60 W Full-Bridge Reference Design for the CS44800

Features

- Eight full-bridge channels, 60 W each
- 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-ST-FB PWM Amplifier demonstrates the CS44800, Cirrus' eight-channel pure digital PMW controller. This reference design implements an eight-channel amplifier which delivers 60 W per full-bridge channel into 8 Ω loads using a single +30 V supply (at 10% THD+N). A 155 W Switched Mode Power Supply (SMPS) is used to power the CRD44800-ST-FB.

As shown below, the CS44800 IC takes four stereo digital audio inputs in I²S 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, peak limiting to prevent amplifier clipping, power supply ripple compensation, and AM frequency interference elimination.
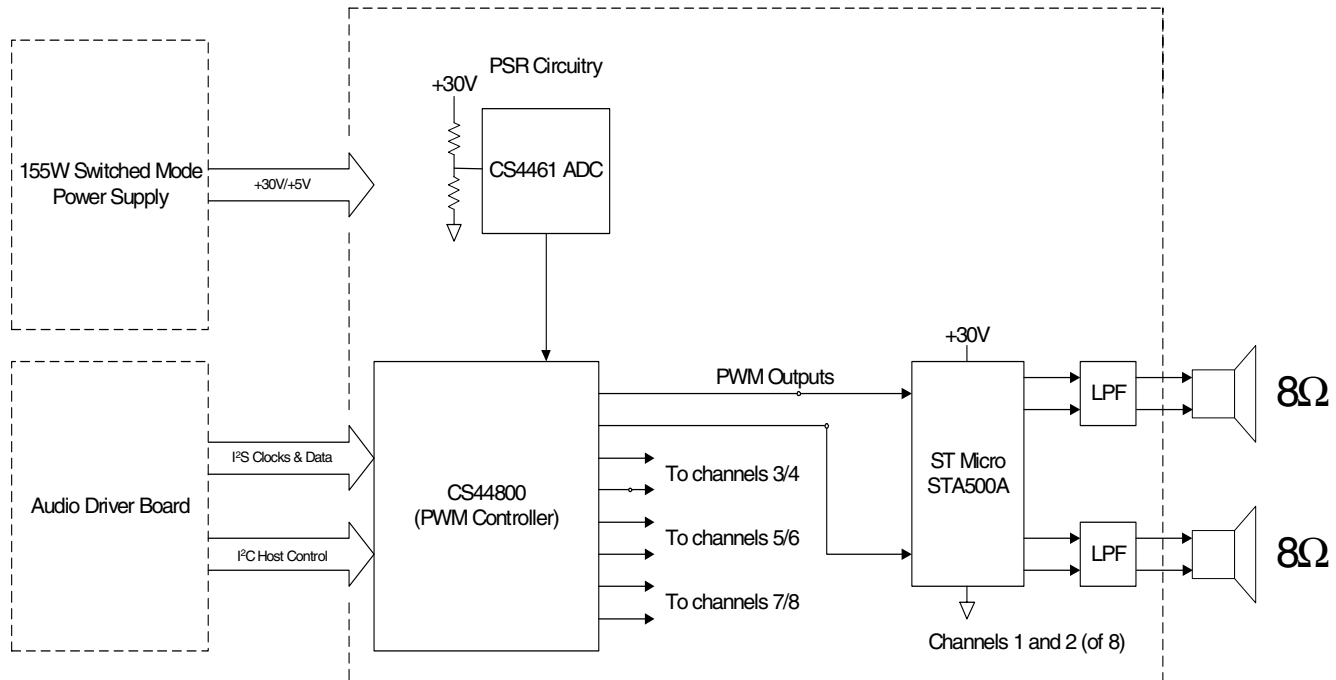
This reference design uses the the ST Micro STA500, an integrated power stage back end for digital amplifiers (four STA500 parts configured as full-bridges are used for this eight-channel design). Current limiting and thermal protection are provided by the STA500.

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

ORDERING INFORMATION

CRD44800-ST-FB   Reference Design

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1. SCHEMATIC DESCRIPTIONS

1.1 CRD44800-ST-FB PWM Amplifier

The CS44800 shown in Figure 2 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 ST Micro STA500s provide the power back end to drive the speaker loads. Each STA500 consists of a pair of fully current and temperature protected full-bridge PWM output stages. The STA500 is optimized for use in open loop Class-D amplifier systems.

1.2 CRD44800-ST-FB Driver Board

The CRD44800-ST-FB Driver board provides a convenient source of PCM I²S signals to drive the CRD44800-ST-FB 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 digital input signals are distributed to each STA500.

The CRD44800-ST-FB 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 enable or disable switching on the PWM output (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-ST-FB is a 155 W OEM supply. The supply provides +30 V for the STA500 PWM back ends, and +5 V 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-ST-FB, but the PWM output stage will continue switching.

RAMP UP/DN Pushbutton (S3) - enables/disables the PWM output stage from switching.

MUTE LED (D16) - indicates that the audio output is muted. The MUTE LED is also used during CRD44800-ST-FB 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-ST-FB 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-ST-FB evaluation system is prewired for stand-alone 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 speaker positive, and the Black terminal is speaker negative. Note that in a full-bridge system like the CDRD44800-ST-FB, neither speaker terminal is grounded. As a result, speaker switch boxes with common negative terminals should not be used.

Rx   Lx   Rs   Ls   S   C   **R   L**
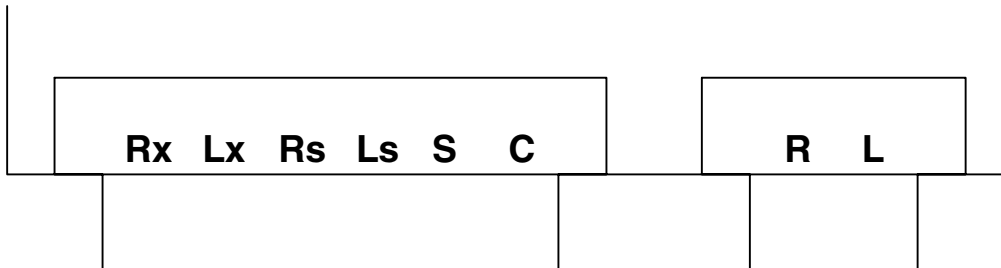
Figure 1. Speaker Terminal Configuration

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-ST-FB 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 enable or disable switching on the PWM back end.

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-ST-FB 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

| Selected Input	Mute LED	Fault LED
Coaxial S/PDIF	On	On

4) Connect the DB-9 RS-232 port (J14) on the CRD44800-ST-FB Driver board to a PC serial port.

5) Copy the CRD44800-ST-FB 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.
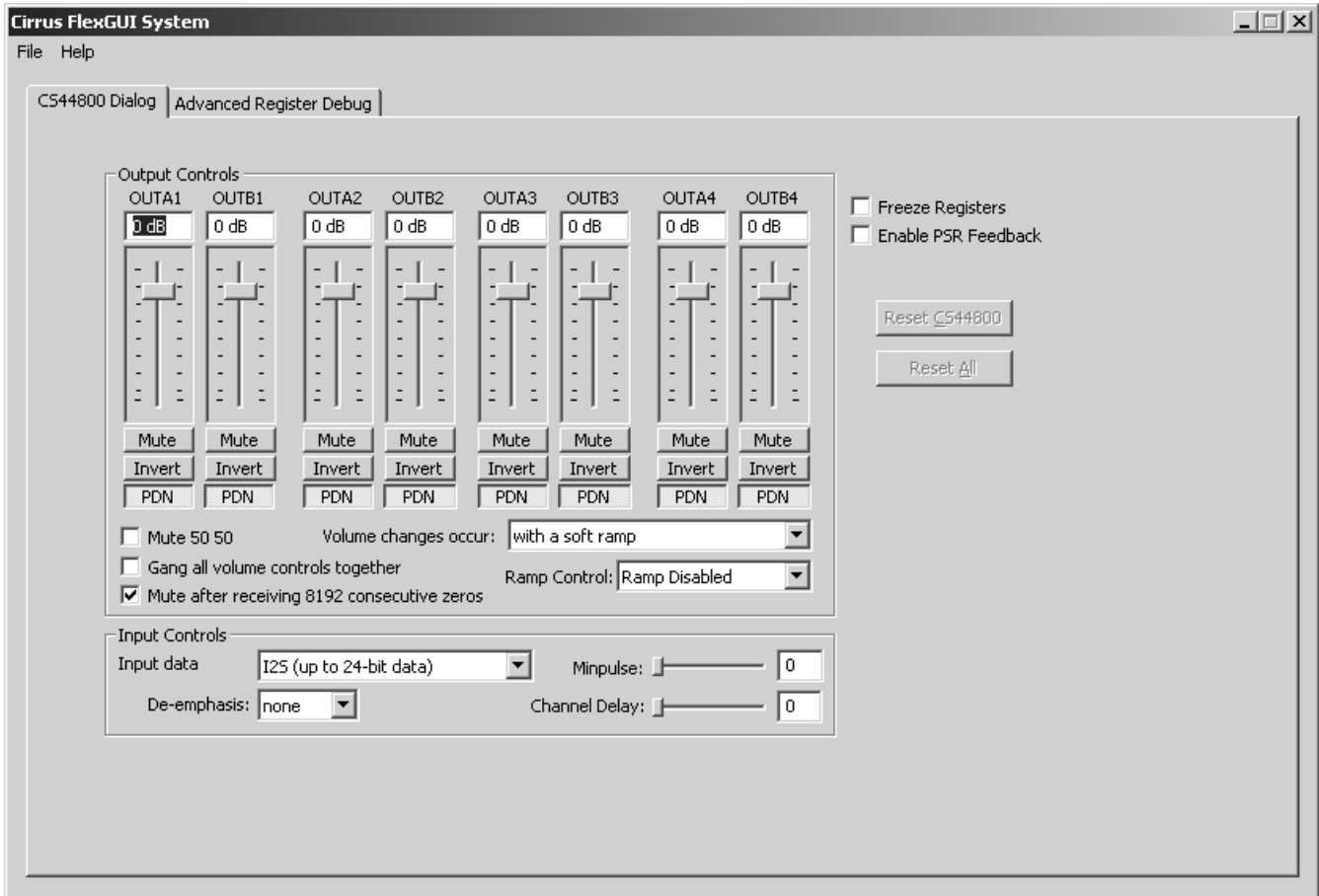
Figure 2. CS44800 Dialog Tab

