Class D audio reference board with 100 V CoolGaN™ transistors and MERUS™ IRS20957S audio IC

About this document

Scope and purpose

This user guide provides an overview and detailed feature description of the REF_Audio_GaNb_750W class D audio reference board with the CoolGaN™ power transistor IGB110S10S1 and MERUS™ IRS20957S audio controller IC. It demonstrates the superior power density and audio performance of CoolGaN™ power transistors in class D audio systems.

Intended audience

This document is for power electronic engineers, technicians, and developers of class D audio systems who are interested in evaluating the performance of the 100 V CoolGaN™ power transistor IGB110S10S1 in combination with MERUS™ IRS20957S audio controller IC.

About this product group

Target applications

- Consumer electronics
- Information and communication technologies
- Motor drives
- Robotics
- Energy Storage Systems
- Renewables

Product family

Infineon's CoolGaN™ solution offers unmatched quality that operate at higher switching speeds resulting in lower power losses, higher efficiency paving the way for smaller and lighter power supplies with the same power supplies with the same size but increased power capability.

Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	**Caution:** *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	**Caution:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	**Caution:** *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

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1 REF_Audio_GaNb_750W overview

The REF_Audio_GaNb_750W features the 100 V CoolGaN™ transistors combined with the MERUS™ IRS20957S class D audio driver ICs. This two-channel design is scalable up to 375 W x 2 channel at 2 Ω without heatsink. The design includes all the required power supplies and connectors for ease of use and lab bench evaluation. This topology represents an analog version of a second-order sigma-delta modulation, having a class D switching stage inside the loop.

The benefit of the sigma-delta modulation, in comparison to the carrier-signal based modulation, is that all the error in the audible frequency range is shifted to the inaudible upper-frequency range by the nature of its operation. Additionally, sigma-delta modulation enables the designer to apply sufficient error correction.

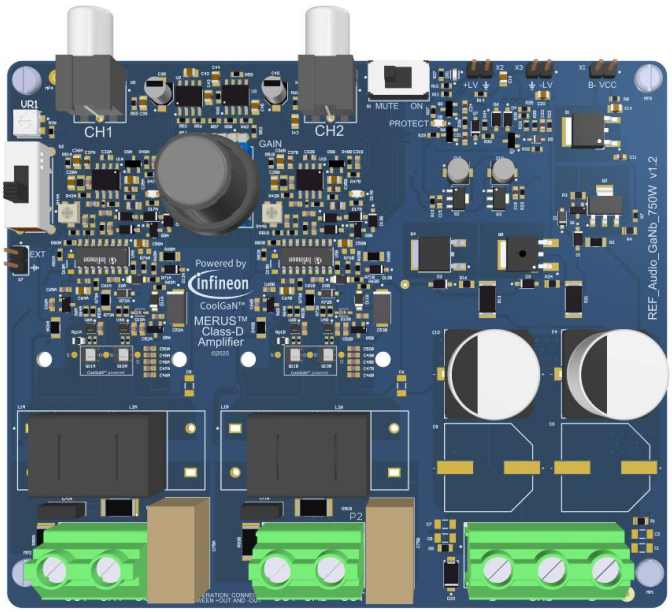

Figure 1 REF_Audio_GaNb_750W reference board

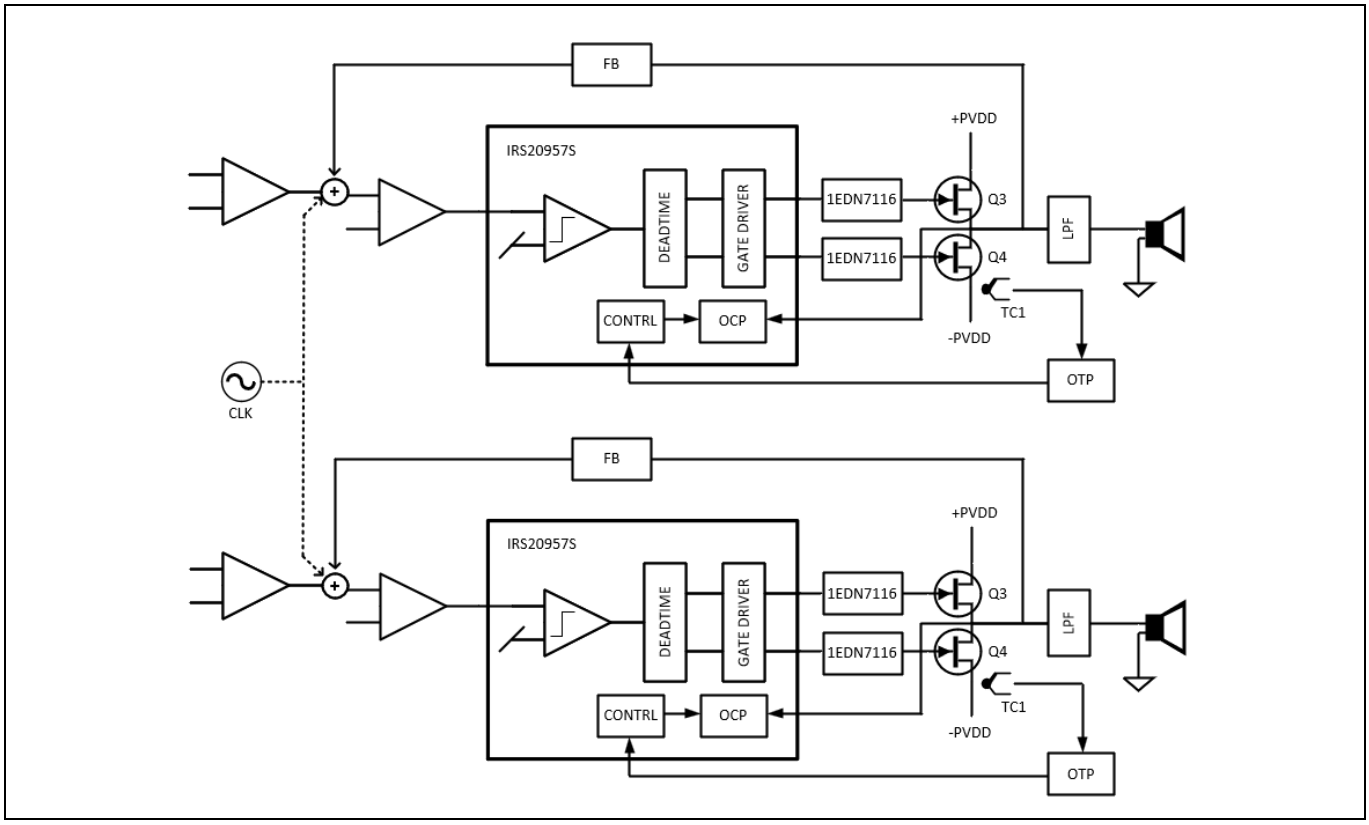

Figure 2 Simplified block diagram of REF_Audio_GaNb_750W reference board

1.1 Features

- Overcurrent protection (OCP)
- Overvoltage protection (OVP)
- Undervoltage protection (UVP)
- Overtemperature protection (OTP)
- Self-oscillating half-bridge topology
- Optional clock synchronization
- Configured for single-ended (SE) and bridge-tied-load (BTL) operation
- Quiet turn on, turn off

1.2 Board description

Table 1 General specifications

Condition	Value	Notes
Rated load impedance	2 Ω to 4 Ω	Resistive load
Self-oscillating frequency	Typ. 1 MHz	No input signal, adjustable
Voltage gain	19 – 32 dB	Class D fixed at 14 dB
Number of audio channels	2 x single-ended or 1 x BTL	–
Audio input format	Analog	–

Table 2 Electrical specifications

Condition	Min.	Typ.	Max.	Note
Supply voltage	± 27 V	± 36 V	± 40 V	–
Power supply current at 10% THD+N, 2 Ω	± 10 A at ± 27 V	± 12 A at ±36 V	± 13 A at ± 40 V	–
Input signal level	–	3.5 V_{RMS}	3.9 V_{RMS}	R54 full ccw
Idling supply current	–	+110 mA -120 mA	–	No input signal ±36 V

Table 3 Audio performance

Parameter	Value	Notes
Output power (1% THD+N) Single Ended	195 W x 2 ch	1 kHz, RL = 4 Ω, ±40 V
	300 W x 2 ch	1 kHz, RL = 2 Ω, ±36 V
Output power (10% THD+N) Single Ended	240 W x 2 ch	1 kHz, RL = 4 Ω, ±40 V
	375 W x 2 ch	1 kHz, RL = 2 Ω, ±36 V
Output power (1% THD+N) BTL	600 W x 1 ch	1 kHz, RL = 4 Ω, ±36 V
Output power (10% THD+N) BTL	750 W x 1 ch	1 kHz, RL = 4 Ω, ±36 V
Signal-to-noise Ratio (SNR)	>120 dB	Filter: A-weighting (12017), 20 kHz SPCL
Residual noise	<30 µV	Filter: A-weighting (12017), 20 kHz SPCL

All connections of the REF_Audio_GaNb_750W reference board are shown in Figure 3. The corresponding description for each connector is mentioned in Table 4.

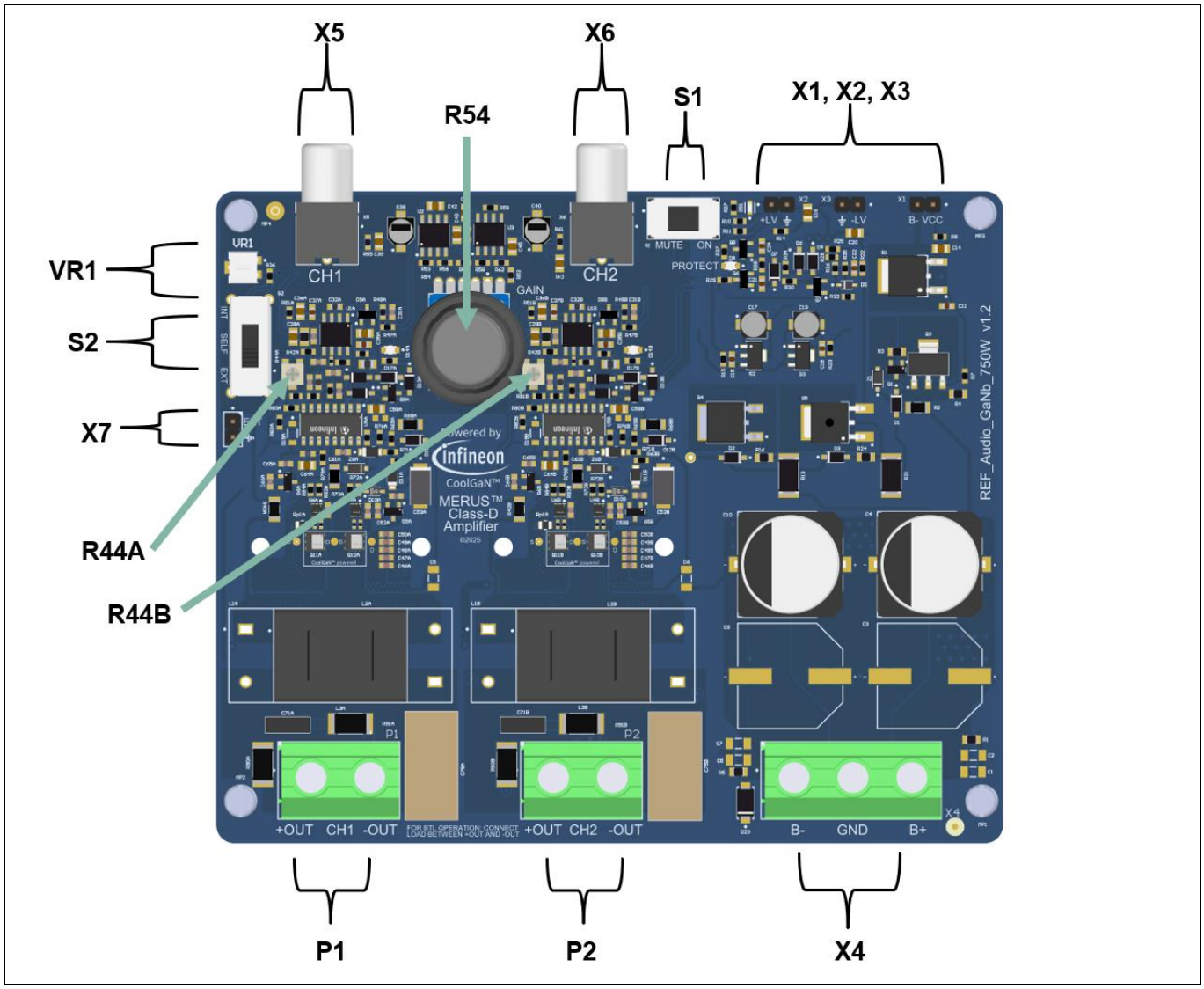

Figure 3 Main board connections

Following are the main board connections:

- Although the board includes all the house-keeping power supplies, use the connectors (X1, X2, X3) if separate low-voltage (LV) supply is of interest
- The external clock input at X7 is optional and it's recommended to use the self-oscillating clock by setting the slider (S2) to its middle position
- Slider (S1) offers a mute feature to turn off both audio channels
- Connect a bipolar DC power supply to the connector (X4) with a minimum voltage of ±27 V and a maximum voltage of ±40 V
- Ensure that the audio input signals for both channels are connected to X5/X6 using the RCA unbalanced connectors
- Use R54 to modify the pre-amplifier gain
- P1 and P2 are the speaker output of the board where the resistive load can be connected

See Table 2 for the other electrical specifications.

Table 2 Function description of the main REF_Audio_GaNb_750W board connections

Designator	Function	Note
X1, X2, X3	External LV supply	Optional LV supply, not required for operation
X4	Bipolar DC power supply	>12-16 AWG preferred
X5, X6	Analog audio input	RCA analog unbalanced
X7	External clock input	5 Vpp input, optional
S1	Mute	Slider to turn on/off
S2	Sync clock	Internal, self-oscillating, external
P1, P2	Speaker output	>16-18 AWG preferred
R54	Preamplifier gain	Adjustable
VR1	Internal sync clock adjustment	500 kHz – 1 MHz
R44A, R44B	Self-oscillating frequency adjustment	Preset to 1 MHz

1.3 CoolGaN™ 100 V power transistors

The REF_Audio_GaNb_750W reference board is using the 100 V CoolGaN™ power transistor IGB110S10S1 [1]. Alternatively, IGB070S10S1 [2] can be used in the final system depending on the targeted power range, frequency, and audio performance as its package is footprint compatible.

Both IGB110S10S1 and IGB070S10S1 come in a 3 x 3 mm PQFN package with very low inductance in the pH range, as well as dual-side cooling with an exposed thermal pad on the top side of the transistor. They can be operated at high switching frequencies and short dead-times due to its fast-switching transitions and low switching loss. This enables reducing the size of output filter, capacitors, and heatsinks in the application to improve power density and the overall system efficiency and audio performance.

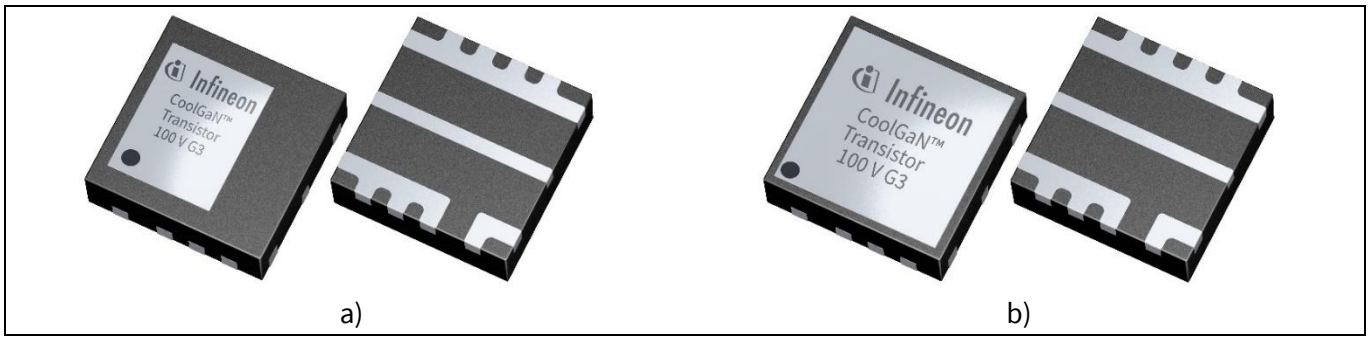

Figure 4 (a) IGB110S10S1; (b) IGB070S10S1

1.4 MERUS™ IRS20957S protected digital audio driver

The MERUS™ IRS20957S [3] is a high-voltage, high-speed driver with a floating PWM input designed for class D audio amplifier applications. It features a bi-directional current sensing to detect overcurrent conditions during positive and negative load currents without any external shunt resistors.

A built-in protection control block provides a secure protection sequence against overcurrent conditions and a programmable reset timer. The internal dead-time generation block enables accurate gate switching and optimum dead-time setting for better audio performance, such as lower THD and lower audio noise floor.

1.4.1 Features

- Floating PWM input enables easy half bridge implementation
- Programmable bidirectional overcurrent protection with self-reset function
- Programmable preset dead-time for improved THD performance
- High noise immunity
- +/- 100 V rating
- 3.3 V/ 5 V logic compatible input
- Operates up to 1 MHz

1.5 EiceDRIVER™ 1EDN7116U gate driver

EiceDRIVER™ 1EDN7116U is an optimized gate driver IC that is designed for driving CoolGaN™ power transistors. It features a truly differential input (TDI), active Miller clamp, bootstrap voltage clamp, and low inductance TSNP package, which are all essential for a high-performance system design with fast-switching transistors. TDI allows the gate driver output state to be controlled solely by the voltage difference between the two inputs. This is regardless of the driver's reference potential, as long as the common-mode voltage remains below 150 V (static) and 200 V (dynamic). This feature eliminates the risk of false triggering caused by ground bounce in low-side driving and enables 1EDN7116U to be used as a high-side driver. The driver can be used with gate resistors (RG_{ON}/RG_{OFF}) on the split source and sink outputs.

1.5.1 Features

- 2.0 A peak source/sink current
- 20 ns input pulse blanking time
- 55 ns typical propagation delay

There are four variants of the EiceDRIVER™ 1EDN71x6U family with different driving strengths available in the same package type and footprint. A more detailed description of the driver is available online [3].

