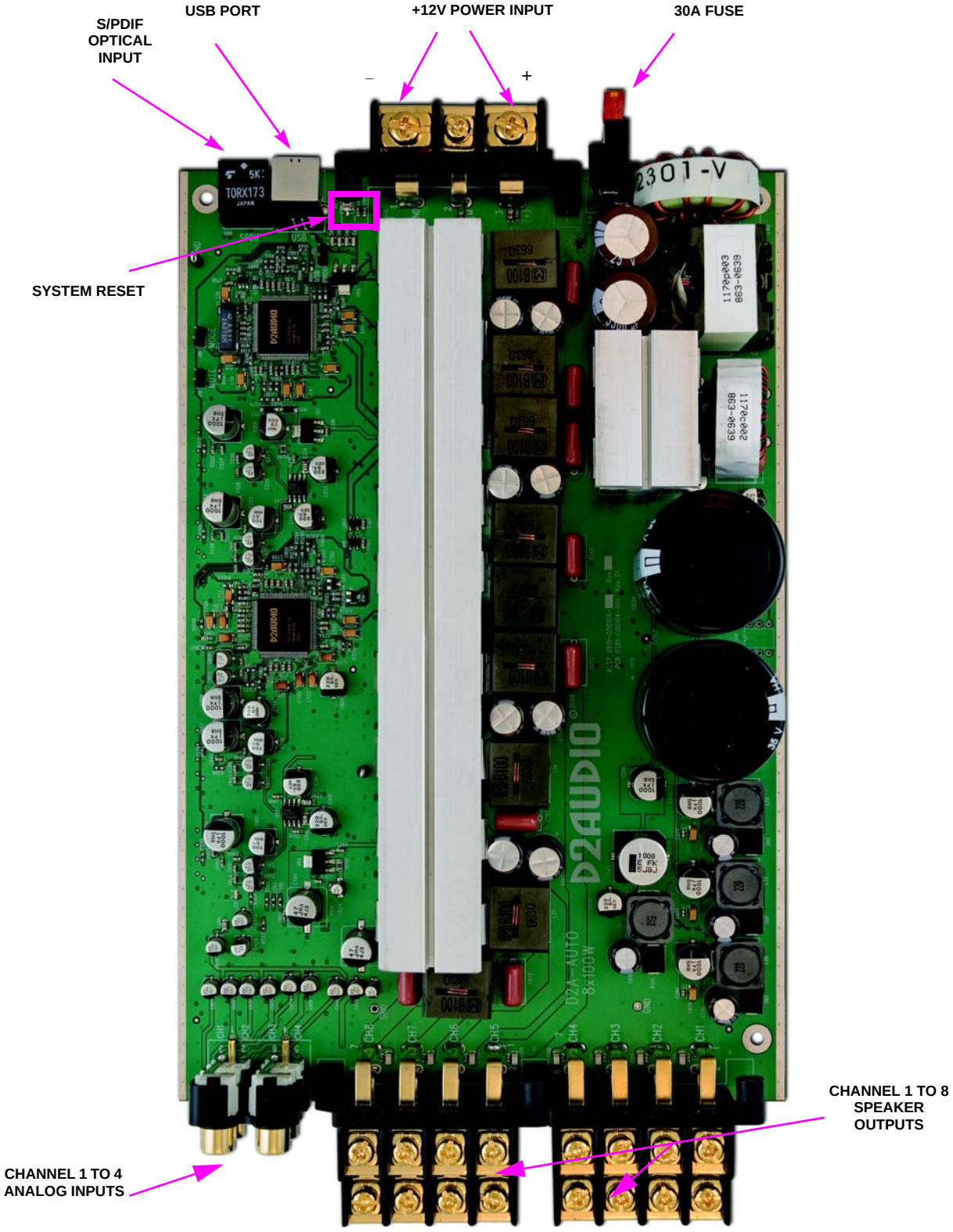

FIGURE 2. VA100-8 BOARD LAYOUT AND CONNECTION PLACEMENTS

Primary Connections To VA100-8

VA100-8 LOUDSPEAKER CONNECTIONS

The VA100-8 Digital Amplifier Module provides connections for the loudspeakers on 8 pairs of screw terminals, shown in Figure 3. The VA100-8 Digital Amplifier Module is designed to drive 2Ω loads. Other impedances can be driven without fear of damaging the amplifier as a current limit function is part of the design.

