

## 50 W Half-Bridge Reference Design for the CS44800

### Features

- Eight half-bridge channels, 50 W each
- Least amount of discrete components per channel
- Programmable load compensation
- Power Supply Rejection (PSR) feedback allowing amplifier to operate from low cost linear unregulated power supplies
- Peak signal limiting
- Thermal and over-current protection
- > 85% amplifier efficiency
- Works with GUI to configure the board or in a standalone mode for easy operation.
- Demonstrates recommended layout and grounding arrangements

### Description

The CRD44800 PWM Amplifier demonstrates the CS44800, Cirrus' eight-channel pure digital PWM controller. This reference design implements an eight-channel amplifier which delivers 50 W per half-bridge

channel into 6 Ω loads using a single +45 V supply (at 10% THD+N). A 155 W Switched Mode Power Supply (SMPS) is used to power the CRD44800.

As shown below, the CS44800 IC takes four stereo digital audio inputs in I<sup>2</sup>S format and converts them to PWM outputs. This 64-pin LQFP IC provides an integrated sample rate converter for 32 kHz-192 kHz input sample rate support, volume up/down, speaker load compensation, PopGuard® to prevent pops in single voltage rail half-bridge applications, peak limiting to prevent amplifier clipping, power supply ripple compensation, and AM frequency interference elimination.

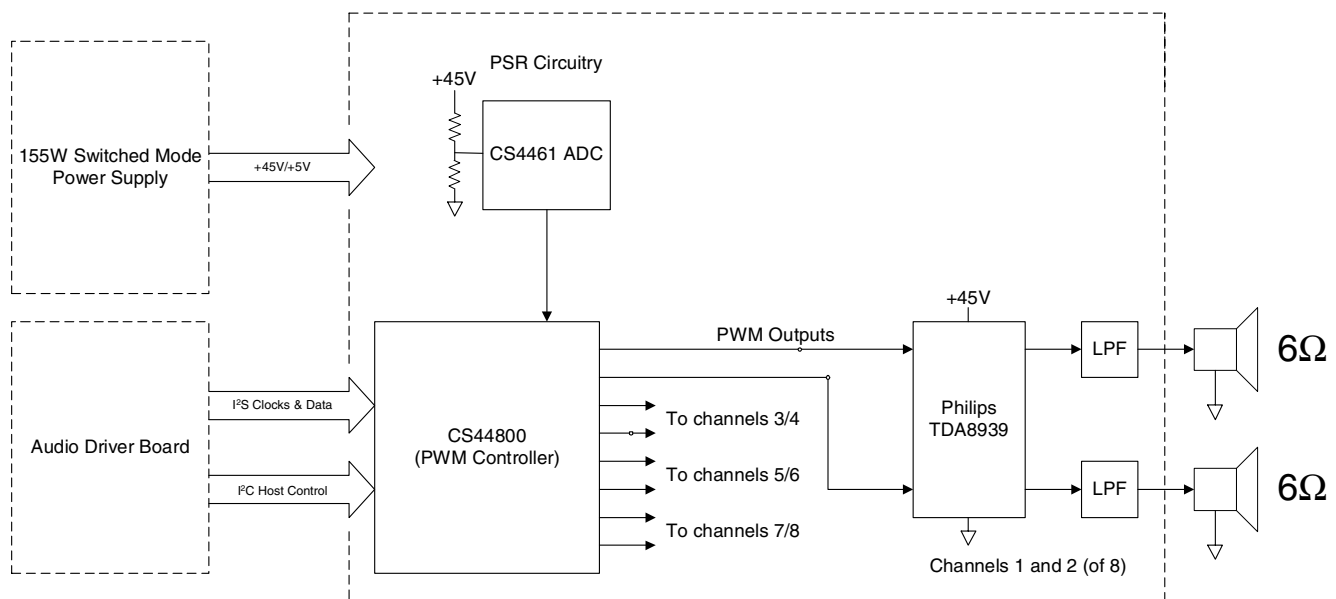
This reference design uses the the Philips TDA8939, an integrated power stage back end for digital amplifiers (four TDA8939 parts configured as half-bridges are used for this eight-channel design). Current limiting and thermal protection are provided by the TDA8939.

The inductor/capacitor 2<sup>nd</sup> order low pass filter (LPF) removes high frequency components from the output signal effectively converting it from digital to analog.

### ORDERING INFORMATION

CRD44800

Reference Design



## TABLE OF CONTENTS

<b>1. SCHEMATIC DESCRIPTIONS .....</b>	<b>3</b>
1.1 CRD44800 PWM Amplifier .....	3
1.2 CRD44800 Driver Board .....	3
1.3 Switched Mode Power Supply .....	4
<b>2. OPERATION INFORMATION .....</b>	<b>5</b>
2.1 Power Supply Ratings .....	10
2.2 Power Supply Decoupling .....	10
2.3 Electromagnetic Interference (EMI) .....	11
2.3.1 Suppression of EMI at the Source .....	11
<b>3. SCHEMATICS .....</b>	<b>13</b>
<b>4. LAYOUT .....</b>	<b>20</b>
<b>5. BILL OF MATERIALS .....</b>	<b>23</b>
<b>6. TYPICAL PERFORMANCE PLOTS .....</b>	<b>25</b>
<b>7. REVISION HISTORY .....</b>	<b>29</b>

## LIST OF FIGURES

Figure 1. Speaker Terminal Configuration .....	6
Figure 2. CS44800 Dialog Tab.....	8
Figure 3. Advanced Register Debug Tab - CS44800.....	9
Figure 4. Power and Connectors.....	13
Figure 5. CS44800 .....	14
Figure 6. Left/Right Back Surround Channels.....	15
Figure 7. Left/Right Surround Channels.....	16
Figure 8. LFE/Center Channels.....	17
Figure 9. Left/Right Channels.....	18
Figure 10. PSR Feedback .....	19
Figure 11. Silk Screen Top.....	20
Figure 12. Topside Layer .....	21
Figure 13. Bottomside Layer .....	22
Figure 14. Bill of Materials.....	23
Figure 15. Bill of Materials.....	24
Figure 16. Frequency Response .....	25
Figure 17. THD+N vs. Frequency at 1 W, 10 W, and 20 W .....	26
Figure 18. THD+N vs. Power at 1 kHz .....	27
Figure 19. FFT at -60 dBFS and 1 kHz .....	28

## LIST OF TABLES

Table 1. RMS Output Voltage for Given Load Impedance .....	3
Table 2. Revision History .....	29

## 1. SCHEMATIC DESCRIPTIONS

### 1.1 CRD44800 PWM Amplifier

The CS44800 shown in Figure 5 employs a built-in Sample Rate Converter (SRC) to support all popular sampling frequencies between 32 kHz and 192 kHz. The CS44800 produces a PWM frequency of either 384 kHz or 768 kHz (refer to CS44800 data sheet). In this design, analog or digital audio signals are always output at a 384 kHz PWM rate.

The CS4461 ADC is used to monitor the signal and line frequency related ripple that is inevitable on the power supply rail when the amplifiers operate. The ripple voltage is digitized and fed back to the CS44800. The CS44800 uses this information to substantially reduce ripple related distortion and noise in the audio output signal.

Four Philips TDA8939 power stages provide the power back end to drive the speaker loads. Each TDA8939 consists of a pair of over current and temperature protected half-bridge PWM output stages. The TDA8939 is performance optimized for use in open loop Class D amplifier systems. By changing the power supply voltage and/or the load impedance, RMS output power at the speaker can be increased. Table 1 illustrates measured RMS output voltage when using the TDA8939 configured as a half-bridge:

Supply Voltage		RMS Output Power with an 8 $\Omega$ Load	RMS Output Power with a 6 $\Omega$ Load	RMS Output Power with a 4 $\Omega$ Load
45 V	1% THD+N	25 W	33 W	47 W
	10% THD+N	38 W	50 W	70 W
50 V	1% THD+N	32 W	41 W	57 W
	10% THD+N	47 W	61 W	86 W
55 V	1% THD+N	38 W	50 W	69 W
	10% THD+N	57 W	74 W	105 W
60 V	1% THD+N	44 W	58 W	81 W
	10% THD+N	67 W	88 W	124 W

**Table 1. RMS Output Voltage for Given Load Impedance**

### 1.2 CRD44800 Driver Board

The CRD44800 Driver board provides a convenient source of PCM I<sup>2</sup>S signals to drive the CRD44800 PWM Amplifier board. Eight analog inputs allow multi-channel analog audio signals to be used for evaluation of the amplifier. In addition, either optical or coaxial stereo S/PDIF signals can be used to evaluate the amplifier. In this case, the left and right channel digital data are distributed to each of the additional channel pairs.

The CRD44800 Driver board provides two modes of operation: stand-alone and remote. In the stand-alone mode, basic evaluation of the CS44800 is possible. The user can select between analog and digital S/PDIF input signals (jumpers J17 and J18), control the system volume, mute and unmute the system (switch S2), and ramp the PWM output up and down (switch S3).

In the Remote mode, the DB-9 connector (J14, labelled RS-232) is connected to a host PC. All aspects of the CS44800 may then be evaluated using the supplied software.