2 Board setup

The board can be set up for two main load configurations:

- Two-channel single-ended (SE) configuration
- Single-channel bridge tied load (BTL) configuration

2.1 Two-channel SE configuration wiring setup

Perform the following steps to set up the board for the two-channel single-ended (SE) configuration:

1. Connect 2 Ω > 400 W capable loads(s) to the output connectors P1 and P2
2. Connect P1 and P2 to **Audio Precision AUX-0040** or **AUX-0025**
3. Connect **AUX-0025** to **Audio Precision** balanced inputs
4. Connect the unbalanced source signal to X5 and X6
5. Connect the DC power supplies to X4
6. Ground **Audio Precision** chassis to power supply ground

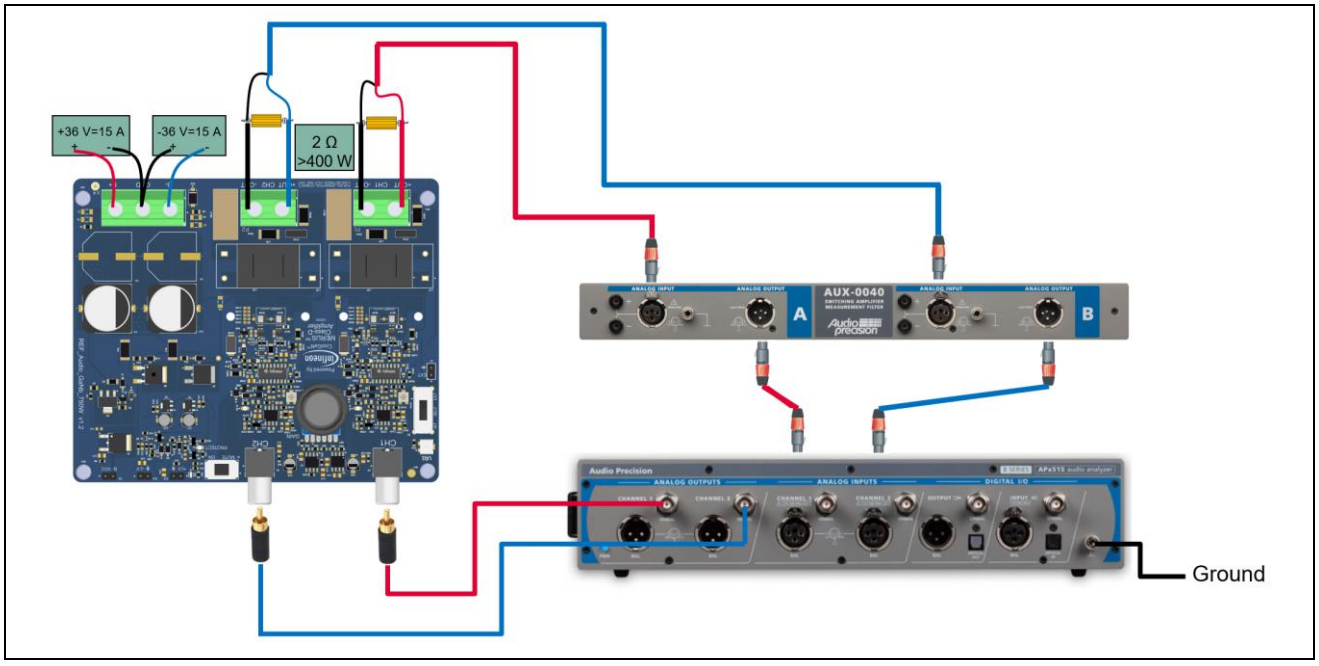

Figure 5 Typical operation setup for SE operation of REF_Audio_GaNb_750W

2.2 One-channel BTL configuration wiring setup

Perform the following steps to set up the board for the one-channel BTL configuration wiring setup:

1. Connect 4 Ω > 800 W capable load to output connectors (P1 and P2)
2. Connect P1 and P2 to **Audio Precision** balanced input
3. Connect **AUX-0040** to **Audio Precision** balanced input
4. Connect the unbalanced source signal to X5 and X6
5. Connect the DC power supplies to X4
6. Ground **Audio Precision** chassis to power supply ground

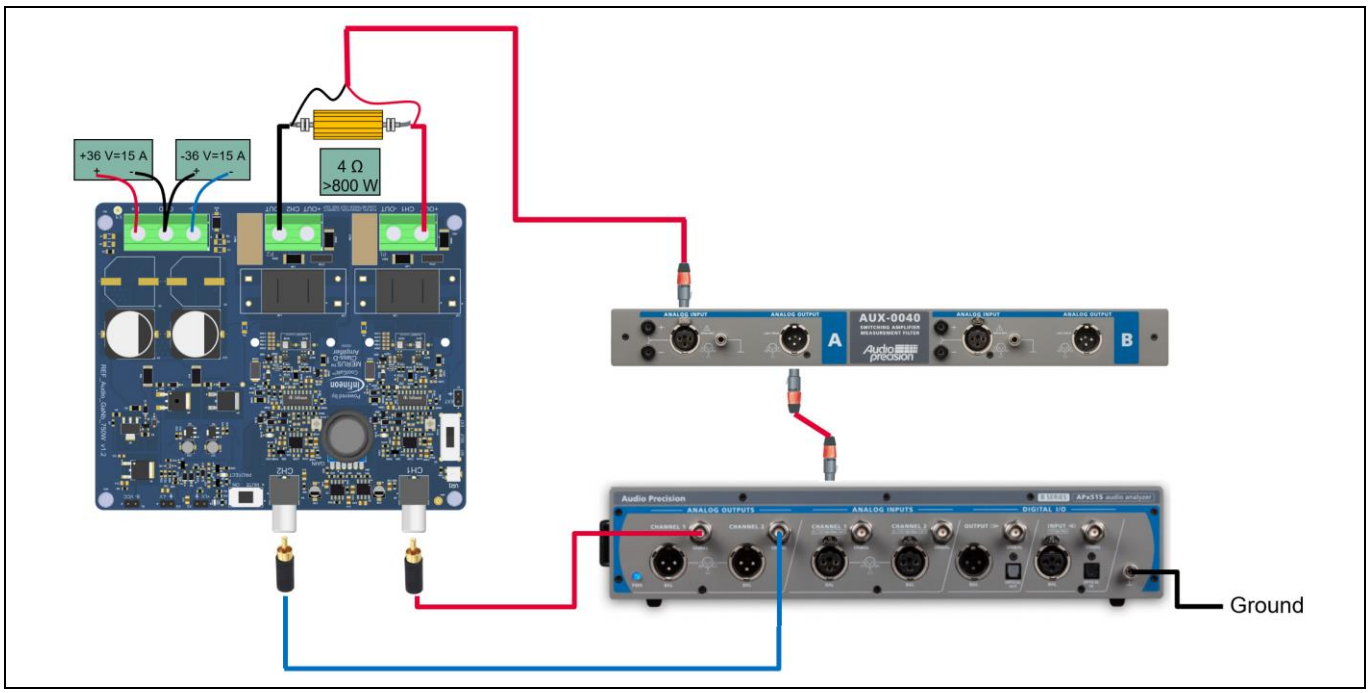

Figure 6 Typical operation setup for BTL operation of REF_Audio_GaNb_750W

3 Audio analyzer setup

3.1.1 Two-channel single-ended configuration

Perform the following steps to set up the **Audio Precision** for two-channel single-ended operation as shown in Figure 7:

Output Configuration settings:

- **Connection**: Analog Unbalanced
- **Channels:** 2

Input Configuration settings:

- Under **Input 1** > **Connection:** Analog balanced
- **Channels:** 2

Filters settings:

- **High-pass:** AC (< 10 Hz)
- **Low-pass:** AES17 (20 kHz)

Verify Connections settings:

- **Waveform:** Sine
- Check the **Levels Track Ch1** box and set the **Ch** as **1 V_{RMS}**
- **Frequency:** 1 kHz

Input References settings:

- Under **Analog**,
  W (watts): 2 ohms

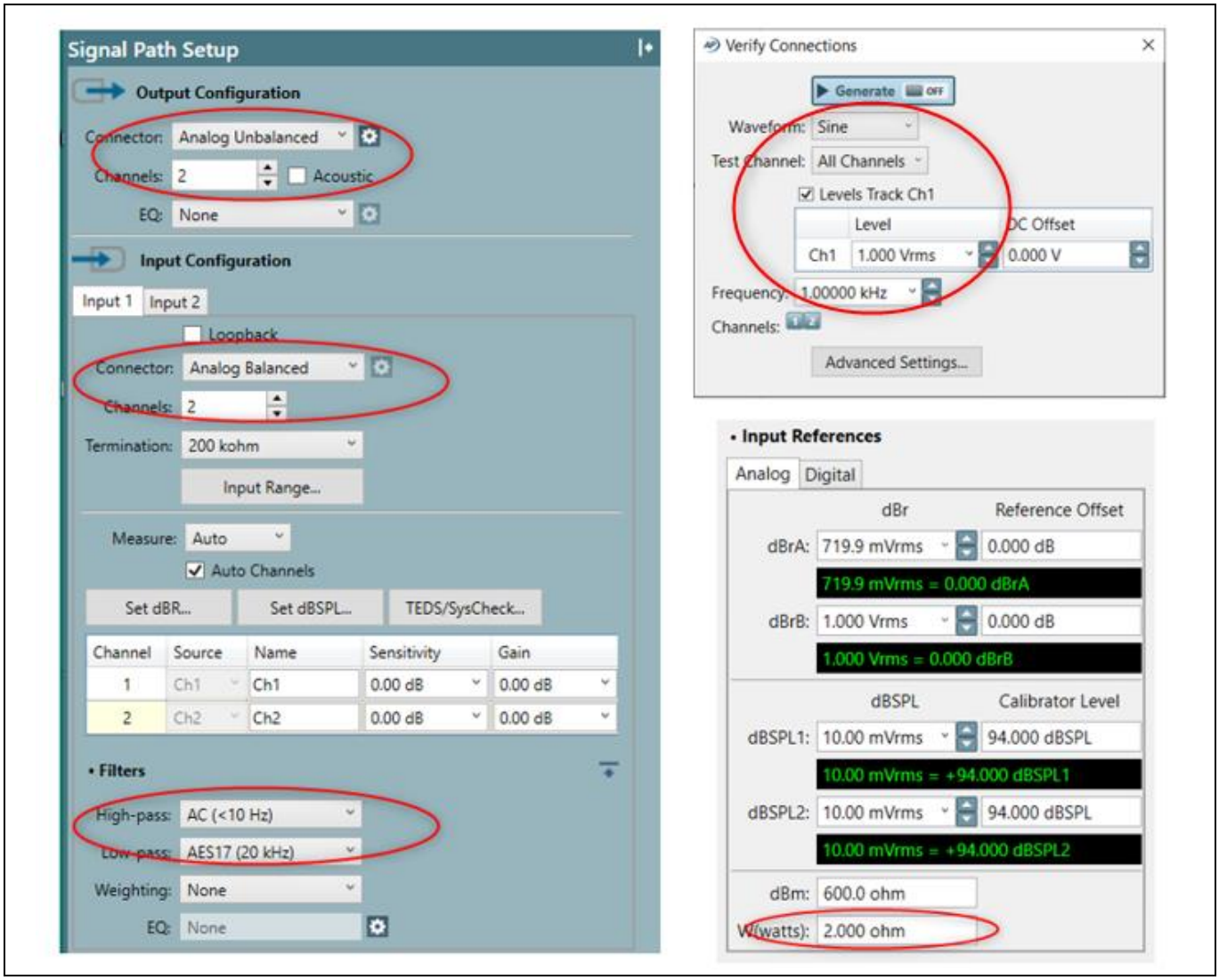

Figure 7 Typical analyzer setup for SE operation of REF_Audio_GaNb_750W

3.1.2 One-channel BTL configuration

Perform the following steps to set up the **Audio Precision** for one-channel single-ended operation as shown in Figure 8:

Output Configuration settings:

- **Connection**: Analog Unbalanced
- **Channels:** 2

Input Configuration settings:

- Under **Input 1** > **Connection:** Analog balanced
- **Channels:** 1

Filters settings:

- **High-pass:** AC (< 10 Hz)
- **Low-pass:** AES17 (20 kHz)

Audio analyzer setup

Verify Connections settings:

- **Waveform:** Sine
- Check the **Levels Track Ch1** box and set the **Ch** as **1 V_{RMS}**
- **Frequency:** 1 kHz

Input References settings:

- Under **Analog**,
  W (watts): 4 ohms

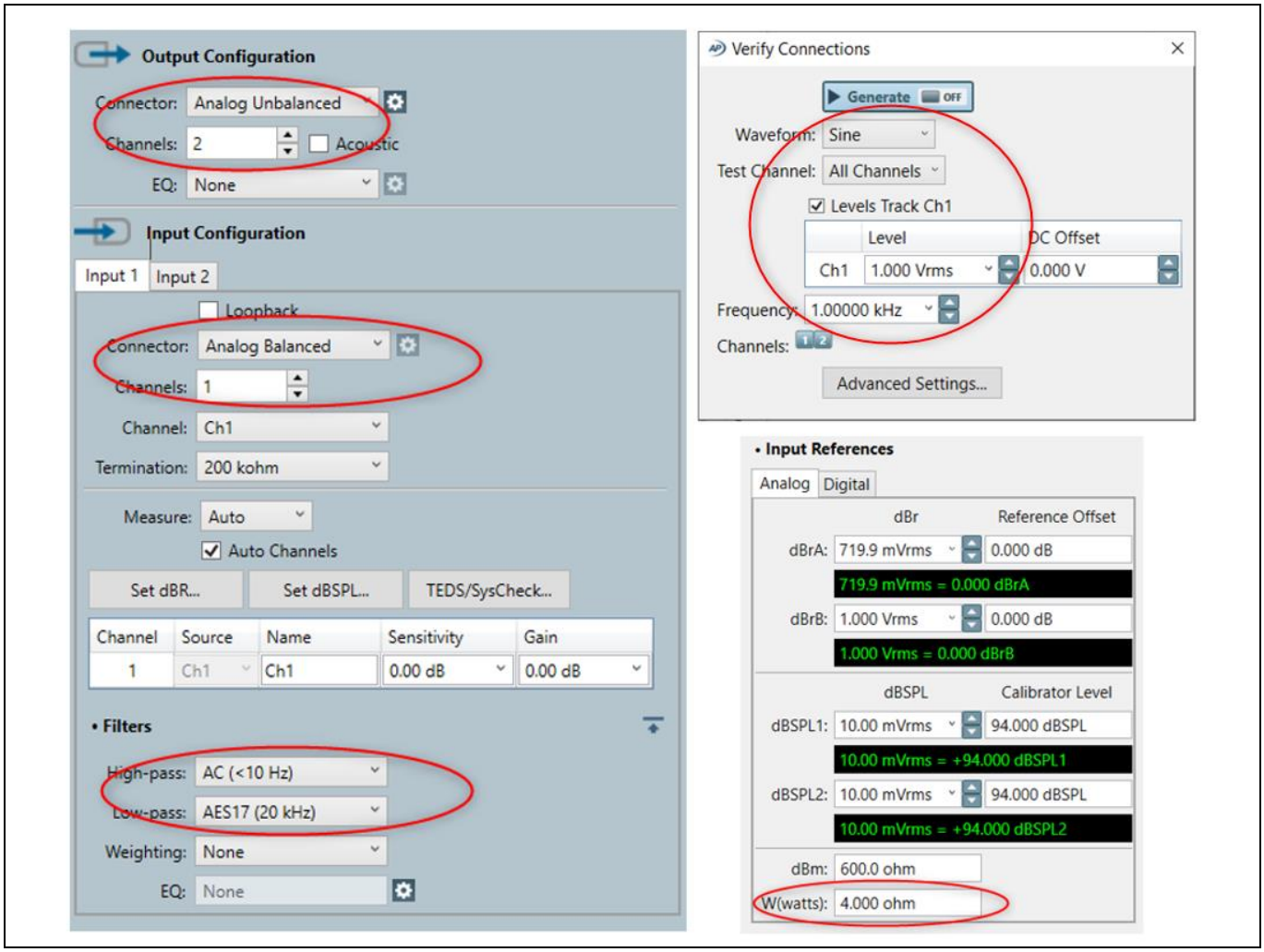

Figure 8 Typical analyzer setup for BTL operation of REF_Audio_GaNb_750W

4 Reference board operations

4.1 Test setup

1. For SE, connect 2 Ω > 400 W capable dummy loads according to Figure 5
2. For BTL, connect 4 Ω > 800 W capable dummy load according to Figure 6
3. Connect the audio analyzer according to Figure 5 for SE and Figure 6 for BTL
4. Connect the **Audio Signal Generator** (ASG) of AP to X5 and X6 as shown in Figure 5
5. Set up the dual power supply with voltages of ±36 V; set current limit to 15 A
6. Turn off the dual power supply before connecting the unit under test
7. Set switch S2 to the middle position (self-oscillating)
8. Set switch S1 to “MUTE”
9. Set the gain potentiometer R54 counterclockwise to the maximum limit
10. Connect the dual power supply to X4 as shown in Figure 5

4.2 Analyzer settings

1. Set the **Audio Precision** settings to match Figure 7 for SE operation and Figure 8 for BTL operation

4.3 Power up

1. Turn ON the dual power supplies
   The ±B supplies must be applied and removed at the same time
2. Red LEDs (Protection) turn on
3. Switch S1 to the unmute position
4. Blue LED (Normal) turns on, red LEDs turn off
5. Quiescent current for the positive supply should be 110 mA ± 10 mA at +36 V
6. Quiescent current for the negative supply should be 120mA ± 10 mA at –36 V
7. Monitor the switching waveform for CH1 at VS1 and VS2 for CH2 using an oscilloscope. See Figure 9.
8. Confirm the self-oscillating switching frequency is 1 MHz ± 30 kHz

4.4 Functional audio test

1. Set the AP’s analog analyzer to 20 kHz AES17 filter
2. Connect the audio signal from the AP to X5 and X6
3. Apply 2.8 V_{RMS} at 1kHz sinusoidal signal from the ASG
   The 2.8 V_{RMS} input generates an output voltage of 22.5 V_{RMS} SE or 45 V_{RMS} in BTL
4. Sweep the audio input signal from 50 m V_{RMS} to 3.5 V_{RMS}
5. Monitor the output signals at P1 and P2 with an oscilloscope and audio analyzer

4.5 Internal sync clock function

1. Monitor VS1 and VS2 switching frequency
2. Set S2 to “INT” (internal clock) position in order to enable the onboard clock oscillator
3. Monitor VS1 and VS2, adjust VR1 to achieve 1 MHz, and ensure that the switching frequencies are synced at 1 MHz
4. Sweep the audio input signal from 50 m V_{RMS} to 3.5 V_{RMS}

4.6 External sync clock function

1. Monitor VS1 and VS2 switching frequency
2. Adjust R44A and R44B on the board to change the self-oscillating frequency to 20-30% higher than the desired external clock
3. Set S2 to “EXT” (external clock) position
4. Apply 5 Vpp external clock to X7
5. Monitor VS1 and VS2 and ensure that the switching frequency signals are synced
6. Sweep the audio input signal from 50 m V_{RMS} to 3.5 V_{RMS}

4.7 Power down

1. Switch S1 to the mute position
2. Turn off +/- power supplies at the same time

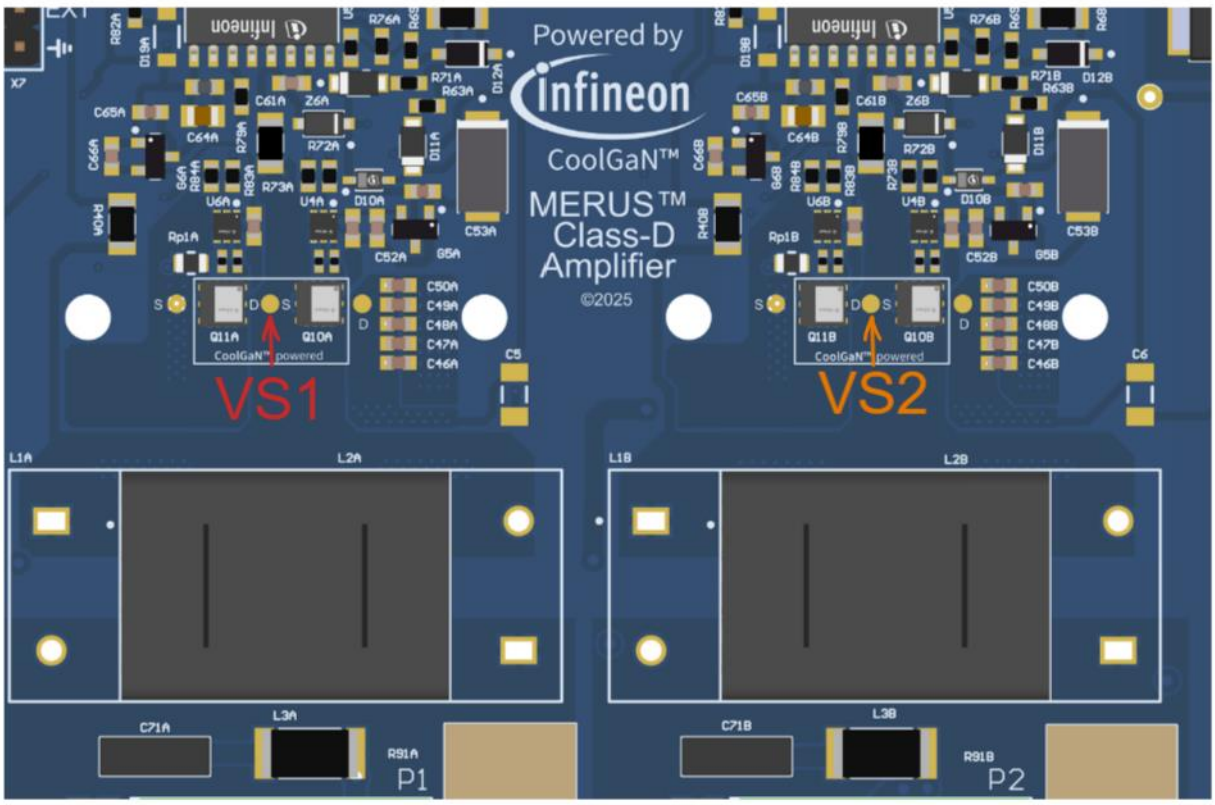

Figure 9 VS1 and VS2 test points

5 Audio performance

This section shows the results of the audio performance of REF_Audio_GaNb_750W that can be achieved using the 100 V CoolGaN™ transistors in combination with the MERUS™ IRS20957S class D audio driver ICs.