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 bytewise. For bitwise, click the appropriate pushbutton for the desired bit. For bytewise, the desired hex value can be typed directly in the register address box in the register map.

CRD44800-ST-FB

Cirrus FlexGUI System

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   00 Read Only Register   ■ Undefined Register   [Reset All]   [Reset]   [Update]

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. 45 W is used as the reference output power because this represents the typical full scale output with no clipping. Assume the efficiency, η, is approximately 85% (this accounts for power to supply control electronics and overhead), then for 45 W / 8 channels:

$$P_{Total} = \frac{P_{Out}}{\eta} = \frac{360\,W}{0.85} = 424\,W$$

$$P_{Supply} = \frac{P_{Total}}{2} = \frac{424\,W}{2} = 212\,W$$

Consequently the supply current is:

$$I_{Supply} = \frac{P_{Supply}}{V_{Supply}} = \frac{212\,W}{30\,V} = 7.1\,A$$

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 ½ the total requirement for all channels operating at full power. This design guide is still quite conservative, and gives more that 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-ST-FB PWM amplifier board, good decoupling practice is shown. Notice that the 0.1 µF ceramic capacitors are as close as physically possible to the power pins of the STA500. 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 µF 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 STA500 includes "snubbing" components. For example, OUT1 of U4 includes snubber components R10 (20 Ω), and C46 (330 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.
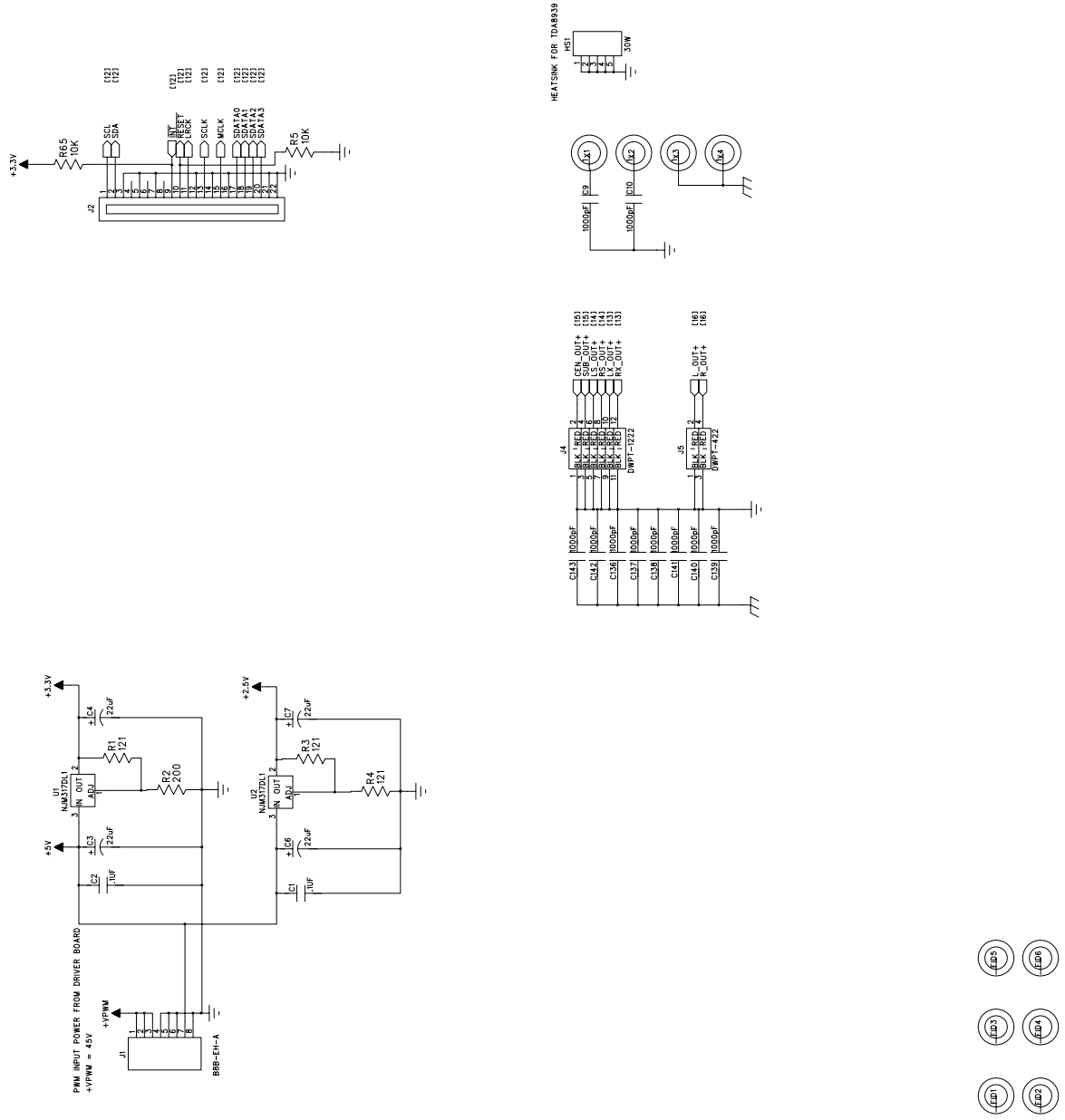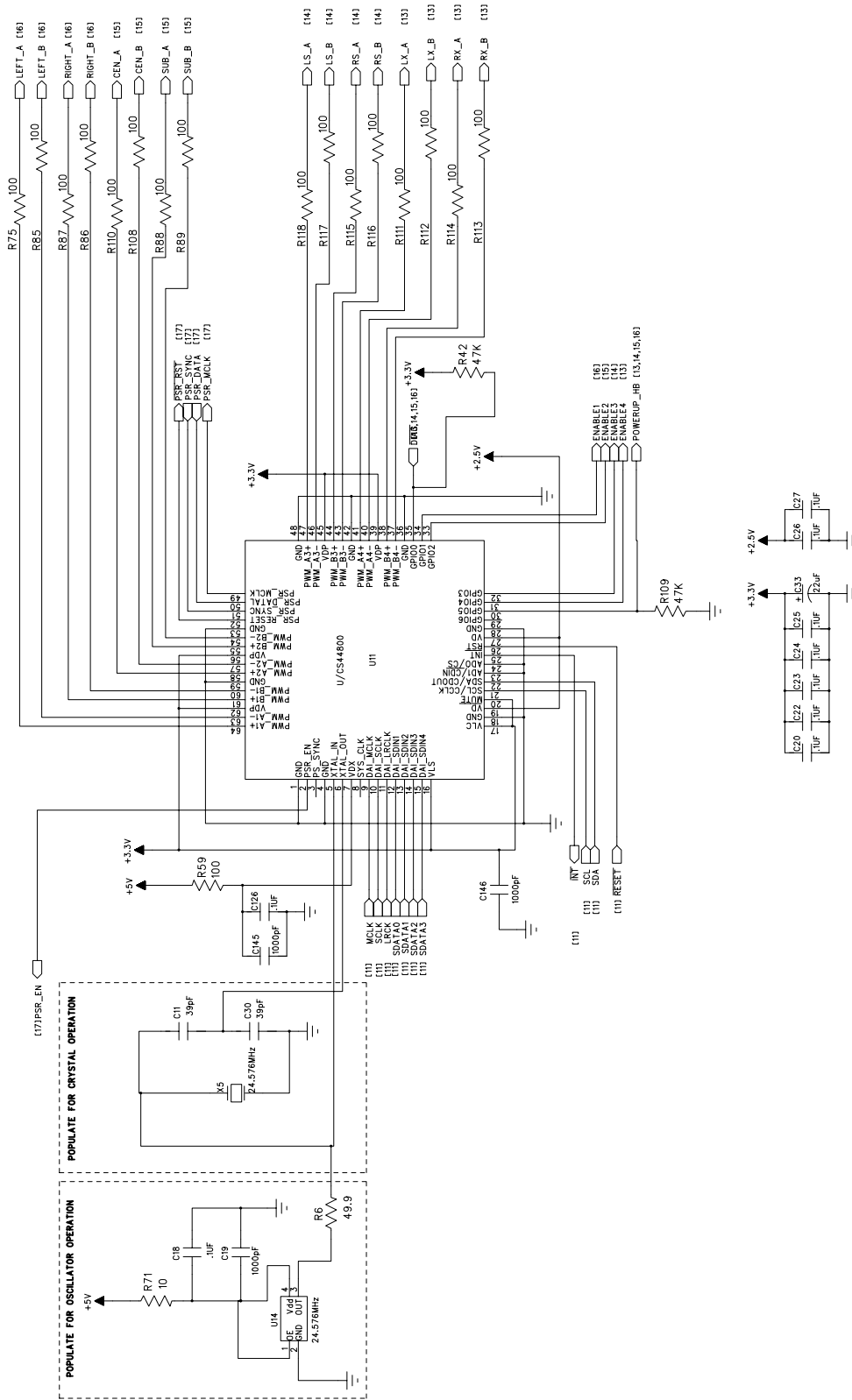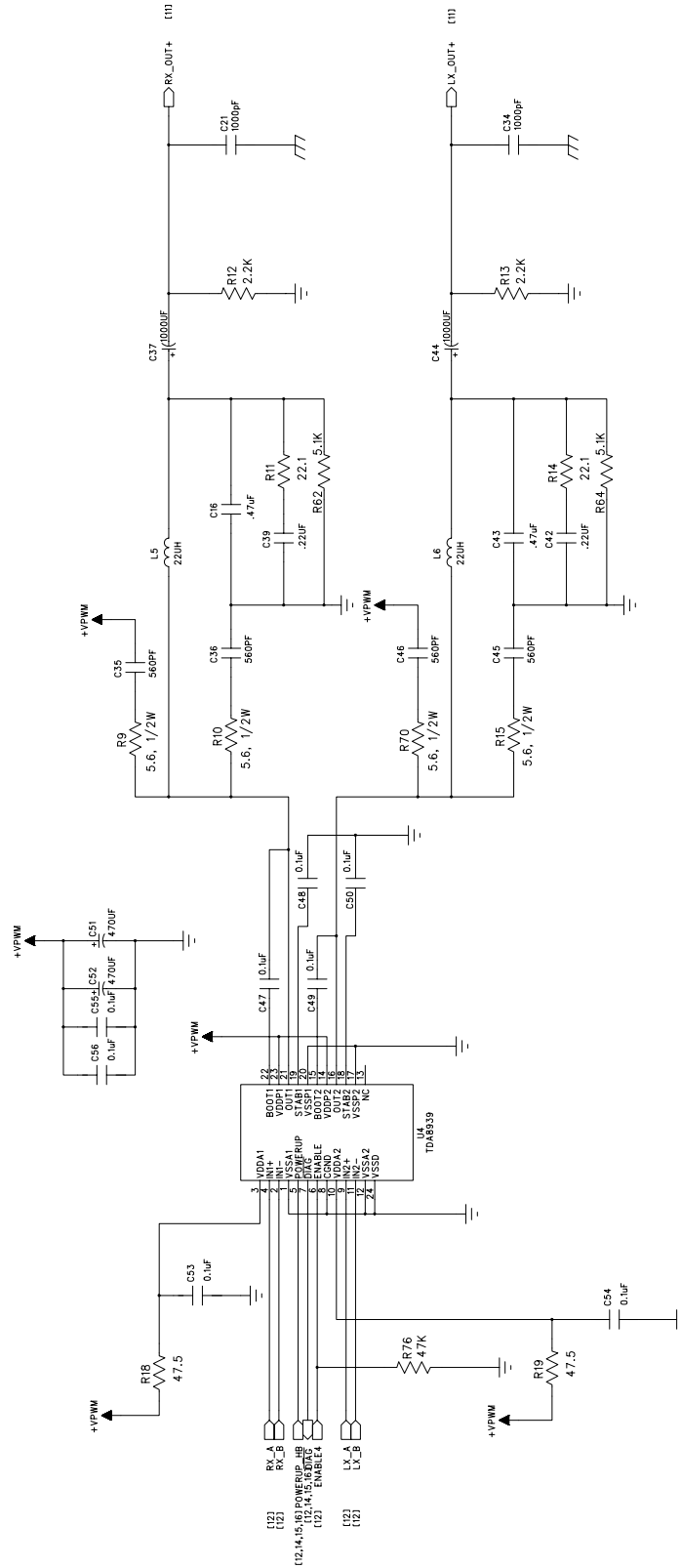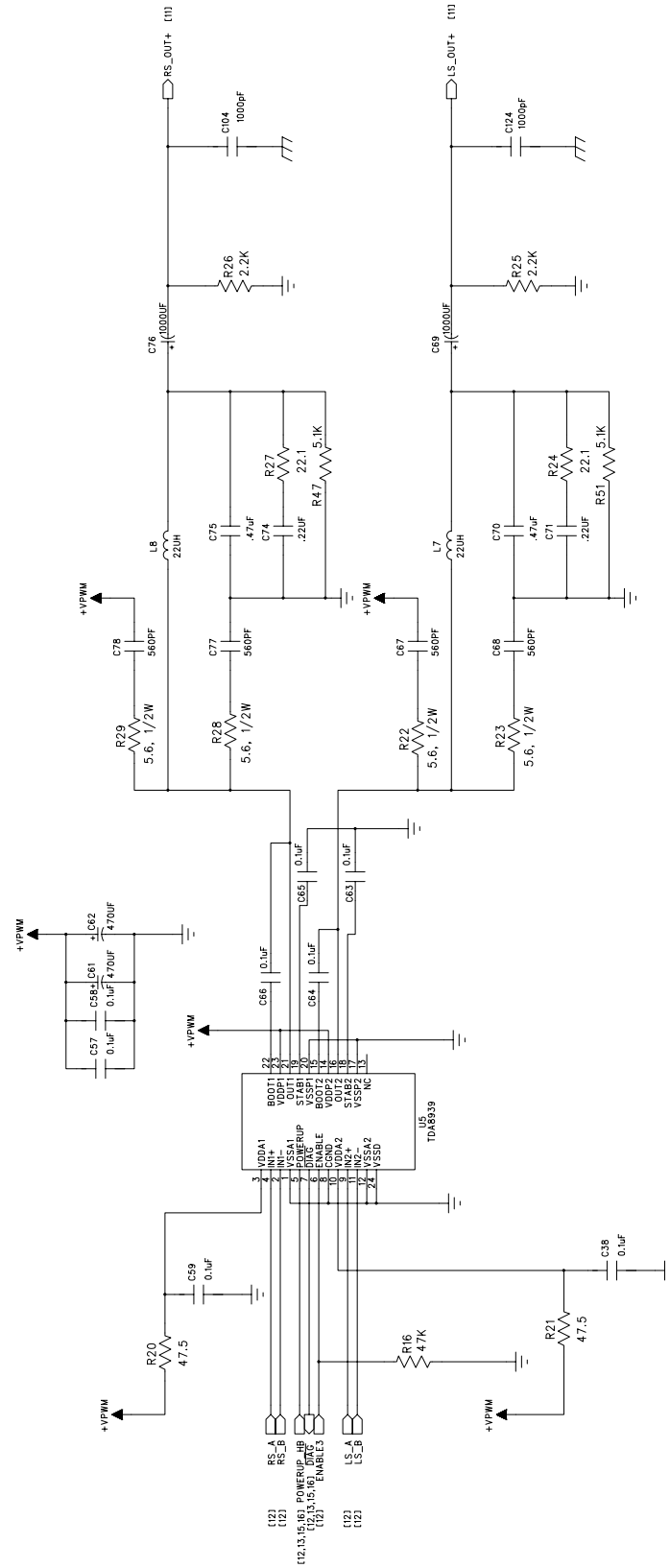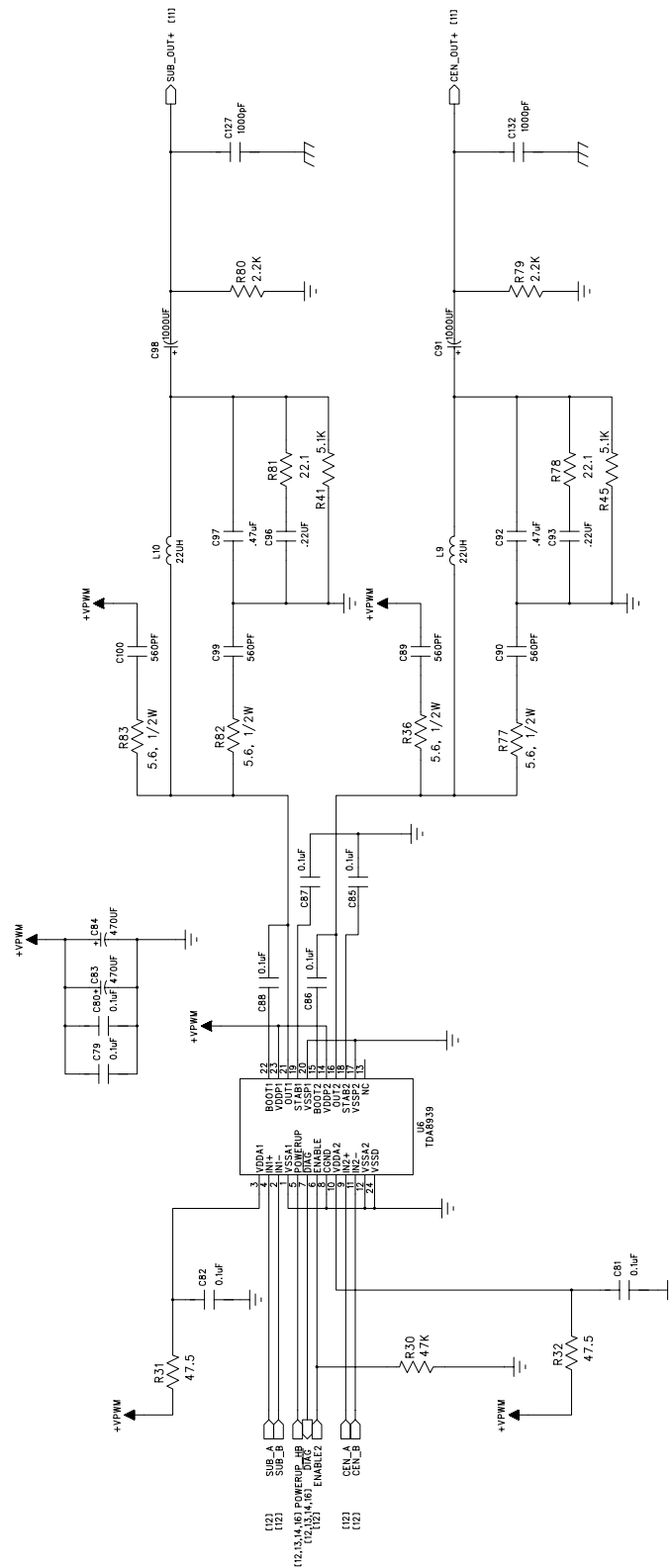
3. SCHEMATICS