### **1.3 Switched Mode Power Supply**

The SMPS used for the CRD44800 is a 155W OEM supply. The supply provides +45V for the TDA8939 PWM back ends, and +5V to power all the signal level circuitry. The SMPS is fully over-current and over-temperature protected.

## 2. OPERATION INFORMATION

### Switches and Indicators (Located on the Driver Board):

**RESET** Pushbutton (S1) - forces a complete system reset.

**MUTE** Pushbutton (S2) - mutes the audio output of the CRD44800, but the PWM output stage will continue switching.

**RAMP UP/DN** Pushbutton (S3) - forces a ramp down or a ramp up of the PWM switching output. After a ramp down, the PWM output stage is no longer switching.

**MUTE LED** (D16) - indicates that the audio output is muted. The MUTE LED is also used during CRD44800 initialization (see below).

**FAULT LED** (D19) - indicates several types of fault conditions. If one (or more) of the PWM outputs is shorted, or the PWM back end overheats, the FAULT LED will light. Also, if either the Optical or Coax digital input is selected as the system input and a valid digital signal is not present, the FAULT LED will light. The FAULT LED is also used during CRD44800 initialization (see below).

**S/PDIF ERROR LED** (D6) - indicates the absence of a valid S/PDIF signal into the CS8416.

### Stand-alone Operation

The CRD44800 evaluation system is prewired for operation. The SMPS is a universal input, 90-260VAC, 50/60Hz.

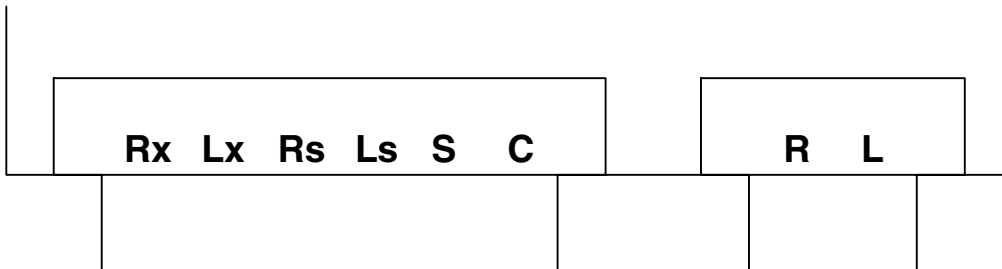
- 1) Attach the supplied power cord to the power entry module. Do not turn on the power yet.
- 2) Configure jumper J10 for the desired volume control mode. If J10 is in, the gain of the CS44800 will be forced to 0dB, irrespective of the position of the volume control pot. If J10 is out, the volume control pot determines the CS44800 gain.
- 3) Configure jumpers J17 and J18 for the desired mode of operation. The first three options are stand-alone, while the final option is remote.

Function	J17	J18
Analog Inputs	1 - 2	1 - 2
Coaxial S/PDIF	2 - 3	1 - 2
Optical S/PDIF	1 - 2	2 - 3
Remote Mode	2 - 3	2 - 3

- 4) If the Analog input mode is selected, configure jumpers J6 and J7 to select the sampling frequency for the CS5341s.

Sample Rate (Fs)	J6	J7
48 kHz	2 - 3	2 - 3
96 kHz	1 - 2	2 - 3
192 kHz	2 - 3	1 - 2

- 5) Supply either analog signals (if the Analog input option is selected) or either coaxial or optical digital PCM inputs (if the digital S/PDIF option is selected).
- 6) Connect loudspeakers to the speaker output terminals. The Red terminal is positive, and the Black terminal is ground.



**Figure 1. Speaker Terminal Configuration**

Turn the volume control fully counterclockwise and apply power using the power switch on the power entry module. The Fault and Mute LEDs will both light briefly as the system is initialized. Note that if either the Coax or the Optical input is selected, a valid digital signal must be provided to the selected input so that the CRD44800 can complete initialization. If a valid signal is not present at the selected input, both the Fault and Mute LEDs will remain lit.

If one of the stand-alone modes is selected, the amplifiers should now be operating. Slowly advance the volume control clockwise until the desired volume is achieved. The **MUTE** pushbutton (S2) may be used to mute and unmute the audio output. The **RAMP UP/DN** pushbutton (S3) will initiate a ramp up or ramp down of the audio output. Ramping down the audio output stops any audio output. In order to avoid a “pop” in the speakers, you should ramp down the outputs before turning off the AC power.

Note that in the stand-alone mode, several system faults are indicated by the lighting of the red Fault LED, D19. Typical causes for fault conditions are short circuited speaker outputs, thermal shutoff of the power back end, or lack of a S/PDIF signal when either of the S/PDIF inputs is selected.

### Remote Operation

The CRD44800 may also be operated remotely via the Cirrus FlexGUI for complete control of all the features of the CS44800. Note that the Fault and Mute LEDs operate differently in the remote mode. They indicate the selected audio signal input as explained below. Follow the procedure below to set up remote operation.

- 1) Attach the supplied power cord to the power entry module. Do not turn on the power yet.
- 2) Configure jumpers J17 and J18 for remote operation. Jumpers J17 and J18 should have pins 2 and 3 connected for remote operation. Jumpers J6 and J7 should be removed completely.
- 3) Turn on the AC power. Press the Reset button on the driver board. Select the desired audio

input source by pressing the Mute button. The following table shows the inputs selections:

Selected Input	Mute LED	Fault LED
Analog Inputs	On	Off
Optical S/PDIF	Off	On
Coaxial S/PDIF	On	On

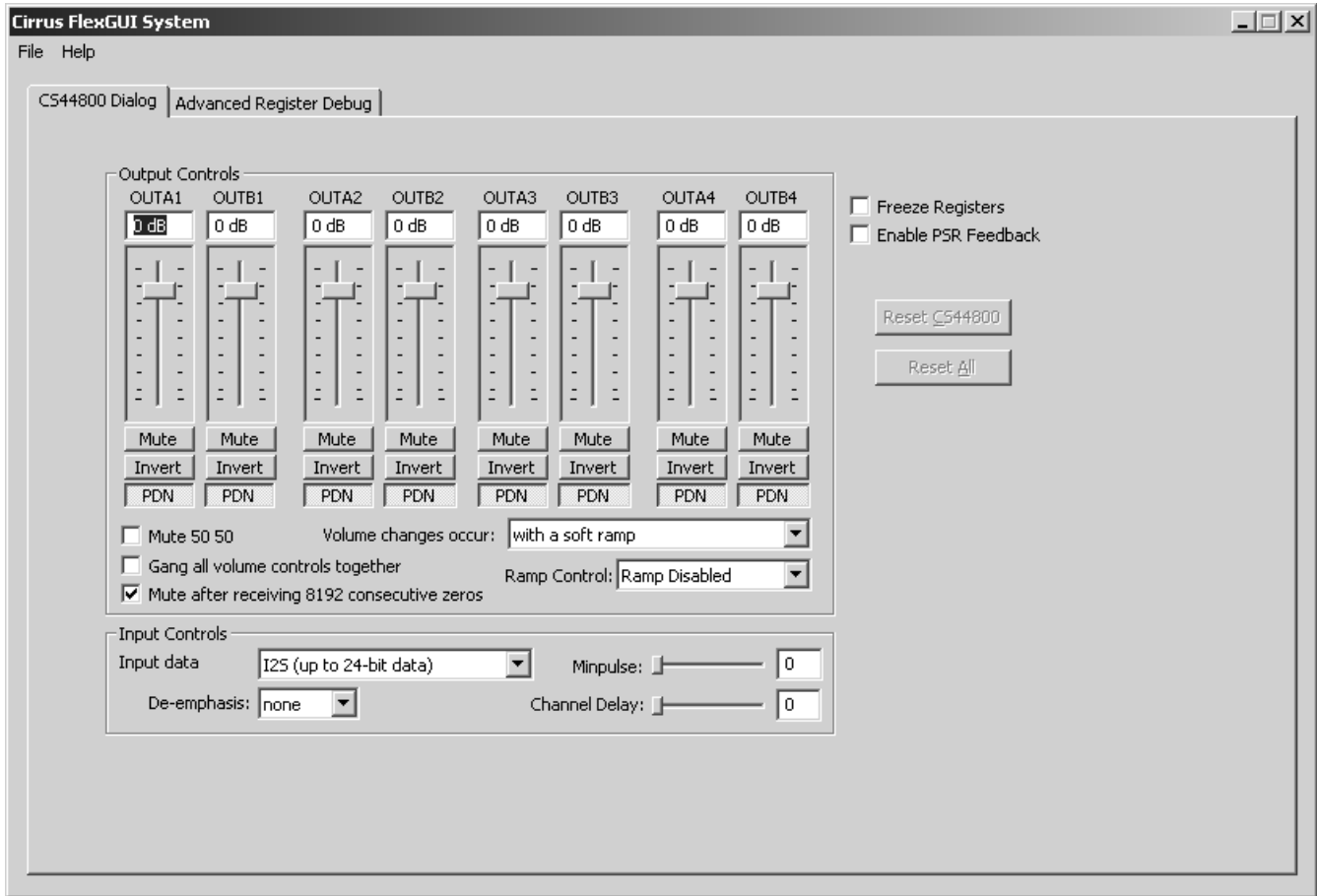
- 4) Connect the DB-9 RS-232 port (J14) on the CRD44800 Driver board to a PC serial port.
- 5) Copy the CRD44800 directory from the included CD-ROM to the users local hard drive. Note that FlexGUI is only compatible with systems running Windows 98 or better (i.e. Windows 98, ME, 2000, XP, etc.).
- 6) Modify the following line in the file "flexconfig.ini", which is found in the FlexLoader application directory. This line is found in the [CDB44800Comm] section of the ini file.

```
SERIAL = PI_Serial.dll, 2500, COM1, 38400
```

Replace "COM1" with the number of the serial communications (RS-232) port you are using (COM1/COM2/COM3/COM4).