5.1 Total harmonic distortion - THD+N

Test conditions:

- V_{bus} ±40 V
- Input signal = 1 kHz
- Load impedance = 4 Ω
- F_{PWM} = 1 MHz

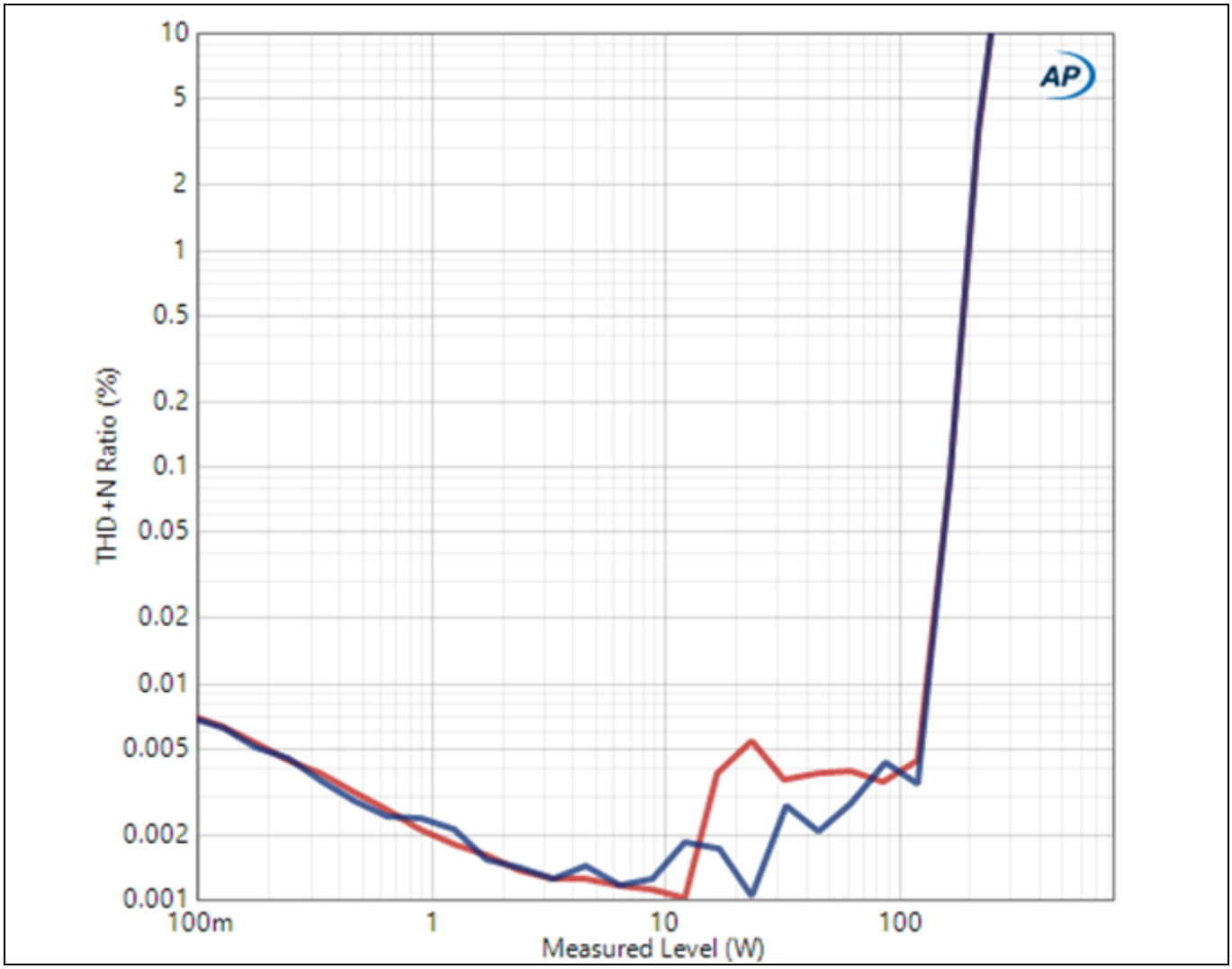

Figure 10 Power vs. THD+N 4 Ω load single ended

Audio performance

Test conditions:

- V_{bus} ±36 V
- Input signal = 1 kHz
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

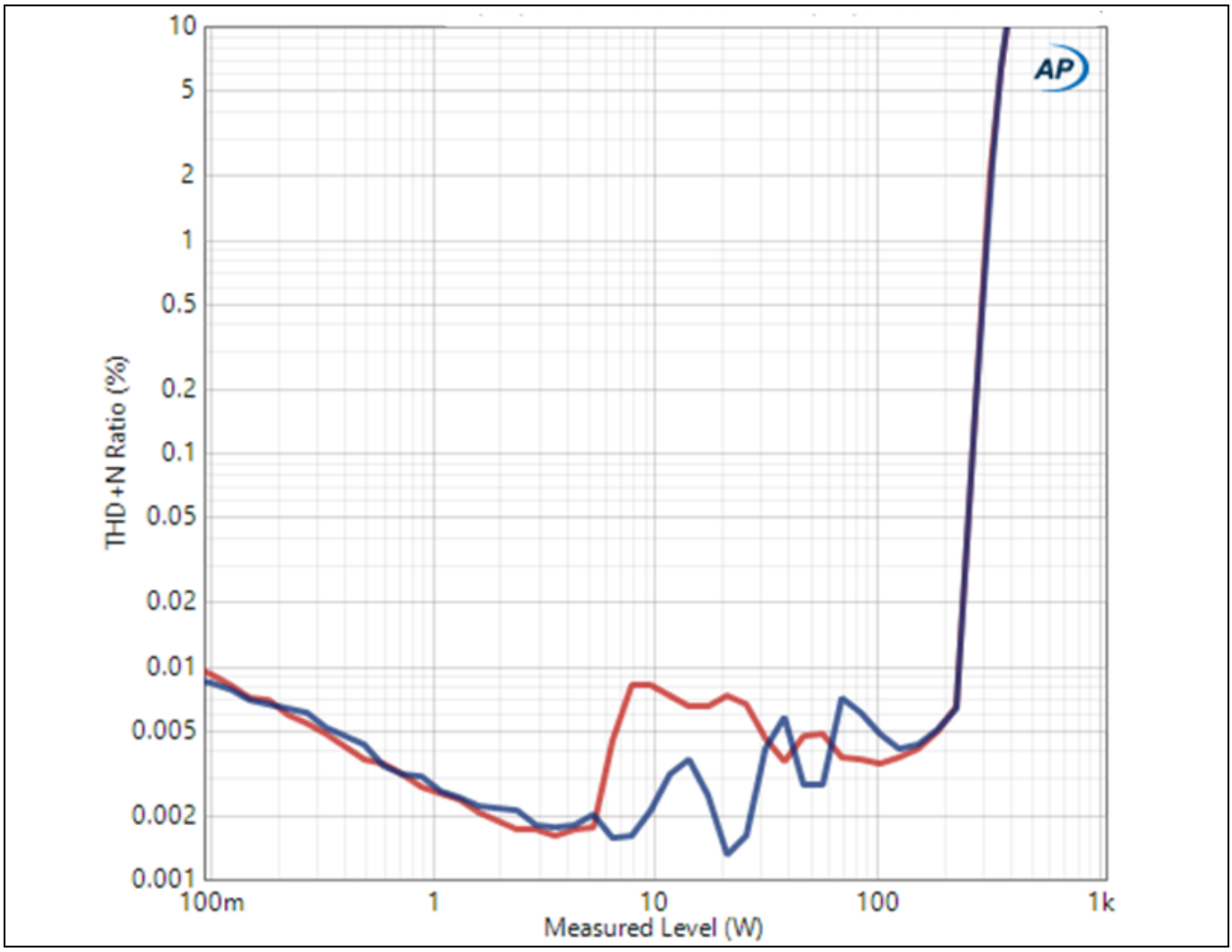

Figure 11 Power vs. THD+N 2 Ω load singled ended

Audio performance

Test conditions:

- V_{bus} ±36 V
- Input signal = 1 kHz
- Load impedance = 4 Ω
- F_{PWM} = 1 MHz

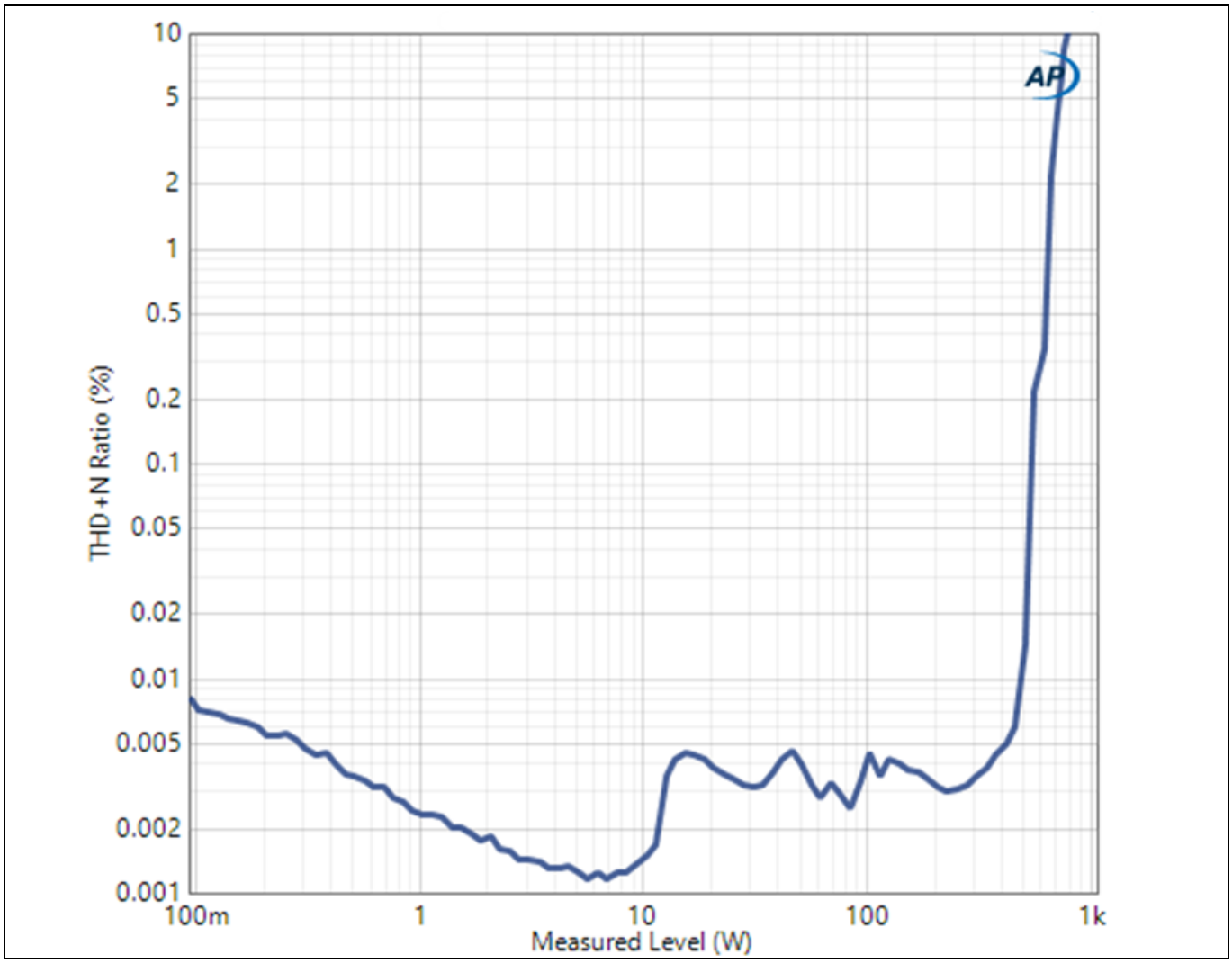

Figure 12 Power vs. THD+N 4 Ω load BTL

Audio performance

Test conditions:

- V_{bus} ±36 V
- Output power = 1 W
- Load impedance = 4 Ω
- F_{PWM} = 1 MHz

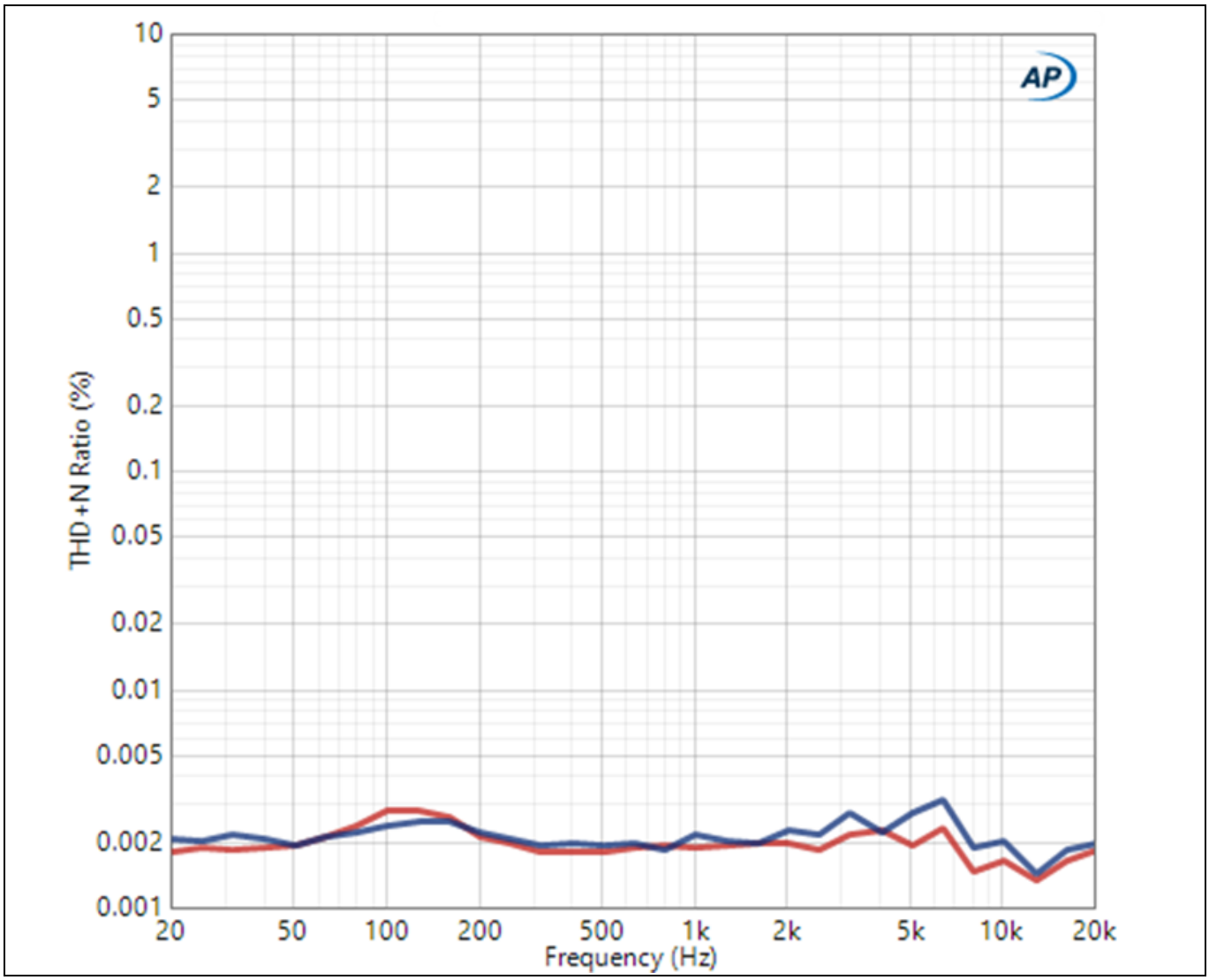

Figure 13 THD+N at 4 Ω load 1 W singled ended

Audio performance

Test conditions:

- V_{bus} ±36 V
- Output power = 1 W
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

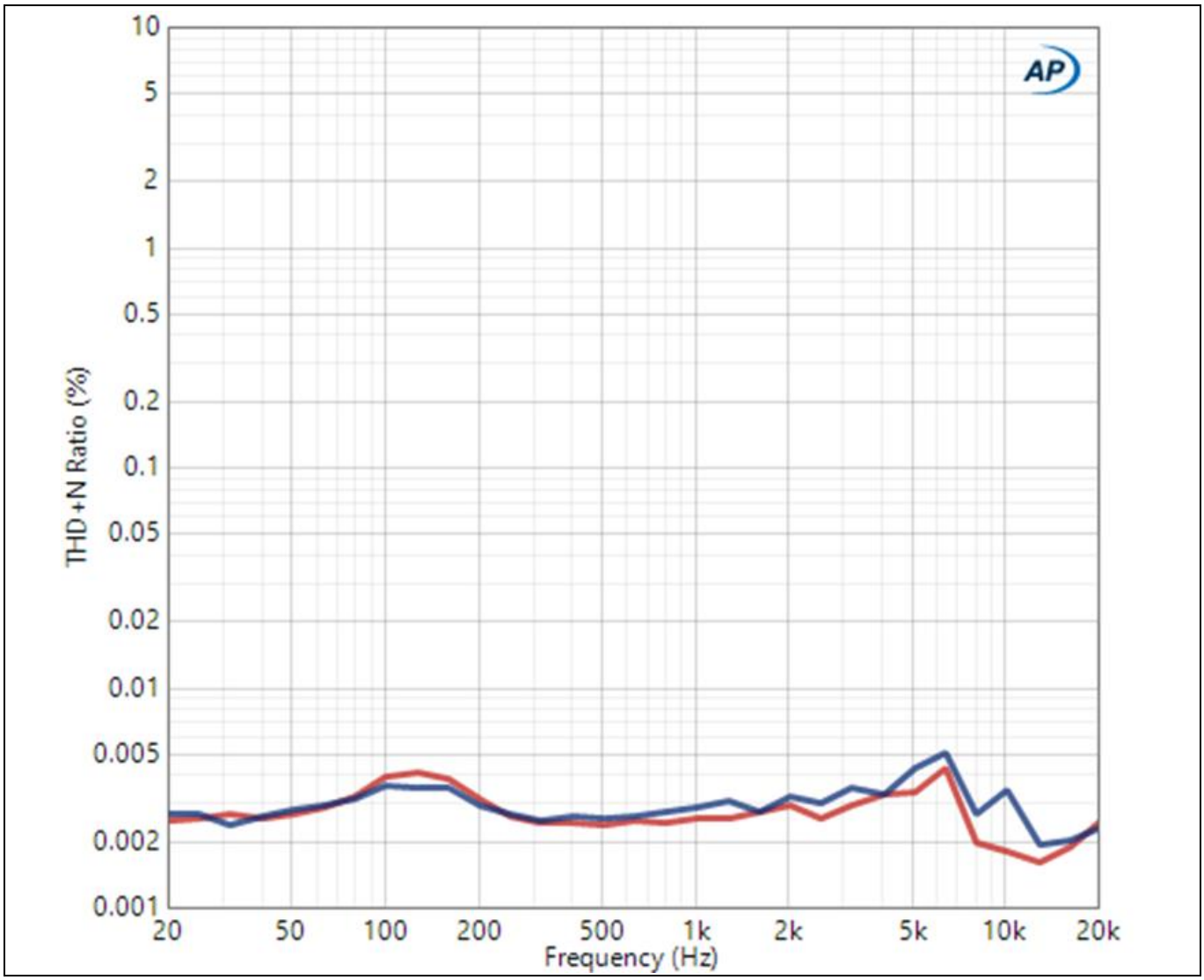

Figure 14 THD+N at 2 Ω load 1 W singled ended

5.2 Frequency response

Test conditions:

- V_{bus} ±36 V
- Output power = 1 W
- Load impedance = 4 Ω
- F_{PWM} = 1 MHz

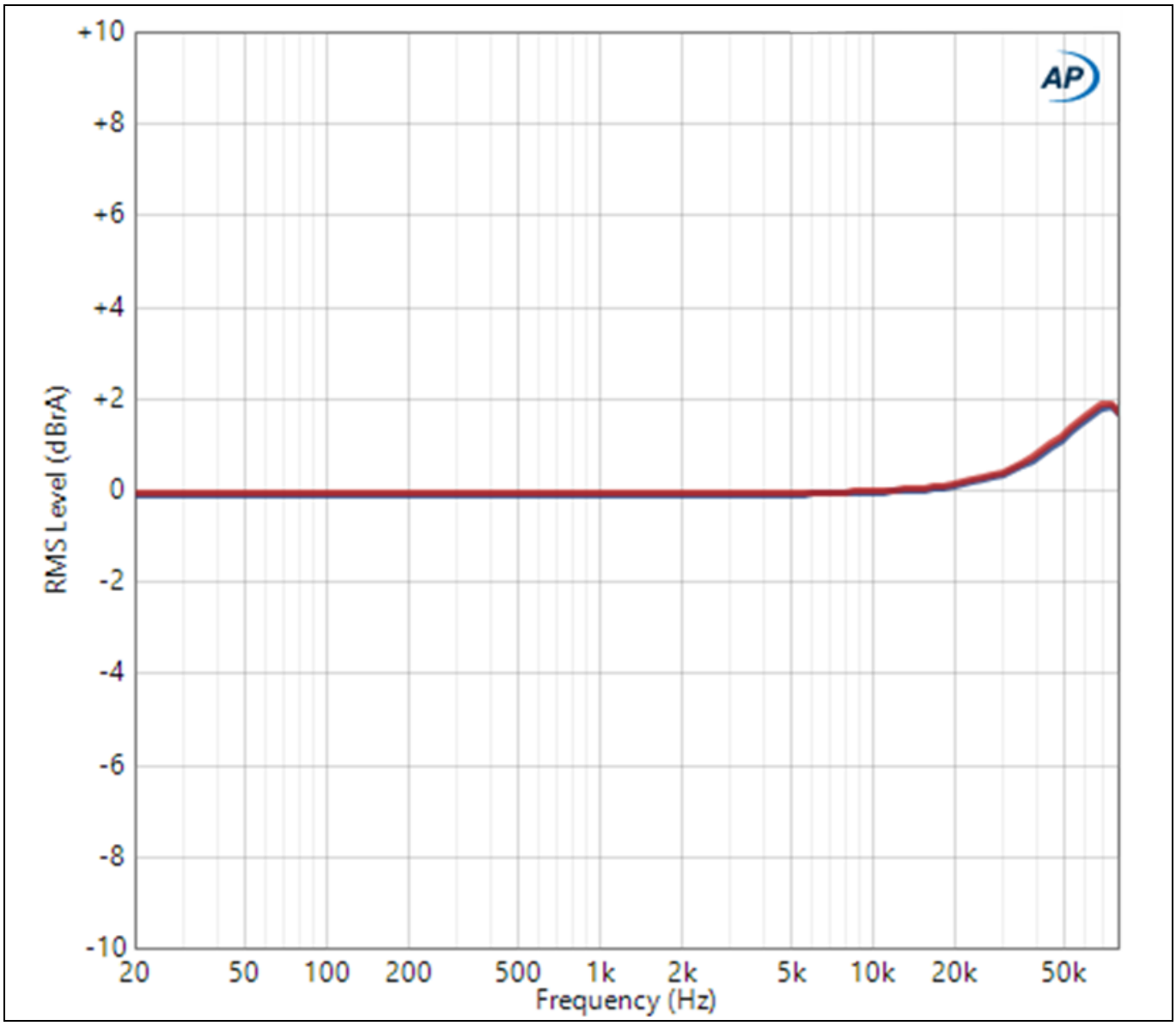

Figure 15 Frequency response 4 Ω load

Audio performance

Test conditions:

- V_{bus} ±36 V
- Output power = 1 W
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