Figure 4. Power and Connectors
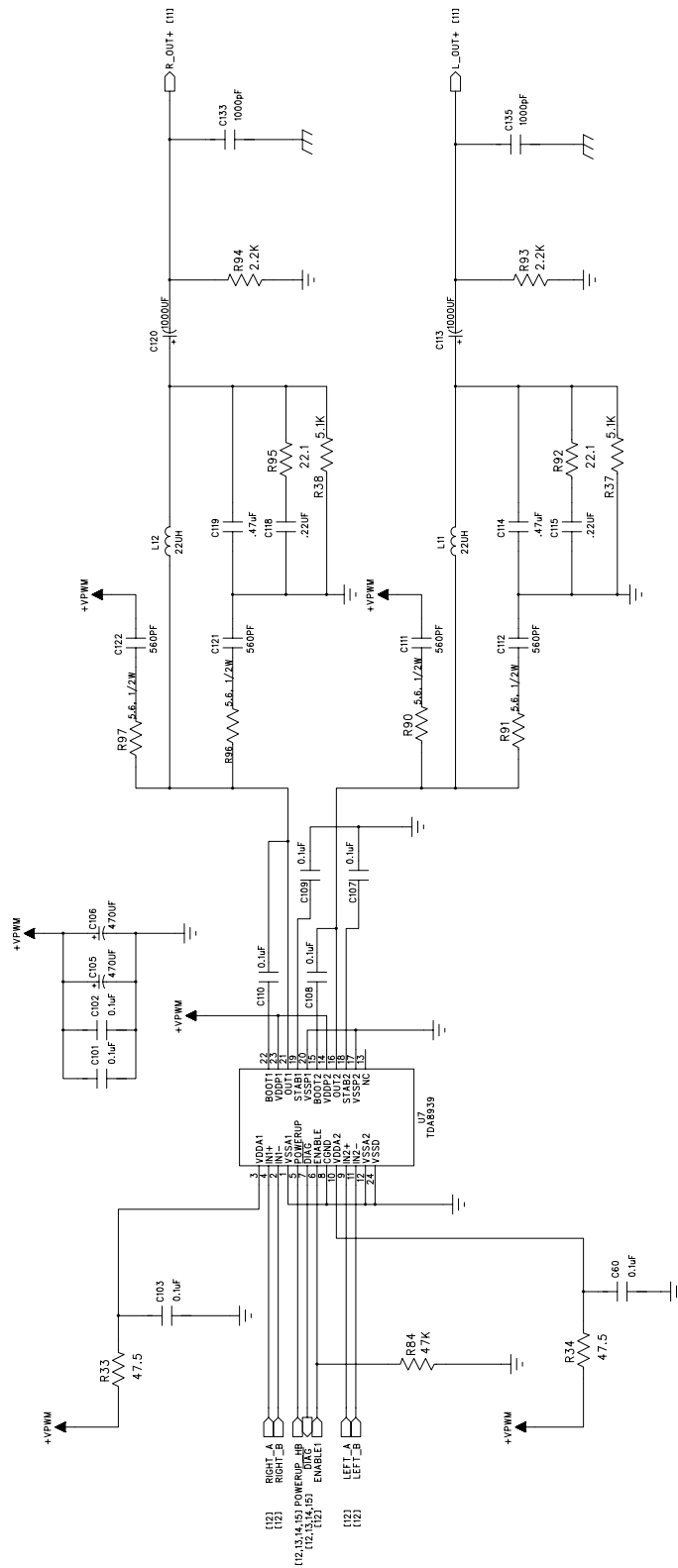
Figure 5. CS44800