- 7) Start FlexGUI opening FlexLoader.exe. This application can be used to read and modify any CS44800 register, and provides easy control over individual channel volumes.

The CS44800 Dialog tab provides high level control over the CS44800's registers. Controls are provided to change volume, mute, power down, ramp control, quantization level, SAI input format, minimum pulse width, and channel delay.



**Figure 2. CS44800 Dialog Tab**

The Advanced Register Debug tab provides low level control over the CS44800 and CS8416 individual register settings. Each device is displayed on a separate tab. Register values can be modified bitwise or byte-wise. For bitwise, click the appropriate pushbutton for the desired bit. For byte-wise, the desired hex value can be typed directly in the register address box in the register map.

**Cirrus FlexGUI System** [ \_ [ X ]

File Help

CS44800 Dialog | Advanced Register Debug |

**CS44800**

	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00		C1	81	FF	20	01	41	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	10	20	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	80	00	80	00	7F	00	00	7F
30	00	00	00	00	00	22	58	68				40	00	00		

Grid Legend

Read/Write Register   
  Read Only Register   
  Undefined Register

**Figure 3. Advanced Register Debug Tab - CS44800**

## System Issues

### 2.1 Power Supply Ratings

The required power supply current rating can be estimated as follows. 33 W is used as the reference output power because this represents the typical full scale output with no clipping. Assume the efficiency,  $\eta$ , is approximately 85% (this accounts for power to supply control electronics and overhead), then for 33 W / 8 channels:

$$P_{Total} = \frac{P_{Out}}{\eta} = \frac{264 W}{0.85} = 310 W$$

$$P_{Supply} = \frac{P_{Total}}{2} = \frac{310 W}{2} = 155 W$$

Consequently the supply current is:

$$I_{Supply} = \frac{P_{Supply}}{V_{Supply}} = \frac{155 W}{45 V} = 3.4 A$$

The factor of 2 in the denominator of the  $P_{Supply}$  calculation arises from the fact that for typical consumer applications in A/V or DVD receivers, the power supply should be capable of providing  $\frac{1}{2}$  the total requirement for all channels operating at full power. This design guide is still quite conservative, and gives more than adequate headroom in real applications.

### 2.2 Power Supply Decoupling

Proper power supply decoupling is one key to maximizing the performance of a Class-D amplifier. Because the design uses an open loop output stage, noise on the power supply rail will be coupled to the output. While the PSR functionality of the CS44800 helps reduce power supply noise feedthrough to the output, careful decoupling of the power stage supply rails is essential. Referring to Figure 11, the top side of the CRD44800 PWM amplifier board, good decoupling practice is shown. Notice that the 0.1  $\mu$ F ceramic capacitors are as close as physically possible to the power pins of the TDA8939. 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 keeps the high frequency current loop small to minimize power supply variations and EMI. 470  $\mu$ 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. The real time PSR feedback of the CS44800/CS4461 can greatly attenuate the induced voltages due to the power supply ripple current.

## 2.3 Electromagnetic Interference (EMI)

The EMI challenges that face a maker of Class-D amplifiers are largely the same challenges that have been faced by the switch mode power supply industry for many years. The numerous EMI consulting firms that have arisen and the many books that have been written on the subject indicate the scope of potential problems and available solutions. They should be considered a resource - most makers of switch mode equipment would benefit from developing a working relationship with a qualified EMI lab and from bringing their experience to bear on design issues, preferably early in the design process.

This reference design from Cirrus Logic is a board level solution which 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 in close proximity to radio receivers, particularly AM receivers which are notoriously sensitive to interference. Amplifiers also need to operate with speaker leads of unpredictable length and construction which make it possible for any high frequency currents that appear on the outputs to generate nuisance emissions. The criteria for judging successful EMI control is not as well defined for amplifier design as it is for power supplies. While the techniques of measuring conducted and radiated emissions are similar for both types of products, power supplies have a number of clearly defined (and legally imposed) thresholds that are useful mainly as guidelines when testing amplifiers.

### 2.3.1 *Suppression of EMI at the Source*

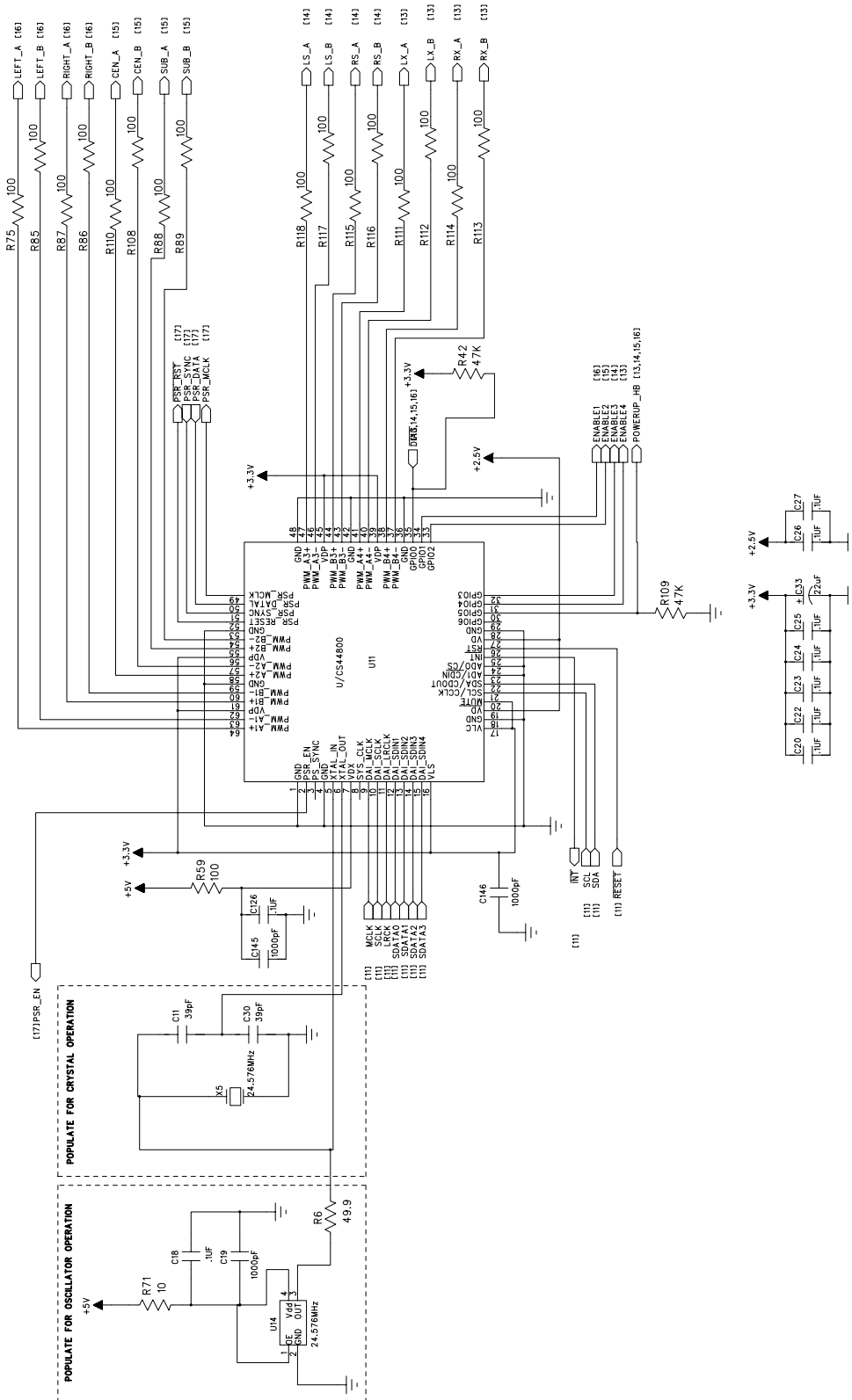
Several techniques are used in the circuit design and board layout to minimize high frequency fields in the immediate vicinity of the high power components. Specific techniques include the following:

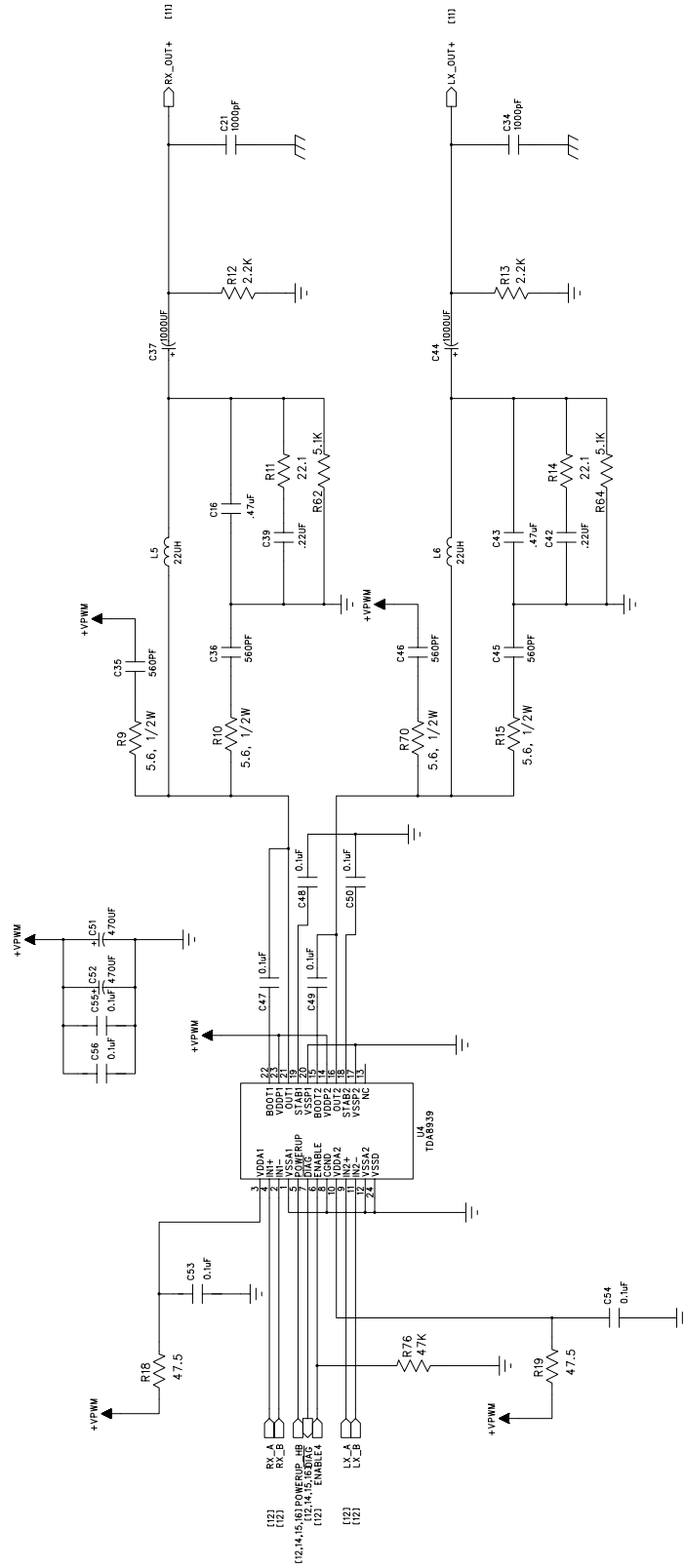
- As was mentioned in Section 2.2, effective power supply decoupling of high frequency currents, and minimizing the loop area of the decoupling loop is one aspect of minimizing EMI.
- Each output of the TDA8939 includes “snubbing” components. For example, OUT1 of U4 includes snubber components R10 and R11 (5.6  $\Omega$ ), and C36 and C39 (560 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. Again, refer to Figure 11 for the preferred component layout.
- A separate ground plane with a solid electrical connection to the chassis and which surrounds the speaker output connector should be implemented. This allows the speaker outputs to be RF decoupled to the chassis just before they exit the chassis from the speaker connector. Again, refer to Figure 11 for the preferred component layout.
- Make use of source termination resistors on all digital signals whose traces are longer

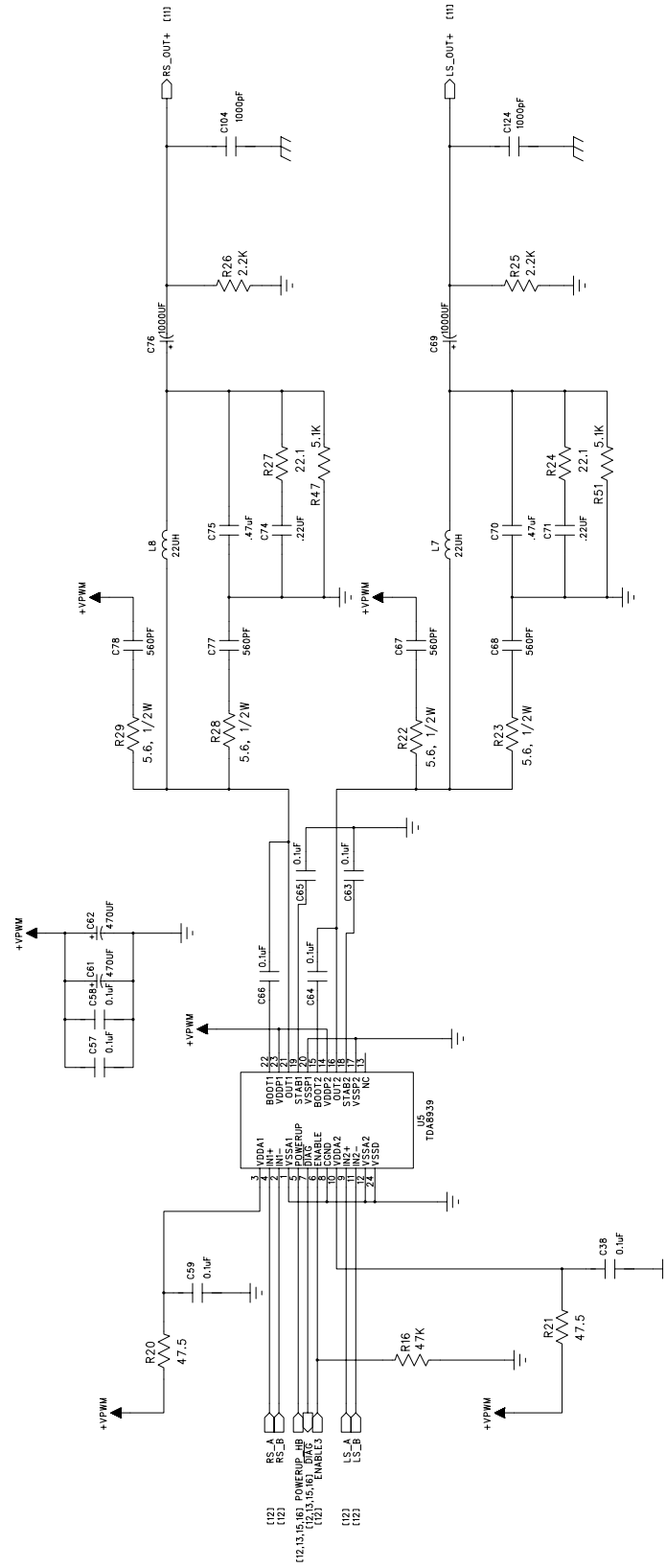
than about 25 mm.

It is extremely critical that the layout of the power amplifier section of the Cirrus Logic CS44800 Reference Design be copied as exactly as possible to assure best RF/EMI performance.




