

## 2 x 11 W CS3511 Digital Amplifier Reference Design

### Features

- ◆ Output Filters Optimized for 8 Ω Loads
- ◆ Delivers 9 W/Ch into 8 Ω at 10 % THD+N
- ◆ Delivers 11 W/Ch into 6 Ω at 10 % THD+N
- ◆ Single-Ended Stereo Analog Inputs
  - Source Impedance Matching Circuit
- ◆ Demonstrates Recommended 4-Layer Layout and Grounding Arrangements
- ◆ Operated by Single +8.5-13.2 V Power Supply
- ◆ Configured by On-Board Hardware Control
  - Control Mute, Sleep, and Gain Settings
- ◆ Power and Fault Indicator LEDs
  - Indicates Under-Voltage, Over-Current, or Over-Temperature Faults
- ◆ Versatile Binding Post Connectors for Power Supply and Speaker Outputs

### Description

The CRD3511-Q1 demonstrates the CS3511 high-efficiency Class-D amplifier. This reference design implements a two-channel amplifier that delivers 9 W per full-bridge channel into 8 Ω loads using a single +12 V supply.

Standard RCA phono jacks are provided to easily interface single-ended analog input signals with the evaluation board. A source impedance matching circuit on the board allows the full performance of the CS3511 to be tested with any available audio source.

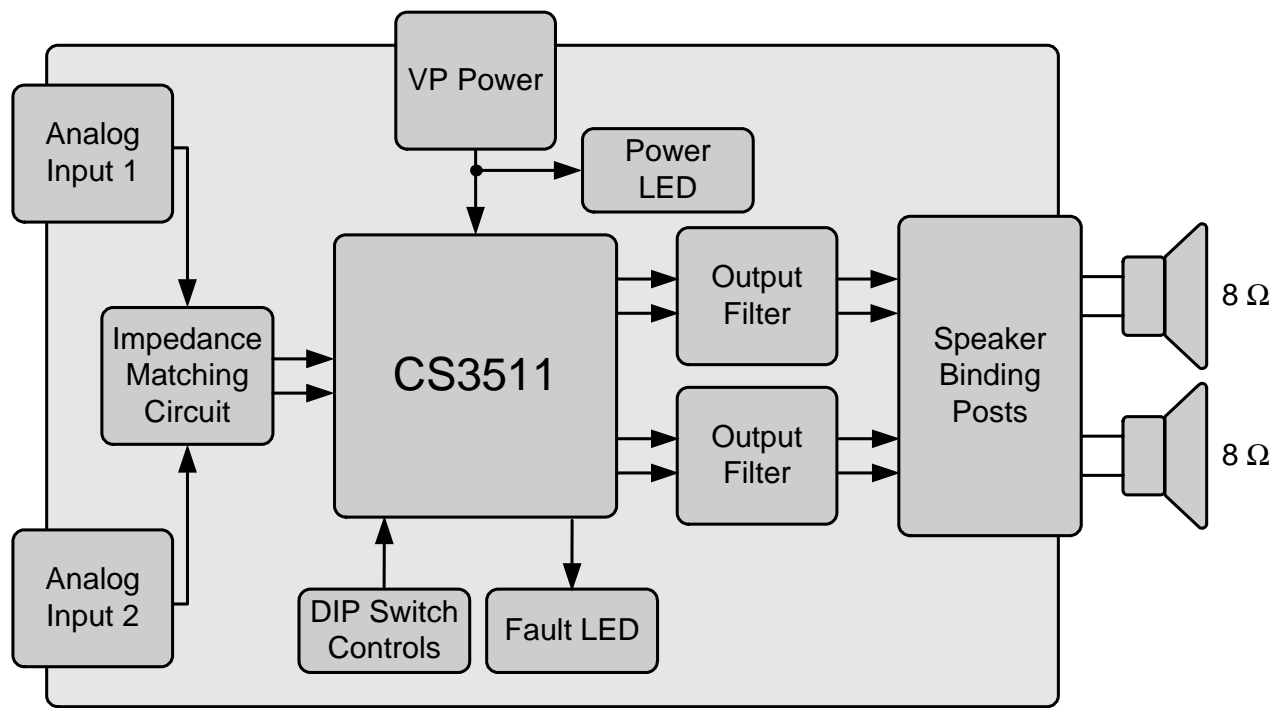
The audio power outputs are routed through an inductor/capacitor 2<sup>nd</sup> order low-pass filter (LPF) to remove high-frequency components from the output signal, effectively converting it from digital to analog.

On-board control switches easily change the configuration pins of the CS3511.

### ORDERING INFORMATION

CRD3511-Q1

CS3511 Reference Design



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## 1. SYSTEM OVERVIEW

The CRD3511-Q1 reference design is an excellent means for evaluating the CS3511 2 x 11 W class-D amplifier with integrated protection circuits. A single-ended stereo analog input signal interface is provided; on-board control switches are used for easy modification of the CS3511's configuration pins.

The CRD3511-Q1 schematic is shown in [Figure 1](#).

### 1.1 Power

A single +8.5 to +13.2 VDC power supply is required to power the CRD3511-Q1. The supply must be capable of delivering sufficient current (typically 2 A) for the intended power output. The supply provides power to the CS3511 and the operational amplifier used in the analog input circuit. The power supply connection to the board is provided by the binding posts J3 (positive terminal) and J9 (ground terminal).