Figure 6. Left/Right Back Surround Channels

Figure 7. Left/Right Surround Channels

Figure 8. LFE/Center Channels
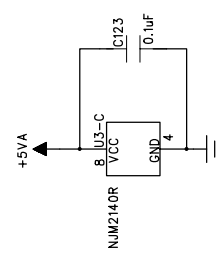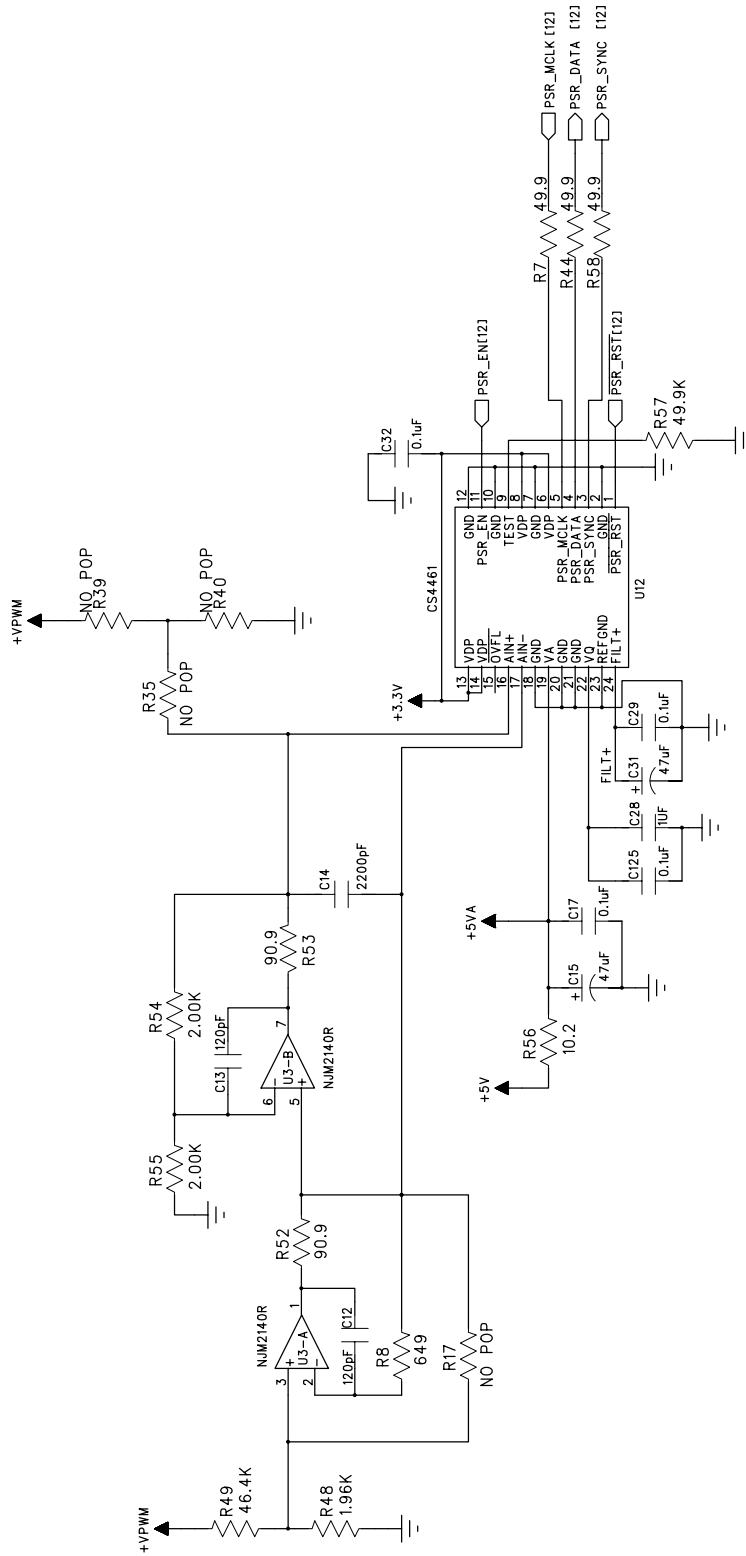
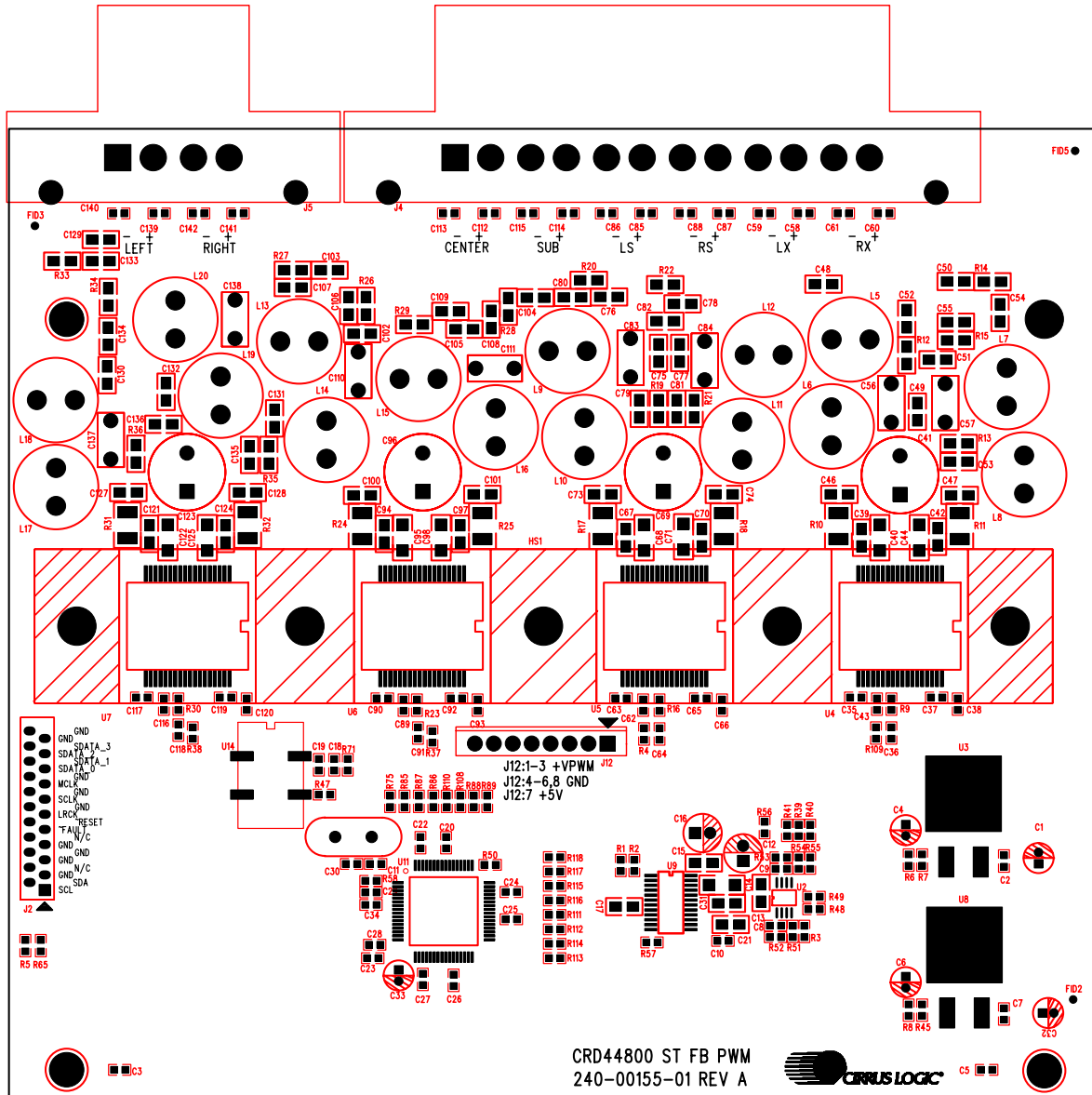**Figure 9. Left/Right Channels**

Figure 10. PSR Feedback

4. LAYOUT

Figure 11. Silk Screen Top
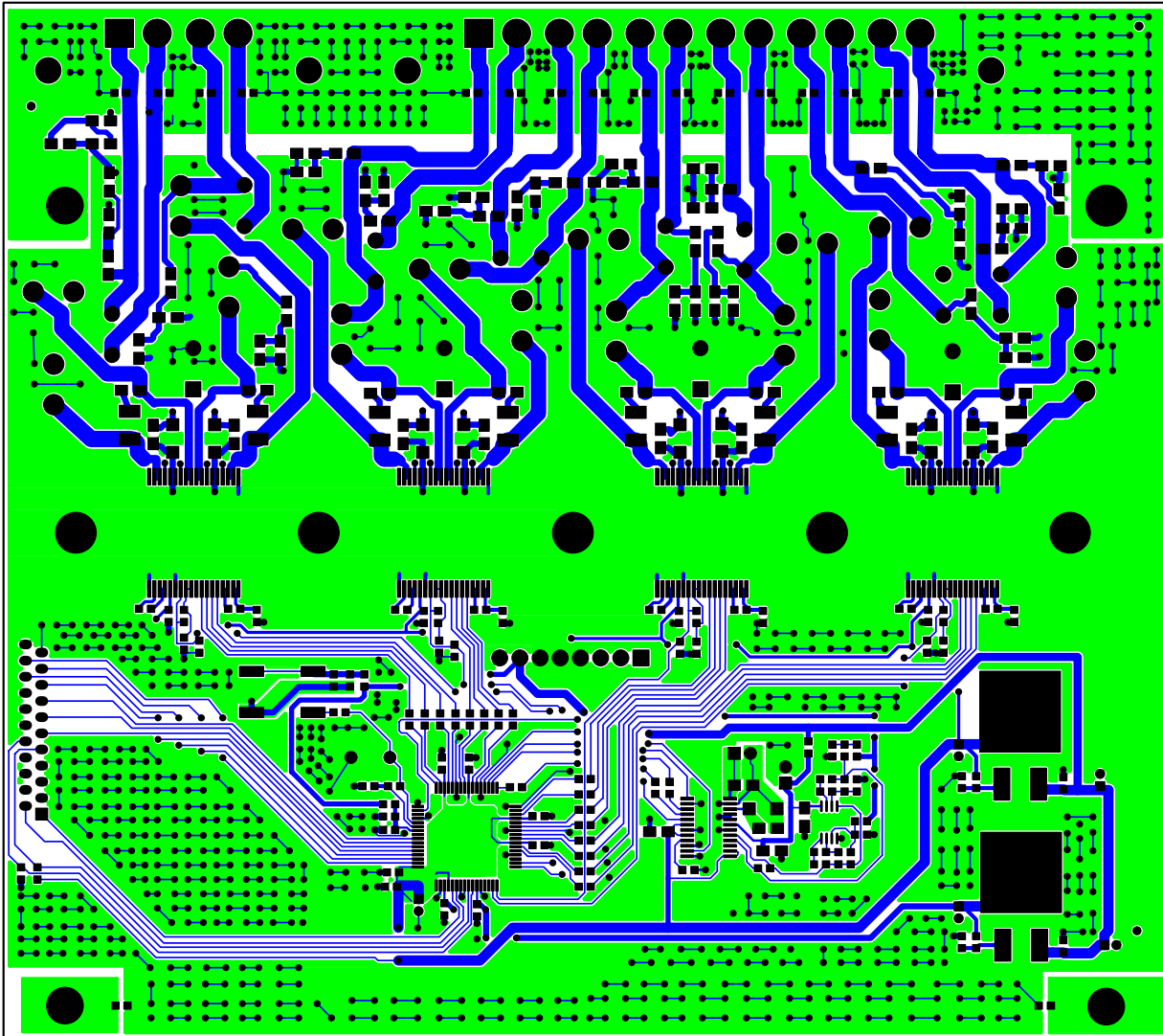
Figure 12. Topside Layer
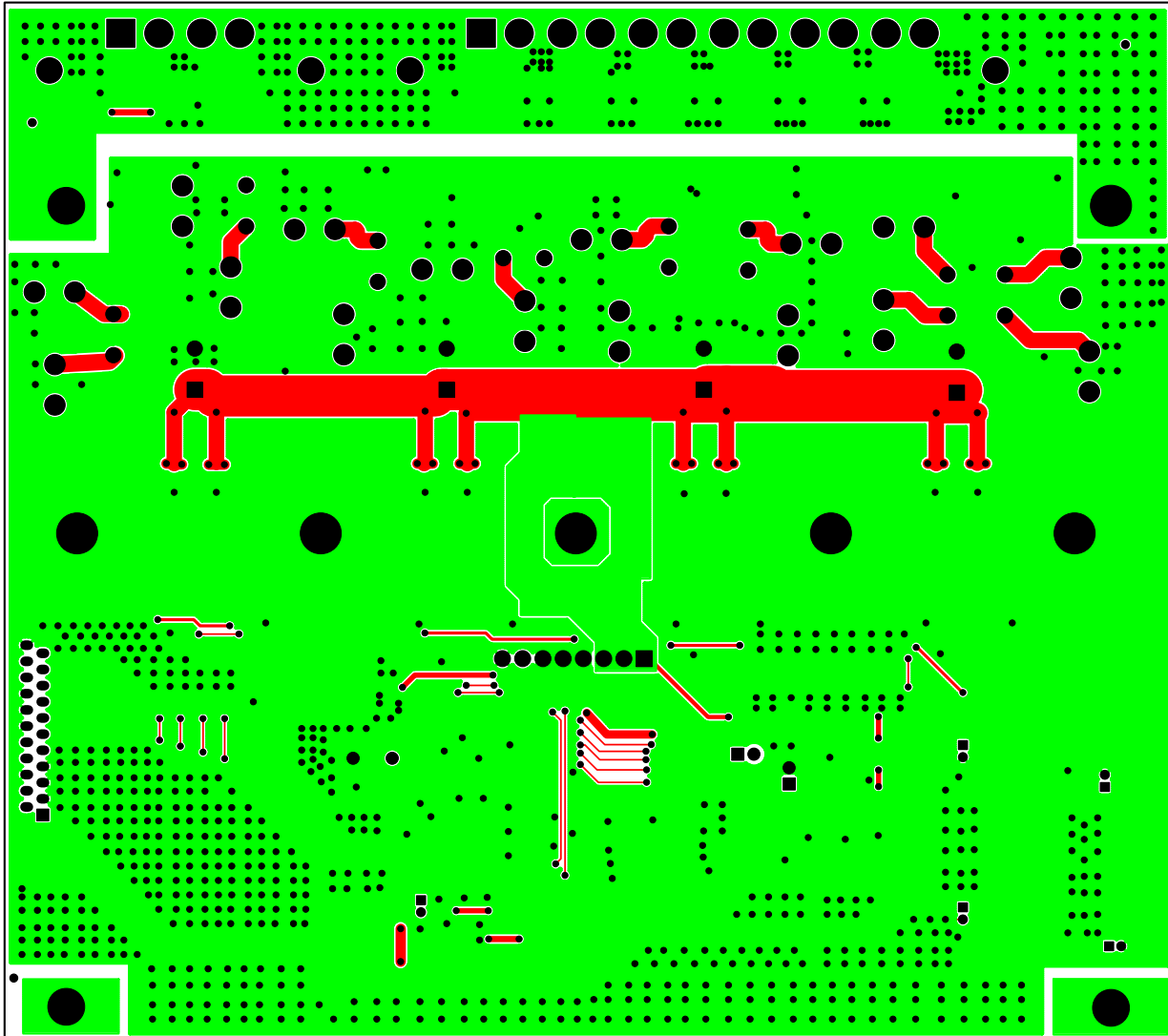
Figure 13. Bottomside Layer