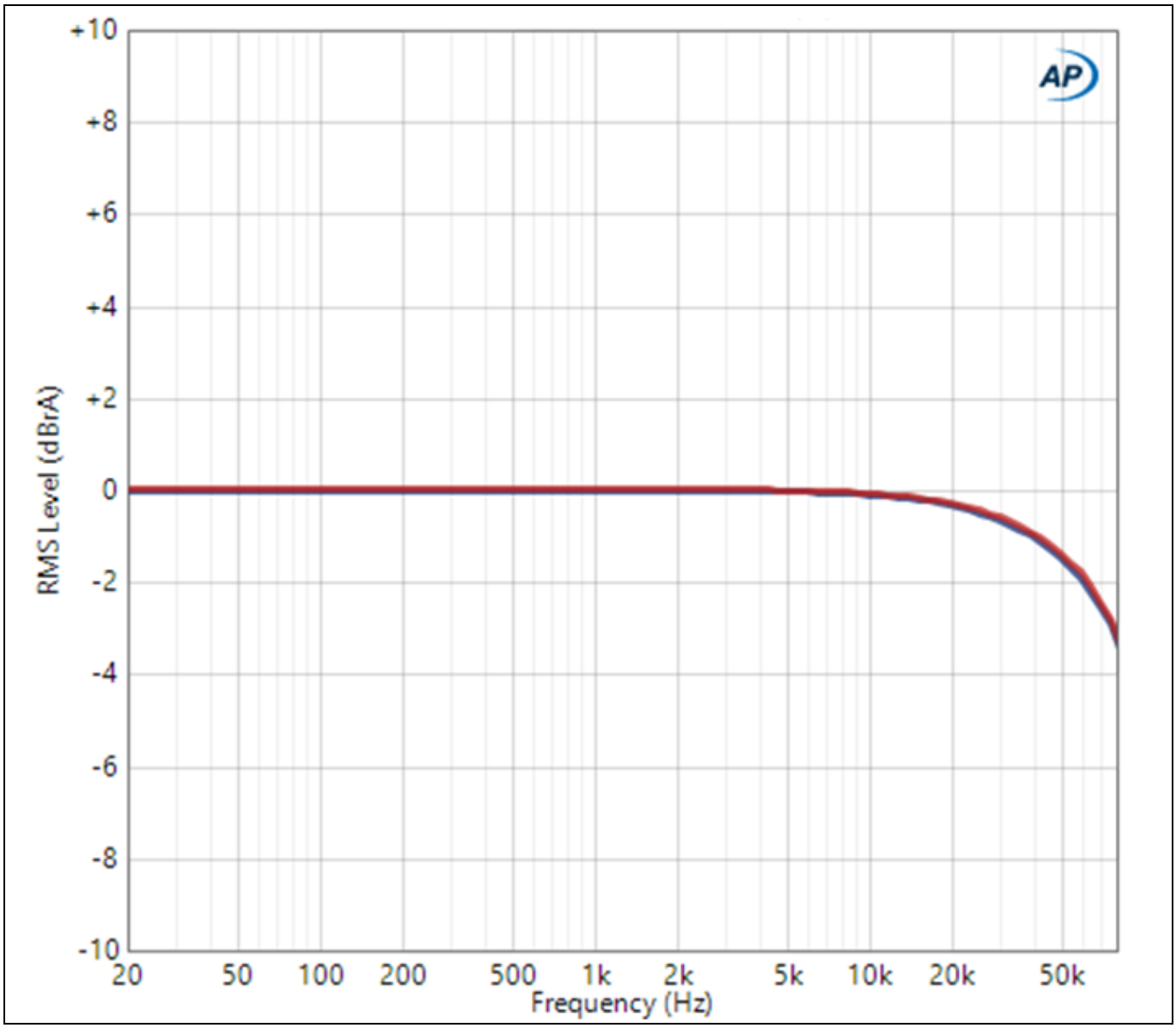

Figure 16 Frequency response 2 Ω load

5.3 Noise floor

Test conditions:

- V_{bus} ±36 V
- No input signal
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

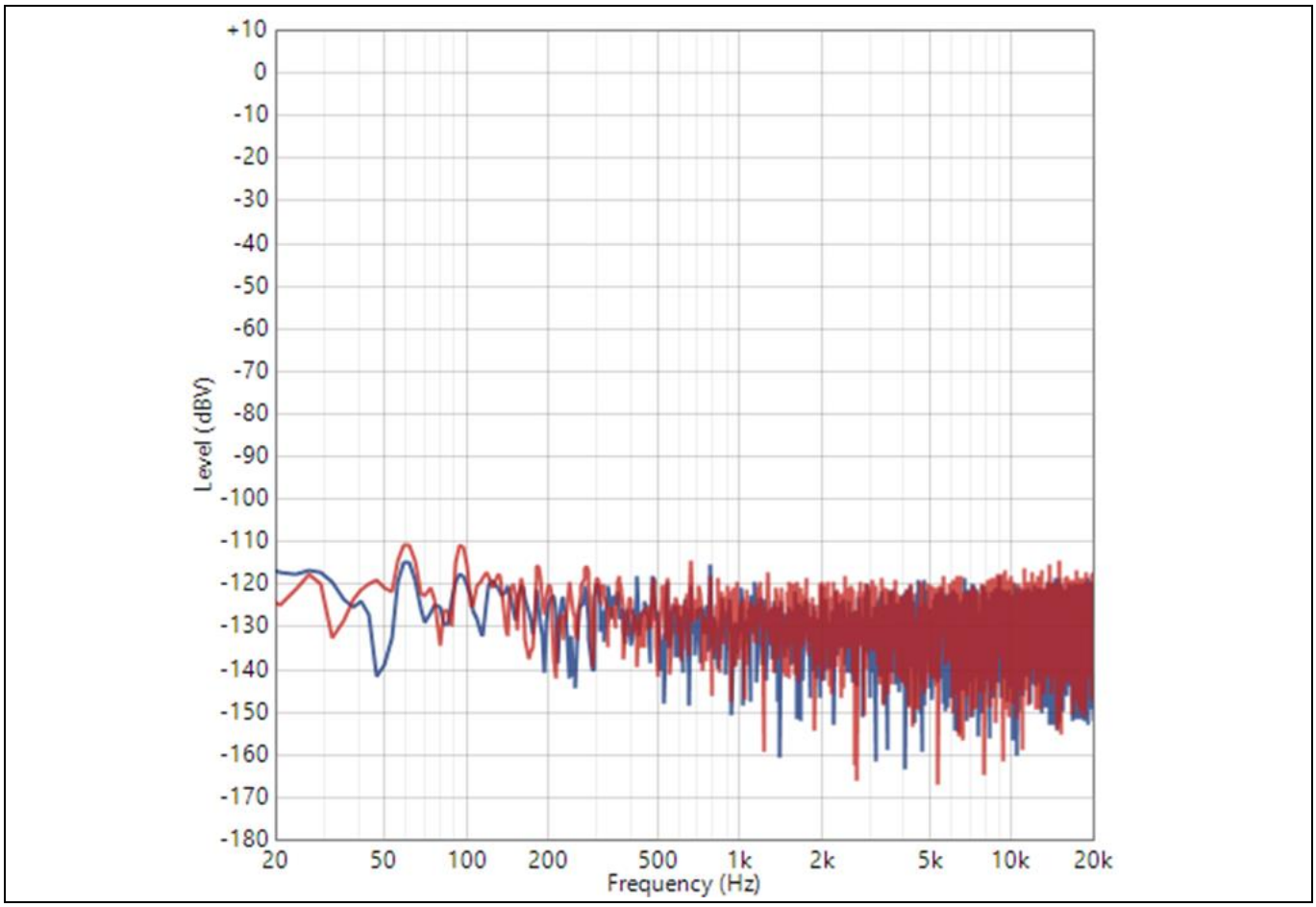

Figure 17 Noise floor idle

Audio performance

Test conditions:

- V_{bus} ±36 V
- Output = 1 V_{RMS} at 1 kHz
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

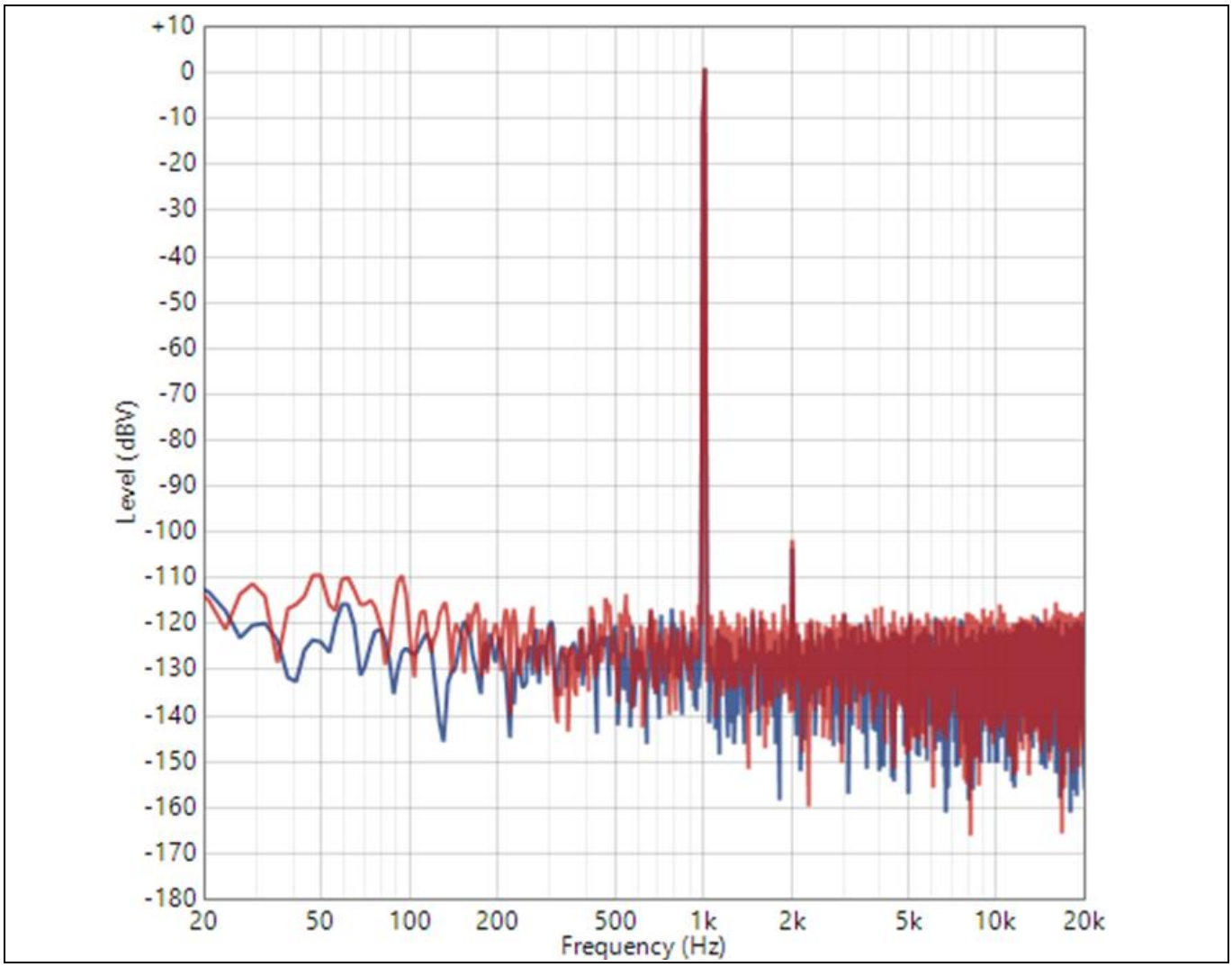

Figure 18 Noise floor 1 V_{RMS} output

6 Efficiency

6.1 Efficiency

Figure 19 and Figure 20 show the efficiency characteristics of REF_Audio_GaNb_750W. The high efficiency is achieved by the following factors:

- Low conduction loss due to the CoolGaN™ offering low $R_{DS(ON)}$
- Low switching loss due to the CoolGaN™ offering low input capacitance for fast rise and fall times
- Secure dead-time provided by the IRS20957SPBF, avoiding cross-conduction

Test conditions:

- V_{bus} ±40 V
- Input Signal = 1 kHz
- Load impedance = 4 Ω
- F_{PWM} = 1 MHz

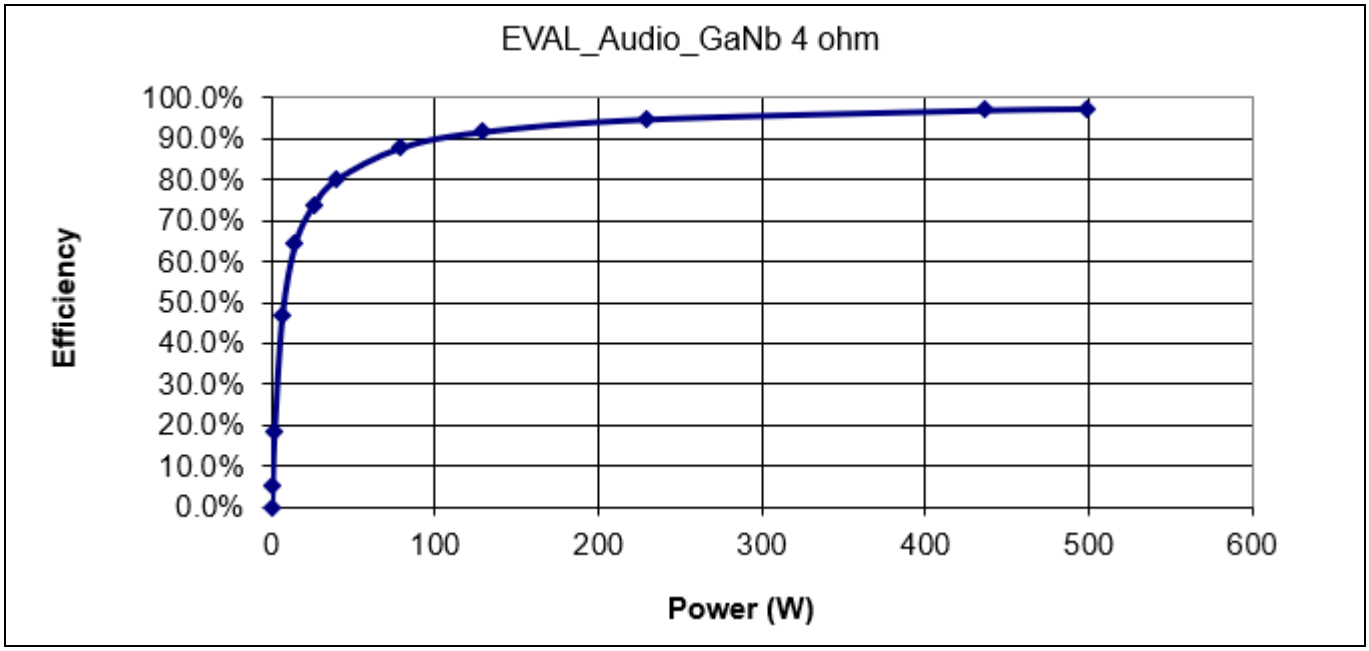

Figure 19 Total power efficiency 4 Ω load

Efficiency

Test conditions:

- V_{bus} ±36 V
- Input signal = 1 kHz
- Load impedance = 2 Ω
- F_{PWM} = 1 MHz

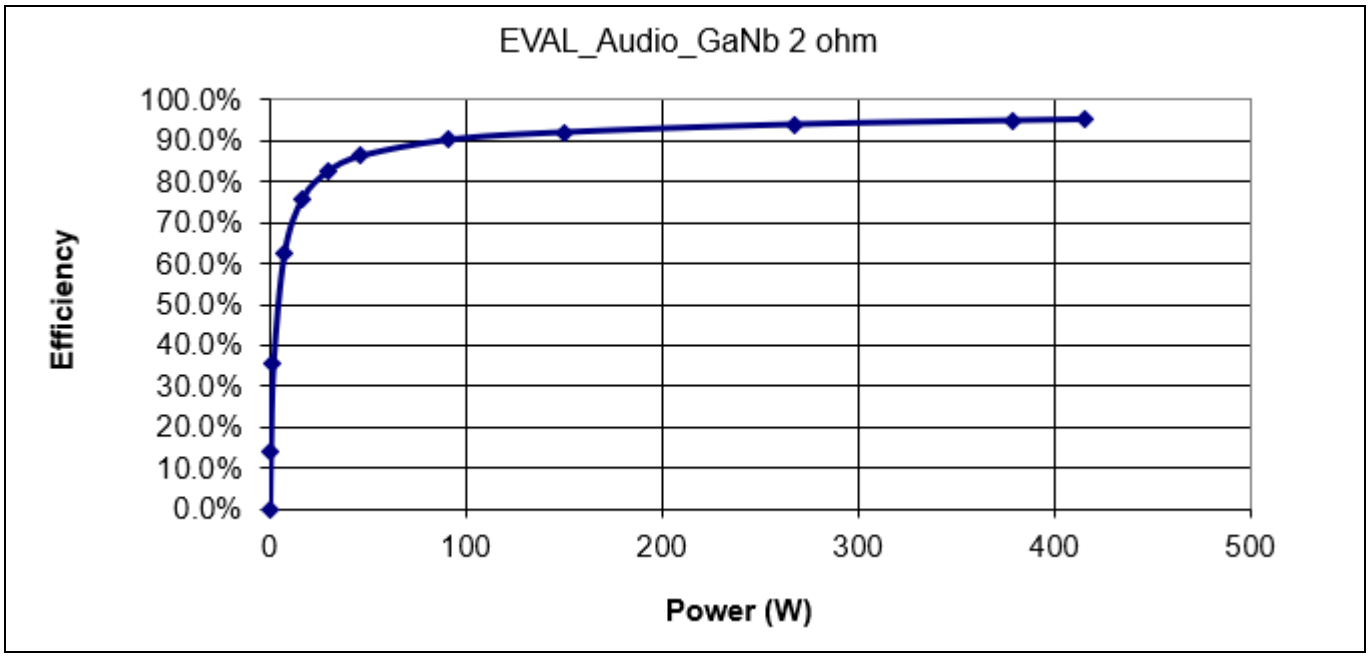

Figure 20 Total power efficiency 2 Ω load

7 Thermal performance

Test conditions:

- Input signal = 1 kHz

Table 4 Peak power without heatsink

Load	±V_{bus}	10% THD+N power	T_{case} Max	Duration (minutes)
4 Ω	40 V	240 W	71°C	>1 min no thermal shutdown
2 Ω	36 V	375 W	150°C	>1 min no thermal shutdown <150°C

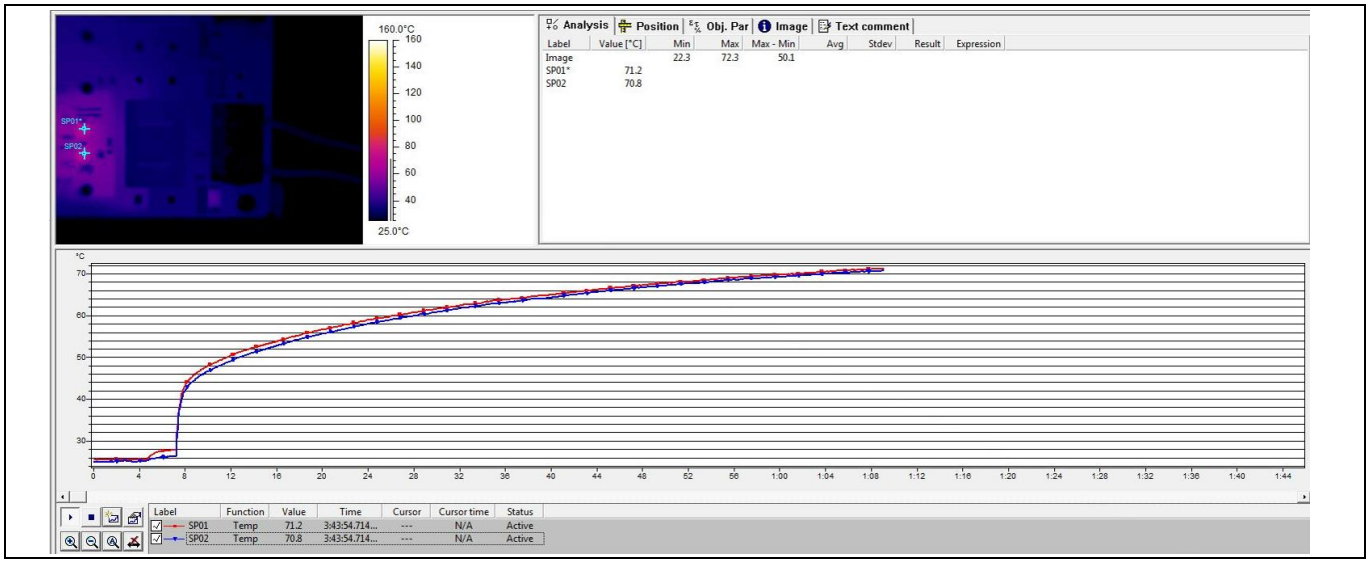

Figure 21 Peak power P_{out} = 240 W with 4 Ω load, ±40 V

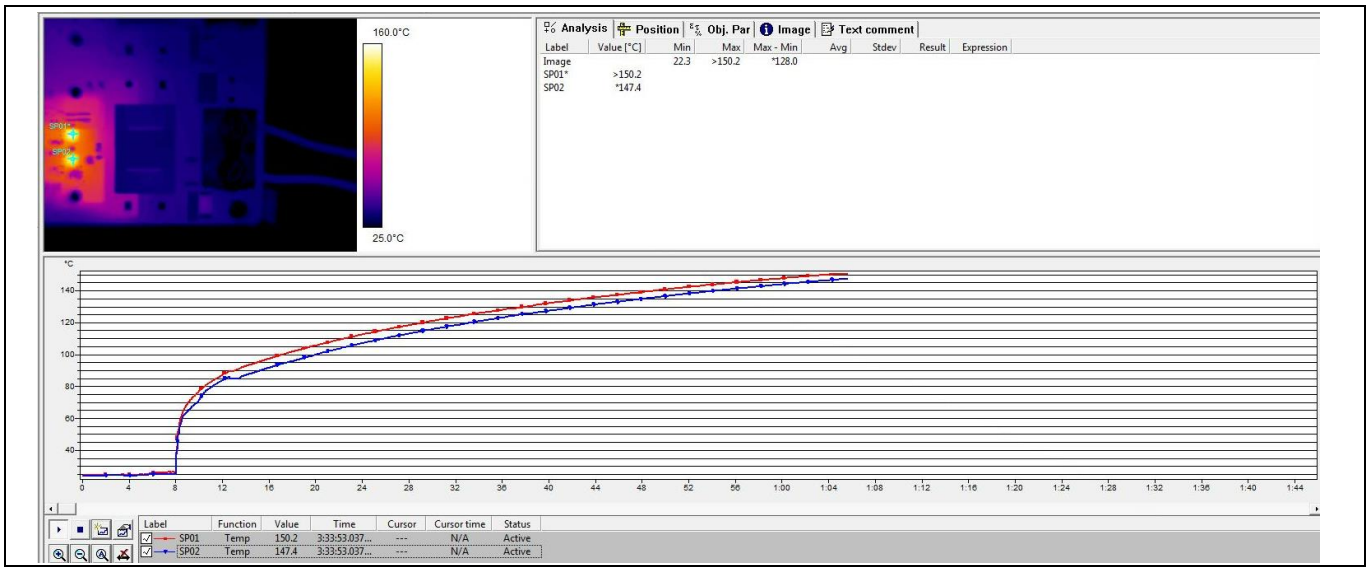

Figure 22 Peak power P_{out} = 375 W with 2 Ω load, ±36 V

Table 6 1/8 power without heatsink

Load	±V_{bus}	1/8 Power	T_{pcb} Max rise	Duration (minutes)
2 Ω	36 V	47 W	60°C	30 minutes <60°C PCB temperature rise