VA100-8 POWER CONNECTIONS

The VA100-8 Digital Amplifier Module requires an external +12VDC (V_{+VDC}) power source. Actual DC power input range is +8VDC to +16VDC, allowing for the nominal 13.6 to 14.4 VDC range typical for most automotive charging systems. Power connections are made to the screw terminals shown in Figure 4. Proper polarity is also indicated on the VA100-8 enclosure.

Power supply remote turn-on is enabled with connection of the remote connection (center terminal as shown in Figure 4) to the +12V source.

FIGURE 3. VA100-8 DIGITAL AMPLIFIER MODULE LOUDSPEAKER CONNECTIONS

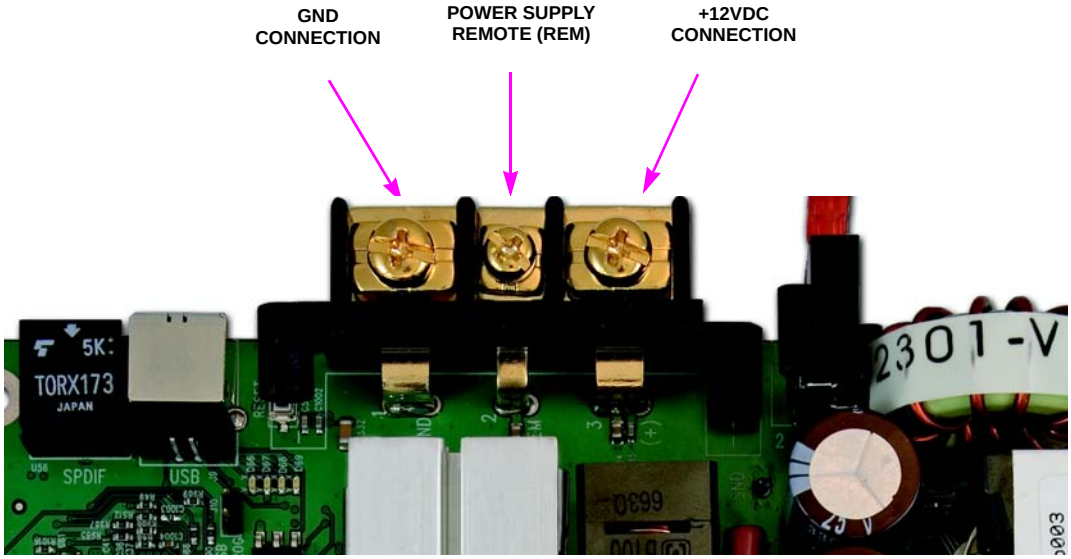

FIGURE 4. VA100-8 MODULE POWER CONNECTION

Audio Signal Flow

The VA100-8 Digital Amplifier Module supports an extensive DSP signal flow including Input Selection, 8x8 Matrix Mixer, Tone Control, Crossovers, 8-Band Parametric EQ, Master Volume Control, Loudness Contour, Compression, and Level Control (Channel Attenuation). Please see Figures 5 and 6 the Pre-mixer and Post mixer DSP Processing Blocks for graphic representation of the signal flow.

Configuration with Audio Canvas Software

All amplifier settings can be changed through the D2Audio Canvas software. This software provides a graphical interface and USB connection to a PC to adjust programmable block settings.

Once the module has powered up, the D2Audio Canvas software can be used to choose input selection to select between S/PDIF and the analog inputs to the module.

All other settings, including master volume, are stored in an EEPROM within the module and are loaded upon reset or power-on. After power-on, the Audio Canvas software can also be used to change these settings and can update the EEPROM with a new set of parameters if desired.