**Figure 5. CS44800**

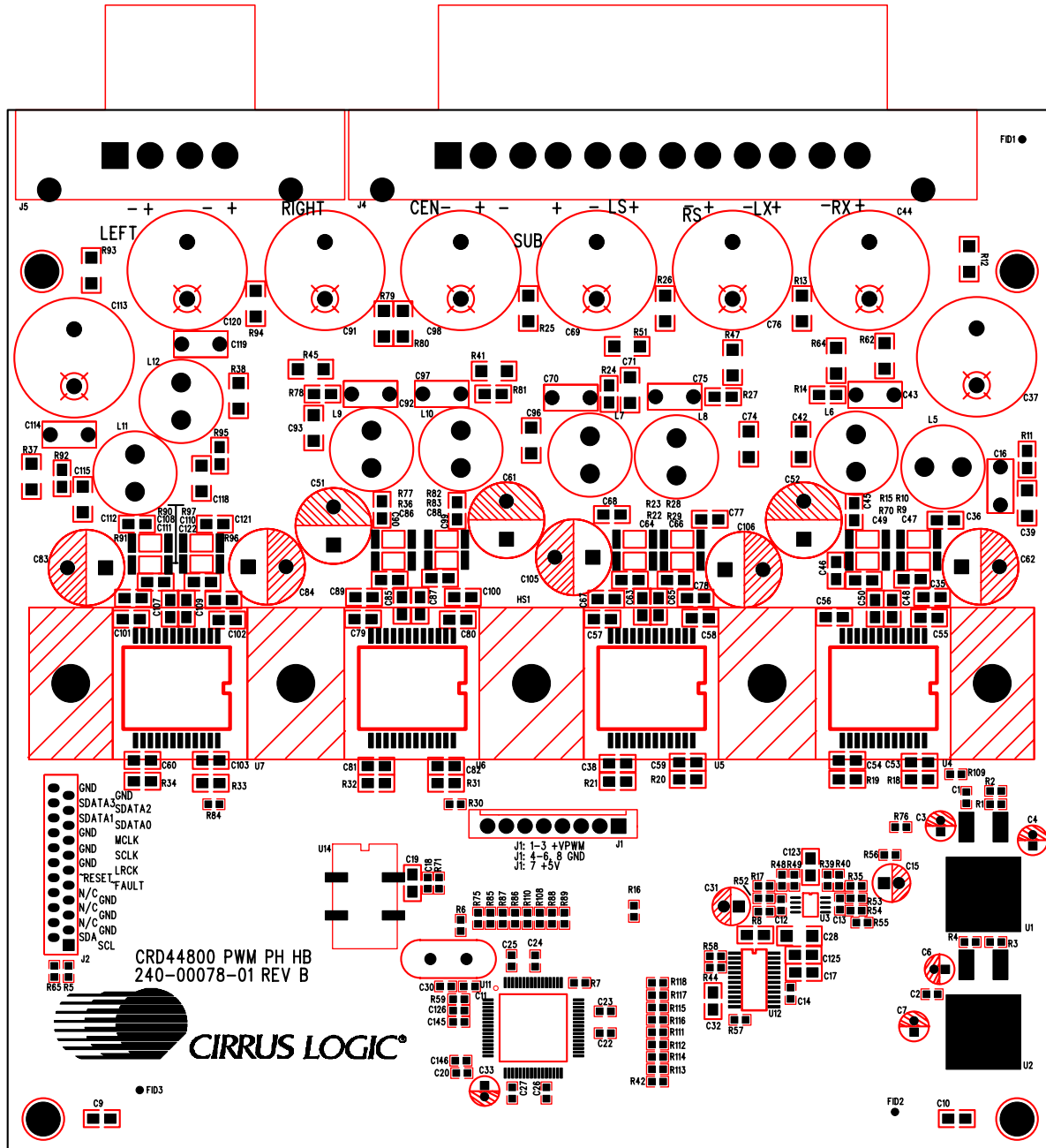

**Figure 6. Left/Right Back Surround Channels**


**Figure 7. Left/Right Surround Channels**







**4. LAYOUT**

**Figure 11. Silk Screen Top**

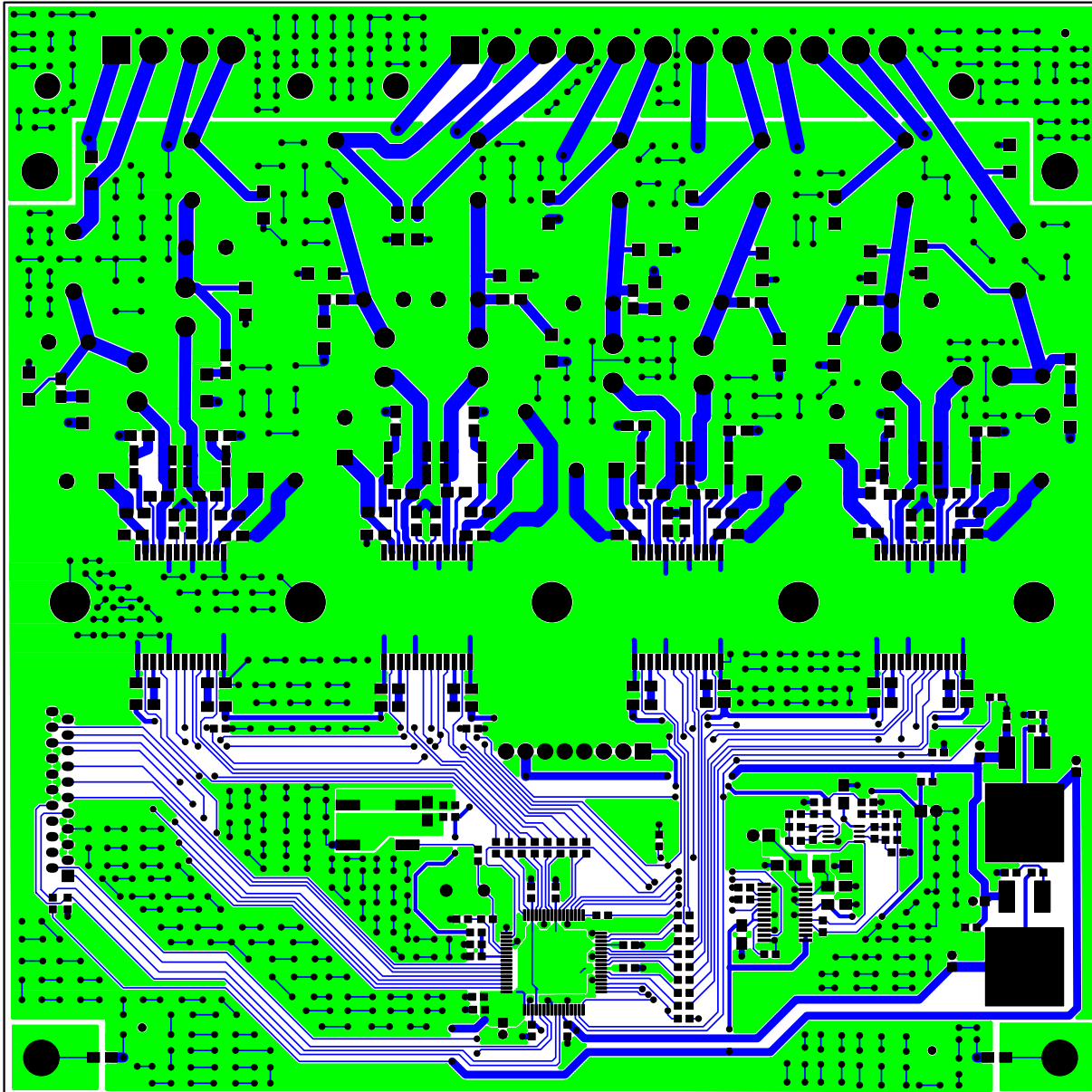


Figure 12. Topside Layer

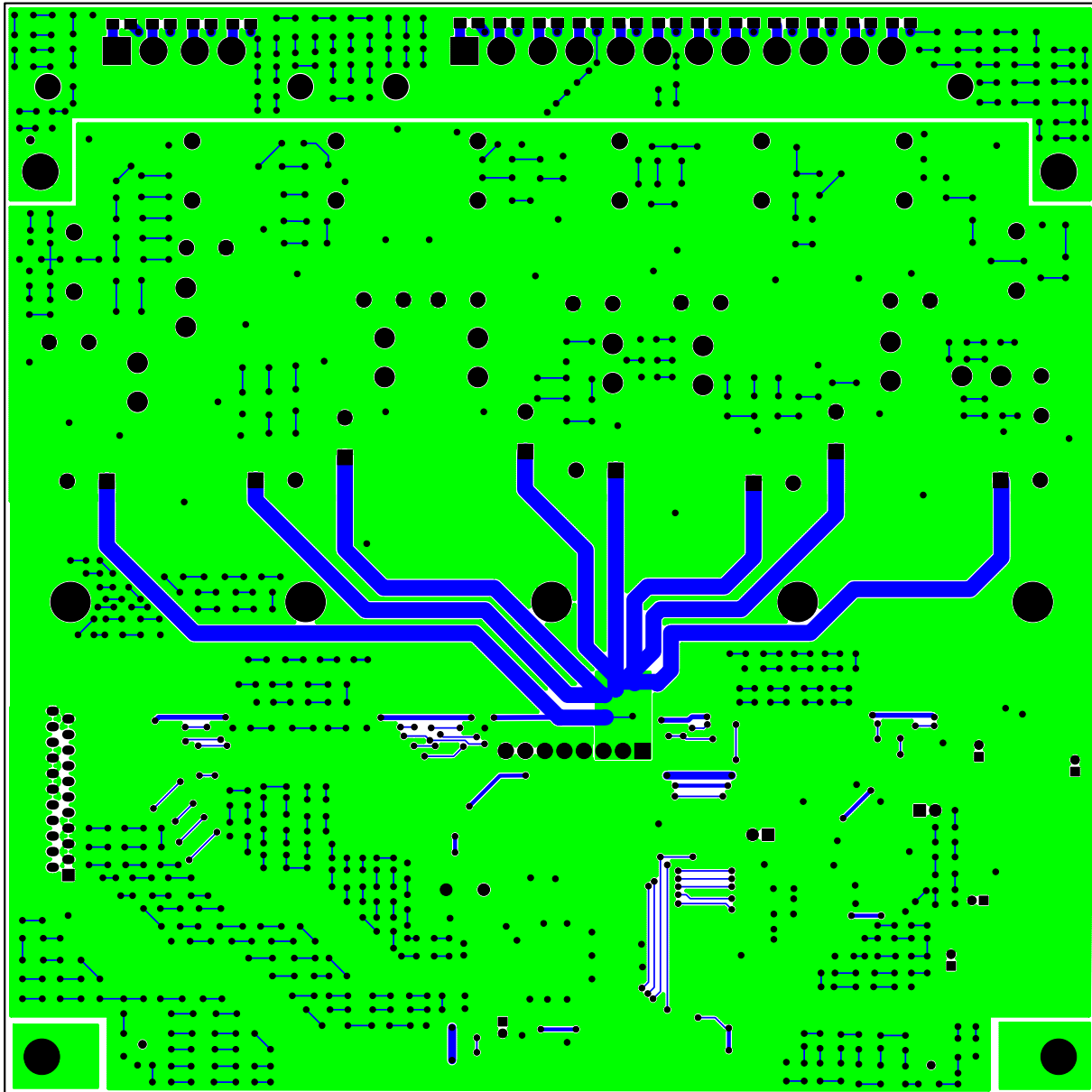


Figure 13. Bottomside Layer

**5. BILL OF MATERIALS**

Line Item	Rev	Description	Qty	U/M	Reference Designator	MFG	MFG. P/N
1	A	CAP 1000pF ±10% 50V X7R 0603	2	EA	C145 C146	PANASONIC	ECJ1VB1H102M
2	A	CAP 1000pF ±10% 50V X7R 0805	19	EA	C9 C10 C19 C21 C34 C104 C124 C127 C132 C133 C135 C136 C137 C138 C139 C140 C141 C142 C143	PANASONIC	ECJ2VB1H102K
3	A	CAP 1uF ±10% 25V X7R 1206	1	EA	C28	PANASONIC	ECJ3YB1E105K
4	A	CAP 1000uF ±20% 50V ELEC RAD 16x25mm	8	EA	C37 C44 C69 C76 C91 C98 C113 C120	NICHICON	UPW1H102MHD
5	A	CAP 120pF ±5% 50V C0G 0603	2	EA	C12 C13	KEMET	C0603C121J5GAC
6	A	CAP 2200pF ±10% 50V X7R 0603	1	EA	C14	KEMET	C0603C22K5RAC
7	A	CAP 22uF ±20% 6.3V ELEC RAD	5	EA	C3 C4 C6 C7 C33	PANASONIC	ECEA0JKS220
8	A	CAP 39pF ±5% 50V C0G 0603	2	EA	C11 C30	KEMET	C0603C390J5GAC
9	A	CAP 0.47uF ±10% 63V MTL FLM RAD	8	EA	C16 C43 C70 C75 C92 C97 C114 C119	BC COMPONENTS	2222 370 11474
10	A	CAP 470uF ±20% 50V ELEC RAD	8	EA	C51 C52 C61 C62 C83 C84 C105 C106	PANASONIC	ECA1HM471
11	A	CAP 47uF ±20% 16V ELEC RAD 6.3x11MM	2	EA	C15 C31	PANASONIC	ECEA1CKS470
12	A	CAP 560pF ±5% 50V C0G 0805	16	EA	C35 C36 C45 C46 C67 C68 C77 C78 C89 C90 C99 C100 C111 C112 C121 C122	PANASONIC	ECJ2VC1H561J
13	A	CAP 0.1uF +80/-20% 25V Y5V 0603	11	EA	C1 C2 C18 C20 C22 C23 C24 C25 C26 C27 C126	PANASONIC	ECJ1VF1E104Z
14	A	CAP 0.1uF ±10% 50V X7R 0805	37	EA	C17 C29 C32 C38 C47 C48 C49 C50 C53 C54 C55 C56 C57 C58 C59 C60 C63 C64 C65 C66 C79 C80 C81 C82 C85 C86 C87 C88 C101 C102 C103 C107 C108 C109 C110 C123 C125	KEMET	C0805C104K5RAC
15	A	CAP 0.22uF ±10% 50V X7R 1206	8	EA	C39 C42 C71 C74 C93 C96 C115 C118	KEMET	C1206C224K5RAC
16	A	HEATSINK, 30W, APOGEE PWM	1	EA	HS1	SUMMIT HEAT SINKS CO LTD	311-00001-01
17	A	CONN, FLEX 22PIN, ST, 1mm PITCH	1	EA	J2	HIROSE	FH21-22S-1DSA
18	A	CONN, 8PIN EH 2.5MM PTCH PWR HDR	1	EA	J1	JST	B8B-EH-A
19	A	CONN, 2x2 SPKR TERMINAL	1	EA	J5	DRAGON CITY INDUSTRIES	PT-422-03
20	A	CONN, 6x2 SPKR TERMINAL	1	EA	J4	DRAGON CITY INDUSTRIES	PT-1222P-03