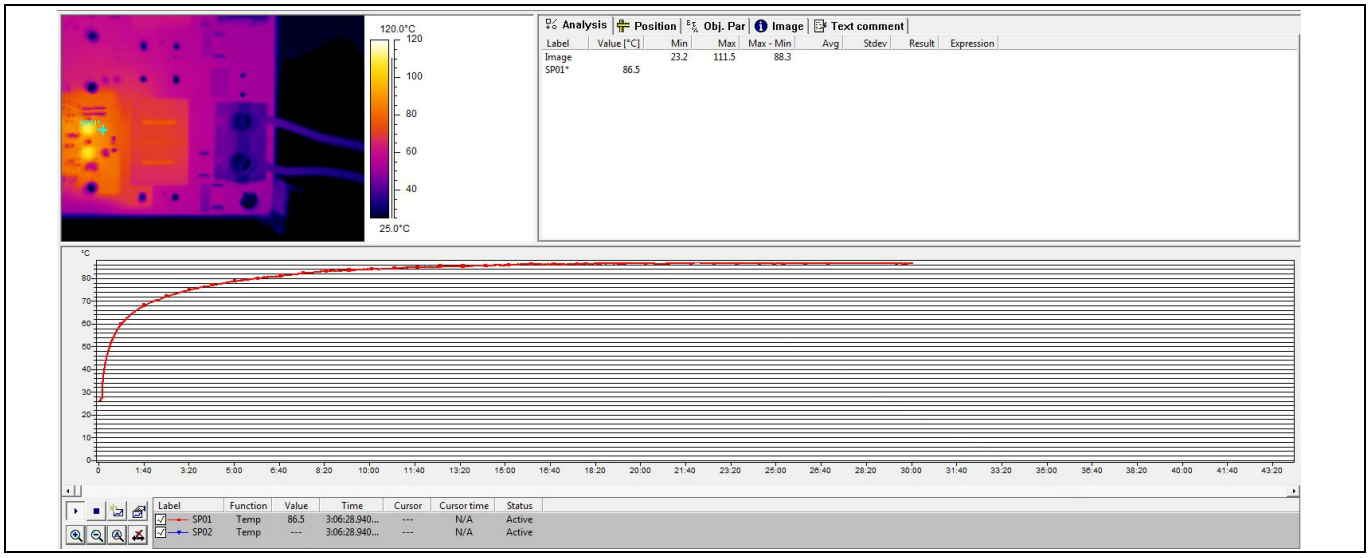

Figure 23 1/8 Power P_{out} = 47 W with 2 Ω load, ±36 V

8 400 kHz variant of REF_Audio_GaNb_750W

The REF_Audio_GaNb_750W reference board is optimized for a 1 MHz switching frequency by default, which enables the use of smaller output filter inductors, resulting in a compact and power-dense solution. For applications that prioritize efficiency and lower switching losses, a 400 kHz variant can be implemented.

While this lower switching frequency requires larger output inductors, the decrease in switching frequency lowers the GaN device temperature when comparing the test results under similar conditions as the 1 MHz variant. This section details the necessary component changes to configure the board for a stable and reliable operation at 400 kHz.

8.1 Rework instructions for the 400 kHz variant

Table 7 Electrical specifications

Designator	Change to	Manufacturers P/N	Function
R36	249k (0603)	Yageo: RT0603BRD07249KL or equivalent	Clock Sync Range (285 kHz - 400 kHz)
C33A, C33B, R9A, R9B	Remove	N/A	PWM
C26A, C26B, C27A, C27B	1 nF	Murata: GRM1885C1H102JA01D or equivalent	PWM
R42A, R42B	100 Ω (0603)	Yageo: RC0603FR-07100RL or equivalent	PWM
C75A, C75B	Remove	N/A	Output capacitor
C72A, C72B, C70A, C70B	Place	Vishay: BFC247076684 or equivalent	Output capacitor
L3A, L3B,	Remove	N/A	Output inductor
L1A, L2A, L1B, L2B	22 uH	Codaca: CPD1715F-220M	Output inductor

8.2 Test setup

1. For SE, connect 2 Ω > 400 W capable dummy loads according to Figure 5
2. For BTL, connect 4 Ω > 800 W capable dummy load according to Figure 6
3. Connect the audio analyzer according to Figure 5 for SE and Figure 6 for BTL
4. Connect the **Audio Signal Generator** (ASG) of AP to X5 and X6 as shown in Figure 5
5. Set up the dual power supply with voltages of **±38 V**; set current limit to 15 A
6. Turn off the dual power supply before connecting the unit under test
7. Set switch S2 to middle position (self-oscillating)
8. Set switch S1 to “MUTE”
9. Set the gain potentiometer R54 counterclockwise to the maximum limit
10. Connect the dual power supply to X4 as shown in Figure 5

8.3 Frequency adjustment

1. Monitor VS1 and VS2 switching frequency with an oscilloscope. See Figure 9
2. Adjust R44A and R44B setting VS1 and VS2 to 400 kHz

8.4 Total harmonic distortion - THD+N

Test conditions:

- V_{bus} ±38 V
- Input signal = 1 kHz
- Load impedance = 4 Ω
- FPWM = 400 kHz

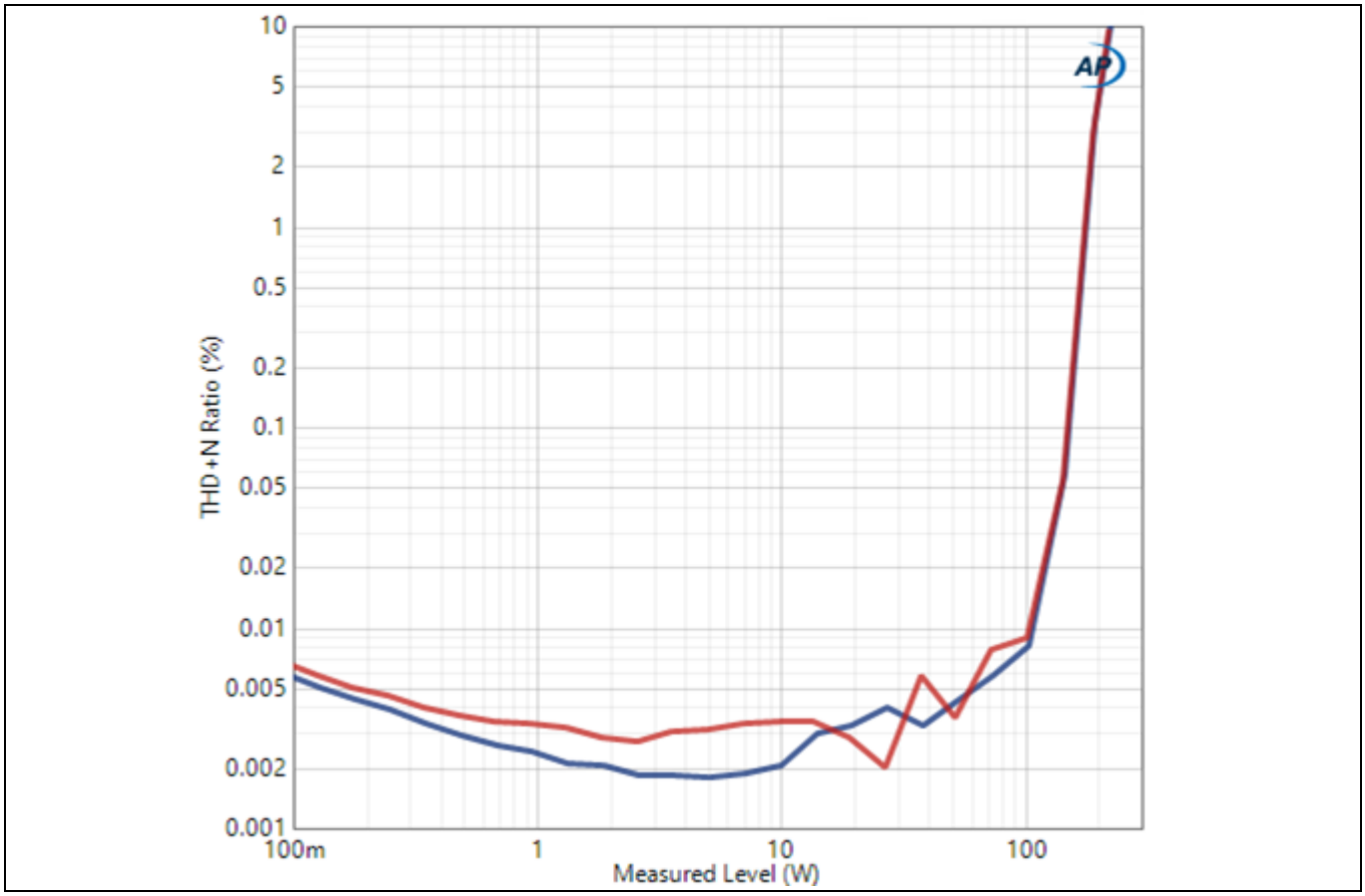

Figure 24 Power vs. THD+N 4 Ω load single ended

Test conditions:

- V_{bus} ±38 V
- Input signal = 1 kHz
- Load impedance = 2 Ω
- F_{PWM} = 400 kHz

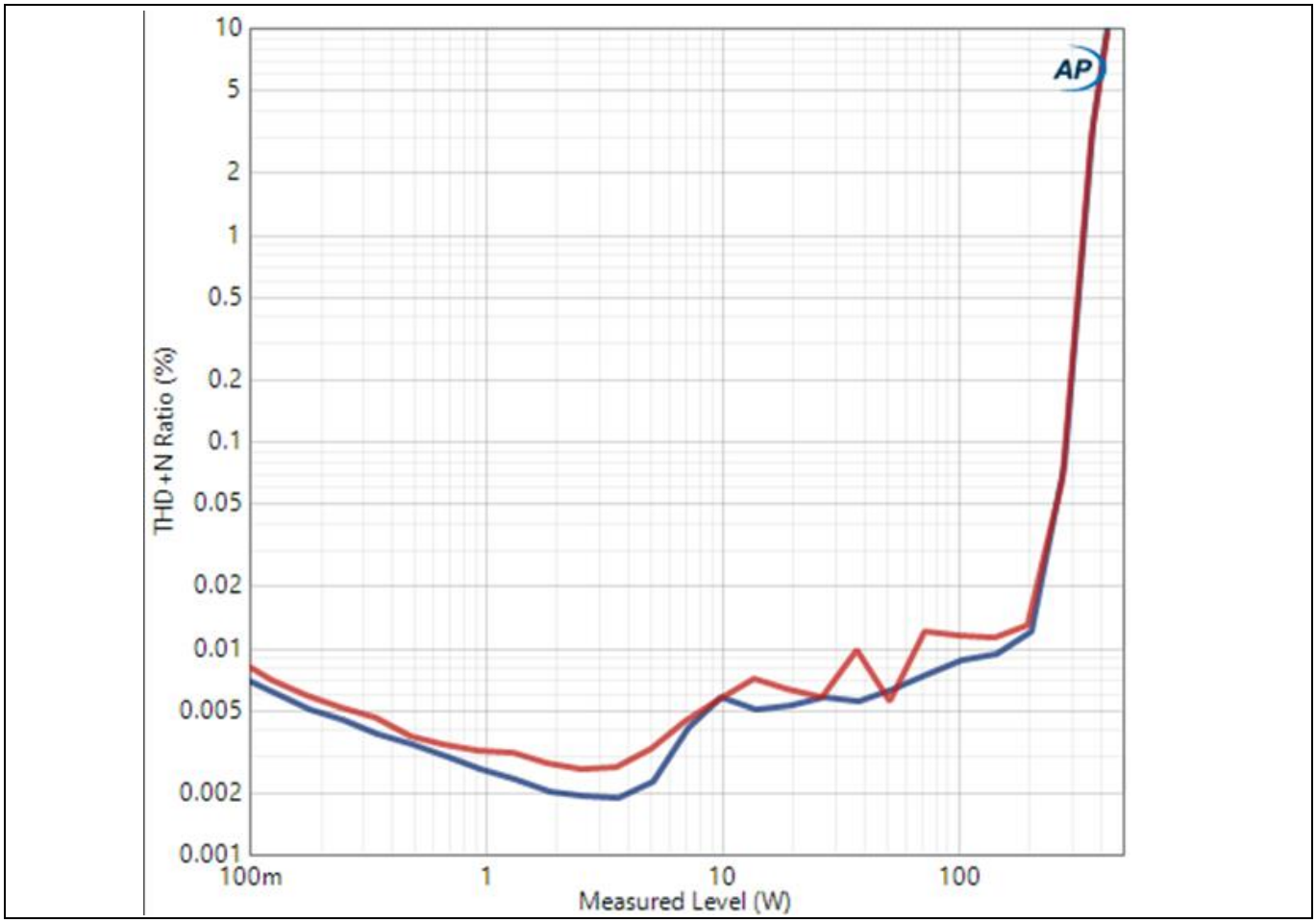

Figure 25 Power vs. THD+N 2 Ω load single ended

8.5 Frequency response

Test conditions:

- V_{bus} ±38 V
- Output power = 1 W
- Load impedance = 2 Ω
- F_{PWM} = 400 kHz

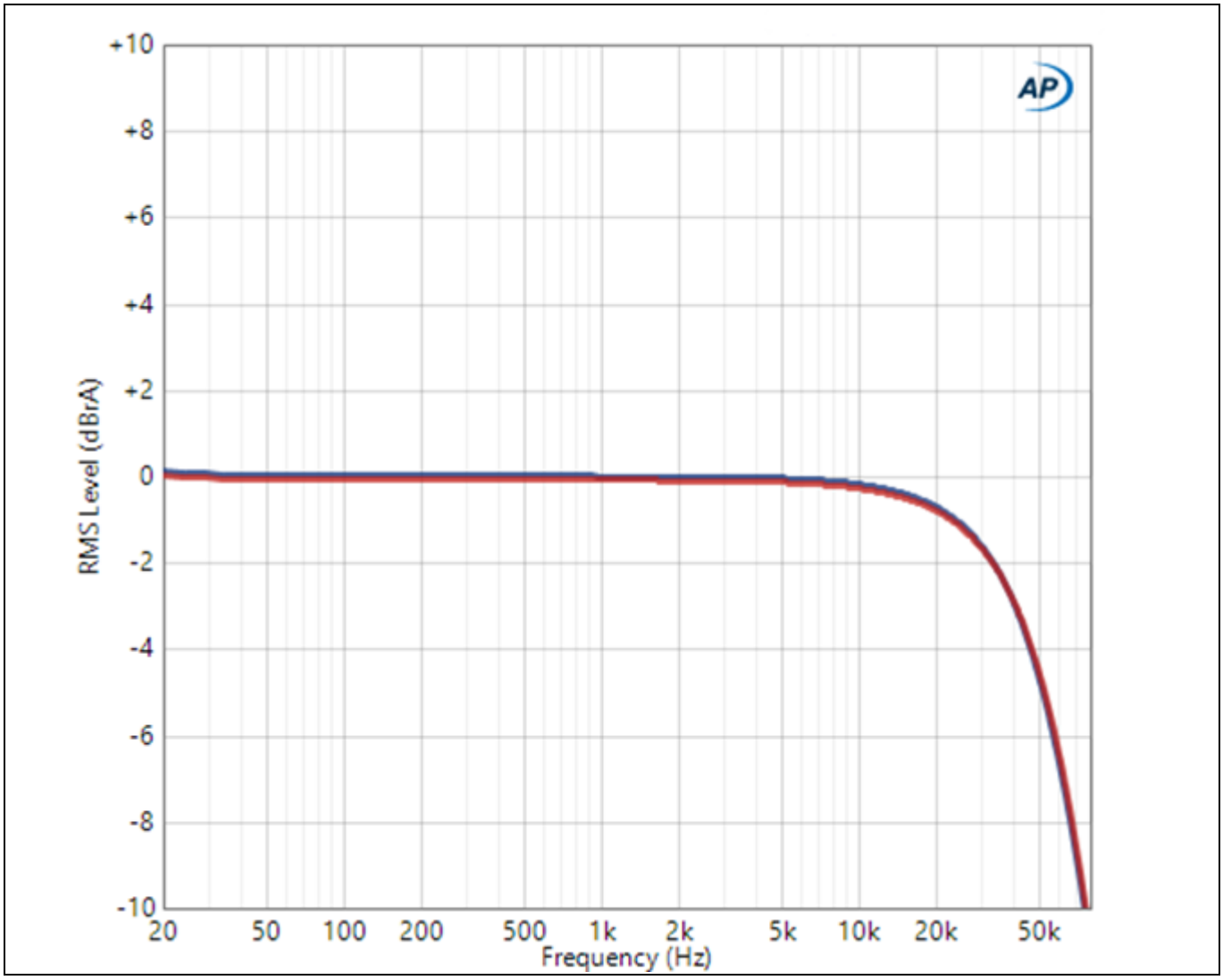

Figure 26 Frequency response 2 Ω load

8.6 Efficiency

Test conditions:

- V_{bus} ±38 V
- Input signal = 1 kHz
- Load impedance = 2 Ω
- F_{PWM} = 400 kHz

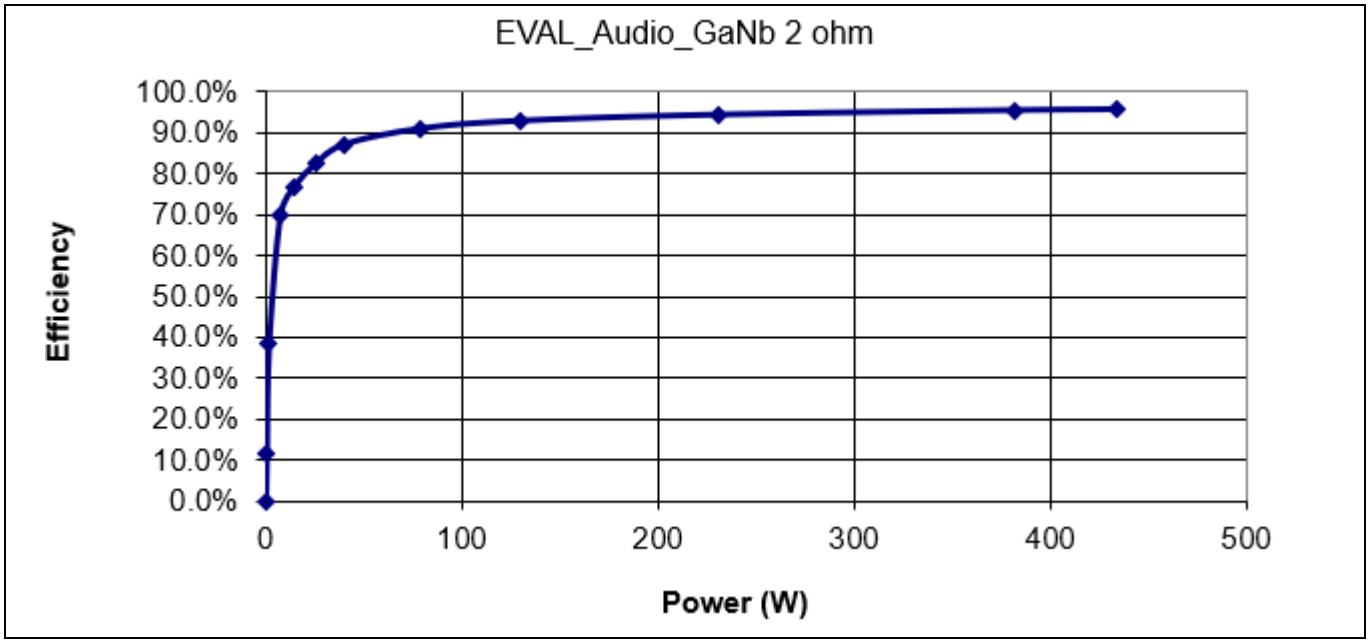

Figure 27 Total power efficiency 2 Ω load 400 kHz

8.7 Thermal performance

Test conditions:

- Input signal = 1 kHz
- F_{PWM} = 400 kHz

Table 8 Peak power with no heatsink

Load	±V_{bus}	10% THD+N power	T_{case} Max	Duration (minutes)
2 Ω	38 V	400 W	139°C	>1 min no thermal shutdown <150°C

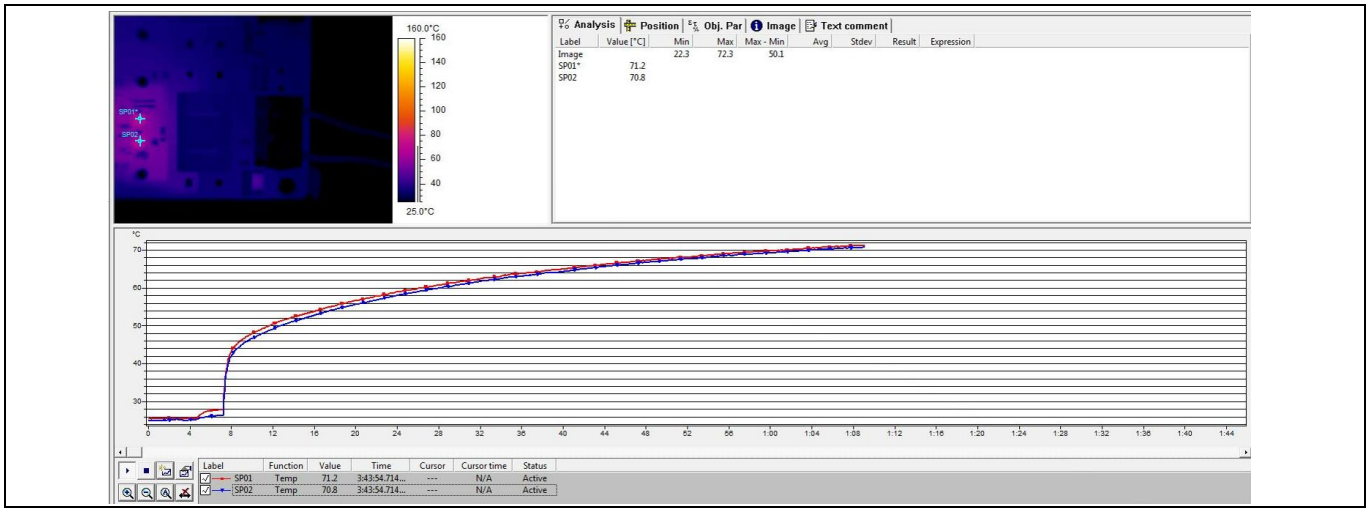

Figure 28 Peak power P_{out} = 400 W with 2 Ω load, ±38 V, no heatsink

Table 9 1/8 power without heatsink

Load	±V_{bus}	1/8 Power	T_{pcb} Max rise	Duration (minutes)
2 Ω	38 V	50 W	40°C	30 minutes <60°C PCB temperature rise