### 1.2 CS3511 Class-D Amplifier

A complete description of the CS3511 is included in the CS3511 product data sheet. User configuration settings of the CS3511 are provided through the on-board control switches (see [Section 1.5](#)).

### 1.3 Analog Inputs

RCA connectors J7 (IN1) and J1 (IN2) supply the CS3511 with single-ended analog inputs through an optional source impedance matching circuit.

#### 1.3.1 *Optional Input Impedance Matching Circuit*

The CS3511 contains differential analog input stages, which require that the positive and negative input pins have the same series input impedance. In order to use a single-ended analog source with unknown source impedance with the CRD3511-Q1, an optional active input circuit is connected between the input connections on the board and the CS3511's input pins to match the source impedance on the CS3511's differential input pins.

The circuit consists of an operational amplifier which acts as a buffer to change the output impedance of the connected source seen by the CS3511. The operational amplifier, which has a near-zero output impedance, drives the positive analog input pin of the CS3511 while the negative analog input pin is AC coupled to ground. The operational amplifier circuit also implements a 2-pole low-pass filter to attenuate high-frequency energy prior to the inputs of the CS3511.

**Note:** The source impedance matching circuit may be removed by depopulating the operational amplifier, U2, and soldering across the capacitor pads of C43 and C45. 0  $\Omega$  series resistors (R3, R9, R10, R11) are present on each positive and negative input path to modify the series input impedance if needed.

#### 1.3.2 *Differential Audio Inputs*

The CRD3511 board is designed to accept single-ended audio inputs through the J1 and J7 RCA jacks. If it is desired to connect a differential audio input to the CS3511, the 0  $\Omega$  resistors (R3, R9, R10, R11) can be removed and the differential audio source can be connected to the resistor pads. Input coupling capacitors C3 and C4 will need to be reversed as noted in the schematic when operating the board with a differential audio input.

## 1.4 Speaker Outputs

The CS3511 power outputs are configured for stereo full-bridge operation. The outputs are routed through a 2<sup>nd</sup> order low-pass filter to remove high-frequency content from the output signals and then presented at the binding post terminals J5 (OUT1+), J6 (OUT1-), J2 (OUT2+), and J4 (OUT2-). The output filters are optimized for 8  $\Omega$  speaker loads.

## 1.5 CS3511 Configuration

The CRD3511-Q1 is controlled through the settings on switch S1. The switch can toggle the mute, sleep, and gain settings of the CS3511. See [Table 2](#) for details on each switch setting of S1.

**Note:** The MUTE switch should be set to HIGH (mute enabled) before powering on or off the CRD3511-Q1 to eliminate audible transients.

## 2. GROUNDING AND POWER SUPPLY DECOUPLING

The CS3511 requires careful attention to power supply and grounding arrangements to optimize performance and heat dissipation and minimize radiated emissions. [Figure 2 on page 7](#) shows the component placement. [Figure 3 on page 7](#) shows the top layout. [Figure 6 on page 9](#) shows the bottom layout. The decoupling capacitors are located as close to the CS3511 as possible. Extensive use of ground plane fill in the evaluation board yields large reductions in radiated noise.

### 2.1 Power Supply Decoupling

Proper power supply decoupling is one key to maximizing the performance of a Class-D amplifier. [Figure 2 on page 7](#) demonstrates good decoupling capacitor placement. Notice that the small value decoupling capacitors are placed as close as physically possible to the power pins of the CS3511. The ground side of the capacitors is connected directly to top-side ground plane, which is also used by the power supply return pins. This placement keeps the high-frequency current loop small to minimize power supply variations and EMI. 220  $\mu$ F electrolytic capacitors are also located in close proximity to the power supply pins to supply the current locally for each channel. These are not required to be expensive low-ESR capacitors. General-purpose electrolytic capacitors that are specified to handle the ripple current can be used.

### 2.2 Electromagnetic Interference (EMI)

This reference design is a board-level solution that is meant to control emissions by minimizing and suppressing them at the source, in contrast to containing them in an enclosure.

The EMI requirements for an amplifier have added dimensions beyond those imposed on power supplies. Audio amplifiers are usually located close to radio receivers, particularly AM receivers. This situation can create interference for the receiver due to the amplifier switching frequency's proximity to the receiver's bandwidth. Amplifiers also need to operate with speaker leads of unpredictable length and construction which makes it possible for any high-frequency currents that appear on the outputs to generate nuisance emissions.

#### 2.2.1 Suppression of EMI at the Source

Several techniques are used in the circuit design and board layout to minimize high-frequency fields in the immediate vicinity of the high-power components. Specific techniques include the following:

- As mentioned in [Section 2.1](#), effective power supply decoupling of high-frequency currents and minimizing the loop area of the decoupling loop is one aspect of minimizing EMI.