**Figure 14. Bill of Materials**

Line Item	Rev	Description	Qty	U/M	Reference Designator	MFG	MFG. P/N
21	A	IND, 22UH, 3.5A	8	EA	L5 L6 L7 L8 L9 L10 L11 L12	TRANSTEK MAGNETICS	TMP50612CT
22	A	RES 10 OHM 1/10W ±5% 0603	1	EA	R71	PANASONIC	ERJ3GEYJ100V
23	A	RES 10.2 OHM 1/16W ±1% 0603 FILM	1	EA	R56	DALE	CRCW060310R2F
24	A	RES 100 OHM 1/16W ±1% 0603 FILM	17	EA	R59 R75 R85 R86 R87 R88 R89 R101 R110 R111 R112 R113 R114 R115 R116 R117 R118	DALE	CRCW06031000F
25	A	RES 10k OHM 1/16W ±1% 0603 FILM	2	EA	R5 R65	PANASONIC	ERJ3EKF1002V
26	A	RES 121 OHM 1/16W ±1% 0603 FILM	3	EA	R1 R3 R4	DALE	CRCW06031210F
27	A	RES 1.96k OHM 1/16W ±1% 0603 FILM	1	EA	R48	DALE	CRCW06031961F
28	A	RES 200 OHM 1/16W ±1% 0603 FILM	1	EA	R2	DALE	CRCW06032000F
29	A	RES 2k OHM 1/16W ±1% 0603 FILM	2	EA	R54 R55	DALE	CRCW06032001F
30	A	RES 22.1 OHM 1/10W ±1% 0805 FILM	8	EA	R11 R14 R24 R27 R78 R81 R92 R95	DALE	CRCW080522R1F
31	A	RES 2.2k OHM 1/8W ±1% 1206 FILM	8	EA	R12 R13 R25 R26 R79 R80 R93 R94	DALE	CRCW12062201F
32	A	RES 46.4k OHM 1/16W ±1% 0603 FILM	1	EA	R49	DALE	CRCW06034642F
33	A	RES 47k OHM 1/10W ±5% 0603 FILM	6	EA	R16 R30 R42 R76 R84 R109	PANASONIC	ERJ3GEYJ473V
34	A	RES 47.5 OHM 1/10W ±1% 0805 FILM	8	EA	R18 R19 R20 R21 R31 R32 R33 R34	PANASONIC	ERJ6ENF47R5V
35	A	RES 49.9 OHM 1/16W ±1% 0603 FILM	4	EA	R6 R7 R44 R58	DALE	CRCW060349R9F
36	A	RES 49.9k OHM 1/16W ±1% 0603 FILM	1	EA	R57	DALE	CRCW060349R2F
37	A	RES 5.1K OHM 1/4W +5% 1206	8	EA	R37 R38 R41 R45 R47 R51 R62 R64	YAGEO	9C12063A5101JLHFT
38	A	RES 5.6 OHM 1/2W ±5% 2010 FILM	16	EA	R9 R10 R15 R22 R23 R28 R29 R36 R70 R77 R82 R83 R90 R91 R96 R97	DALE	CRCW20105R6J
39	A	RES 649 OHM 1/16W ±1% 0603 FILM	1	EA	R8	DALE	CRCW06036490F
40	A	RES 90.9 OHM 1/16W ±1% 0603 FILM	2	EA	R52 R53	PANASONIC	ERJ3EKF90R9V
		NO POP	4	EA	R17 R35 R39 R40		
41	D	IC CRUS A/D PSR FEEDBACK TSSOP24	1	EA	U12	CIRRUS LOGIC	CS4461-CZZID
42	A	IC CRUS, MULTI CHNL PWM CONTR QFP64	1	EA	U11	CIRRUS LOGIC	CS44800-CQ/A
43	A	IC, 1.5A ADJ V REG, TO-252	2	EA	U1 U2	NJR	NJM317DL1
44	A	IC LNR DUAL OP AMP LOW V RRO VSP8	1	EA	U3	NJR	NJM2140R
45	A	IC LOG CLASS D PWR COMP HSOP24	4	EA	U4 U5 U6 U7	PHILLIPS	TDA8939TH
46	A	OSC, 24.576MHz 100ppm 5V, SG-531	1	EA	U14	CITIZEN	CMX309FLC24.576MT
47	A	SCREW PANHEAD, 4-40, PH, 1/2"L	5	EA		BUILDING FASTENERS	PMS 440 0050 PH