DSP Processing Blocks

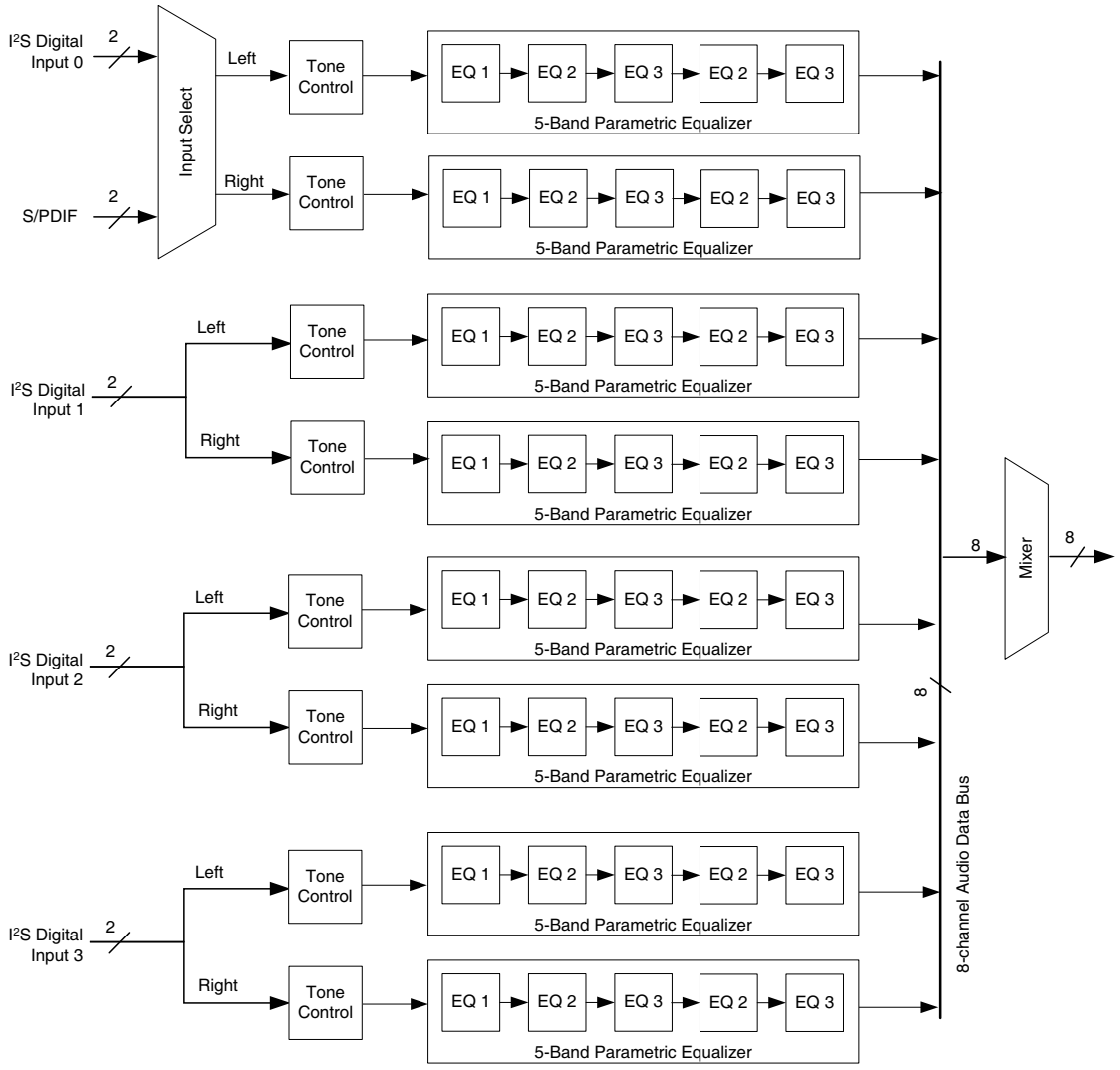

FIGURE 5. PRE-MIXER DSP PROCESSING BLOCKS

DSP Processing Blocks (Continued)