- Each output of the CS3511 includes “snubbing” components. For example, OUT1+ includes snubber components R13 (5.62 Ω) and C23 (680 pF). These components serve to damp ringing on the switching outputs in the 30-50 MHz range. The snubbing components should be as close as practical to the output pins to maximize their effectiveness.
- A separate ground plane with a solid electrical connection to the chassis, and which surrounds the speaker output connectors, should be implemented. This practice allows the speaker outputs to be RF-decoupled to the chassis just before they exit the chassis from the speaker connectors.
- A solid ground plane on the adjacent PCB layer underneath all high-frequency traces to minimize the loop area of the return path.

### 3. SYSTEM CONNECTORS AND JUMPERS

Connector Name	Reference Designator	Signal Direction	Connector Function
PWR	J3	Input	Positive connection from power supply, +8.5 to +13.2 VDC.
GND	J9	Input	Ground connection from power supply.
IN1 IN2	J7 J1	Input	Analog input to CS3511.
OUT1+ OUT1- OUT2+ OUT2-	J5 J6 J2 J4	Output	Analog output from CS3511.

**Table 1. System Connections**

Control Name	Position	Function Selected
MUTE	1	Low = Mute disabled High = Mute enabled
SLEEP	2	Low = Sleep disabled High = Sleep enabled
GAIN[1:0]	3,4	[Low:Low] = Invalid gain setting [Low:High] = Gain is 21.6 dB [High:Low] = Gain is 26 dB [High:High] = Gain is 29.5 dB

**Table 2. S1 Settings**

# 4. CRD SCHEMATIC

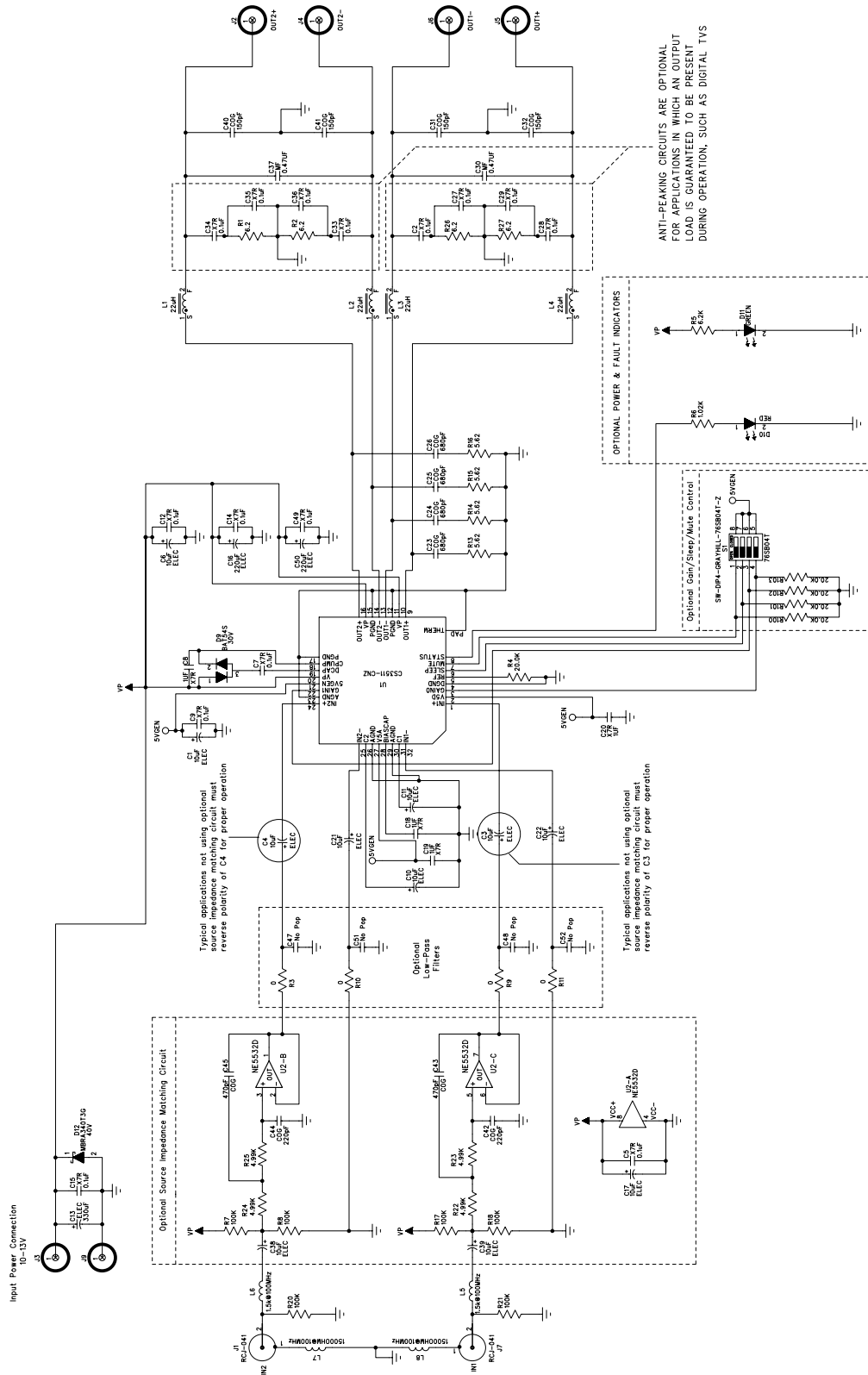
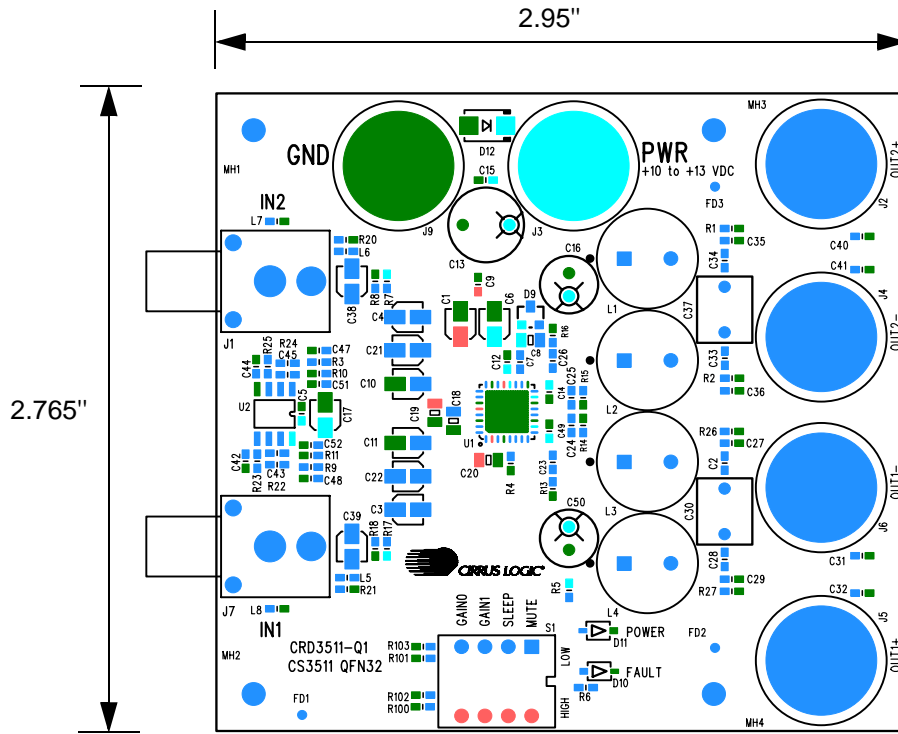
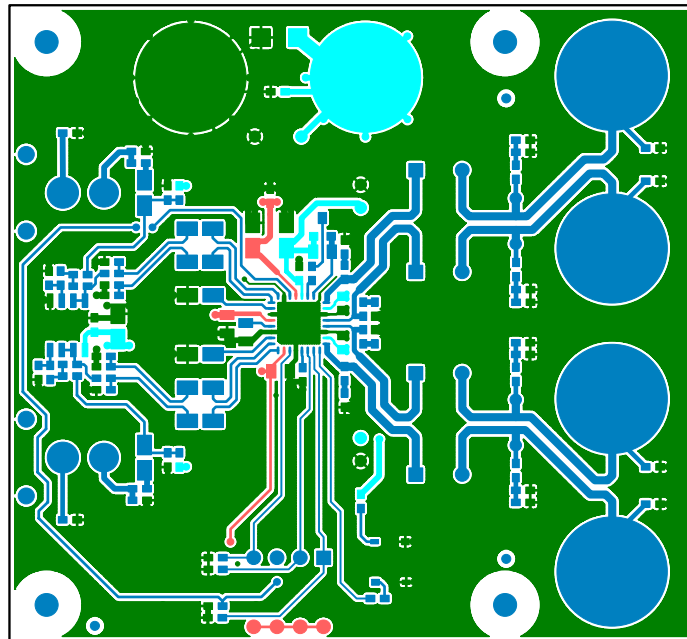