9 Schematics

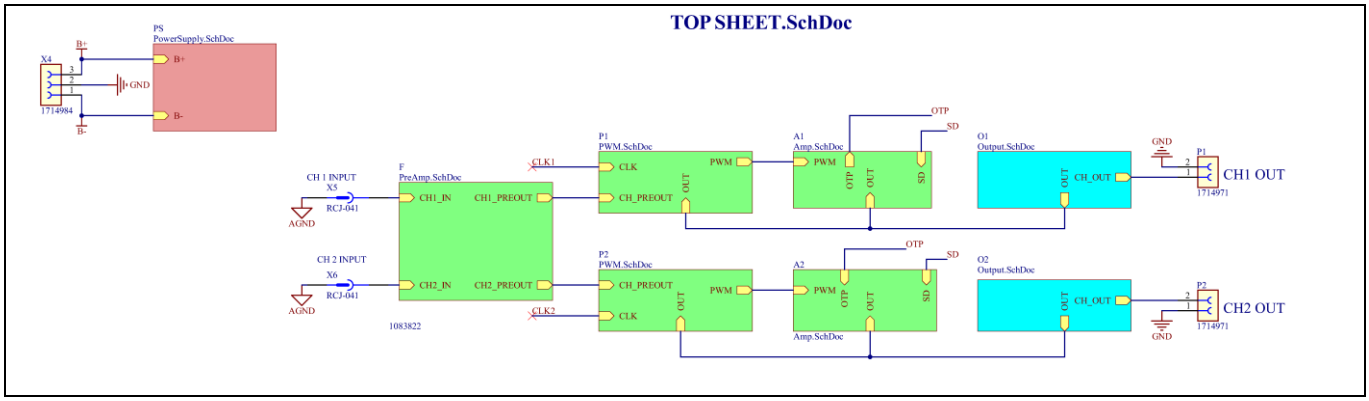

Figure 29 Signal chain

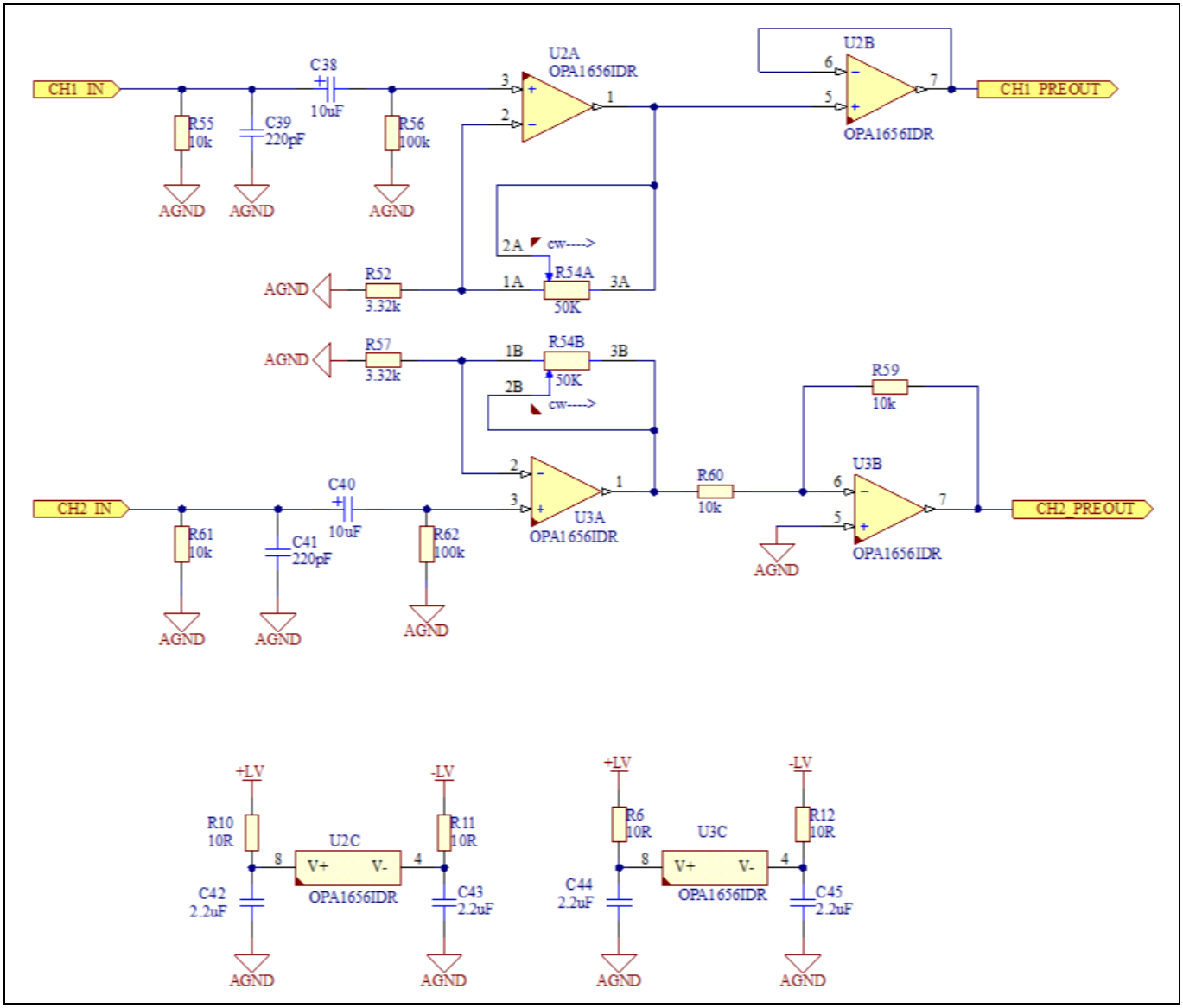

Figure 30 Preamplifier

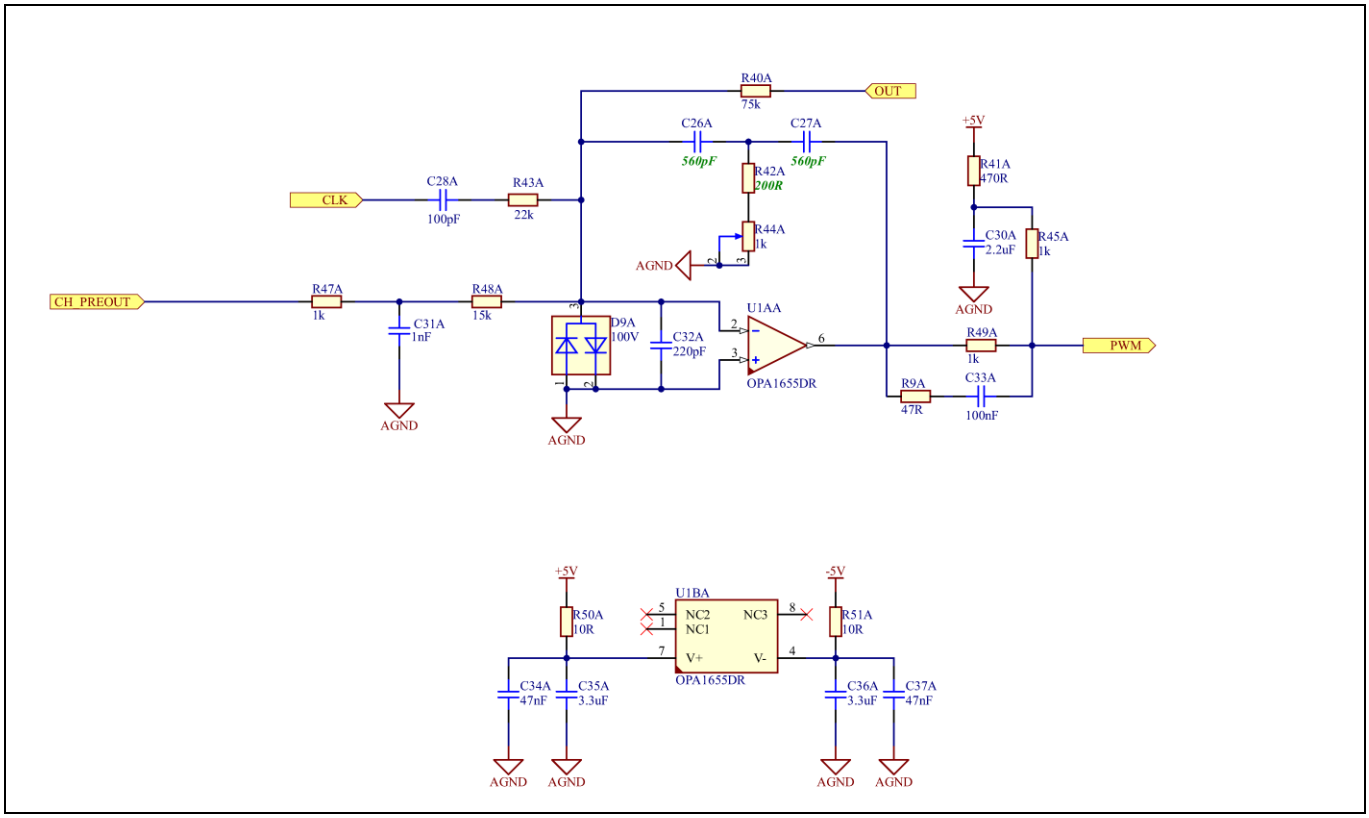

Figure 31 Self-oscillating PWM modulator

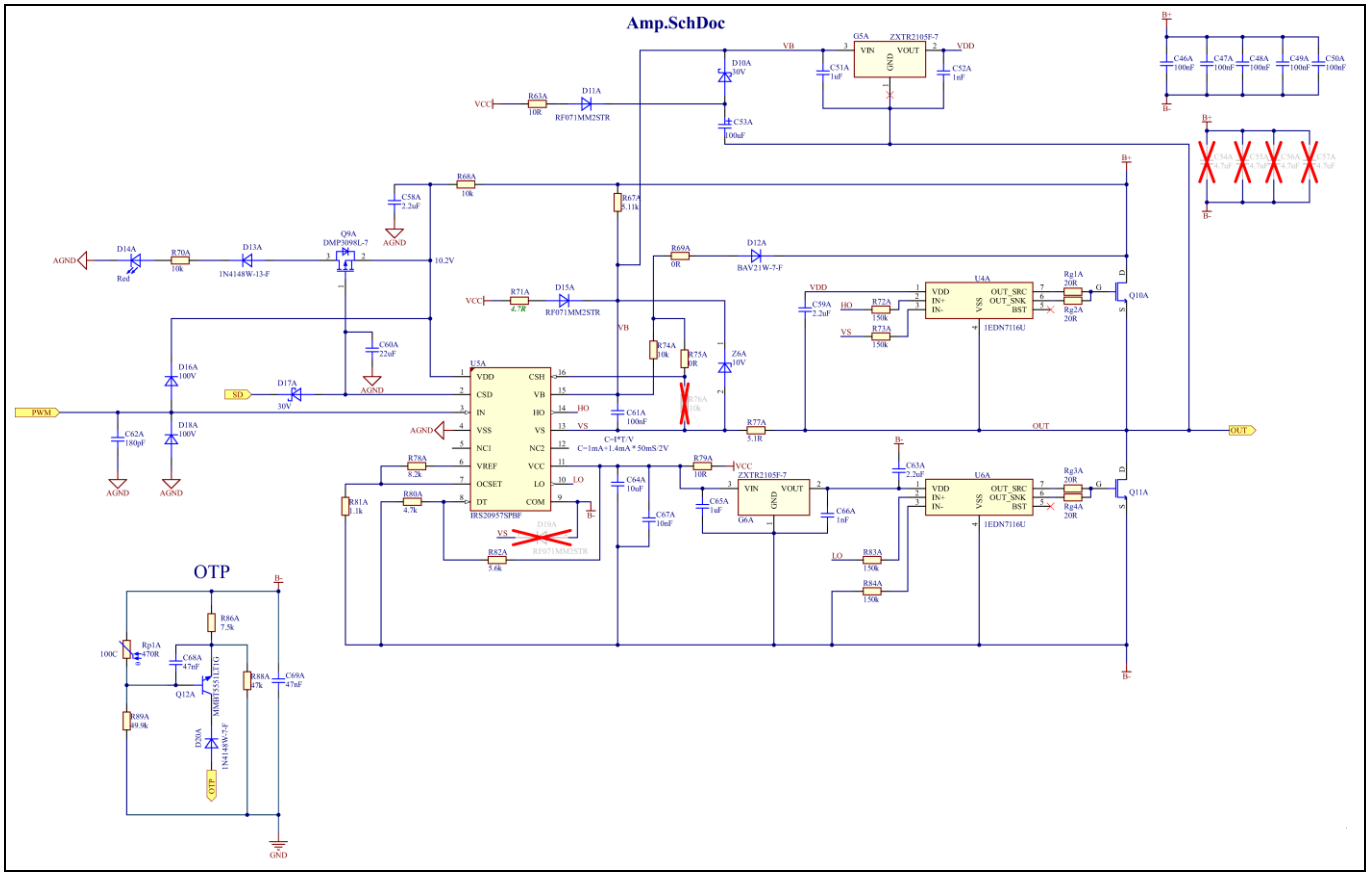

Figure 32 Class D amplifier stage

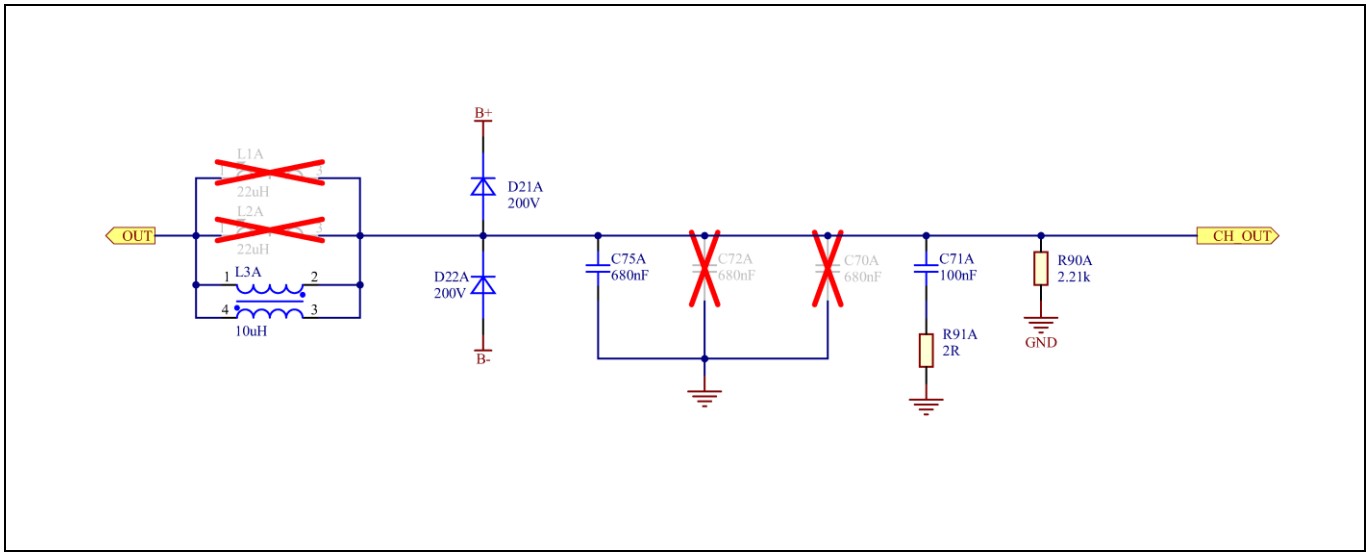

Figure 33 Class D output stage

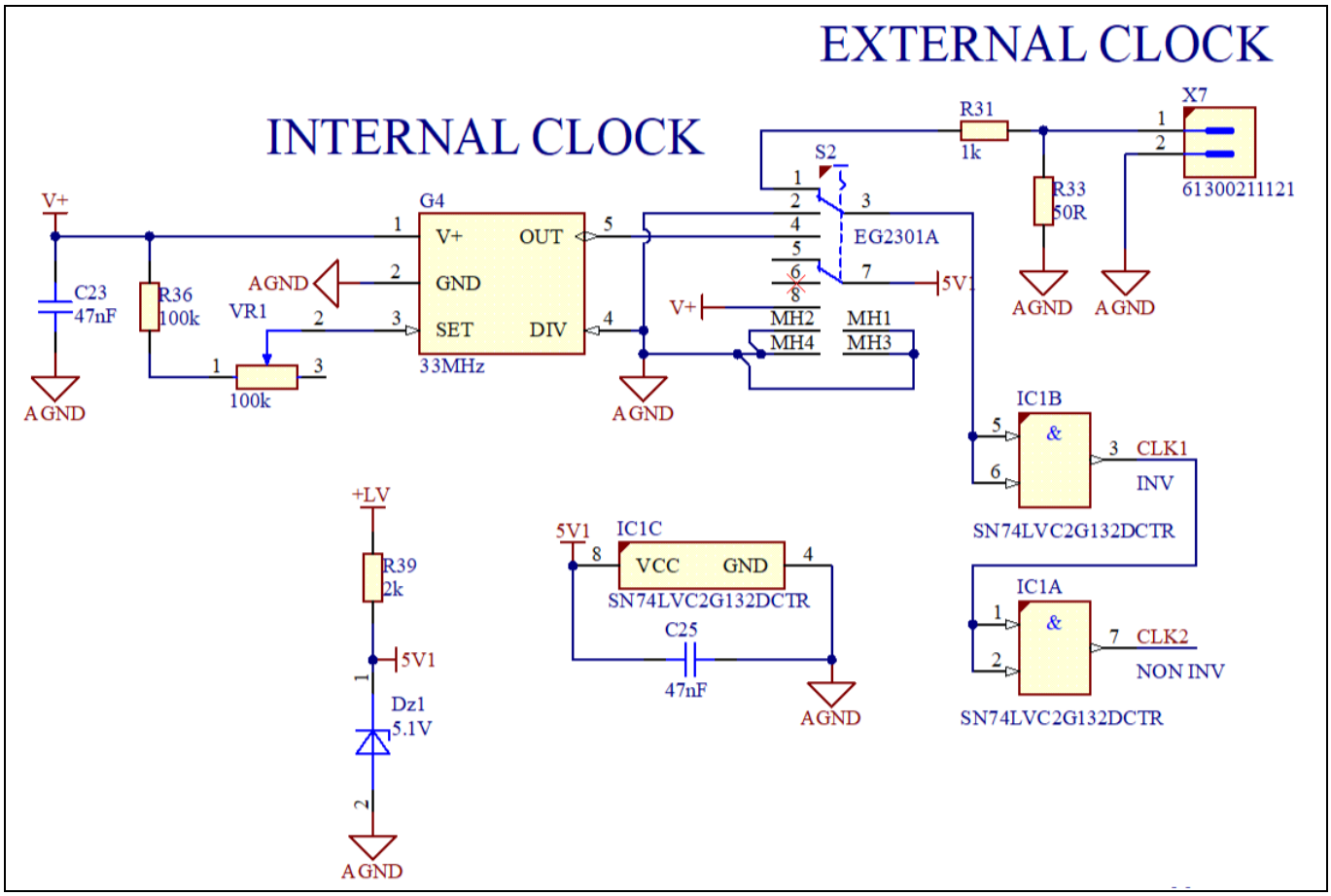

Figure 34 Channel sync

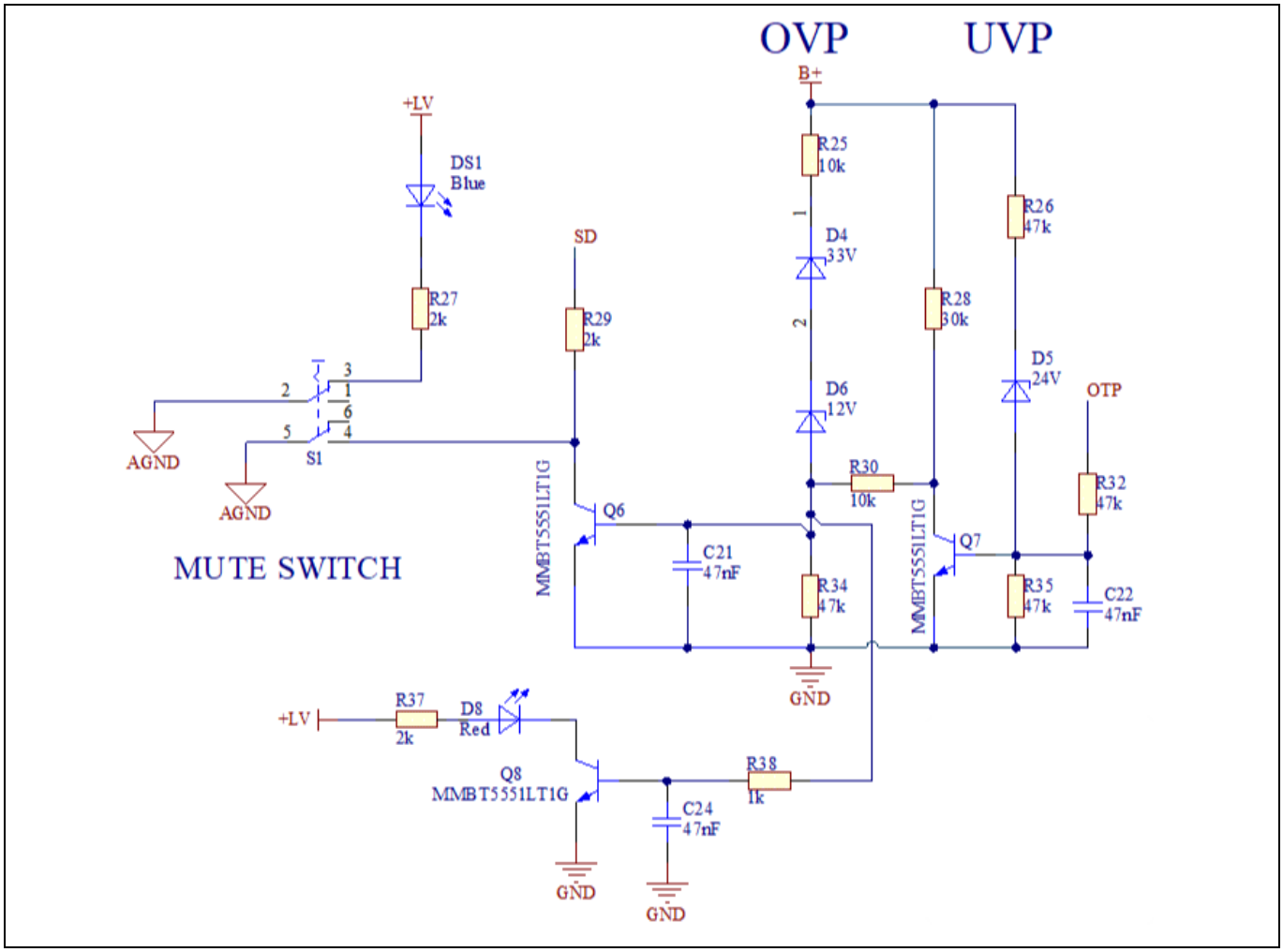

Figure 35 Over/undervoltage protection

Schematics

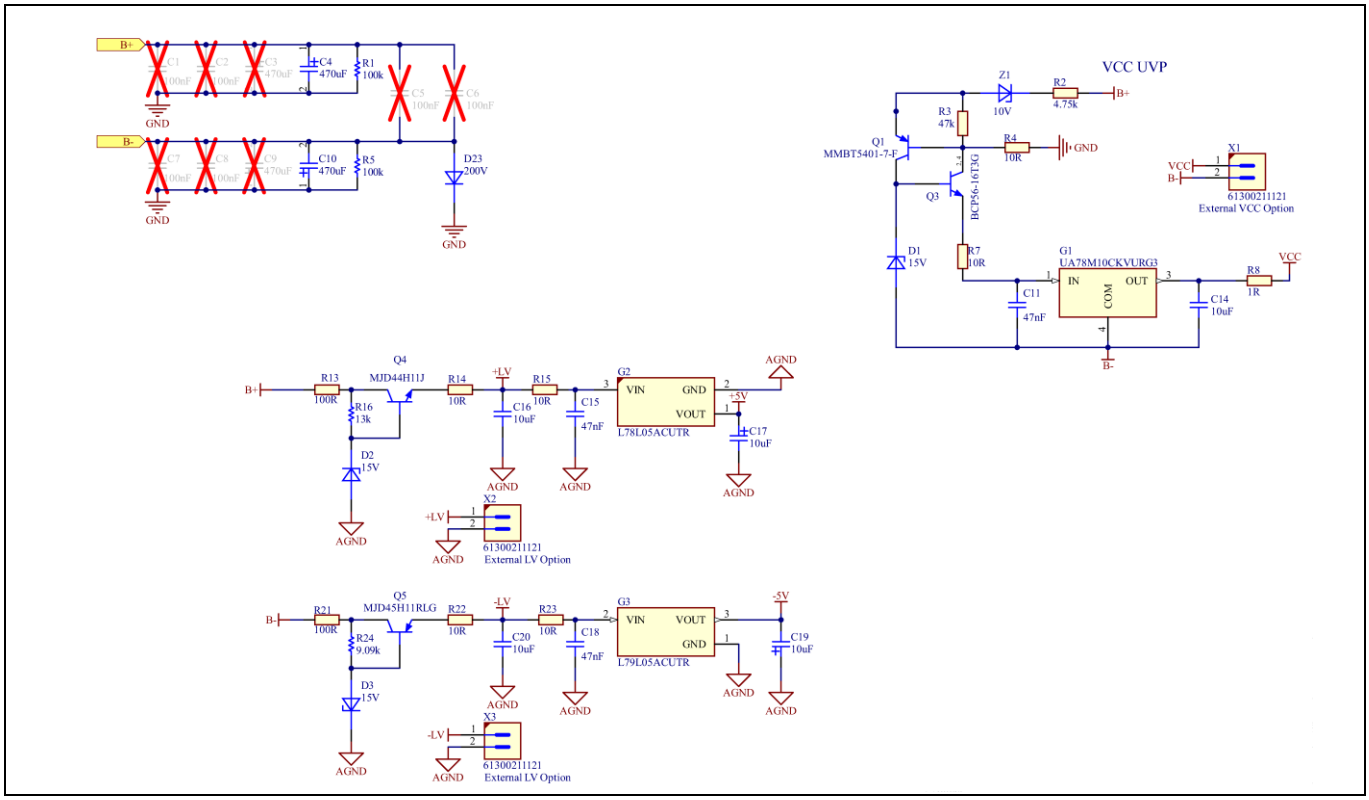

Figure 36 Housekeeping power supplies

10 PCB specifications and layout

10.1 PCB specifications

- Fabricate per ipc-601x series, class 2, and inspect per IPC-A-600 class 2
- U.l. rating: 94 V-0 minimum
- Fr4, per ipc4101, final thickness to be 1.6 mm +/- 10%
- 2 oz. Finished min all layers
- Control all conductor width and spacing to +/- 20%
- Thieving is acceptable on all copper layers, maintaining a clearance of 0.125" from all pads, etch, and planes. Vendors may use whatever patterns best suit their process
- Printed wiring board shall comply with requirements of J-STD-003 method 1 (edge dip test) with no evidence of measling or delamination
- All (pth) to have a tolerance of +/- 0.004"
- Plating finish shall be immersion silver, silver plating thickness shall be no less than 0.15 microns thick
- Solder mask: LPI soldermask (lpi) both sides material shall meet all the requirements of ipc-sm-840 class 2, color blue
- Silkscreen legend to be applied per gerbers, on primary or secondary side, or both, using white non-conductive epoxy ink