5. BILL OF MATERIALS

Line Item	Cirrus P/N	Rev	Description	Qty	U/M	Reference Designator	MFG	MFG. P/N
1	001-01790-01	A	CAP 1000pF ±10% 50V X7R 0603	21	EA	C3 C5 C19 C28 C29 C58 C59 C60 C61 C85 C86 C87 C88 C112 C113 C114 C115 C139 C140 C141 C142	PANASONIC	ECJ1VB1H102K
2	001-07078-01	A	CAP 1uF ±10% 25V X7R 1206	9	EA	C14 C40 C44 C68 C71 C95 C98 C122 C125	PANASONIC	ECJ3YB1E105K
3	001-10097-01	A	CAP 120pF ±5% 50V C0G 0603	2	EA	C8 C9	KEMET	C0603C121J5GAC
4	001-01865-01	A	CAP 2200pF ±10% 50V X7R 0603	1	EA	C10	KEMET	C0603C222K5RAC
5	012-00035-01	A	CAP 22uF ±20% 6.3V ELEC RAD	5	EA	C1 C4 C6 C32 C33	PANASONIC	ECEA0JKS220
6	001-03379-01	A	CAP 330pF ±5% 50V C0G 0805	8	EA	C46 C47 C73 C74 C100 C101 C127 C128	KEMET	C0805C331J5GAC
7	001-10043-01	A	CAP 39pF ±5% 50V C0G 0603	2	EA	C11 C30	KEMET	C0603C390J5GAC
8	011-00007-01	A	CAP 0.47uF ±10% 63V MTL FLM RAD	8	EA	C56 C57 C83 C84 C110 C111 C137 C138	BC COMPONENTS	2222 370 11474
9	012-00071-01	A	CAP 470uF ±20% 35V ELEC RAD	4	EA	C41 C69 C96 C123	PANASONIC	ECA1VM471B
10	012-00064-01	A	CAP 47uF ±20% 16V ELEC RAD 6.3x11MM	2	EA	C12 C16	PANASONIC	ECEA1CKS470
11	001-02189-01	A	CAP 0.1uF ±10% 16V X7R 0603	31	EA	C2 C7 C18 C20 C22 C23 C24 C25 C26 C27 C34 C35 C36 C37 C38 C43 C62 C63 C64 C65 C66 C89 C90 C91 C92 C93 C116 C117 C118 C119 C120	KEMET	C0603C104K4RAC
12	001-04345-01	A	CAP 0.1uF ±10% 50V X7R 0805	45	EA	C13 C15 C17 C21 C31 C39 C42 C48 C49 C50 C51 C52 C53 C54 C55 C67 C70 C75 C76 C77 C78 C79 C80 C81 C82 C94 C97 C102 C103 C104 C105 C106 C107 C108 C109 C121 C124 C129 C130 C131 C132 C133 C134 C135 C136	KEMET	C0805C104K5RAC
13	311-00001-01	A	HEATSINK, 30W, APOGEE PWM	1	EA	HS1	SUMMIT HEAT SINKS CO LTD	311-00001-01
14	110-00078-01	A	CONN, FLEX 22PIN, ST, I mm PITCH	1	EA	J2	HIROSE ELECTRIC	FH21-22S-1DSA
15	110-00091-01	A	CONN, 8PIN EH 2.5MM PTCH PWR HDR	1	EA	J12	JST	B8B-EH-A
16	110-00094-01	A	CONN, 2x2 SPKR TERMINAL	1	EA	J5	DRAGON CITY INDUSTRIES	PT-422-03
17	110-00095-01	A	CONN, 6x2 SPKR TERMINAL	1	EA	J4	DRAGON CITY INDUSTRIES	PT-1222P-03
18	040-00022-01	A	IND 22uH 3.5A ±10% 400 DIA TH	16	EA	L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18 L19 L20	TRANSTEK MAGNETICS	TMP50612CT
19	020-00788-01	A	RES 10 OHM 1/16W ±1% 0603 FILM	1	EA	R71	DALE	CRCW060310R0F
20	020-00789-01	A	RES 10.2 OHM 1/16W ±1% 0603 FILM	1	EA	R56	DALE	CRCW060310R2F
21	020-00902-01	A	RES 100 OHM 1/16W ±1% 0603 FILM	17	EA	R58 R75 R85 R86 R87 R88 R89 R108 R110 R111 R112 R113 R114 R115 R116 R117 R118	DALE	CRCW0603100OF
22	020-01130-01	A	RES 10k OHM 1/16W ±1% 0603 FILM	10	EA	R4 R5 R9 R16 R23 R30 R37 R38 R65 R109	PANASONIC	ERJ3EKF1002V
23	020-00911-01	A	RES 121 OHM 1/16W ±1% 0603 FILM	3	EA	R7 R8 R45	DALE	CRCW06031210F
24	020-01047-01	A	RES 1.96k OHM 1/16W ±1% 0603 FILM	1	EA	R48	DALE	CRCW06031961F
25	020-00934-01	A	RES 200 OHM 1/16W ±1% 0603 FILM	1	EA	R6	DALE	CRCW06032000F
26	020-01048-01	A	RES 2k OHM 1/16W ±1% 0603 FILM	2	EA	R54 R55	DALE	CRCW06032001F
27	021-00718-01	A	RES 20 OHM 1/4W ±5% 1210 FILM	8	EA	R10 R11 R17 R18 R24 R25 R31 R32	DALE	CRCW12102000J
28	020-01181-01	A	RES 29.4k OHM 1/16W ±1% 0603 FILM	1	EA	R49	DALE	CRCW06032942F
29			DELETED LINE ITEM					
30	020-00867-01	A	RES 49.9 OHM 1/16W ±1% 0603 FILM	4	EA	R1 R2 R47 R50	DALE	CRCW060349R9F
31	020-01209-01	A	RES 49.9k OHM 1/16W ±1% 0603 FILM	1	EA	R57	DALE	CRCW060349992F