Figure 1. CRD3511-Q1 Schematic

**5. CRD LAYOUT**

**Figure 2. Component Map**

**Figure 3. Top-Side Copper Layer**

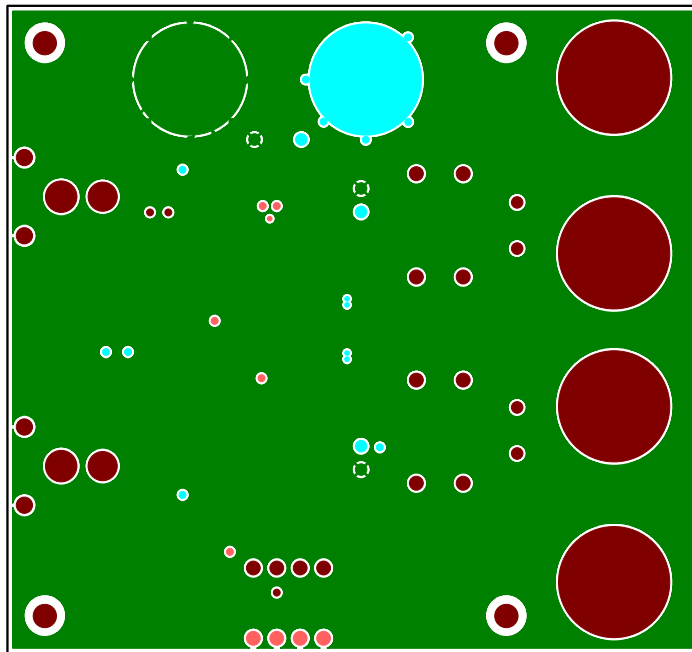


Figure 4. Inner Copper Layer 1

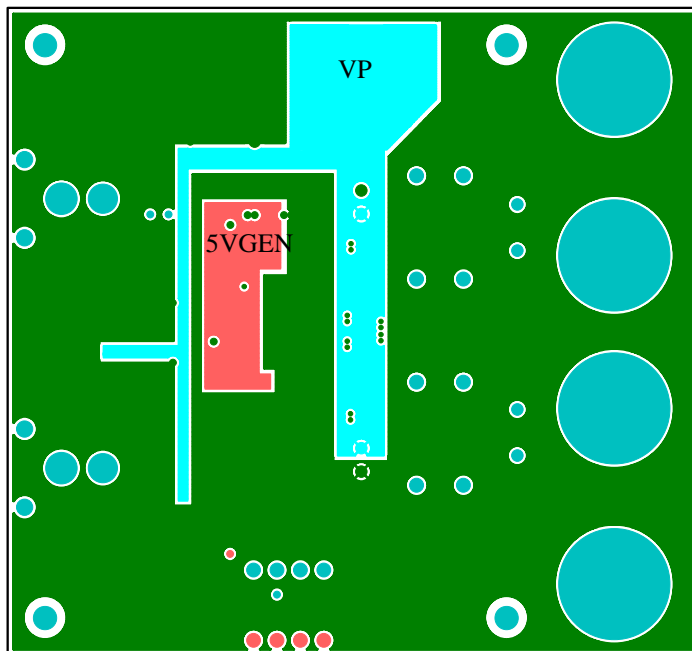


Figure 5. Inner Copper Layer 2

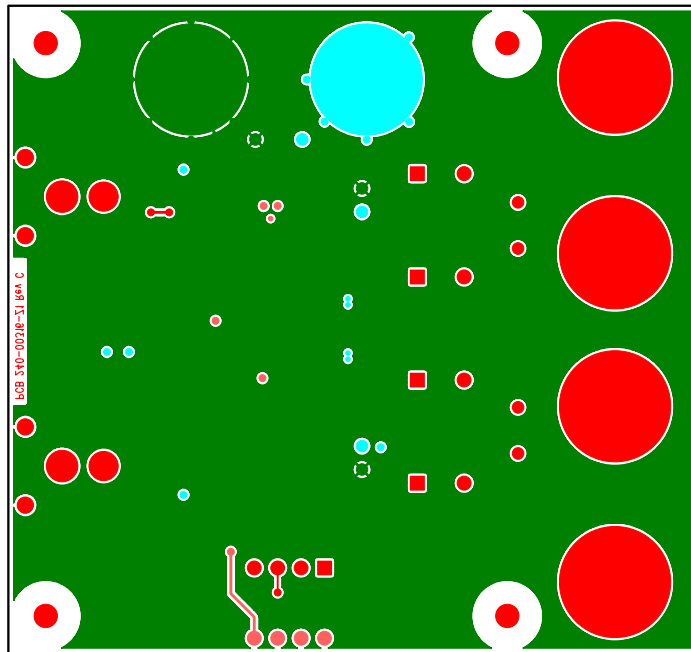
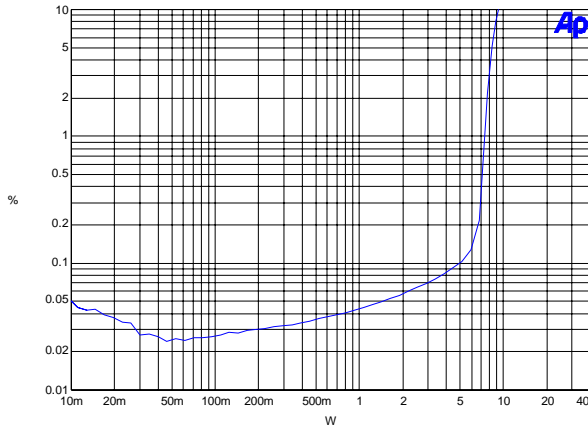