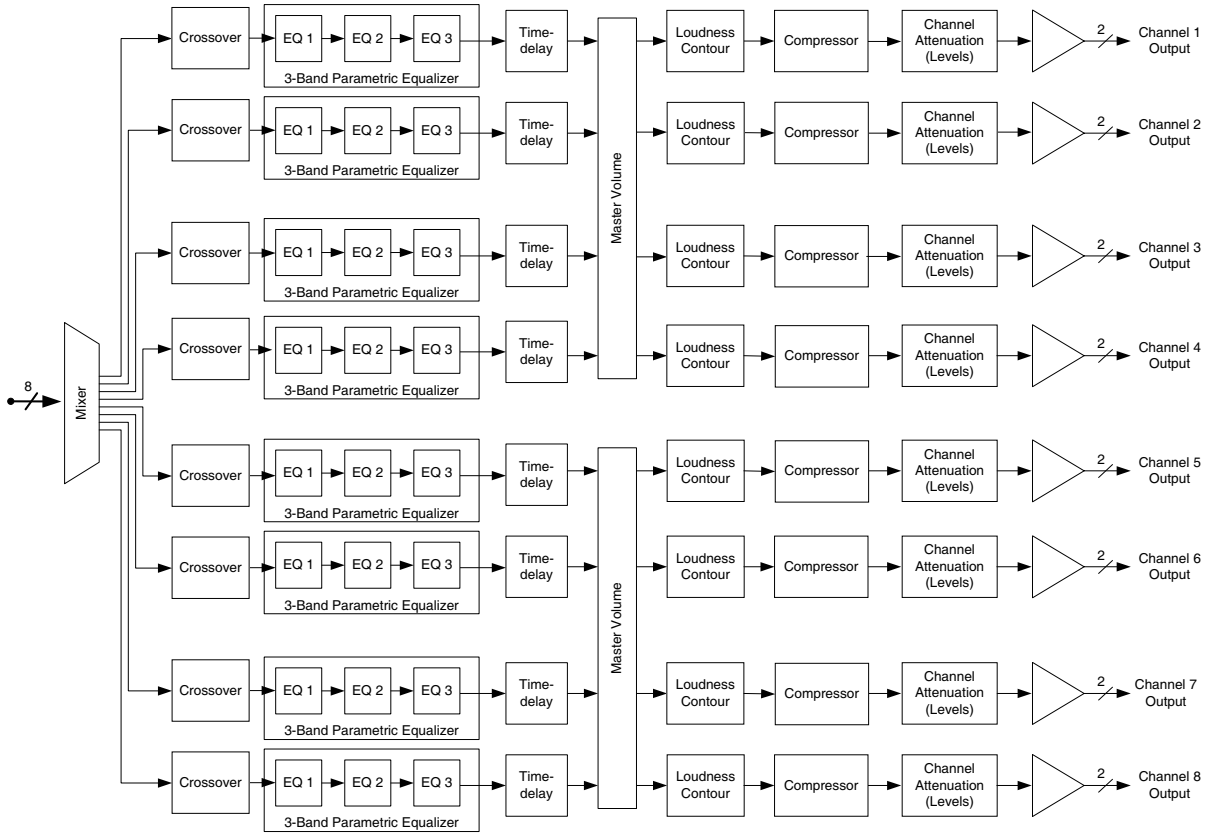

FIGURE 6. POST-MIXER DSP PROCESSING BLOCKS

Default DSP Settings

The VA100-8 Evaluation Kit ships from the factory with a default set of parameters typical to a commercial application.

- Input Mixer - Left and Right, -6dB
- Tone Control - Bass 0dB, Treble 0dB
- Subsonic Filter - 20.4Hz, 24dB/octave, butterworth
- Low Pass Filter - 24dB/octave, butterworth
- 8-Band Parametric EQ - 0dB all bands
- Time Delay - 0ms
- Loudness - off
- Compressor - Threshold 0dB, Gain 0dB
- Channel Attenuation - 0dB

VA100-8 Operation

Amplifier Operation

The inputs to the DAE-2 ICs, which are the PWM controllers with integrated DSP for the VA100-8 amplifier portion of the VA100-8 Evaluation Kit, are 2 digital SAI ports (Analog Inputs from the outside connected to internal ADCs) and 1 S/PDIF port. The input sources must be configured through software settings via the MCI port. This can be done via the USB port using the Canvas II GUI as well.