10.2 Layout

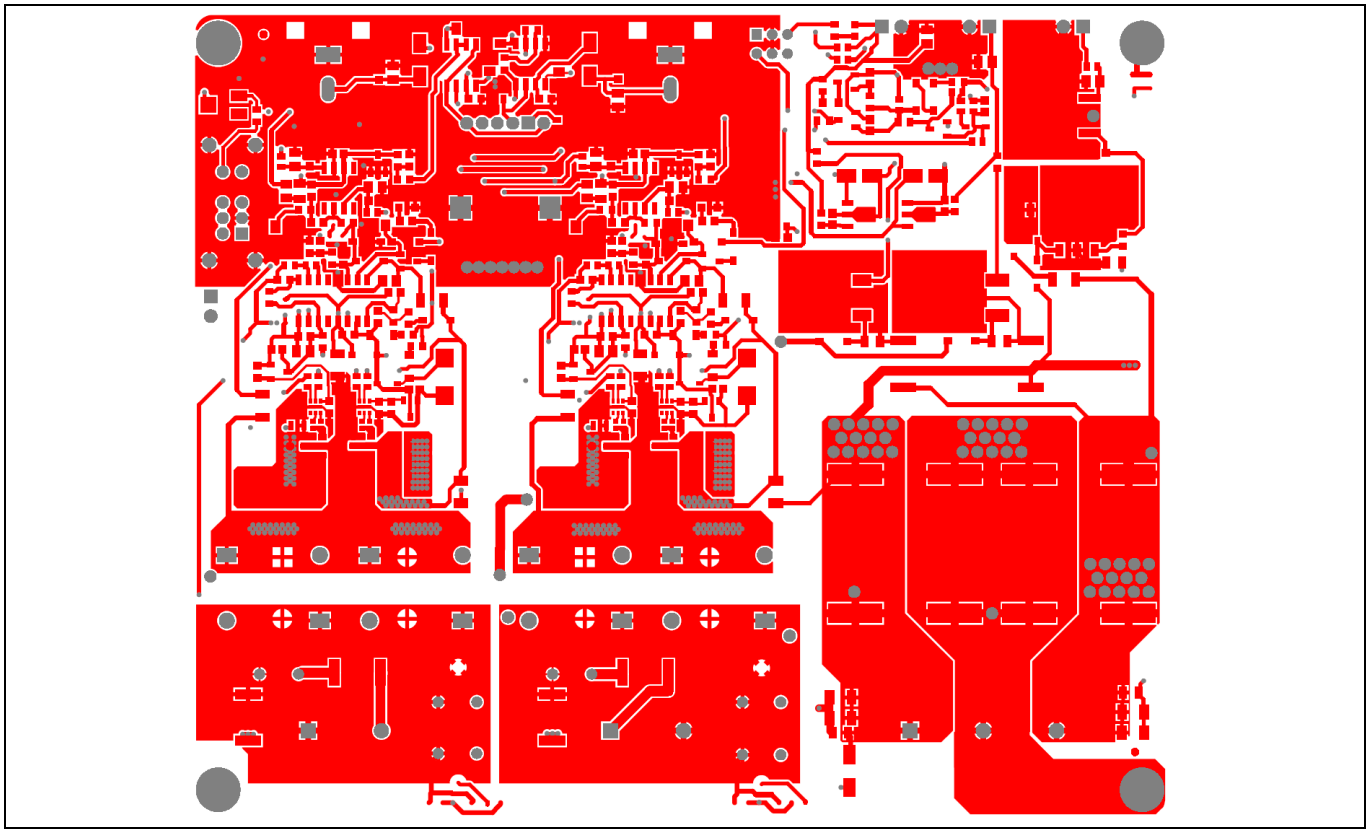

Figure 37 Layer 1

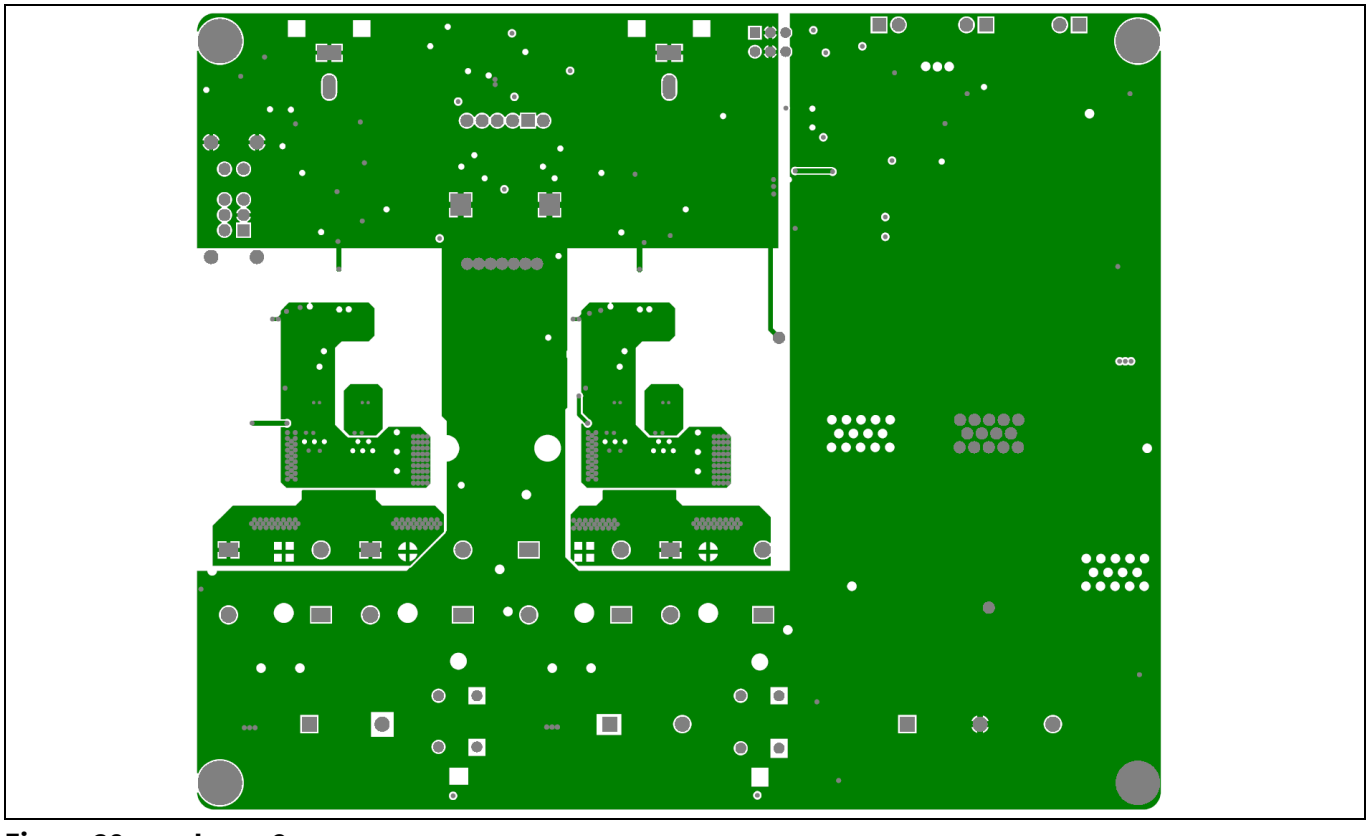

Figure 38 Layer 2

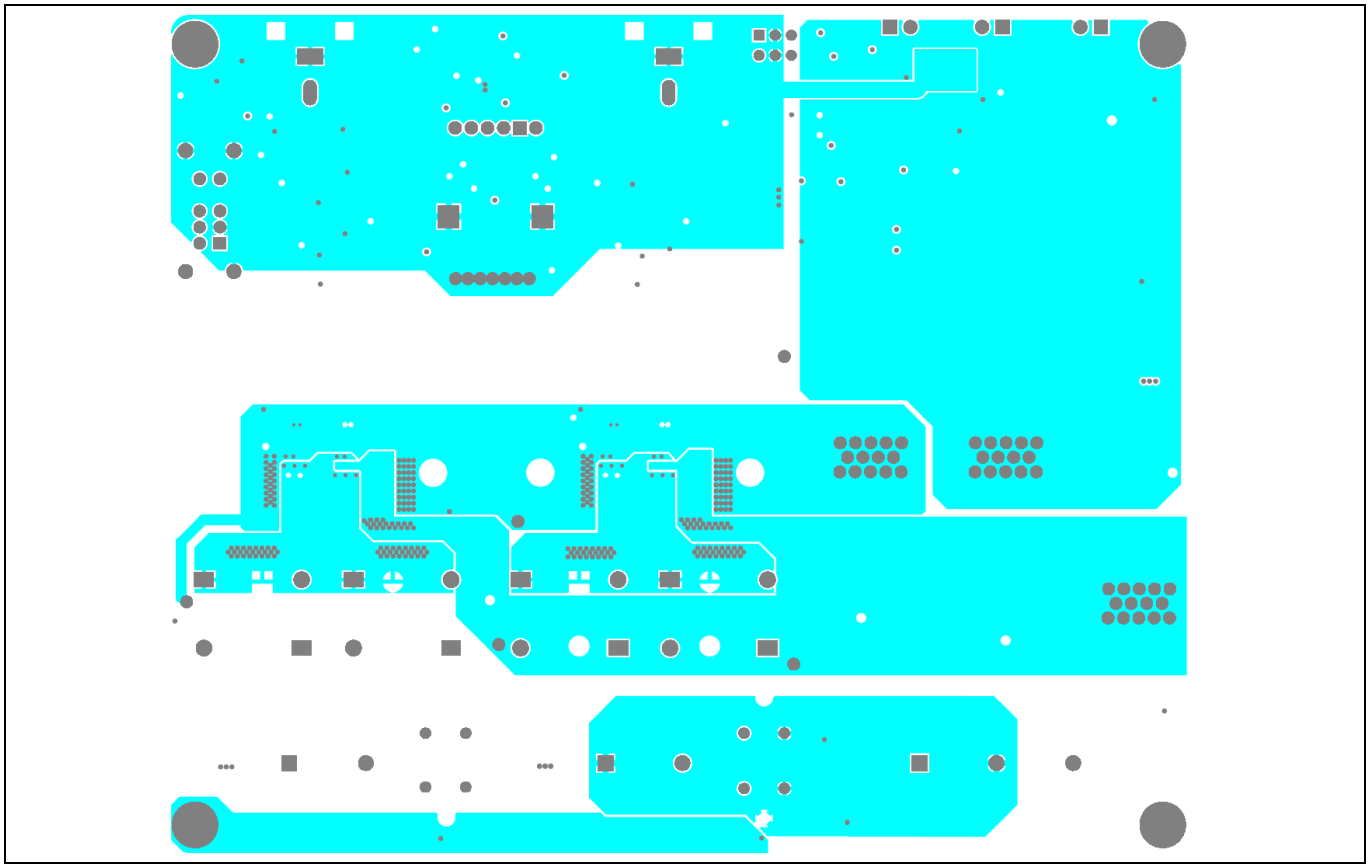

Figure 39 Layer 3

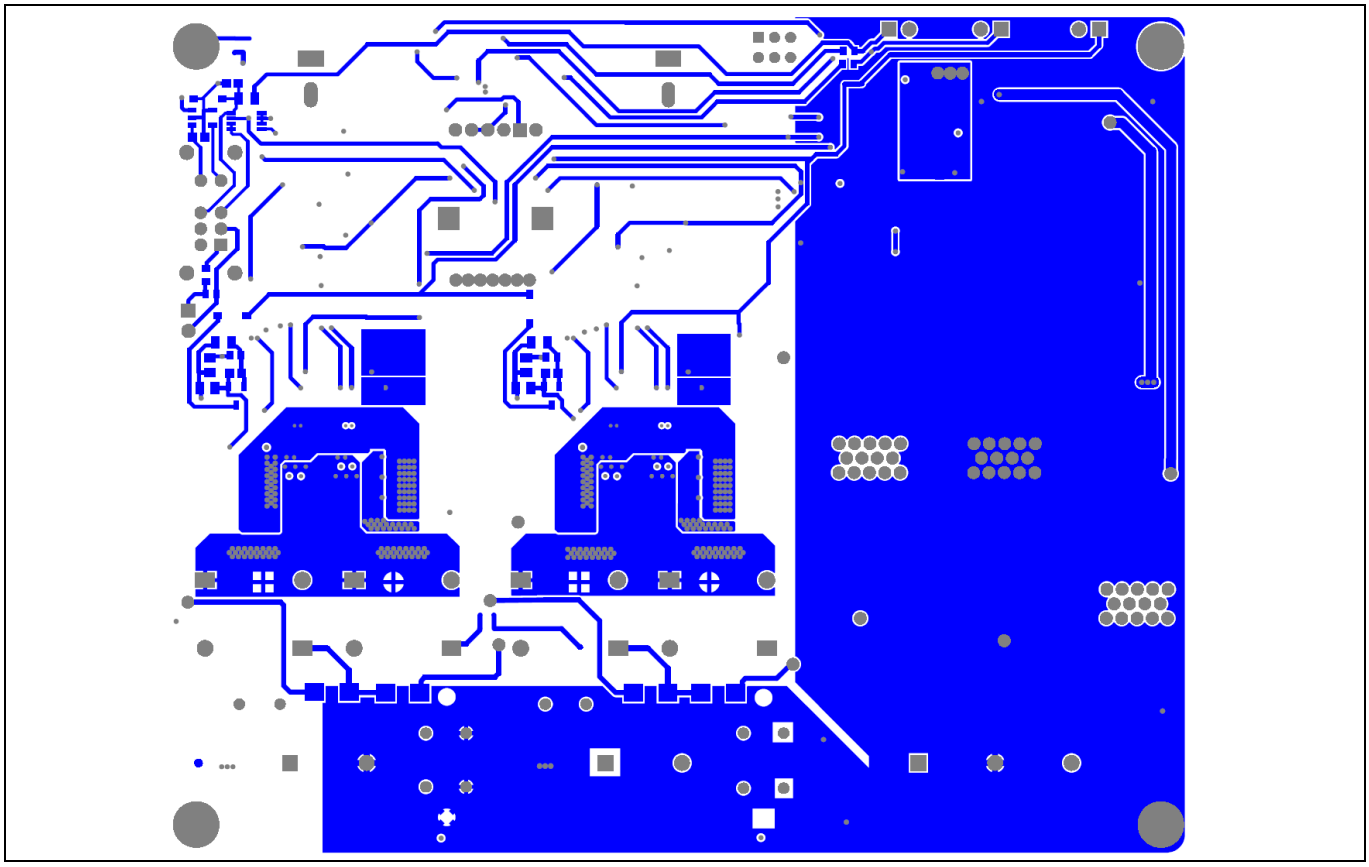

Figure 40 Layer 4

11 Bill of Materials

Table 5 Bill of materials

No.	Part number	Designator	Description	Quantity	Vendor
1	1441142	K1	KNOB	1	Farnell
2	445-173687-1-ND	C11, C15, C18, C21, C22, C23, C24, C25, C68A, C68B	CAP CER 0.047UF 50V X7R 0603	10	DigiKey
3	1N4148W-FDITR-ND	D20A, D20B	DIODE STANDARD 100V 300MA SOD123	3	DigiKey
4	BCP56-16T3GOSTR-ND	Q3	TRANS NPN 80V 1A SOT223	1	DigiKey
5	541-10.0HCT-ND	R6, R10, R11, R12, R50A, R50B, R51A, R51B	RES SMD 10 OHM 1% 1/10W 0603	8	DigiKey
6	P4.70KHCT-ND	R80A, R80B	RES SMD 4.7K OHM 1% 1/10W 0603	2	DigiKey
7	565-EMVE630ARA471MLN0SCT-ND	C4, C10	CAP ALUM 470UF 20% 63V SMD	2	Digikey
8	490-GRM21BZ71E106KE15LCT-ND	C14, C16, C20	CAP CER 10UF 25V X7R 0805	3	Digikey
9	PCE3782CT-ND	C17, C19	CAP ALUM 10UF 20% 16V SMD	2	Digikey
10	311-1079-1-ND	C26A, C26B, C27A, C27B	CAP CER 560PF 50V X7R 0603	4	Digikey
11	399-C0805C101J1GACTUTR-ND	C28A, C28B	CAP CER 100PF 100V C0G/NP0 0805	2	Digikey
12	490-4520-6-ND	C30A, C30B, C59A, C59B, C63A, C63B	CAP CER 2.2UF 10V X7R 0603	6	Digikey
13	490-1451-1-ND	C31A, C31B	CAP CER 1000PF 50V C0G/NP0 0603	2	Digikey
14	311-3891-1-ND	C32A, C32B	CAP CER 220PF 50V C0G/NPO 0603	2	Digikey
15	445-5885-1-ND	C33A, C33B, C61A, C61B	CAP CER 0.1UF 25V X8R 0603	4	Digikey
16	399-C0603C473K5RACTUDKR-ND	C34A, C34B, C37A, C37B	CAP CER 0.047UF 50V X7R 0603	4	Digikey
17	445-7582-2-ND	C35A, C35B, C36A, C36B	CAP CER 3.3UF 16V X7R 0805	4	Digikey

Bill of Materials

No.	Part number	Designator	Description	Quantity	Vendor
18	10-EEE-FN0J100RCT-ND	C38, C40	CAP ALUM 10UF 20% 6.3V SMD	2	Digikey
19	399-C0805C221K5RAC7800CT-ND	C39, C41	CAP CER 220PF 50V X7R 0805	2	Digikey
20	478-5719-1-ND	C42, C43, C44, C45, C58A, C58B	CAP CER 2.2UF 25V X7R 0805	6	Digikey
21	1276-6807-6-ND	C46A, C46B, C47A, C47B, C48A, C48B, C49A, C49B, C50A, C50B	CAP CER 0.1UF 100V X7R 0603	10	Digikey
22	445-6931-2-ND	C51A, C51B, C65A, C65B	CAP CER 1UF 25V X7R 0603	4	Digikey
23	399-C0603C102J3GAC7867CT-ND	C52A, C52B, C66A, C66B	CAP CER 1000PF 25V C0G/NP0 0603	4	Digikey
24	399-11392-1-ND	C53A, C53B	CAP TANT 100UF 10% 16V 2312	2	Digikey
25	1276-6780-1-ND	C60A, C60B	CAP CER 22UF 16V X5R 0805	2	Digikey
26	490-GCM1885G2A181JA16DCT-ND	C62A, C62B	CAP CER 180PF 100V X8G 0603	2	Digikey
27	490-GRM21BZ71E106KE15LCT-ND	C64A, C64B	CAP CER 10UF 25V X7R 0805	2	Digikey
28	399-12987-1-ND	C67A, C67B	CAP CER 10000PF 16V X7R 0603	2	Digikey
29	399-C0805C473K1RACTUCT-ND	C69A, C69B	CAP CER 0.047UF 100V X7R 0805	2	Digikey
30	3013PH-ND	C71A, C71B	CAP FILM 0.1UF 5% 100VDC RADIAL	2	Digikey
31	BC2128-ND	C75A, C75B	CAP FILM 0.68UF 2% 160VDC RADIAL	2	Digikey
32	MMSZ5245B-FDICT-ND	D1, D2, D3	DIODE ZENER 15V 500MW SOD123	3	Digikey
33	MMSZ4714T1GOSCT-ND	D4	DIODE ZENER 33V 500MW SOD123	1	Digikey
34	BZX384C24-E3-08GITR-ND	D5	DIODE ZENER 24V 200MW SOD323	1	Digikey
35	MMSZ4699T1GOSTR-ND	D6	DIODE ZENER 12V 500MW SOD123	1	Digikey

Bill of Materials

No.	Part number	Designator	Description	Quantity	Vendor
36	732-4984-1-ND	D8	LED RED CLEAR 0805 SMD	1	Digikey
37	MMBD4148SECT-ND	D9A, D9B	DIODE ARR GP 100V 200MA SOT23-3	2	Digikey
38	BAT5403WE6327HTSA1CT-ND	D10A, D10B	DIODE SCHOT 30V 200MA PGSOD3233D	2	Digikey
39	RF071MM2SCT-ND	D11A, D11B, D15A, D15B	DIODE STANDARD 200V 700MA PMDU	4	Digikey
40	BAV21W-FDICT-ND	D12A, D12B	DIODE STANDARD 200V 400MA SOD123	2	Digikey
41	1N4148W-13FDICT-ND	D13A, D13B, D16A, D16B, D18A, D18B	DIODE STANDARD 100V 150MA SOD123	6	Digikey
42	732-4984-1-ND	D14A, D14B	LED RED CLEAR 0805 SMD	2	Digikey
43	SMMSD301T1GOSCT-ND	D17A, D17B	DIODE SCHOTTKY 30V 200MA SOD123	2	Digikey
44	ES2DFSCT-ND	D21A, D21B, D22A, D22B	DIODE STANDARD 200V 2A DO214AA	4	Digikey
45	ES1DFSCT-ND	D23	DIODE STANDARD 200V 2A DO214AA	1	Digikey
46	475-LBQ39G-L2OO-35-1CT-ND	DS1	LED BLUE DIFFUSED 0603 SMD	1	Digikey
47	MMSZ4689T1GOSTR-ND	Dz1	DIODE ZENER 5.1V 500MW SOD123	1	Digikey
48	296-19534-1-ND	G1	IC REG LINEAR 10V 500MA TO252-3	1	Digikey
49	497-1183-1-ND	G2	IC REG LINEAR 5V 100MA SOT89-3	1	Digikey
50	497-1219-1-ND	G3	IC REG LINEAR -5V 100MA SOT89-3	1	Digikey
51	505-LTC1799HS5#TRPBFCT-ND	G4	IC OSC SILICON PROG TSOT23-5	1	Digikey
52	ZXTR2105F-7DICT-ND	G5A, G5B, G6A, G6B	IC REG LINEAR 5V 89MA SOT23-3	4	Digikey
53	296-17056-1-ND	IC1	IC GATE NAND SCHMITT 2CH 2IN SM8	1	Digikey
54	4044-CPD1521C-100M-ND	L3A, L3B	CLASS D INDUCTOR FOR DIGITAL AMP	2	Digikey
55	36-29311-ND	MP1, MP2, MP3, MP4	MACH SCREW PAN HEAD SLOTTED M3	4	Digikey
56	36-24435-ND	MP5, MP6, MP7, MP8	HEX STANDOFF M3 ALUMINUM 15MM	4	Digikey

No.	Part number	Designator	Description	Quantity	Vendor
57	277-1271-ND	P1, P2	TERM BLK 2P SIDE ENT 9.53MM PCB	2	Digikey
58	MMBT5401-FDICT-ND	Q1	TRANS PNP 150V 0.6A SOT-23-3	1	Digikey
59	1727-8673-1-ND	Q4	TRANS NPN 80V 8A DPAK	1	Digikey
60	MJD45H11RLGOSCT-ND	Q5	TRANS PNP 80V 8A DPAK	1	Digikey
61	MMBT5551LT1GOSDKR-ND	Q6, Q7, Q8, Q12A, Q12B	TRANS NPN 160V 0.6A SOT23-3	5	Digikey
62	DMP3098LDICT-ND	Q9A, Q9B	P-CHANNEL ENHANCEMENT MODE MOSFET	2	Digikey
63	448-IGB110S101XTMA1CT-ND	Q10A, Q10B, Q11A, Q11B	MV GAN DISCRETE	4	Digikey
64	311-100KCRDKR-ND	R1, R5	RES 100K OHM 1% 1/8W 0805	2	Digikey
65	P4.75KFCT-ND	R2	RES SMD 4.75K OHM 1% 1/4W 1206	1	Digikey
66	311-47.0KCRDKR-ND	R3, R88A, R88B	RES 47K OHM 1% 1/8W 0805	3	Digikey
67	311-10.0CRDKR-ND	R4	RES 10 OHM 1% 1/8W 0805	1	Digikey
68	P10.0HDKR-ND	R7, R14, R15, R22, R23, R63A, R63B, R79A, R79B	RES SMD 10 OHM 1% 1/10W 0603	9	Digikey
69	541-1.00HCT-ND	R8	RES SMD 1 OHM 1% 1/10W 0603	1	Digikey
70	541-47.0LCT-ND	R9A, R9B	RES SMD 47 OHM 1% 1/16W 0402	2	Digikey
71	YAG6206CT-ND	R13, R21	RES 100 OHM 5% 2W 2512	2	Digikey
72	541-13.0KCCT-ND	R16	RES SMD 13K OHM 1% 1/8W 0805	1	Digikey
73	P9.09KCCT-ND	R24	RES SMD 9.09K OHM 1% 1/8W 0805	1	Digikey
74	311-10.0KHRCT-ND	R25, R30, R53, R58, R59, R60	RES 10K OHM 1% 1/10W 0603	6	Digikey
75	311-47.0KHRCT-ND	R26, R32, R34, R35	RES 47K OHM 1% 1/10W 0603	4	Digikey
76	YAG3590CT-ND	R27, R29, R37	RES SMD 2K OHM 1% 1/10W 0603	3	Digikey
77	541-30.0KHDKR-ND	R28	RES SMD 30K OHM 1% 1/10W 0603	1	Digikey

Bill of Materials

No.	Part number	Designator	Description	Quantity	Vendor
78	311-1.00KHRTR-ND	R31, R38, R45A, R45B, R47A, R47B, R49A, R49B	RES 1K OHM 1% 1/10W 0603	8	Digikey
79	541-CRCW060350R0FKTACT-ND	R33	CRCW0603 50 1% 100 RT1	1	Digikey
80	311-100KHRTR-ND	R36	RES 100K OHM 1% 1/10W 0603	1	Digikey
81	P16065CT-ND	R39	RES SMD 2K OHM 1% 1/2W 0805	1	Digikey
82	P75.0KFCT-ND	R40A, R40B	RES SMD 75K OHM 1% 1/4W 1206	2	Digikey
83	311-470HRDKR-ND	R41A, R41B	RES 470 OHM 1% 1/10W 0603	2	Digikey
84	YAG1579CT-ND	R42A, R42B	RES SMD 200 OHM 0.1% 1/10W 0603	2	Digikey
85	311-22.0KCRCT-ND	R43A, R43B	RES 22K OHM 1% 1/8W 0805	2	Digikey
86	3214W-102ETR-ND	R44A, R44B	TRIMMER 1K OHM 0.25W J LEAD TOP	2	Digikey
87	A129702CT-ND	R48A, R48B	RES 15K OHM 1% 1/10W 0603	2	Digikey
88	RMCF0603FT3K32TR-ND	R52, R57	RES SMD 3.32K OHM 1% 1/10W 0603	2	Digikey
89	118-PTV112-4420A-A103-ND	R54	POT 10K OHM 1/20W CARBON LOG	1	Digikey
90	311-100KHRTR-ND	R56, R62	RES 100K OHM 1% 1/10W 0603	4	Digikey
91	541-5.11KFTR-ND	R67A, R67B	RES SMD 5.11K OHM 1% 1/4W 1206	2	Digikey
92	311-10.0KFRTR-ND	R68A, R68B	RES 10K OHM 1% 1/4W 1206	2	Digikey
93	311-0.0GRTR-ND	R69A, R69B, R75A, R75B	RES 0 OHM JUMPER 1/10W 0603	4	Digikey
94	311-10.0KHRCT-ND	R70A, R70B, R74A, R74B, R55, R61	RES 10K OHM 1% 1/10W 0603	4	Digikey
95	RMCF0603FT10R0TR-ND	R71A, R71B	RES 10 OHM 1% 1/10W 0603	2	Digikey
96	311-150KHRTR-ND	R72A, R72B, R73A, R73B, R83A, R83B, R84A, R84B	RES 150K OHM 1% 1/10W 0603	8	Digikey

No.	Part number	Designator	Description	Quantity	Vendor
97	P17617TR-ND	R77A, R77B	RES SMD 5.1 OHM 1% 1/2W 1206	2	Digikey
98	541-8.20KHCT-ND	R78A, R78B	RES SMD 8.2K OHM 1% 1/10W 0603	2	Digikey
99	P1.10KHCT-ND	R81A, R81B	RES SMD 1.1K OHM 1% 1/10W 0603	2	Digikey
100	311-5.60KHRCT-ND	R82A, R82B	RES 5.6K OHM 1% 1/10W 0603	2	Digikey
101	541-7.50KHCT-ND	R86A, R86B	RES SMD 7.5K OHM 1% 1/10W 0603	2	Digikey
102	CR0805-FX-4992ELFTR-ND	R89A, R89B	RES SMD 49.9K OHM 1% 1/8W 0805	2	Digikey
103	541-2.21KAFCT-ND	R90A, R90B	RES SMD 2.21K OHM 1% 1W 2512	2	Digikey
104	PT2.0XCT-ND	R91A, R91B	RES SMD 2 OHM 5% 1W 2512	2	Digikey
105	P20.0LCT-ND	Rg1A, Rg1B, Rg2A, Rg2B, Rg3A, Rg3B, Rg4A, Rg4B	RES SMD 20 OHM 1% 1/10W 0402	8	Digikey
106	490-6993-1-ND	Rp1A, Rp1B	SENSOR PTC 470 OHM 50% 0805	2	Digikey
107	EG1908-ND	S1	SWITCH SLIDE DPDT 100MA 12V	1	Digikey
108	EG1944-ND	S2	SWITCH SLIDE DP3T 200MA 30V	1	Digikey
109	296-OPA1655DRCT-ND	U1A, U1B	SOUNDPLUS ULTRA-LOW NOISE AND DI	2	Digikey
110	296-OPA1656IDRTR-ND	U2, U3	IC AUDIO 2 CIRCUIT 8SOIC	2	Digikey
111	448-1EDN7116UXTSA1CT-ND	U4A, U4B, U6A, U6B	IC GATE DRVR HI/LOW SIDE TSNP-7	4	Digikey
112	IRS20957STRPBFCT-ND	U5A, U5B	IC AMP CLASS D MONO 16SOIC	2	Digikey
113	3314J-2-104ETR-ND	VR1	TRIMMER 100K OHM 0.25W J LEAD TOP	1	Digikey
114	732-5315-ND	X1, X2, X3, X7	CONN HEADER VERT 2POS 2.54MM	4	Digikey
115	277-1272-ND	X4	TERM BLK 3P SIDE ENT 9.53MM PCB	1	Digikey
116	CP-1418-ND	X5, X6	CONN RCA JACK MONO 3.2MM R/A	2	Digikey
117	1727-1596-2-ND	Z1, Z6A, Z6B	DIODE ZENER 10V 375MW SOD123F	3	Digikey

12 Summary

The REF_Audio_GaNb_750W is a high-performance class D audio amplifier reference board developed by Infineon Technologies. It combines 100 V CoolGaN™ transistors (IGB110S10S1) with the MERUS™ IRS20957S digital audio driver to showcase the superior efficiency, power density, and audio quality achievable with GaN technology. This board supports two-channel single-ended or one-channel BTL operation, delivering up to 750 W total output power at 2 Ω.

Key features include a self-oscillating PWM topology, comprehensive protection mechanisms (OCP, OVP, UVP, and OTP), and support for both internal and external clock synchronization. The system operates at a typical 1 MHz switching frequency, with a 400 kHz variant available for enhanced thermal performance.

The design offers over 120 dB signal-to-noise ratio, <30 µV residual noise, and high efficiency due to low conduction and switching losses. Thermal management and power handling are optimized, allowing operation at high power levels without heatsinks. Full setup, analyzer configurations, and performance benchmarks are provided to enable developers to quickly evaluate and integrate this solution into high-fidelity audio applications.

References

[1] Infineon Technologies AG: *IGB110S10S1*; Available online

[2] Infineon Technologies AG: *IGB070S10S1*; Available online

[3] Infineon Technologies AG: *IRS20957SPBF*; Available online

[4] Infineon Technologies AG: *1EDN7116U*; Available online

Revision history

<table>
<tr><th>Document revision</th><th>Date</th><th>Description of changes</th></tr>
<tr><td>V 1.0</td><td>2025-04-11</td><td>Initial release</td></tr>
<tr><td>V 1.1</td><td>2025-05-29</td><td>Updated bill of materials
Updated functional description list</td></tr>
<tr><td>V 1.2</td><td>2025-06-18</td><td>Updated bill of materials</td></tr>
<tr><td>V 1.3</td><td>2025-12-04</td><td>PCB rev (v1.3). Adjusted Sync Clock Range. Preamp gain changed to unity. Other miscellaneous non-critical value changes.
<table>
<tr><th>Designator</th><th>From</th><th>To</th></tr>
<tr><td>PCB</td><td>V1.2</td><td>V1.3</td></tr>
<tr><td>VR1</td><td>10K</td><td>100K</td></tr>
<tr><td>R52, R57</td><td>1.21K</td><td>3.32K</td></tr>
<tr><td>D7</td><td>1N4148</td><td>REMOVED</td></tr>
<tr><td>U2, U3</td><td>LM4562</td><td>OPA1656</td></tr>
<tr><td>R55, R61</td><td>100K</td><td>10K</td></tr>
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Customer shall not touch the Evaluation Board during operation and keep a safe distance.
Customer shall not touch the Evaluation Board after disconnecting the power supply, several components may still store electrical voltage and can discharge through physical contact. Several parts, like heat sinks and transformers, may still be very hot. Allow the components to cool before touching or servicing.
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