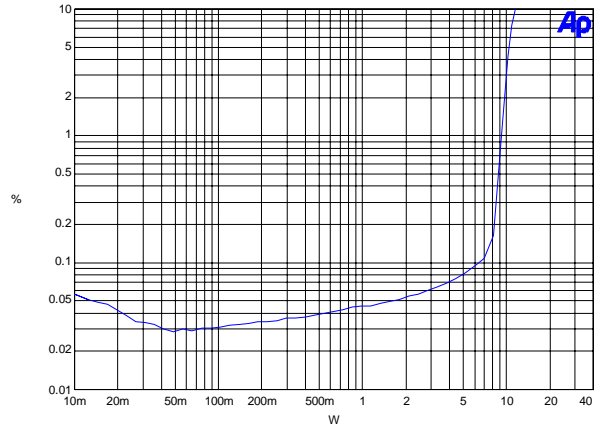
Figure 6. Bottom-Side Copper Layer

## 6. PERFORMANCE PLOTS

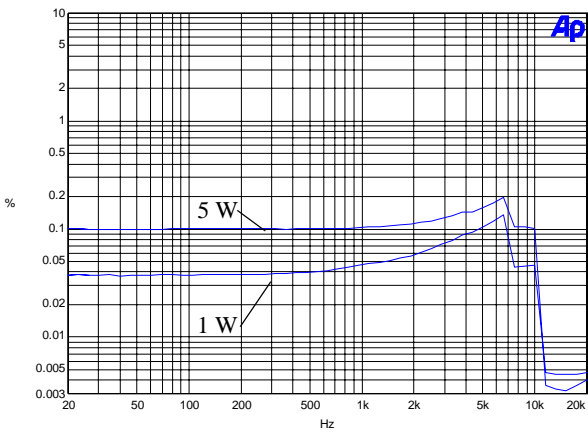
Test Conditions (unless otherwise specified):  $T_A = 25^\circ\text{C}$ ; Performance measurements taken with a full-scale 997 Hz sine wave and AES17 20 Hz to 20 kHz measurement filter; GAIN1 = 0, GAIN0 = 1; VP = 12 VDC.



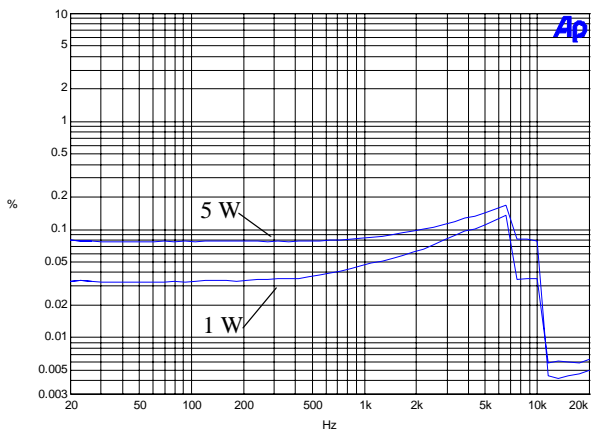
**Figure 7. THD+N vs. Output Power ( $R_L = 8\ \Omega$ )**



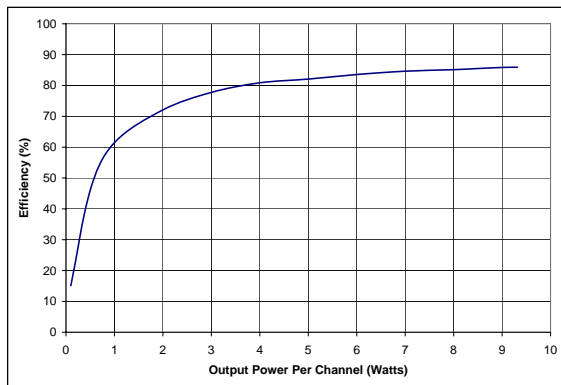
**Figure 8. THD+N vs. Output Power ( $R_L = 6\ \Omega$ )**



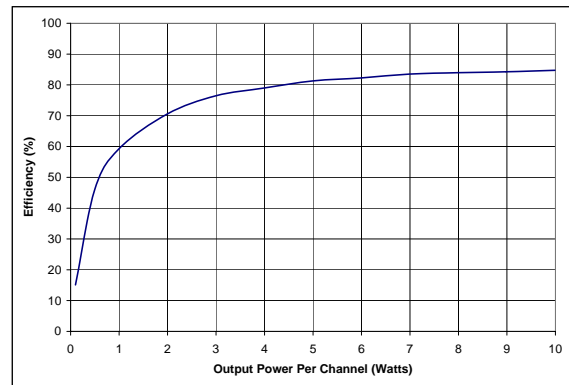
**Figure 9. THD+N vs. Frequency ( $R_L = 8\ \Omega$ )**