Figure 14. Bill of Materials

Line Item	Cirrus P/N	Rev	Description	Qty	U/M	Reference Designator	MFG	MFG. P/N
32	021-00358-01	A	RES 6.2 OHM 1/8W ±5% 0805 FILM	16	EA	R12 R13 R14 R15 R19 R20 R21 R22 R26 R27 R28 R29 R33 R34 R35 R36	DALE	CRCW08056R2J
33	020-00995-01	A	RES 649 OHM 1/16W ±1% 0603 FILM	1	EA	R51	DALE	CRCW06036490F
34	020-00897-01	A	RES 90.9 OHM 1/16W ±1% 0603 FILM	2	EA	R52 R53	PANASONIC	ERJ3EKF90R9V
			NO POP			R3 R39 R40 R41 X1		
35	065-00125-02	D	IC CRUS A/D PSR FEEDBACK TSSOP24	1	EA	U9	CIRRUS LOGIC	CS44461-CZZ/D
36	065-00085-01	A	IC CRUS, MULTI CHNL PWM CONTR QFP64	1	EA	U11	CIRRUS LOGIC	CS44800-CQ/A
37	060-00098-01	A	IC, 1.5A ADJ V REG, TO-252	2	EA	U3 U8	NJR	NJM317DL1
38	060-00286-01	A	IC LNR DUAL OP AMP LOW V RRO VSP8	1	EA	U2	NJR	NJM2140R