**Figure 15. Bill of Materials**

6. TYPICAL PERFORMANCE PLOTS

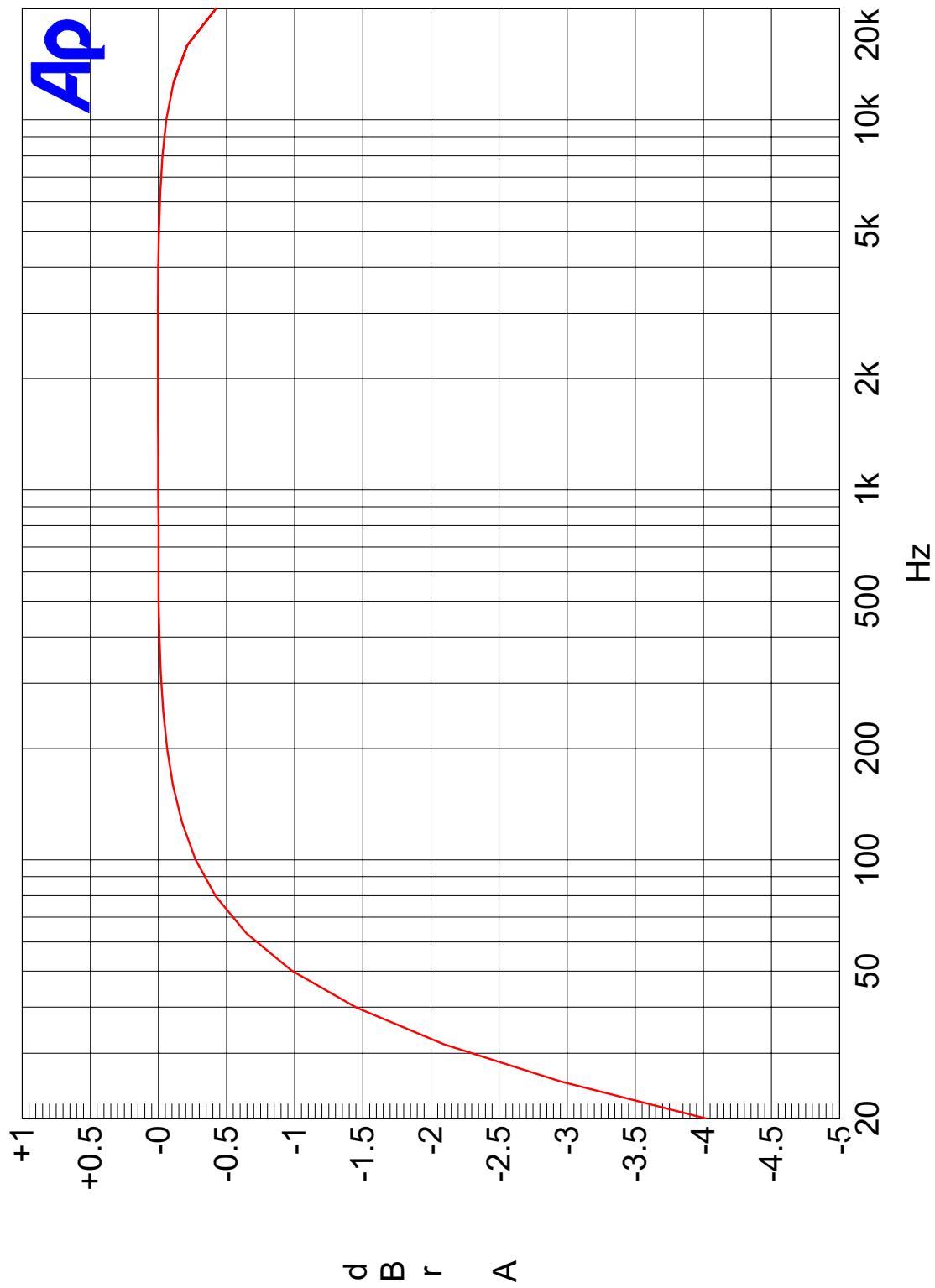


Figure 16. Frequency Response

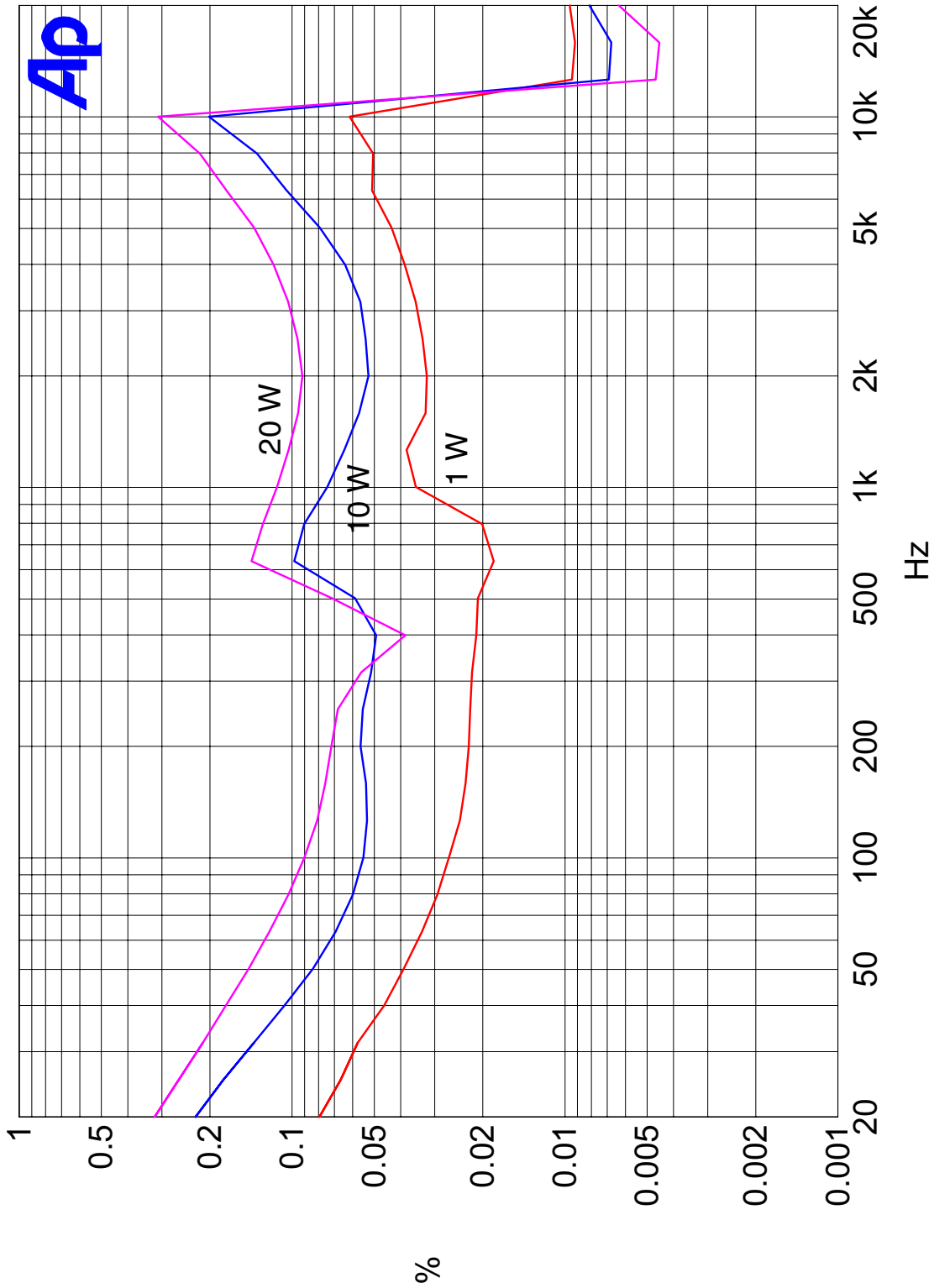


Figure 17. THD+N vs. Frequency at 1 W, 10 W, and 20 W

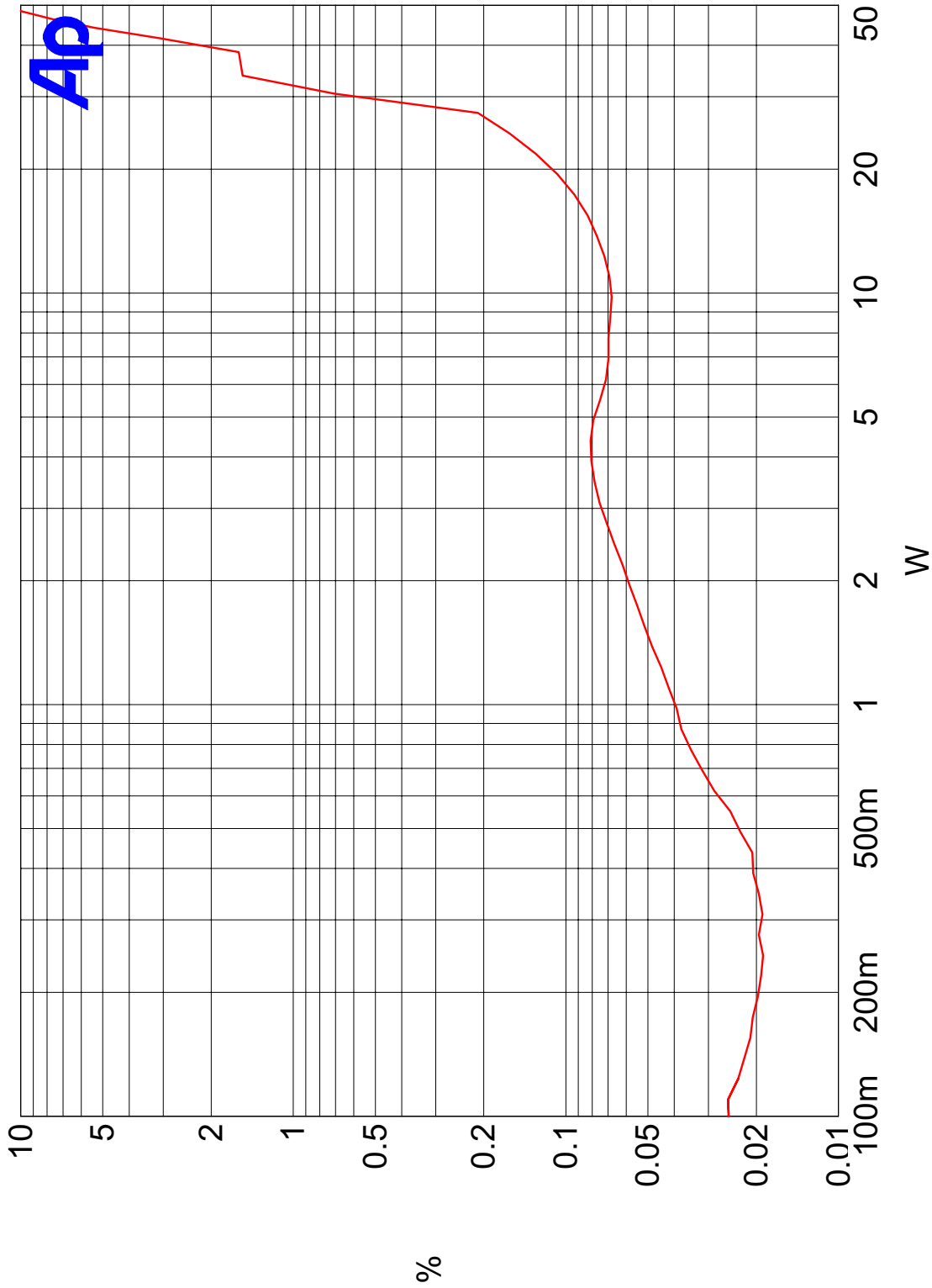


Figure 18. THD+N vs. Power at 1 kHz

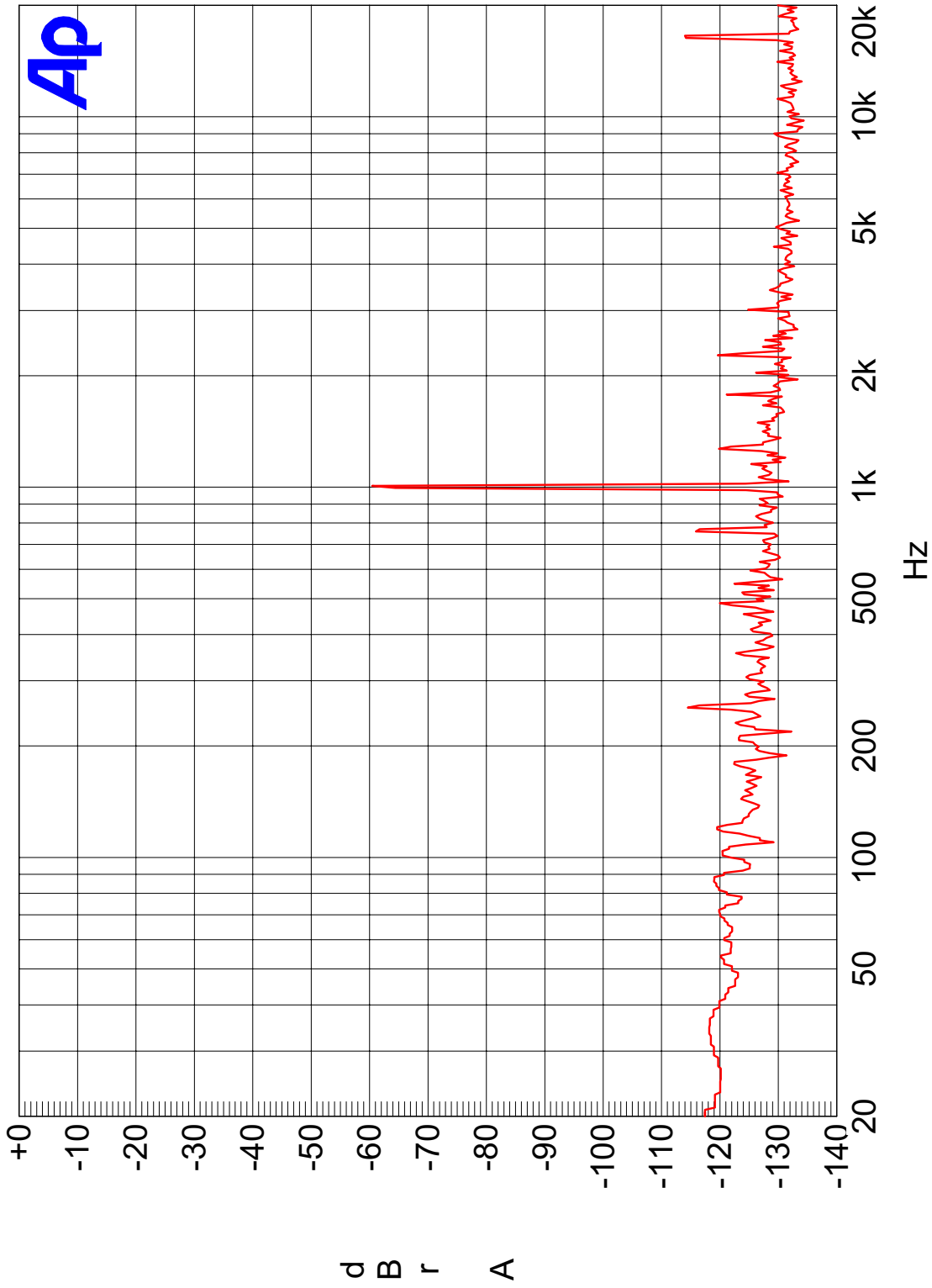


Figure 19. FFT at -60 dBFS and 1 kHz

## 7. REVISION HISTORY

Release	Date	Changes
RD1	June 2004	1st Release
RD2	December 2004	2nd Release -Updated schematics and layout to reflect rev B.

Table 2. Revision History

---

### Contacting Cirrus Logic Support

For all product questions and inquiries contact a Cirrus Logic Sales Representative.  
To find one nearest you go to <http://www.cirrus.com/>

---

#### IMPORTANT NOTICE

Cirrus Logic, Inc. and its subsidiaries ("Cirrus") believe that the information contained in this document is accurate and reliable. However, the information is subject to change without notice and is provided "AS IS" without warranty of any kind (express or implied). Customers are advised to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, indemnification, and limitation of liability. No responsibility is assumed by Cirrus for the use of this information, including use of this information as the basis for manufacture or sale of any items, or for infringement of patents or other rights of third parties. This document is the property of Cirrus and by furnishing this information, Cirrus grants no license, express or implied under any patents, mask work rights, copyrights, trademarks, trade