Class D audio reference board with 175 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_GaNc_1200W class D audio reference board with the CoolGaN™ power transistor IGC090S18S1 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 intended for power electronic engineers, technicians, and developers of class D audio systems who are interested in evaluating the performance of the 175 V CoolGaN™ power transistor IGC090S18S1 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_GaNc_1200W overview

The REF_Audio_GaNc_1200W Reference Board [1] features the 175 V CoolGaN™ transistors combined with the MERUS™ IRS20957S class D audio driver ICs. This two-channel design is scalable up to 600 W x 2 channel at 4 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 errors in the audible frequency range are 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.

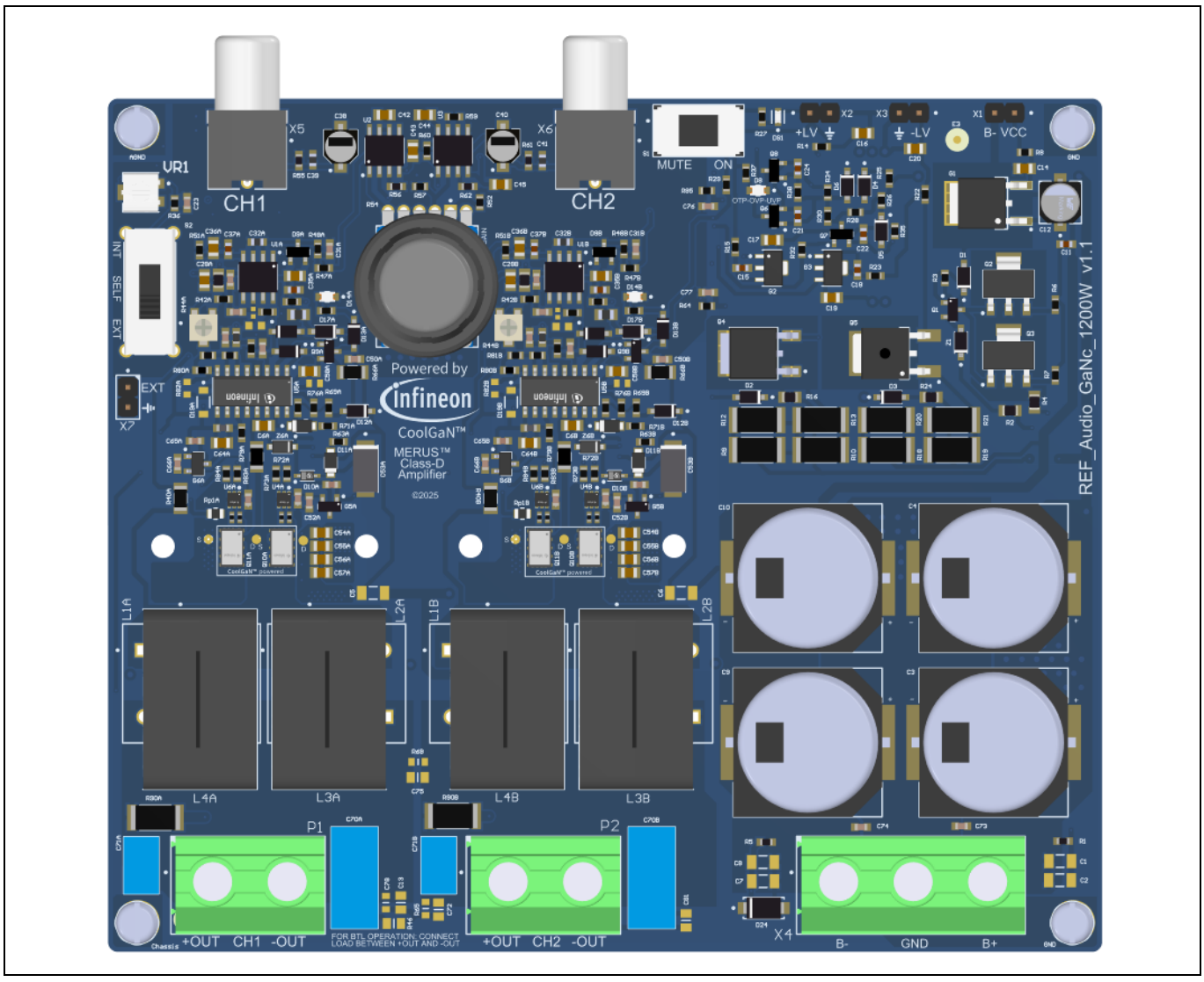

Figure 1 Ref_Audio_GaNc_1200W Reference Board

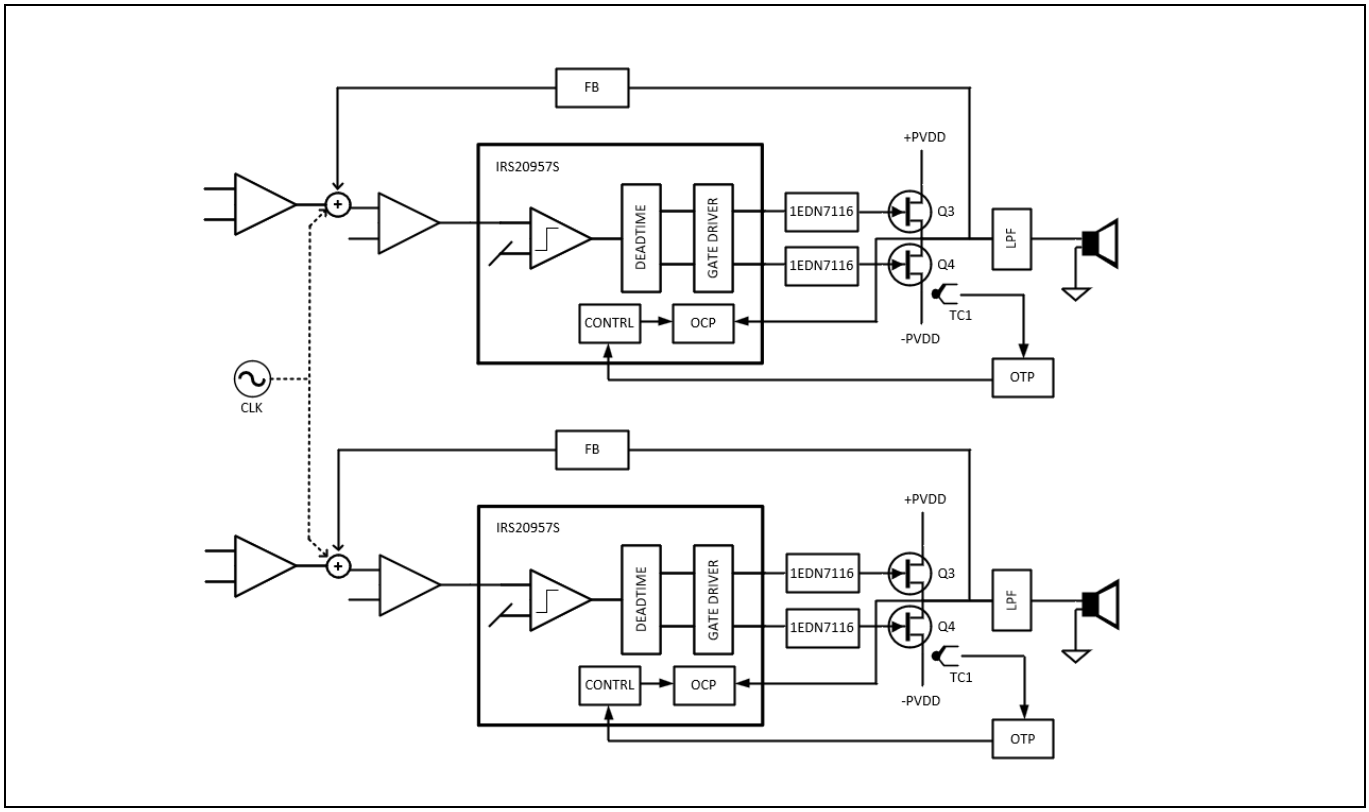

Figure 2 Simplified block diagram of Ref_Audio_GaNc_1200W

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
Supply voltaqges	± 42 V ~ ± 70 V	Bipolar power supply
Rated load impedance	4 Ω to 8 Ω	Resistive load
Self-oscillating frequency	450 kHz	No input signal, adjustable
Voltage gain	17 – 41 dB	Class D fixed at 17.5 dB
Number of audio channels	2 x single-ended or 1 x BTL	–
Audio input format	Analog	–