39	060-00292-01	A	IC 30V 3.5A QUAD PWR BRDG POWERSO36	4	EA	U4 U5 U6 U7	ST MICROELECTRONICS	STA500
40	102-00028-01	A	OSC, 24.576MHz 100ppm 5V, SG-531	1	EA	U14	CITIZEN	CMX309FLC24.576MT
41	300-00009-01	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
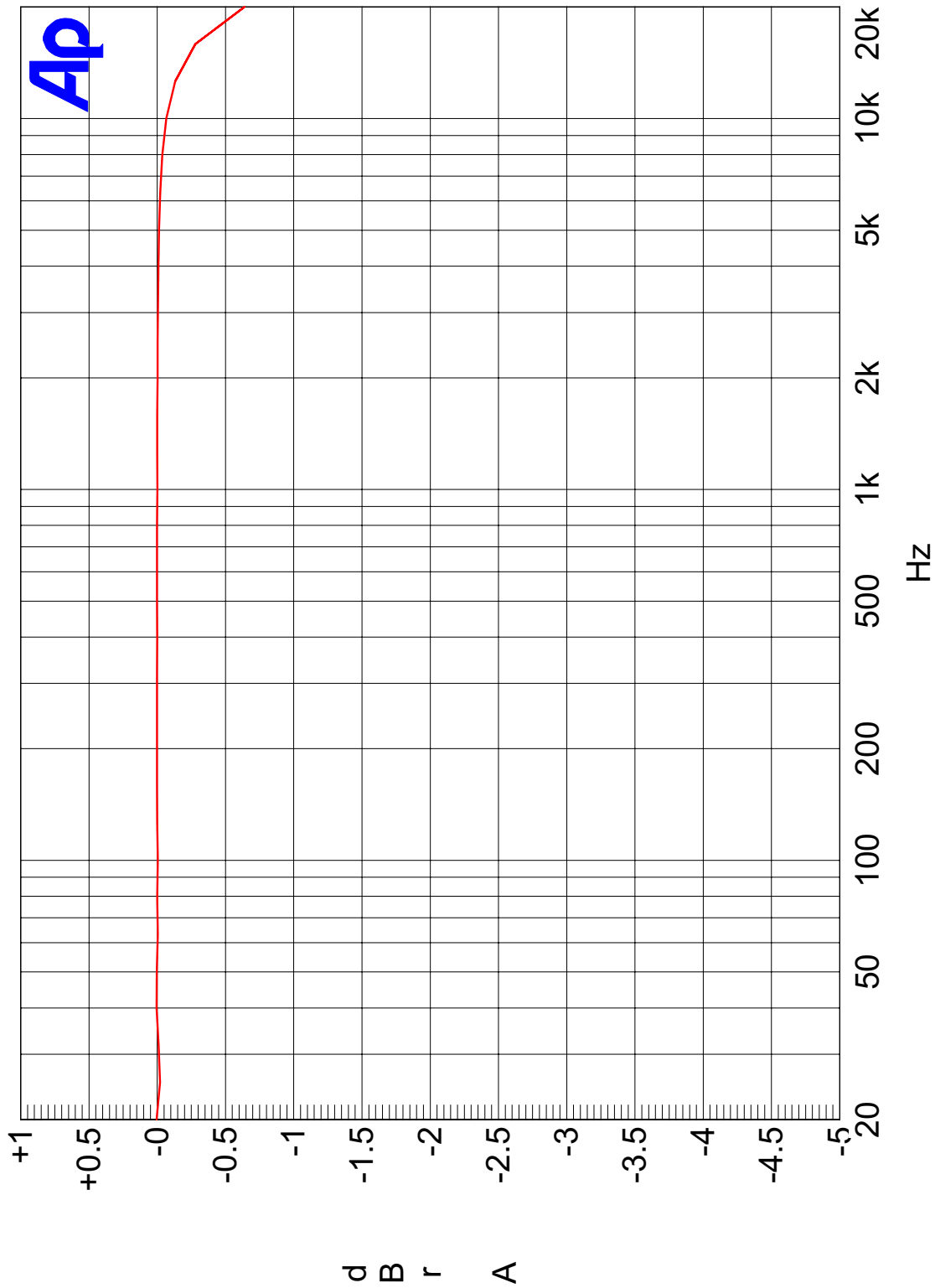
Figure 16. Frequency Response
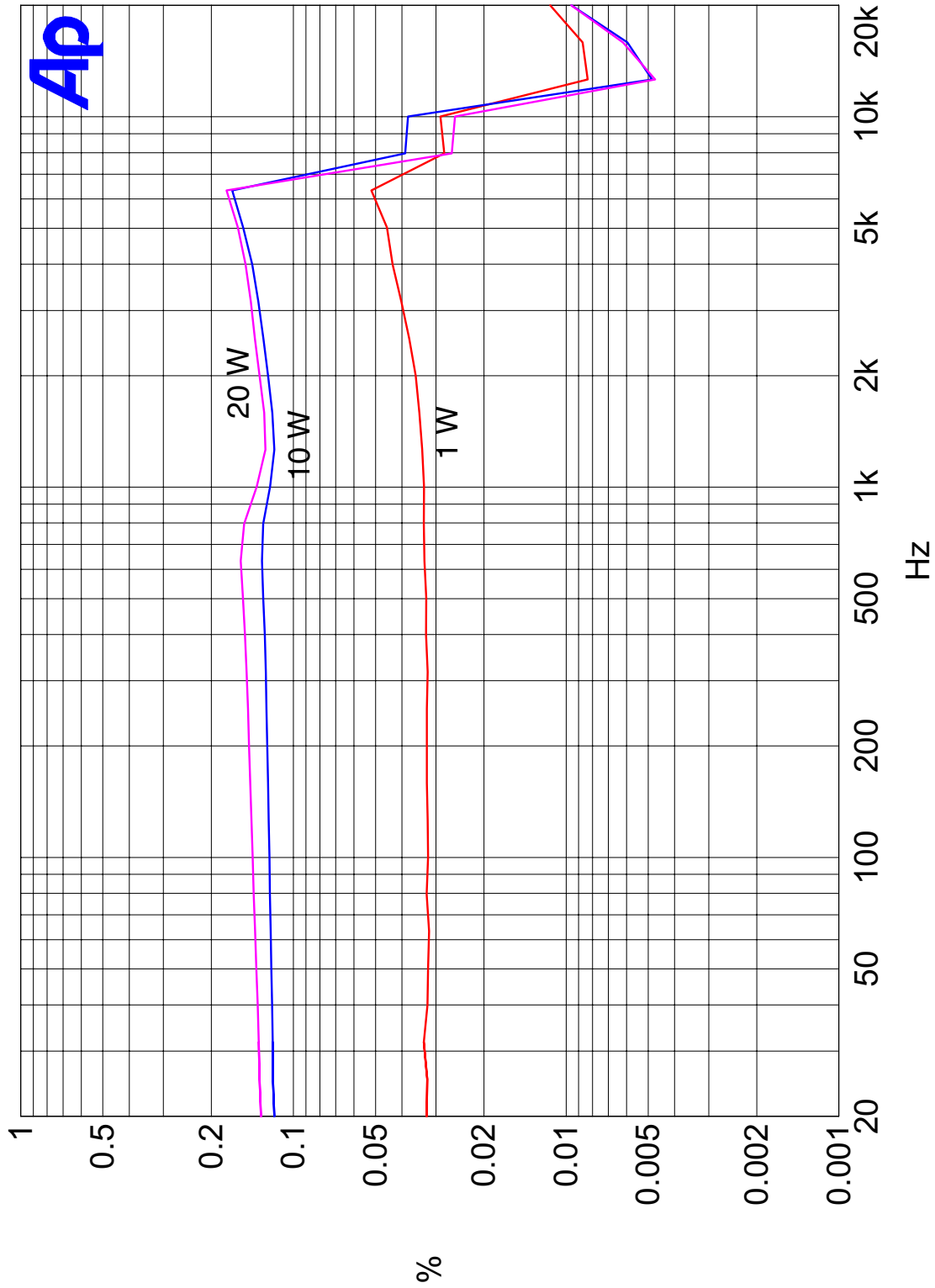
Figure 17. THD+N vs. Frequency at 1 W, 10 W, and 20 W
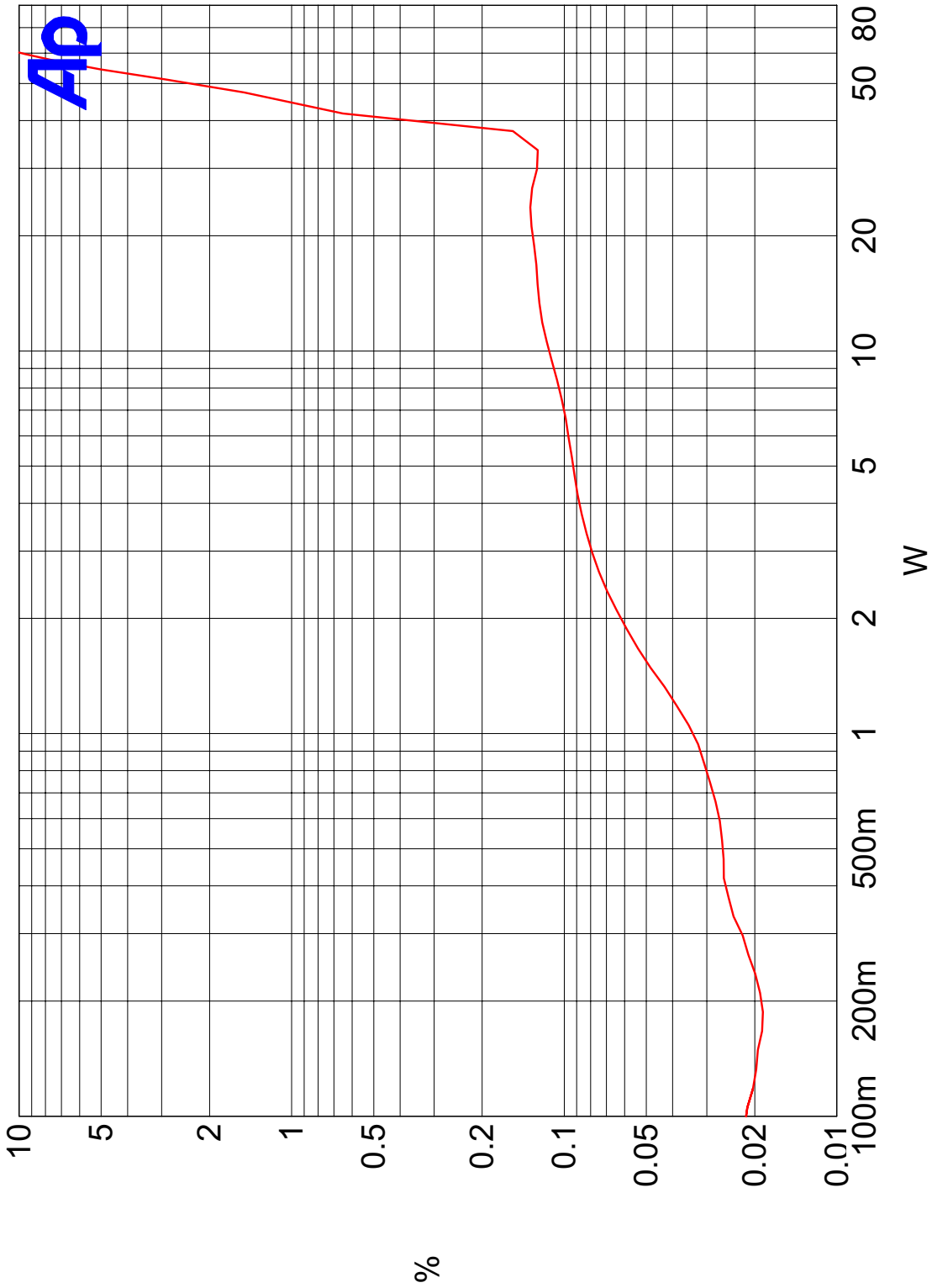
Figure 18. THD+N vs. Power at 1 kHz
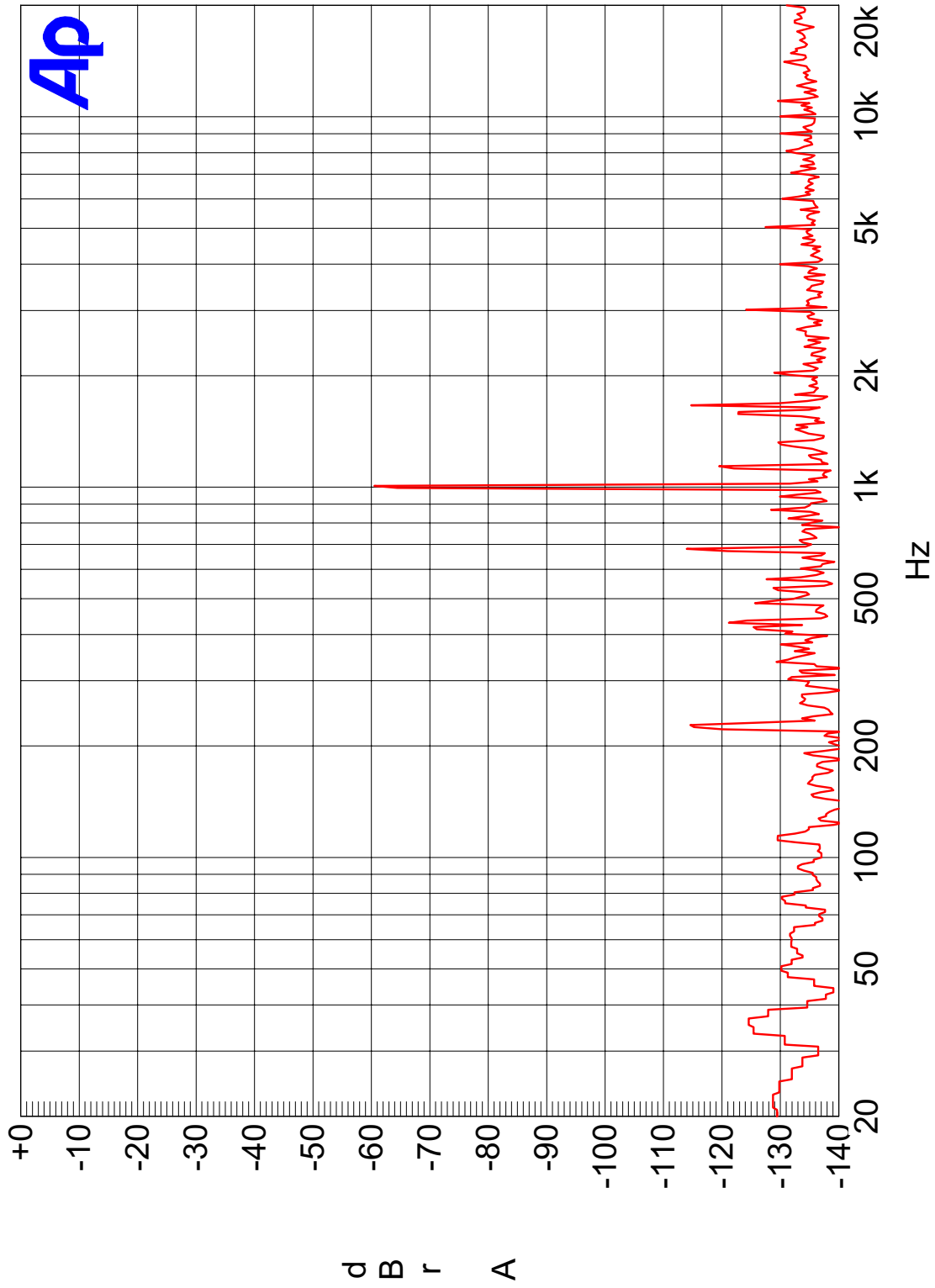
Figure 19. FFT at -60 dBFS and 1 kHz

7. REVISION HISTORY

Release	Date	Changes
RD1	December 2004	1st Release

Table 1. 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/**

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