secrets or other intellectual property rights. Cirrus owns the copyrights associated with the information contained herein and gives consent for copies to be made of the information only for use within your organization with respect to Cirrus integrated circuits or other products of Cirrus. This consent does not extend to other copying such as copying for general distribution, advertising or promotional purposes, or for creating any work for resale.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). CIRRUS PRODUCTS ARE NOT DESIGNED, AUTHORIZED OR WARRANTED FOR USE IN AIRCRAFT SYSTEMS, MILITARY APPLICATIONS, PRODUCTS SURGICALLY IMPLANTED INTO THE BODY, AUTOMOTIVE SAFETY, SECURITY DEVICES, LIFE SUPPORT PRODUCTS OR OTHER CRITICAL. INCLUSION OF CIRRUS PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK AND CIRRUS DISCLAIMS AND MAKES NO WARRANTY, EXPRESS, STATUTORY OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE, WITH REGARD TO ANY CIRRUS PRODUCT THAT IS USED IN SUCH A MANNER. IF THE CUSTOMER OR CUSTOMER'S CUSTOMER USES OR PERMITS THE USE OF CIRRUS PRODUCTS IN CRITICAL APPLICATIONS, CUSTOMER AGREES, BY SUCH USE, TO FULLY INDEMNIFY CIRRUS, ITS OFFICERS, DIRECTORS, EMPLOYEES, DISTRIBUTORS AND OTHER AGENTS FROM ANY AND ALL LIABILITY, INCLUDING ATTORNEYS' FEES AND COSTS, THAT MAY RESULT FROM OR ARISE IN CONNECTION WITH THESE USES.

Cirrus Logic, Cirrus, the Cirrus Logic logo designs, and Popguard are trademarks of Cirrus Logic, Inc. All other brand and product names in this document may be trademarks or service marks of their respective owners.