Table 2 Electrical specifications

Condition	Typ.	Note
Output power (1% THD+N) single-ended	310 W x 2 ch	1 kHz, RL = 8 Ω, ±70 V
	480 W x 2 ch	1 kHz, RL = 4 Ω, ±63 V
Output power (10% THD+N) single-ended	380 W x 2 ch	1 kHz, RL = 8 Ω, ±70 V
	600 W x 2 ch	1 kHz, RL = 4 Ω, ±63 V
Output power (1% THD+N) bridged-tied-load (BTL)	960 W x 1 ch	1 kHz, RL = 8 Ω, ±63 V
Output power (10% THD+N) BTL	1200 W x 1 ch	1 kHz, RL = 8 Ω, ±63 V
Idling supply current	+110 mA -120 mA	No input signal ±63 V, ±10 mA
Channel efficiency	97%	Single-channel driven, 600 W, class D stage

Table 3 Audio performance

Parameter	Value	Notes
Signal-to-noise Ratio (SNR)	>120 dB	Filter: A-weighting (12017), 20 kHz SPCL, ±63 V
Residual noise	<55 µV	Filter: A-weighting (12017), 20 kHz SPCL, ±63 V

All connections of the Ref_Audio_GaNc_1200W board are shown in Figure 3. The corresponding description for connectors and switches is given in the following:

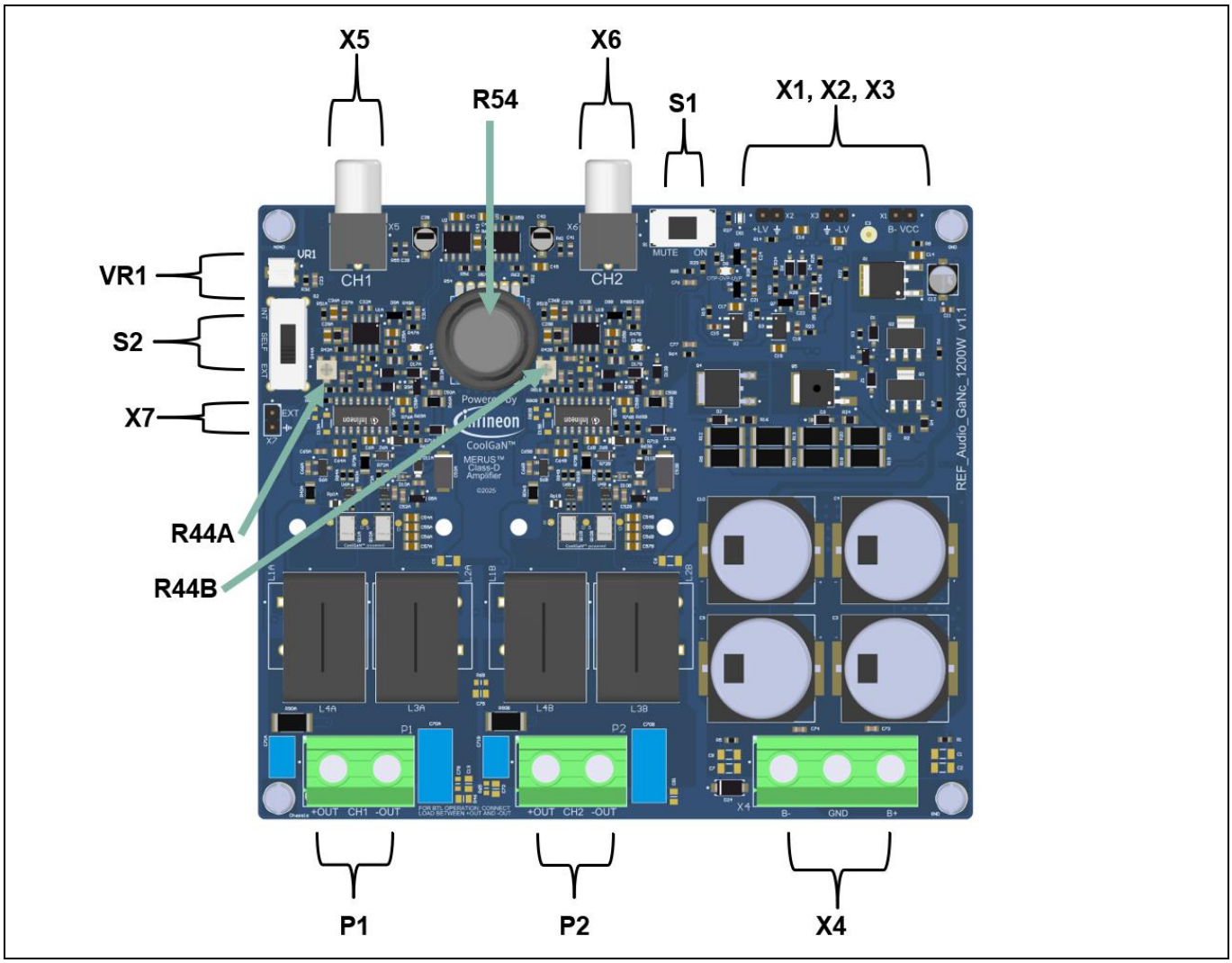

Figure 3 Main board connections

- 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 ±42 V and a maximum voltage of ±80 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 4 for the other electrical specifiactions.

Table 4 Function description of main Ref_Audio_GaNc_1200W 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 prefferred
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	Adjustable from 330 kHz – 500 kHz
R44A, R44B	Self-oscillating frequency adjust	Preset to 450 kHz

1.3 CoolGaN™ 175 V power transistor

The 175 V CoolGaN™ power transistor IGC090S18S1 [1] comes in a 3 x 5 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. IGC090S18S1 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, overall system efficiency, and audio performance.

Figure 4 175 V CoolGaN™ G3 power transistors IGC090S18S1

1.4 MERUS™ IRS20957S protected digital audio driver

The MERUS™ IRS20957S [2] 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 an 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 [3] 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
- One-channel bridge-tied-load (BTL) configuration

2.1 Two-channel SE configuration wiring setup

Perform the following steps to set up the board for 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

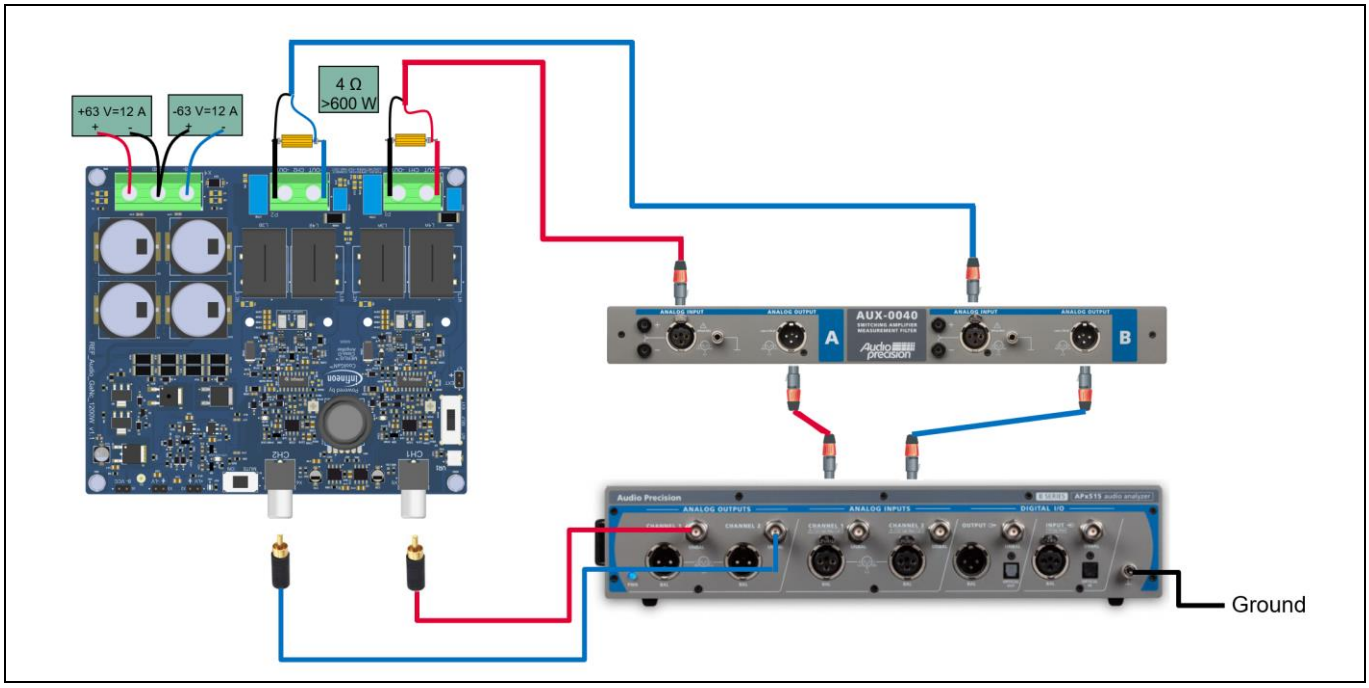

Figure 5 Typical operation setup for SE operation of Ref_Audio_GaNc_1200W

2.2 One-channel BTL configuration wiring setup

Perform the following steps to set up the board for one-channel bridge-tied-load (BTL) configuration:

1. Connect 8 Ω > 1200 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

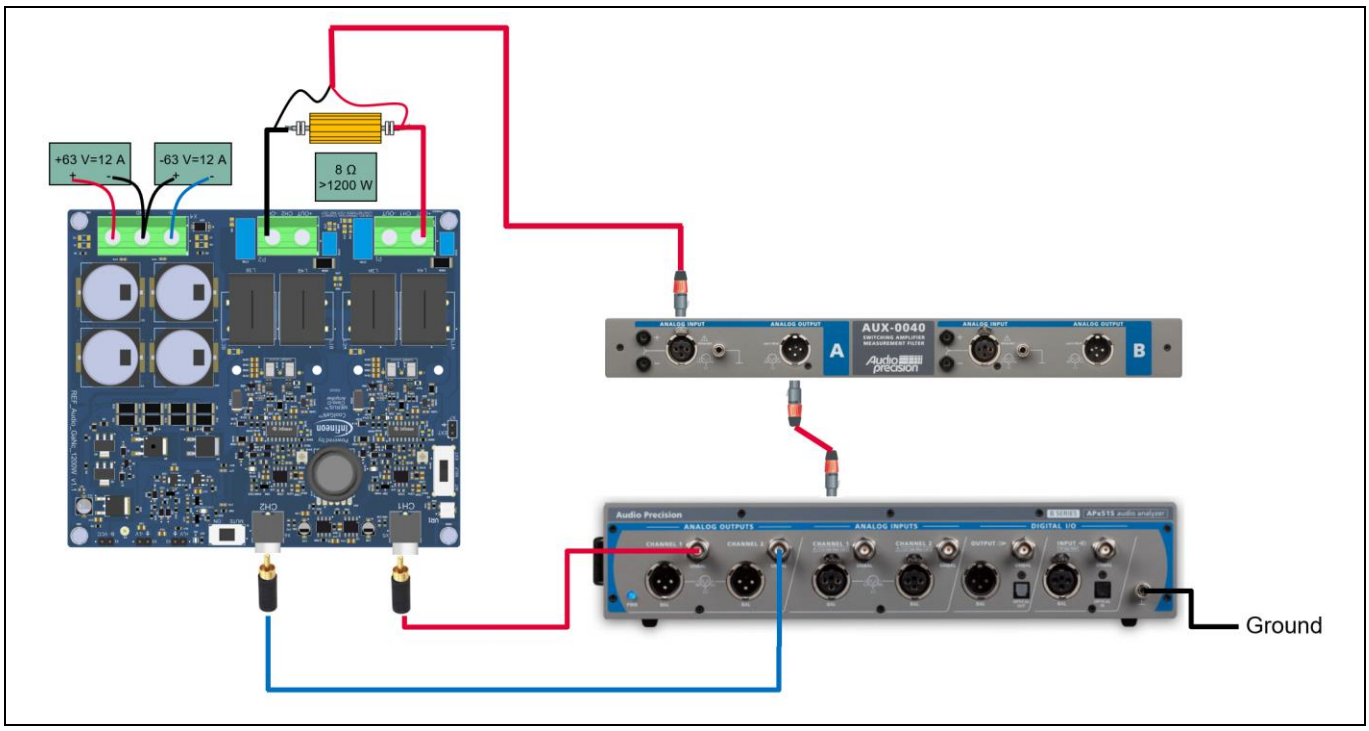

Figure 6 Typical operation setup for BTL operation of Ref_Audio_GaNc_1200W

3 Audio analyzer setup

3.1.1 Two-channel single-ended configuration

Perfrom 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

For the **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):** 4 ohms

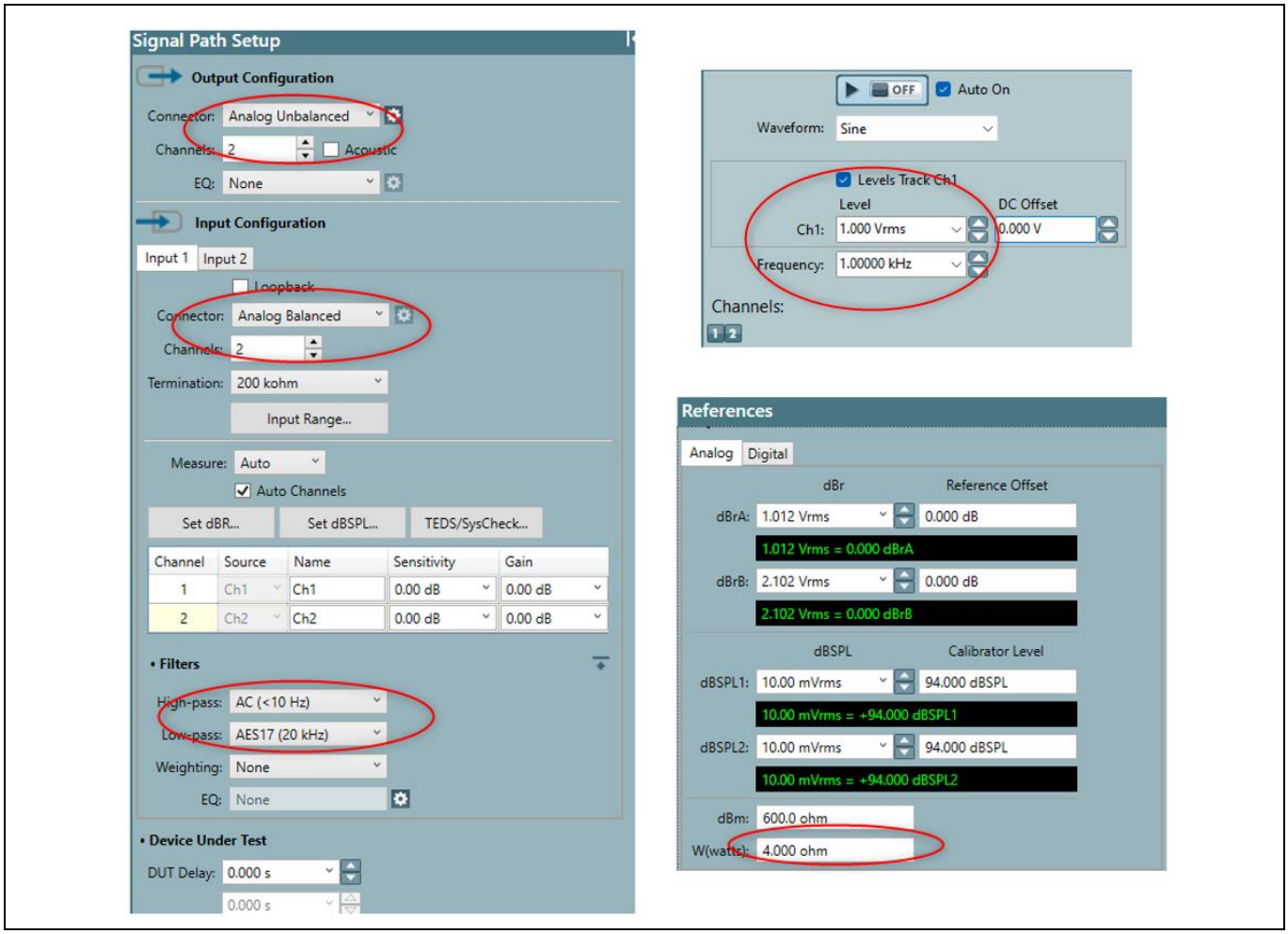

Figure 7 Typical analyzer setup for SE operation of Ref_Audio_GaNc_1200W

3.1.2 One-channel BTL configuration

Perfrom 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

For the **Filters** settings:

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

Verify Connections settings:

- **Waveform:** Sine

Audio analyzer setup

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

Input References settings:

- Under **Analog**,
- **W (watts):** 8 Ω

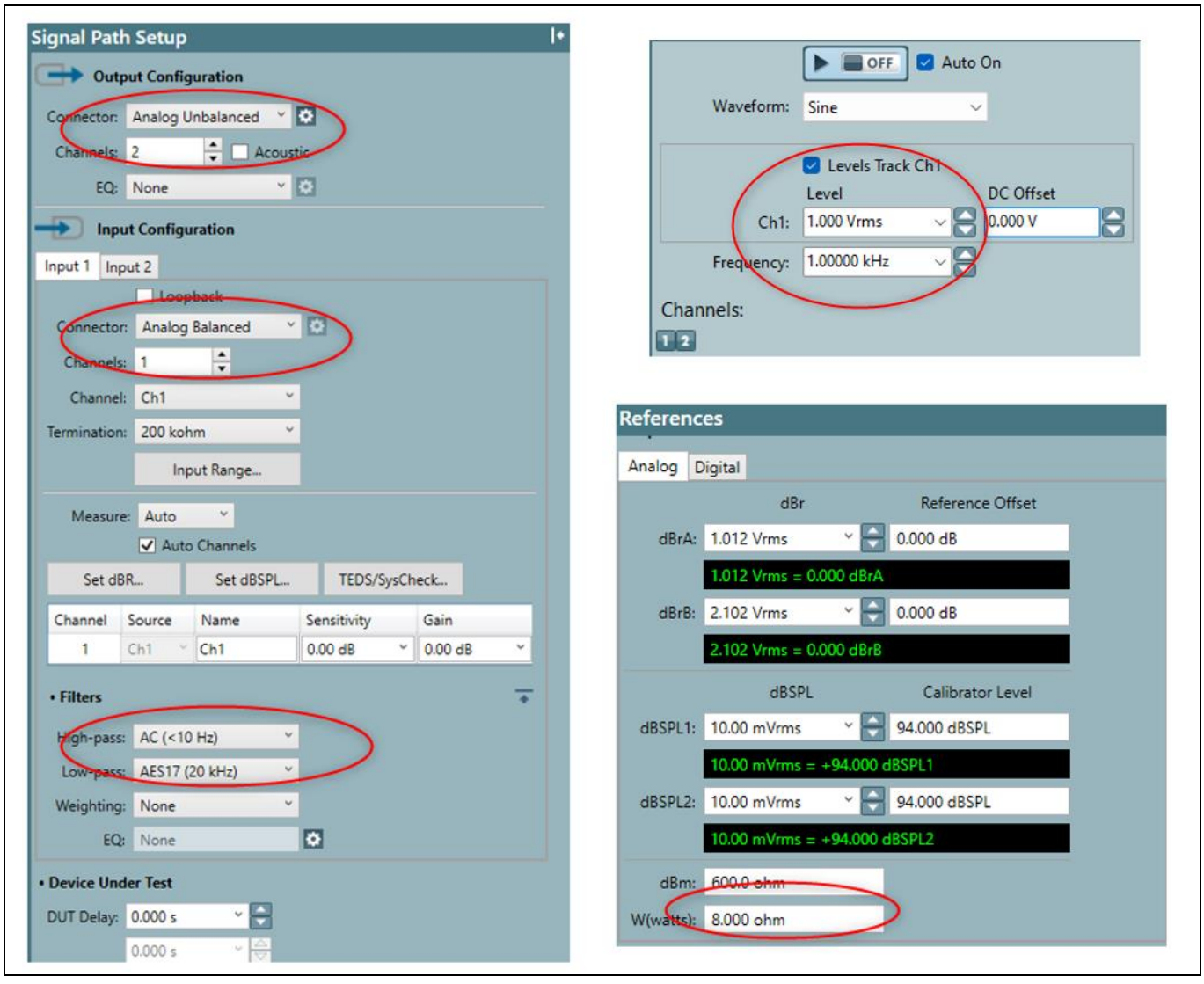

Figure 8 Typical analyzer setup for BTL operation of Ref_Audio_GaNc_1200W

4 Reference board operations

4.1 Test setup

1. For SE, connect 4 Ω > 600 W capable dummy loads according to Figure 5
2. For BTL connect 8 Ω > 1200 W capable dummy load according to Figure 6
3. Connect audio analyzer according to Figure 5 for SE or 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 ±63 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 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 or 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 +63 V
6. Quiescent current for the negative supply should be 120 mA ±10 mA at –63 V
7. Monitor switching waveform for CH1 at VS1 and VS2 for CH2 using an oscilloscope (Figure 9)
8. Confirm the self-oscillating switching frequency is 450 kHz ±10 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 1 V_{RMS} at 1kHz sinusoidal signal from the ASG
4. Adjust gain potentiometer R54 clockwise until 1 V_{RMS} input generates an approximate output voltage of 22.5 V_{RMS} SE or 45 V_{RMS} in BTL
5. Sweep the audio input signal from 50 m V_{RMS} to 2.5 V_{RMS}
6. 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 450 kHz, confirm switching frequencies are sycned at 450 kHz
4. Sweep the audio input signal from 50 m V_{RMS} to 2.5 V_{RMS}

4.6 External sync clock function

1. Monitor VS1 and VS2 switching frequency
2. Adjust R44A, R44B on the board to change 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, confirm switching frequency signals are synced
6. Sweep the audio input signal from 50 m V_{RMS} to 2.5 V_{RMS}

4.7 Power down

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

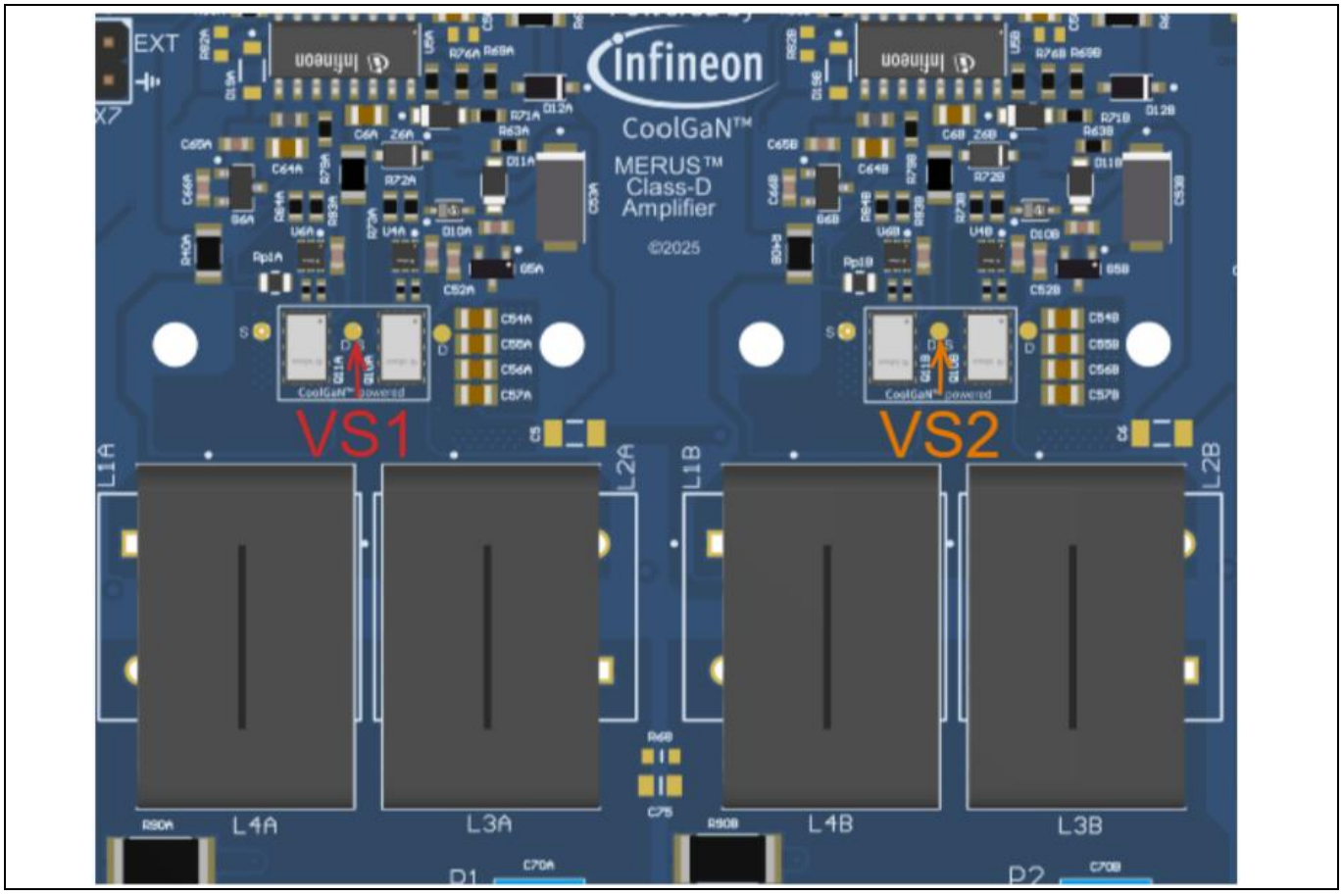

Figure 9 VS1 and VS2 test points

5 Audio performance

This section shows the results of the audio performance of Ref_Audio_GaNc_1200W that can be achieved using the 175 V CoolGaN™ transistors in combination with MERUS™ IRS20957S class D audio driver ICs.