ACTIVATING THE AMPLIFIER

Upon power-up, the internal DAE-2 IC devices are reset and boot from the board's internal EEPROM. The board then becomes operational and no additional function or step is required.

OPERATIONAL LIMITATIONS

Do not operate the VA100-8 with signals with frequency content higher than 20kHz under no-load conditions. Peaking in the output filter can cause the output voltages to exceed the filter capacitor voltage rating. Avoid test tones above 20kHz.

Digital Audio Interfaces

The VA100-8 platform utilizes two internal digital SAI ports and one S/PDIF port. The SAI ports are connected to an on-board A/D Converter (ADC) to accommodate the 4 analog line inputs. Digital audio from the S/PDIF Digital input supports 2 channel digital LPCM sources. The S/PDIF audio input will accept a stereo input from 32kHz up to 192kHz and is a 3.3V input.

Audio Path Configurations

The audio path architecture is established by the board's operational firmware, and this architecture is shown in Figures 5 and 6. However, the individual processing blocks of this architecture are adjustable through the D2Audio Canvas software, allowing for changes such as volume settings, tine settings, and routings through the mixer.

GAIN CONSIDERATIONS

Careful attention must be paid to the signal level at the input and at each stage through the DSP in order to prevent clipping. Changes to DSP parameters must be made only after thorough consideration of the effects on signal level throughout the entire signal path from input to output. Although reducing the gain of the input signal will result in additional DSP headroom, this action will cause a corresponding reduction in the signal-to-noise ratio of the amplifier.

DSP GAIN STRUCTURE

At the input to the DSP, an attenuation of -6dB is applied to allow for headroom within the DSP processing blocks. At the DSP output, +18dB of gain is applied prior to driving the PWM amplifier outputs. This organization is shown in Figure 7.

Once a signal is input, 6dB of headroom is provided for all of the DSP processing blocks and volume controls. Clipping will occur if any of the DSP processing blocks cause the signal level to exceed 0dBFS. At the DSP processing final stage, a maximum of 18dB of gain is added prior to the PWM amplifier outputs. The module is designed to output full power (assuming the high-voltage supply is at the correct voltage) with a -0.5dBFS input signal, all other DSP processing functions and individual channel volume controls at unity gain, and the output master volume control set to +6dB.

GAIN CALCULATIONS

Proper gain management begins with determining the maximum module input level that is expected for the system design. If the S/PDIF or I^2S inputs are used, the maximum level can be as high as 0dBFS if connected directly to source material. If the analog inputs are used, a $2.0V_{RMS}$ sine wave signal is required to produce an input of 0dBFS to the DSP.

INPUT SOURCE CONFIGURATION

Analog inputs or digital S/PDIF inputs are available.

TONE CONTROL

The VA100-8 module provides individual software-controlled Tone Controls for each channel. These are implemented as low-pass and high-pass shelving filters for bass and treble control, respectively, which are added back into the signal flow. Each filter contains a first-order (6dB/octave) rolloff, with programmable corner frequency and gain. The DSP within the module will automatically provide a smooth transition between changes to the Tone Control.

PARAMETRIC EQUALIZER

Eight parametric equalizer bands are available on each channel: five pre-mixer and three post-mixer. Each band contains adjustable Frequency, Gain and Q. Setting the Gain to 0 disables a band. The DSP within the module will automatically provide a smooth transition between changes to the Parametric EQ.

MIXER

Any inputs of the VA100-8 module can be mixed and/or routed to any outputs through the Mixer. A configuration of up to 8-inputs/8-outputs is supported. The DSP within the module will automatically provide a smooth transition between changes to the Mixer.

LOW/HIGH-PASS FILTERS (CROSSOVER)

Four cascaded filter blocks are available for each channel. Each filter may be configured for low-pass or high-pass operation with adjustable slope and Q. Higher order slopes and bandpass functions can be achieved by using multiple low or high pass filters.