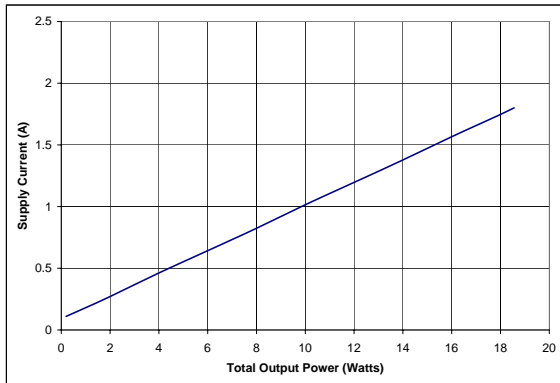
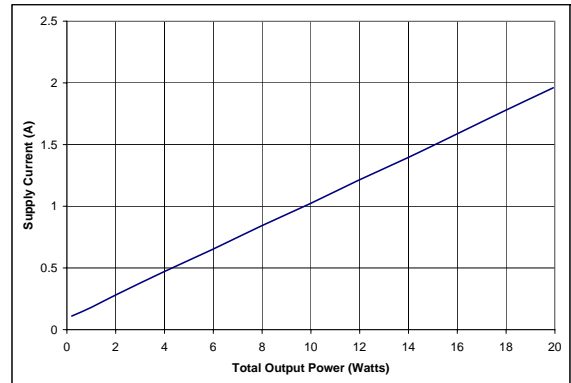
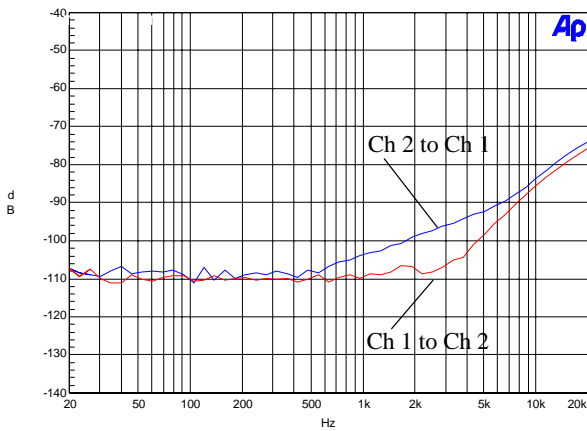
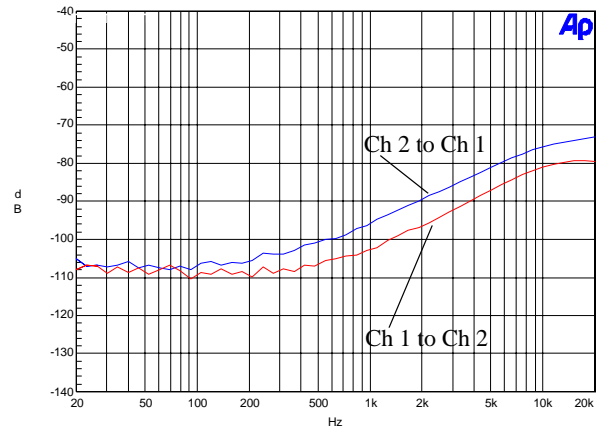
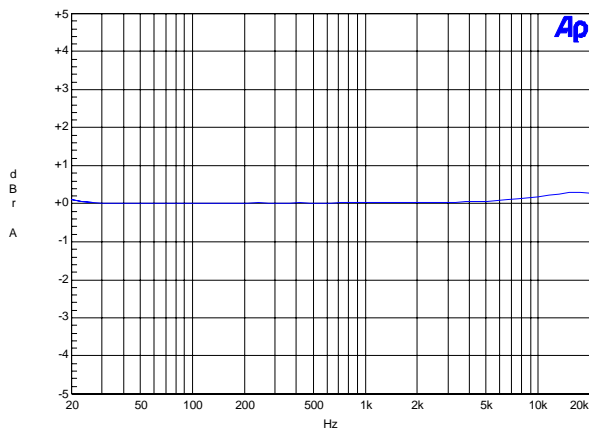
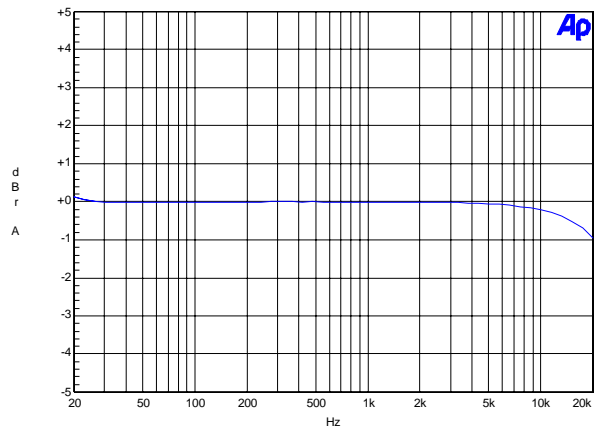
**Figure 10. THD+N vs. Frequency ( $R_L = 6\ \Omega$ )**