ADJUSTABLE TIME DELAY

Each channel of the VA100-8 module contains an Adjustable Time Delay for each channel. The DSP within the module will automatically provide a smooth transition between changes to the Adjustable Time Delay.

LOUDNESS CONTOUR

The VA100-8 module provides an individual software-controlled Loudness Contour for each amplifier channel. The Loudness Contour curve is customized to allow for dynamically and automatically enhancing the frequency response of the audio program material relative to the Master Volume Level setting. The Loudness Contour models the frequency response correction as defined by the Fletcher/Munson audio response curve. It provides for amplitude or volume changes to those signals to which the ear does not respond equally at very low listening levels. The integrated DSP within the module automatically

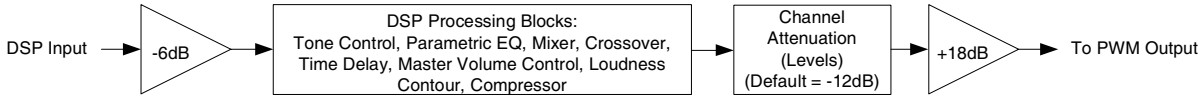

FIGURE 7. DSP GAIN STAGES

provides a smooth transition as the Master Volume Level setting is increased from the setting where the greatest enhancement is added to the point where there is no enhancement required. This Loudness Contour feature is disabled by default, but may be enabled as described in the following. Please refer to the D2Audio Loudness Contour White Paper for additional information about the implementation of this algorithm.

COMPRESSOR

The VA100-8 module provides individual software-controlled Compressors for each channel. Each Compressor has configurable Compression Ratio, Threshold, Attack and Release Time, as well as Makeup Gain. The DSP within the module will automatically provide a smooth transition between changes are written to the Compressor settings.

VOLUME CONTROL

Software-controlled Master Volume Control is provided, which controls the final gain for all output channels. Individual attenuators are also provided for each channel. The DSP within the module will automatically provide a smooth transition between changes to the Volume Control.

Specifications and Performance

Absolute Maximum Ratings

TABLE 1. ABSOLUTE MAXIMUM RATINGS

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Power Source Supply Voltage	V_{+VDC} Supply Source	8	14.4	16	V
Analog Input Signal Level	V_{RMS}	-	-	2	V_{RMS}
Nominal Operating Temperature Range (Note 1)	Amplifier ambient temperature (Note 2)	-40	-	50	°C
Storage Temperature Range	Ambient temperature	-	-	105	°C

NOTES:

1. Normal Operation refers to running the unit with one channel continuously with a sine wave for 5 minutes, or multiple channels running with music content.
2. Temperature surrounding the VA100-8 amplifier.

DC Power Requirements

T_A = +25°C, V_{+VDC} = 14.4V, Ground = 0V

TABLE 2. DC VOLTAGE REQUIREMENTS

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNIT
V_{+VDC}	Power Source Supply Voltage (Note 3)	8	14.4	16	V

NOTE:

3. Amplifier operation with High Voltage supply less than the maximum may result in reduced output power.

TABLE 3. DC CURRENT REQUIREMENTS

SYMBOL	DESCRIPTION	MIN	IDLE	MAX	UNIT
I_{+VDC}	Power Source (V_{+VDC}) Supply Current	0	1.5 (Note 4)	13.0 (Notes 5, 6)	A

NOTES:

4. Idle current measured with the amplifier in operation, but no audio input signal applied.
5. Maximum current measured with 1kHz sine wave output at rated power of 100W into 2Ω.
6. Current specification based on 2Ω loads under 1-Channel driven specification.

Performance Characteristics

Resistance load = 2Ω, T_A = +25°C, V_{+VDC} = 14.4V, Ground = 0V, S/PDIF 24-bit Input Sampled at 48kHz

TABLE 4. PERFORMANCE CHARACTERISTICS

SPECIFICATION	CONDITION	MIN	TYP	MAX	UNIT
Output Power (Note 7)	1-Channel Driven Continuously for 5 Minutes	-	100	-	W
Frequency Response	20Hz to 20kHz, 1W	-0.5	-	-0.5	dB
Dynamic Range		100	103	-105	dB
Output Distortion (THD+N)	20Hz to 20kHz, 100W	-	<1.0	-	%

NOTE:

7. With the appropriate amount of heat distribution via external heat sink. Heat sink size, amplifier ambient temperature, and external power supply voltage to the DC/DC converter all determine the ability for this amplifier to run under such a test. The OEM designer is of course free to use a different heatsink size as well as their own DC/DC converter design, which may increase or decrease the output power and test duration capability of the final amplifier design.