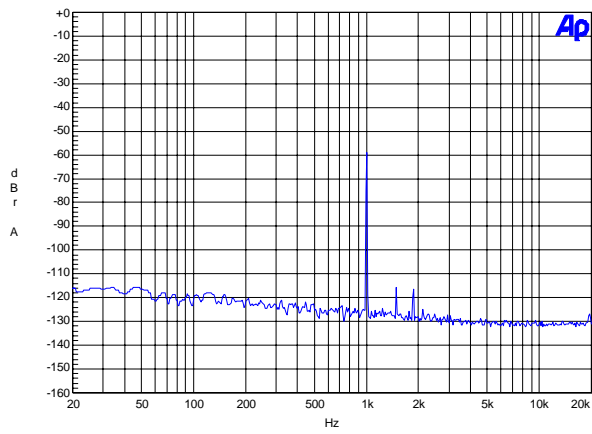
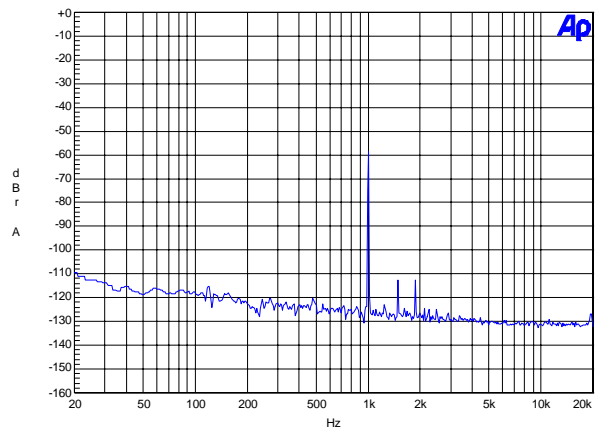
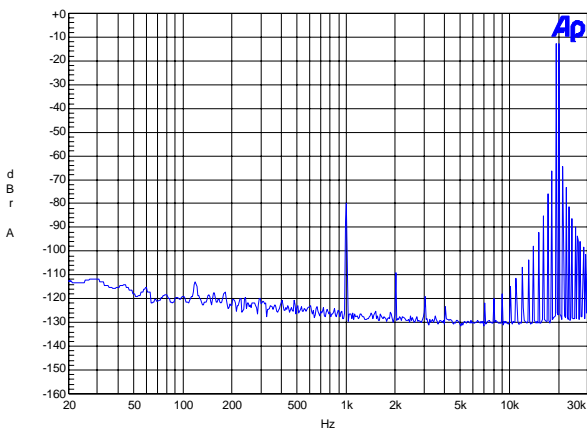
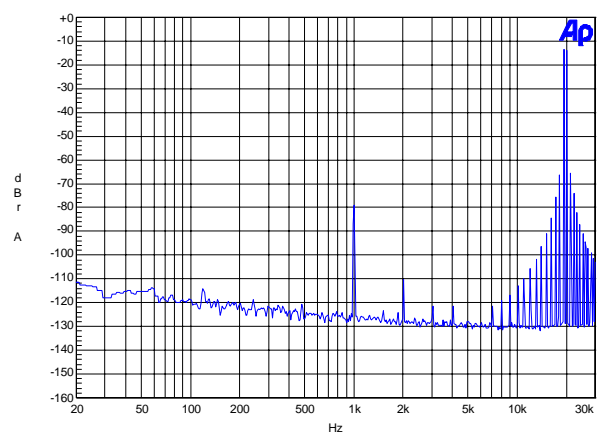


**Figure 11. Efficiency vs. Output Power ( $R_L = 8\ \Omega$ )**



**Figure 12. Efficiency vs. Output Power ( $R_L = 6\ \Omega$ )**


**Figure 13. Supply Current vs.  $P_{OUT}$  ( $R_L = 8 \Omega$ )**

**Figure 14. Supply Current vs.  $P_{OUT}$  ( $R_L = 6 \Omega$ )**

**Figure 15. Crosstalk vs. Frequency ( $R_L = 8 \Omega$ )**

**Figure 16. Crosstalk vs. Frequency ( $R_L = 6 \Omega$ )**

**Figure 17. Frequency Response ( $P_{OUT} = 1 \text{ W}$ ,  $R_L = 8 \Omega$ )**

**Figure 18. Frequency Response ( $P_{OUT} = 1 \text{ W}$ ,  $R_L = 6 \Omega$ )**


**Figure 19. Dynamic Range FFT ( $R_L = 8 \Omega$ )**

**Figure 20. Dynamic Range FFT ( $R_L = 6 \Omega$ )**

**Figure 21. Intermodulation FFT ( $P_{OUT} = 1 W, R_L = 8 \Omega$ )**

**Figure 22. Intermodulation FFT ( $P_{OUT} = 1 W, R_L = 6 \Omega$ )**

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## 7. THERMAL DE-RATING

The CS3511 is available in a compact QFN package. The underside of the QFN package reveals a large metal pad that serves as a thermal relief for maximum heat dissipation. The pad mates with an equally dimensioned copper pad on the PCB and must be electrically connected to ground. This arrangement effectively uses the PCB as the CS3511 amplifier's heat sink.

Several parameters of the amplifier's associated PCB design, such as layout, number of layers, and copper weight, will affect the thermal resistance the PCB presents to the amplifier and can therefore impact the amplifier's maximum sustained output power. During operation, the amplifier will generate heat that will flow into the PCB and then out to the ambient air surrounding the board. The more output power the amplifier is delivering, the more heat it will produce. Because the transfer of heat is less effective at greater ambient temperatures, the amplifier's maximum sustainable output will be related to the ambient temperature.

The CRD3511-Q1 is a four-layer PCB with 1 oz. (0.036 mm thick) copper. It is designed to minimize the thermal resistance from the CS3511 to the ambient air. This optimum board configuration and layout allows the CS3511 to produce and sustain its rated 11 W per channel output power in ambient temperatures as high as 65°C without any thermal errors.

For more information concerning thermal considerations of QFN packages, please refer to Cirrus Logic application note AN315.

## 8. REVISION HISTORY

Release	Changes
RD1	Initial Release.
RD2	<p>Updated <a href="#">Section 1.3.1 “Optional Input Impedance Matching Circuit”</a> on page 3 filter description.</p> <p>Added <a href="#">Section 1.3.2 “Differential Audio Inputs”</a> on page 3.</p> <p>Updated output power rating to 11W with a 6 Ω load on the front page.</p> <p>Updated power input range to +8.5-13.2 V on the front page, in <a href="#">Section 1.1 on page 3</a>, and in <a href="#">Section Table 1. on page 5</a>.</p> <p>Updated to reflect Rev D PCB schematic and layout design.</p>

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