Performance Plots

The following graphs (8 through 12) show the VA100-8 amplifier performance. All inputs are driven with the same input signal, all inputs are mapped to their respective outputs. The output channels are tested one at a time with the channel under test is terminated with a 2Ω load, unless otherwise noted. The other outputs are open.

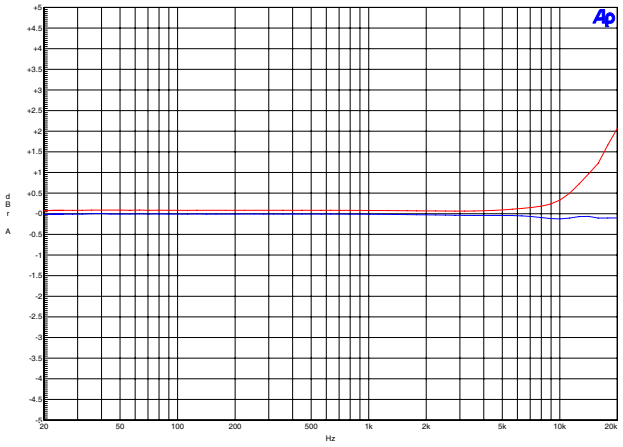

FIGURE 8. FREQUENCY RESPONSE (11W, 2Ω LOAD, 5.5Ω 4Ω LOAD)

Conditions: Typical Supplies, Room Temperature, S/PDIF 24-bit Input Sampled at 48kHz, 1-Channel Driven, Referenced to 11W at 1kHz Sine Wave, 12.5W Output Power, 2Ω Load (Blue Trace), 20Hz to 20kHz. The Red Trace shows 5.5W output into 4Ω below.

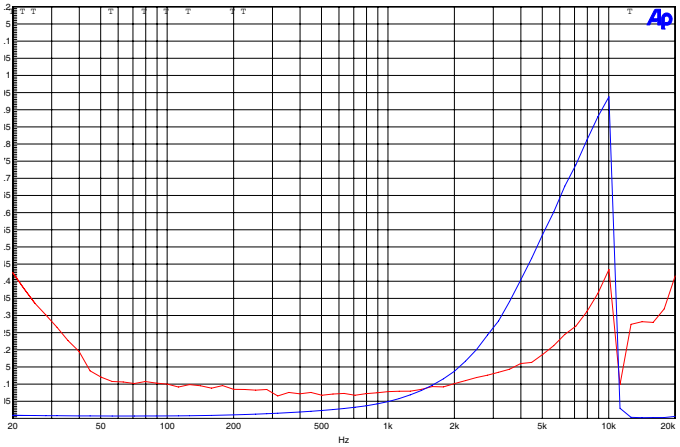

FIGURE 9. THD+N vs FREQUENCY (84W, 2Ω and 70W, 4Ω LOAD)

Conditions: Typical Supplies, Room Temperature, S/PDIF 24-bit Input Sampled at 48kHz, 84W Output Power (Blue Trace), 2Ω Load, and 70W Output Power (Red Trace), 4Ω Load, 20Hz to 20kHz, 20kHz AES17 Filter Enabled

Performance Plots

The following graphs (8 through 12) show the VA100-8 amplifier performance. All inputs are driven with the same input signal, all inputs are mapped to their respective outputs. The output channels are tested one at a time with the channel under test is terminated with a 2Ω load, unless otherwise noted. The other outputs are open. **(Continued)**

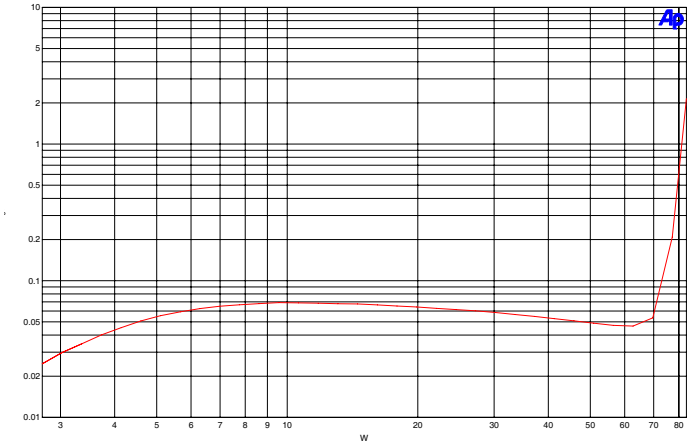

FIGURE 10. THD+N vs AMPLITUDE (1kHz SINE WAVE, 4Ω LOAD)

Conditions: Typical Supplies, Room Temperature, 24-bit I^2S Input Sampled at 48kHz, 1kHz Sine Wave, 20kHz AES17 Filter Enabled at 4Ω Load

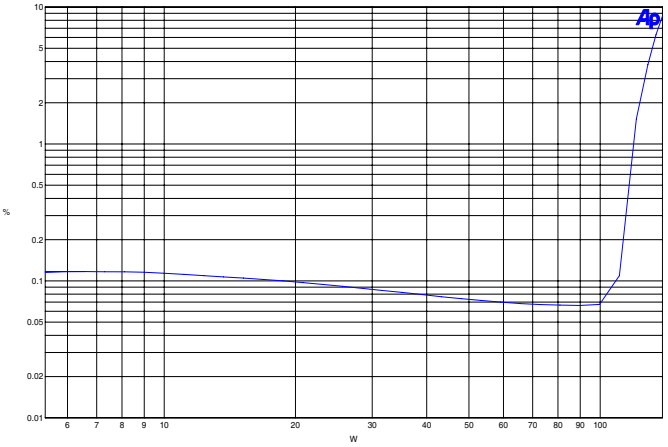

FIGURE 11. THD+N vs AMPLITUDE (1kHz SINE WAVE, 2Ω LOAD)

Conditions: Typical Supplies, Room Temperature, 24-bit I^2S Input Sampled at 48kHz, 1kHz Sine Wave, 20kHz AES17 Filter Enabled at 2Ω Load

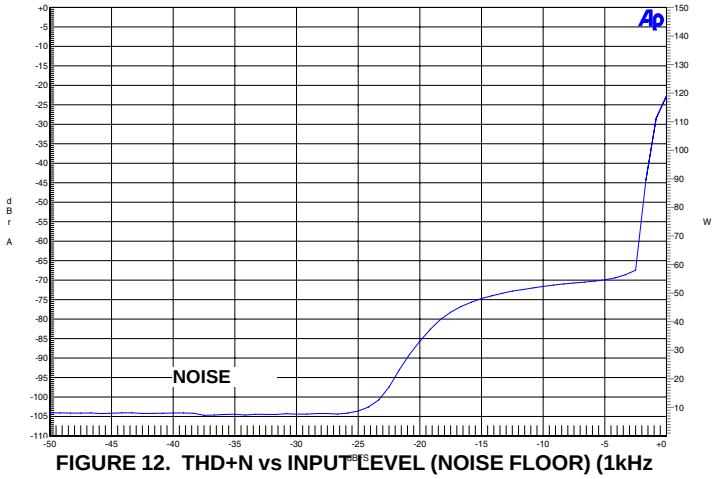

FIGURE 12. THD+N vs INPUT LEVEL (NOISE FLOOR) (1kHz SINE WAVE, 2Ω LOAD)

Conditions: Typical Supplies, Room Temperature, 24-bit I^2S Input Sampled at 48kHz, 1kHz Sine Wave, 2Ω Load, 20kHz AES17 Filter Enabled

Document Revision History

VERSION	DATE	
1.0.0	4/17/08	Initial Release
1.0.1	10/29/08	Conversion from book to Frame

Trademarks

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