5.1 Total harmoic distortion - THD+N

Test conditions:

- V_{bus} ±63 V
- Input signal = 1 kHz
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

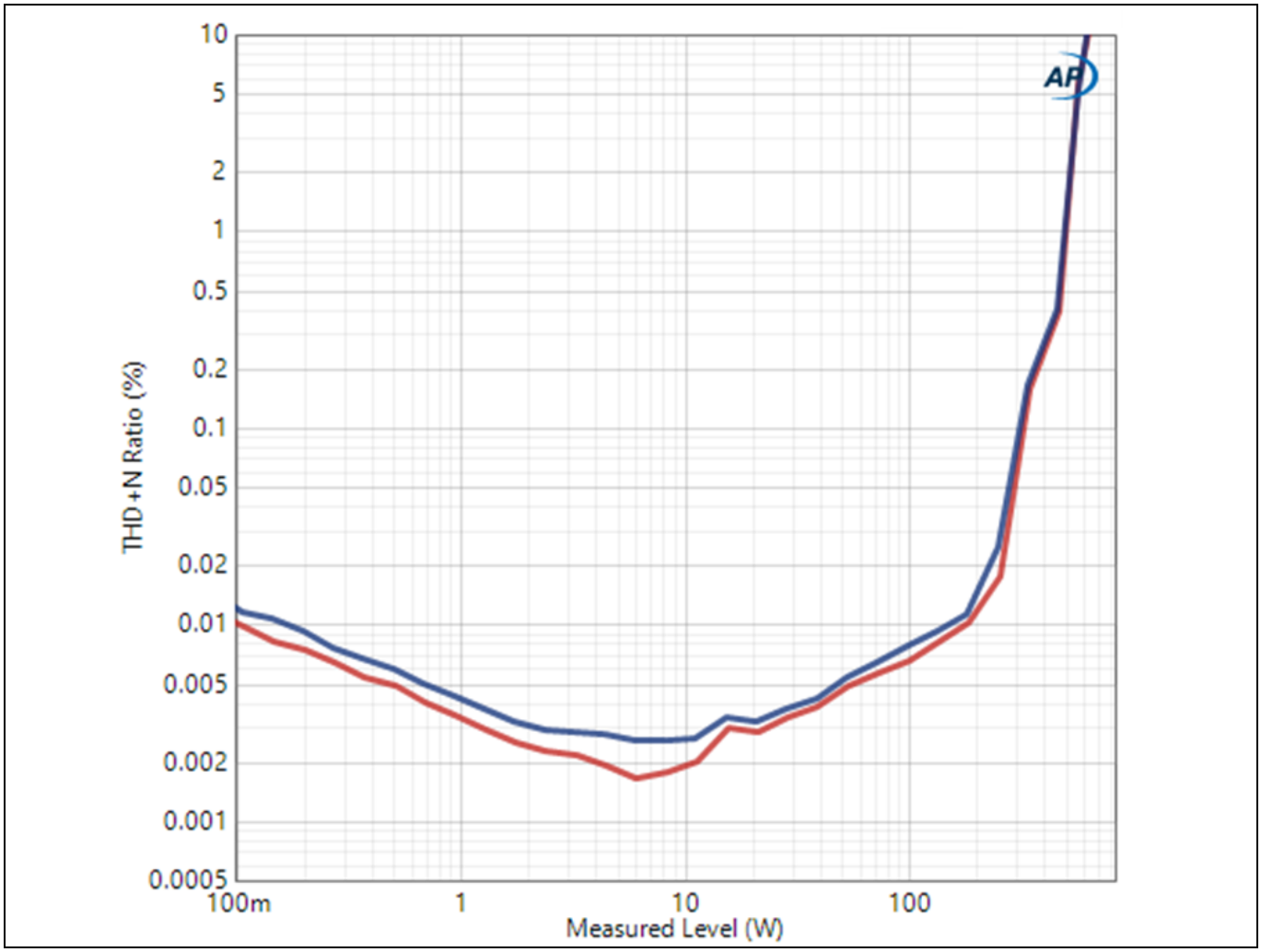

Figure 10 Power vs. THD+N 4 Ω load single ended

Audio performance

Test conditions:

- V_{bus} ±63 V
- Input signal = 1 kHz
- Load impedance = 8 Ω BTL
- F_{PWM} = 450 kHz

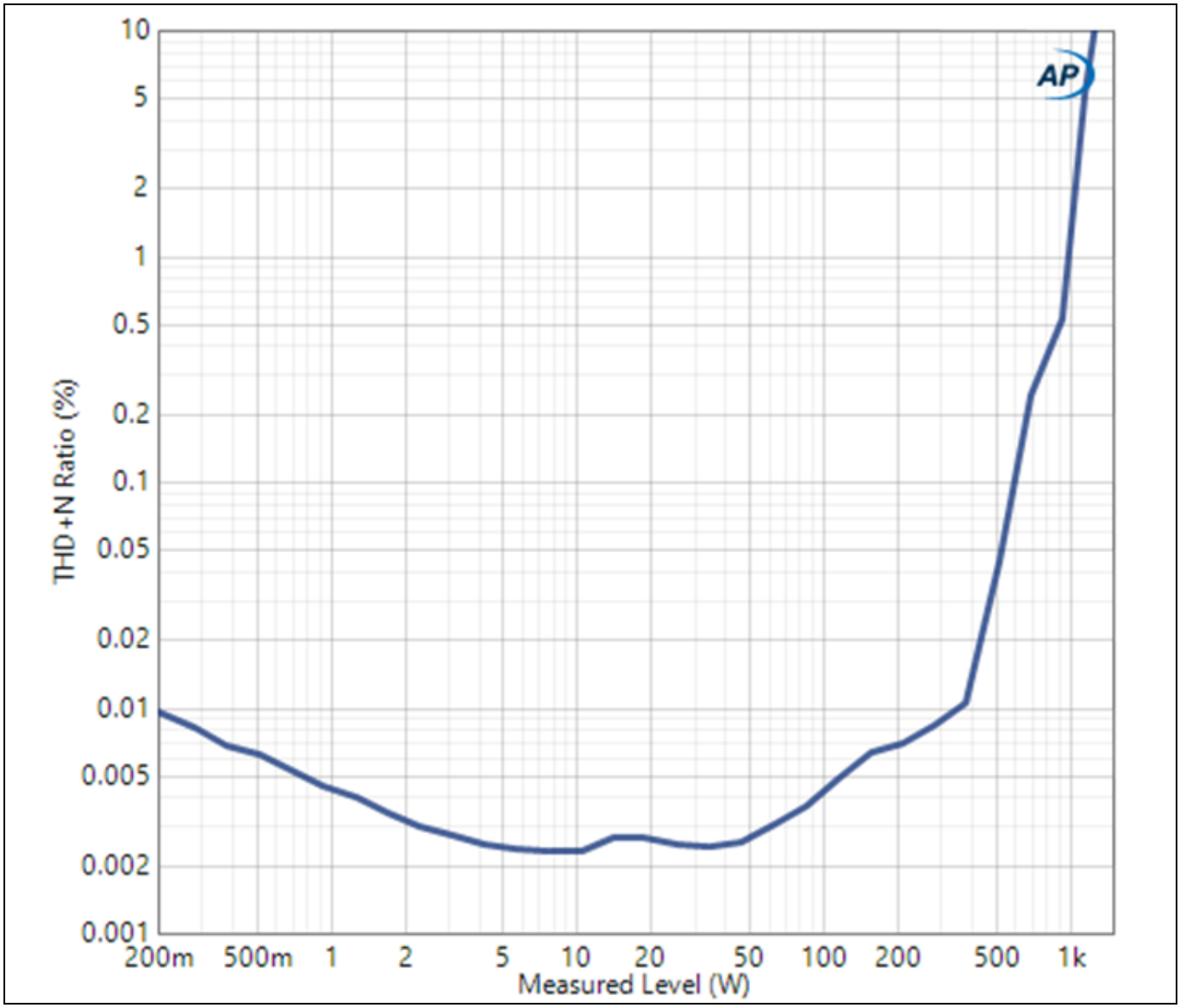

Figure 11 Power vs. THD+N 4 Ω load BTL

Audio performance

Test conditions:

- V_{bus} ±63 V
- Output power = 1 W
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

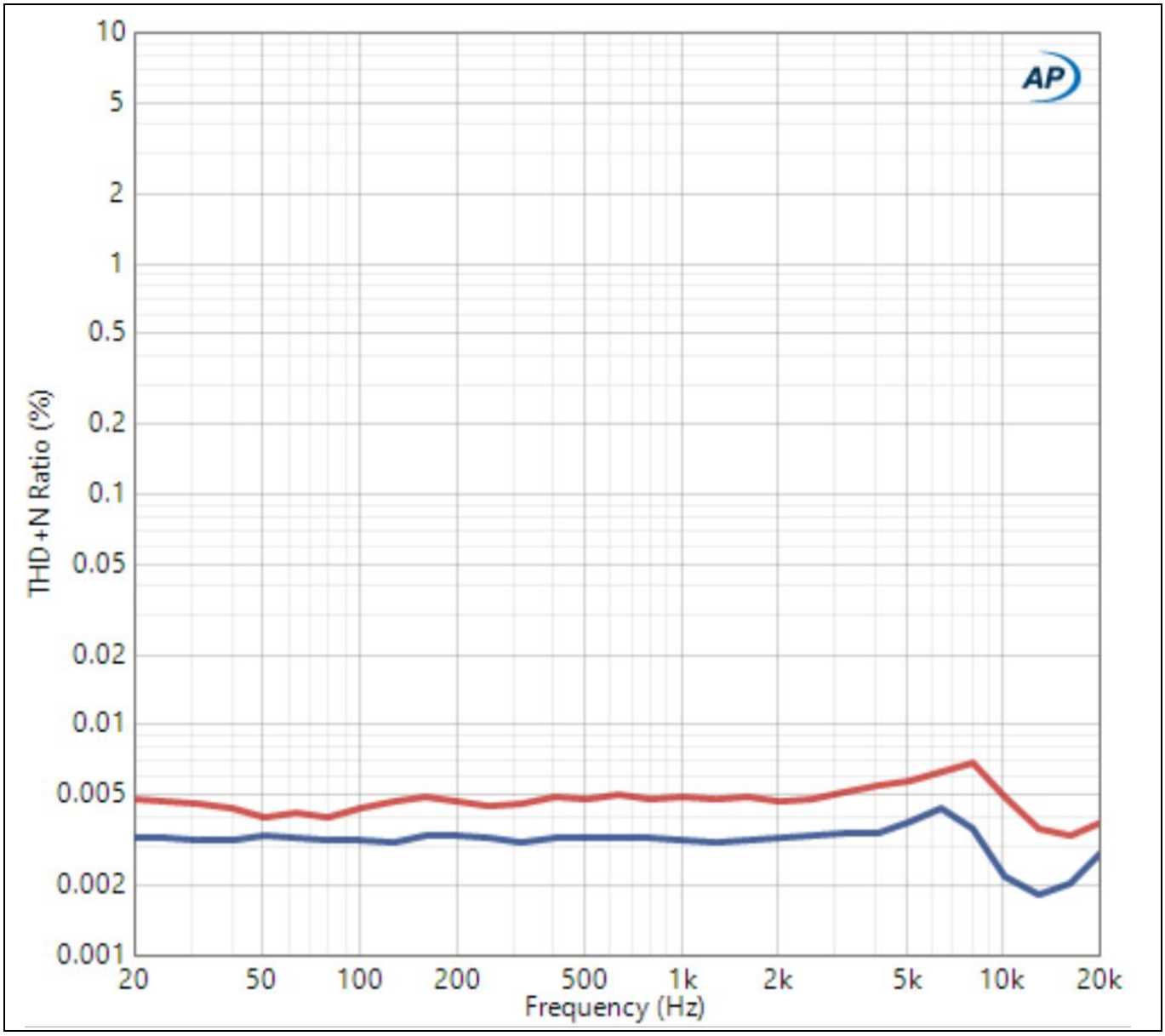

Figure 12 THD+N at 4 Ω load 1 W singled ended

Audio performance

Test conditions:

- V_{bus} ±36 V
- Output power = 10 W
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

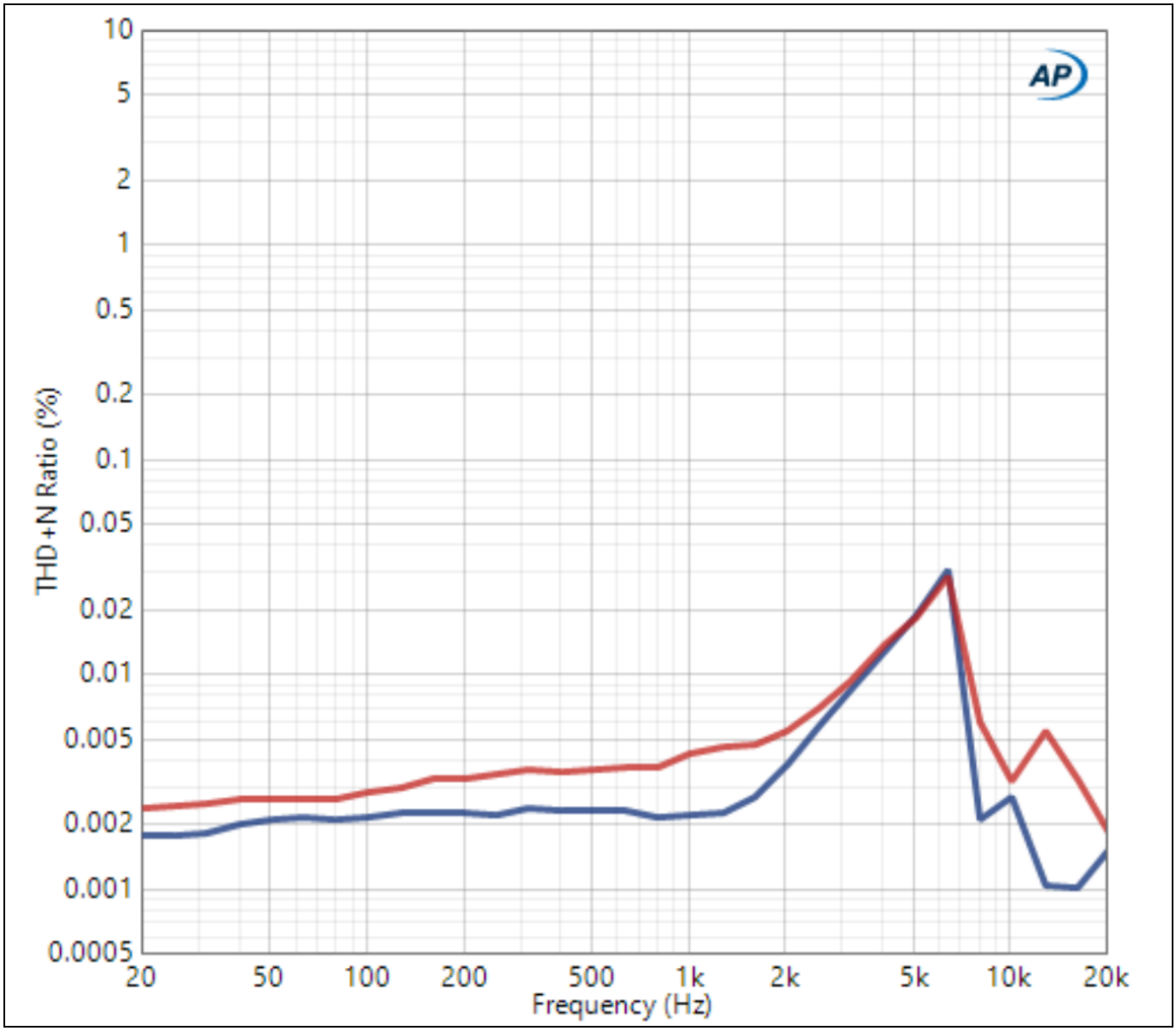

Figure 13 THD+N at 4 Ω load 1 W singled ended

5.2 Frequency response

Test conditions:

- V_{bus} ±63 V
- Output power = 1 W
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

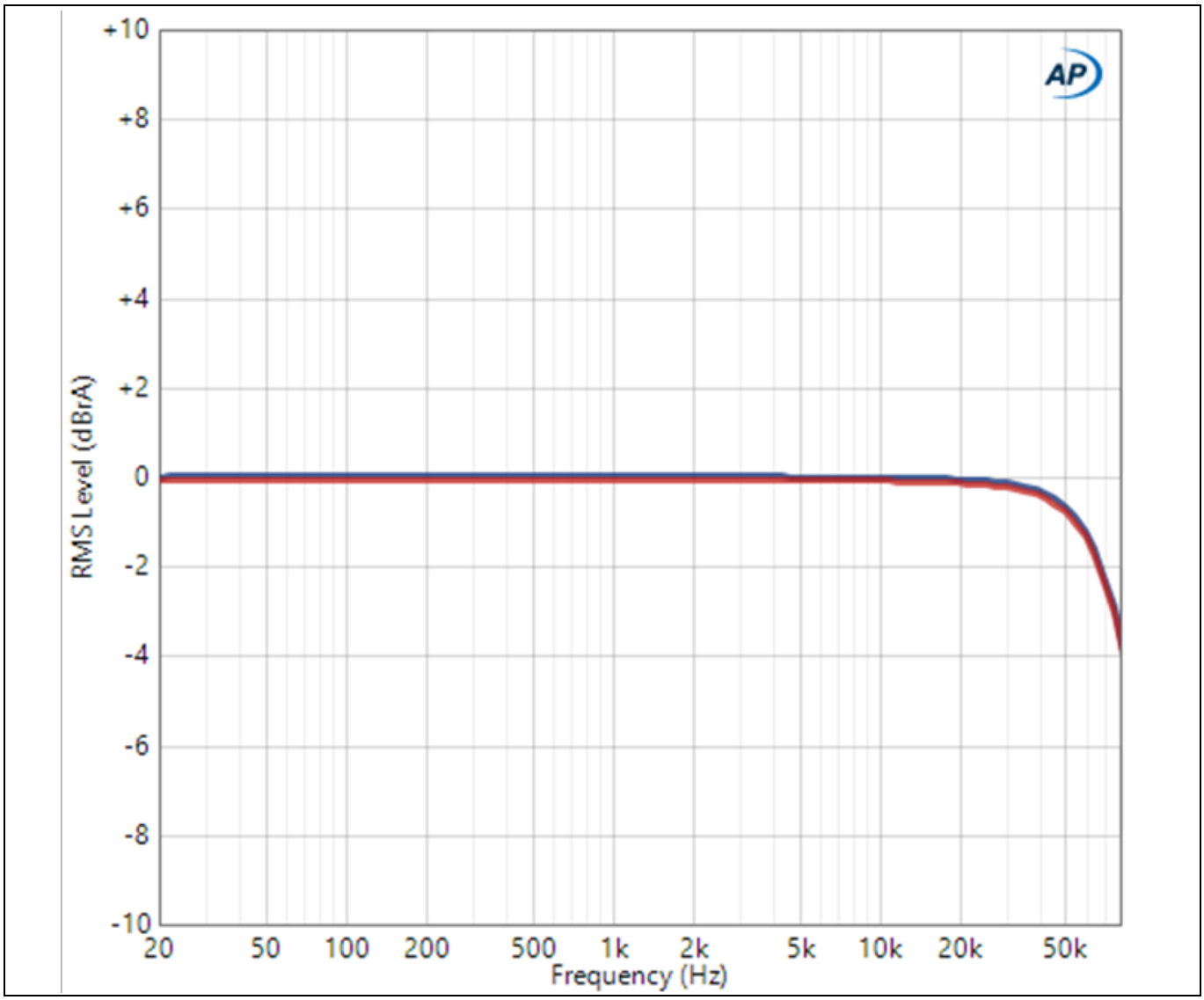

Figure 14 Frequency response 4 Ω load

Audio performance

Test conditions:

- V_{bus} ±63 V
- Output power = 1 W
- Load impedance = 8 Ω SE
- F_{PWM} = 450 kHz

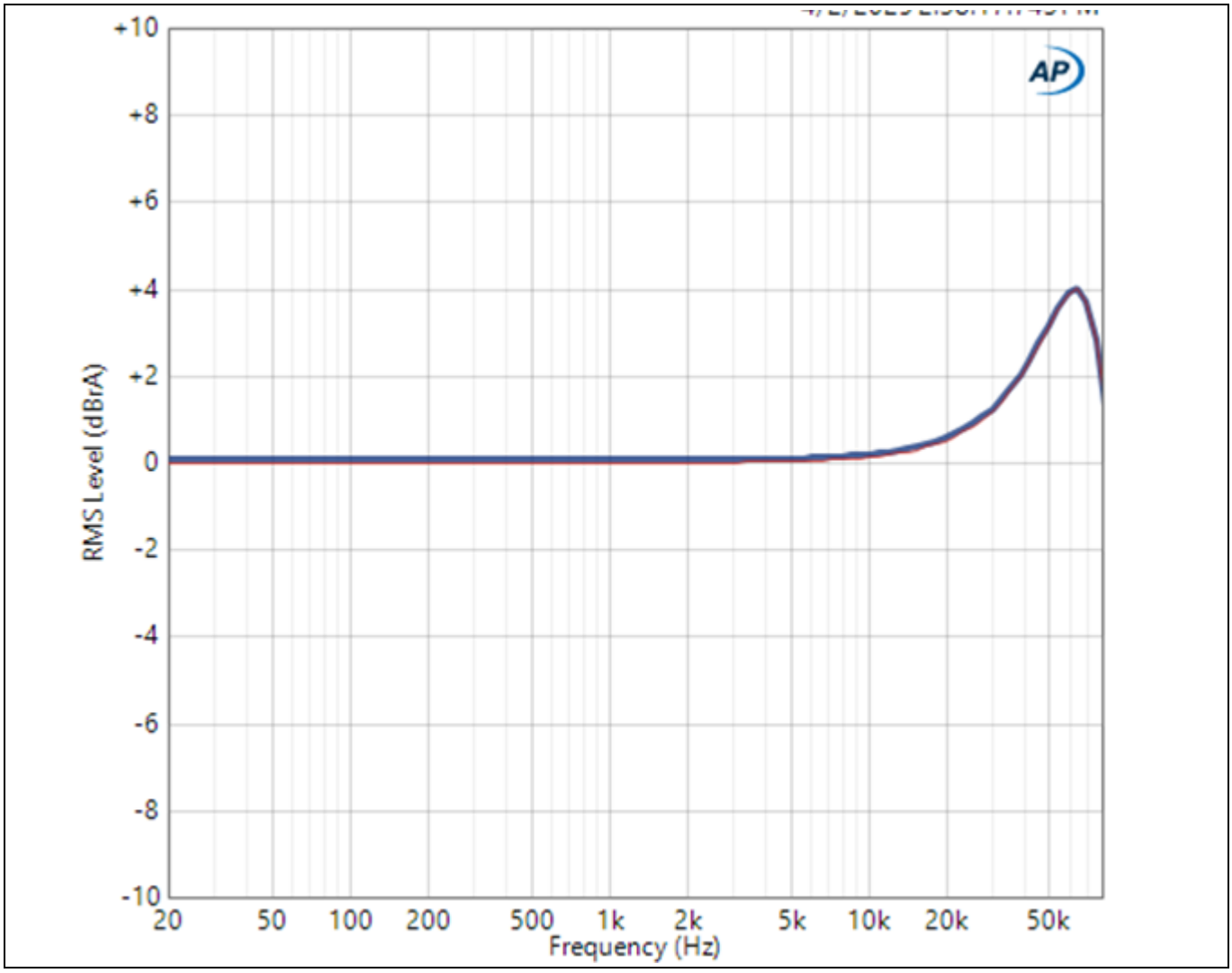

Figure 15 Frequency response 8 Ω load

5.3 Noise floor

Test conditions:

- V_{bus} ±63 V
- No input signal
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

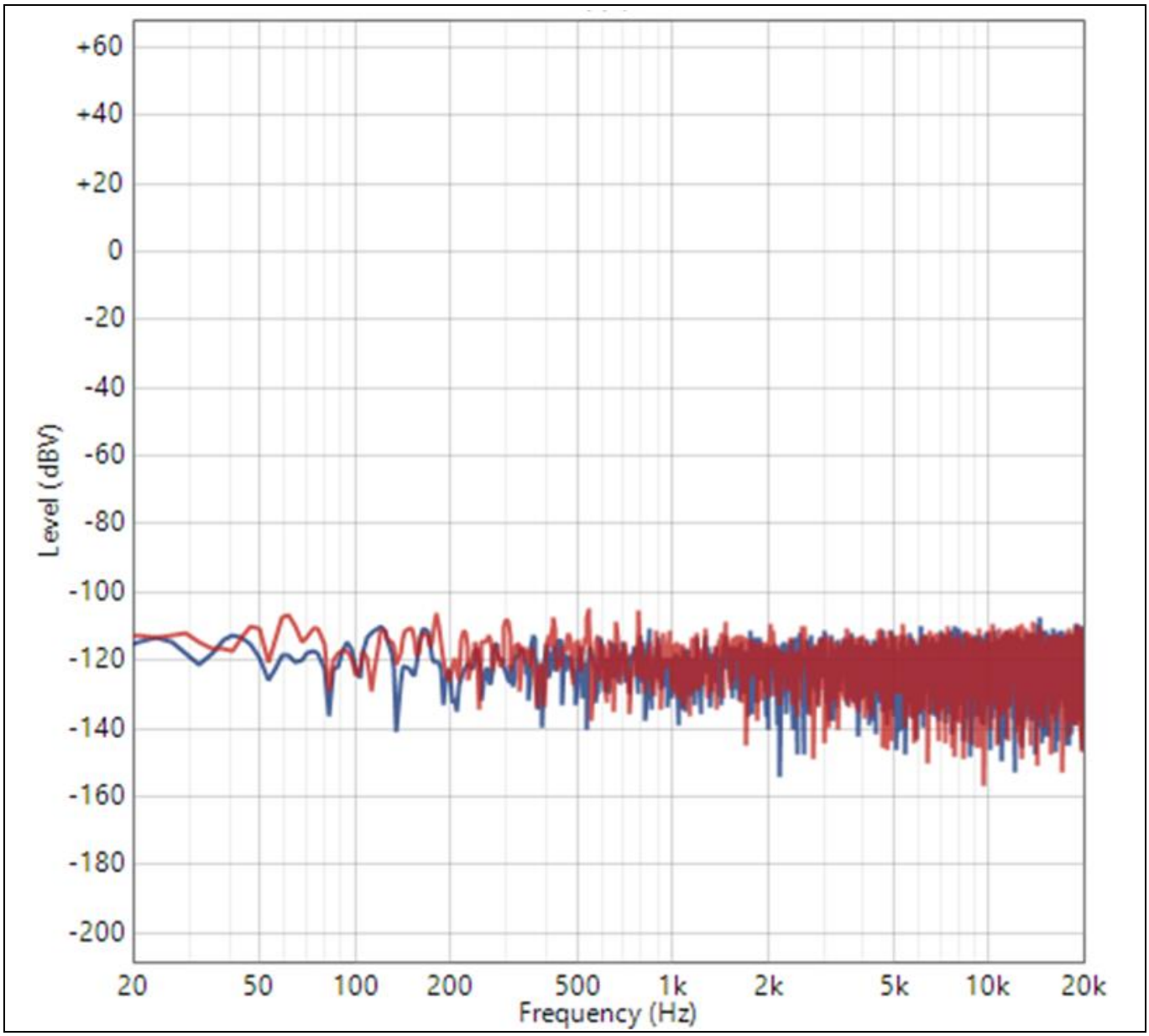

Figure 16 Noise floor idle

Audio performance

Test conditions:

- V_{bus} ±63 V
- Output = 1 V_{RMS} at 1 kHz
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

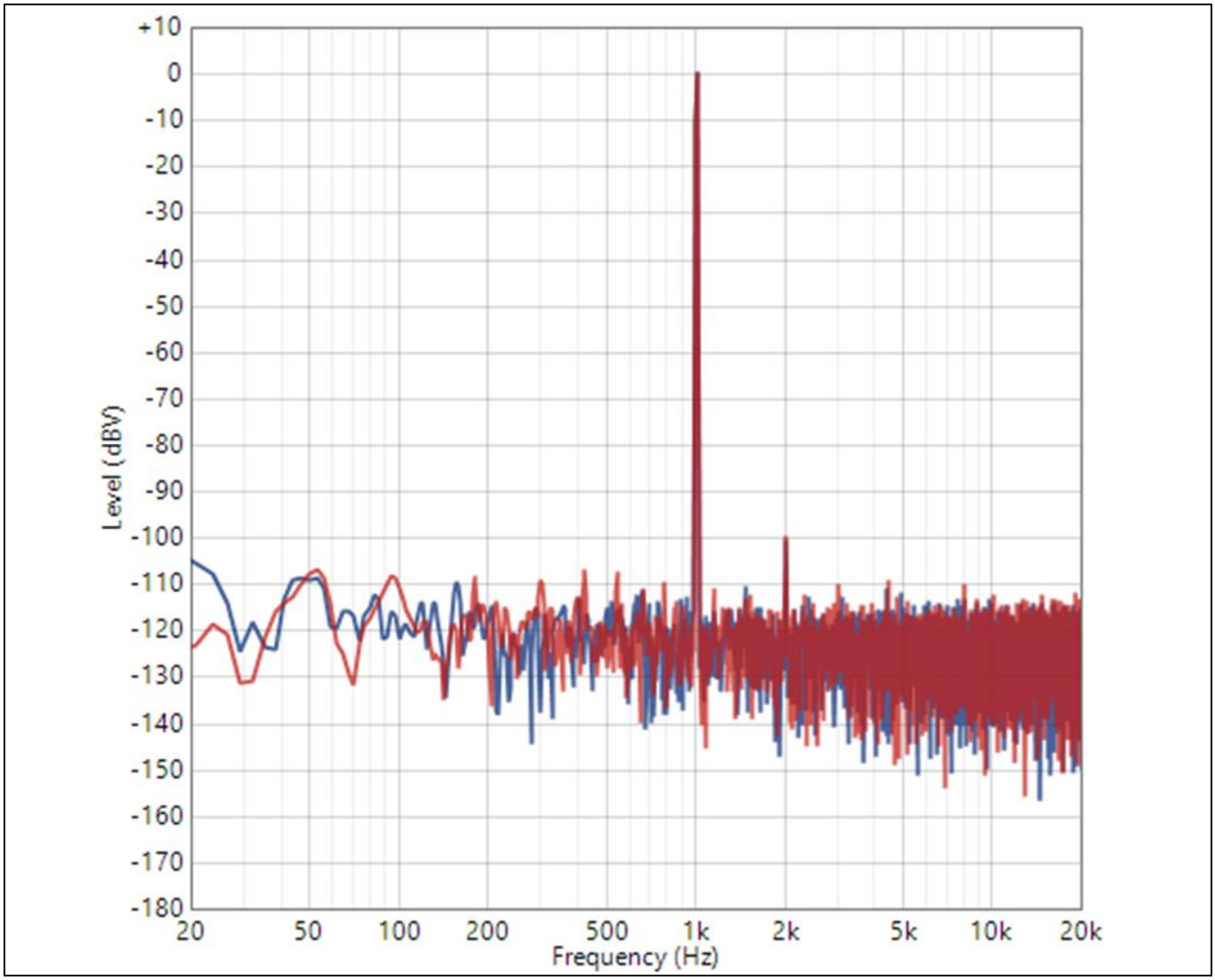

Figure 17 Noise floor 1 V_{RMS} output

6 Efficiency

6.1 Efficiency

Figure 18 and Figure 19 show the efficiency characteristics of Ref_Audio_GaNc_1200W. 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} ±63 V
- Input signal = 1 kHz
- Load impedance = 4 Ω SE
- F_{PWM} = 450 kHz

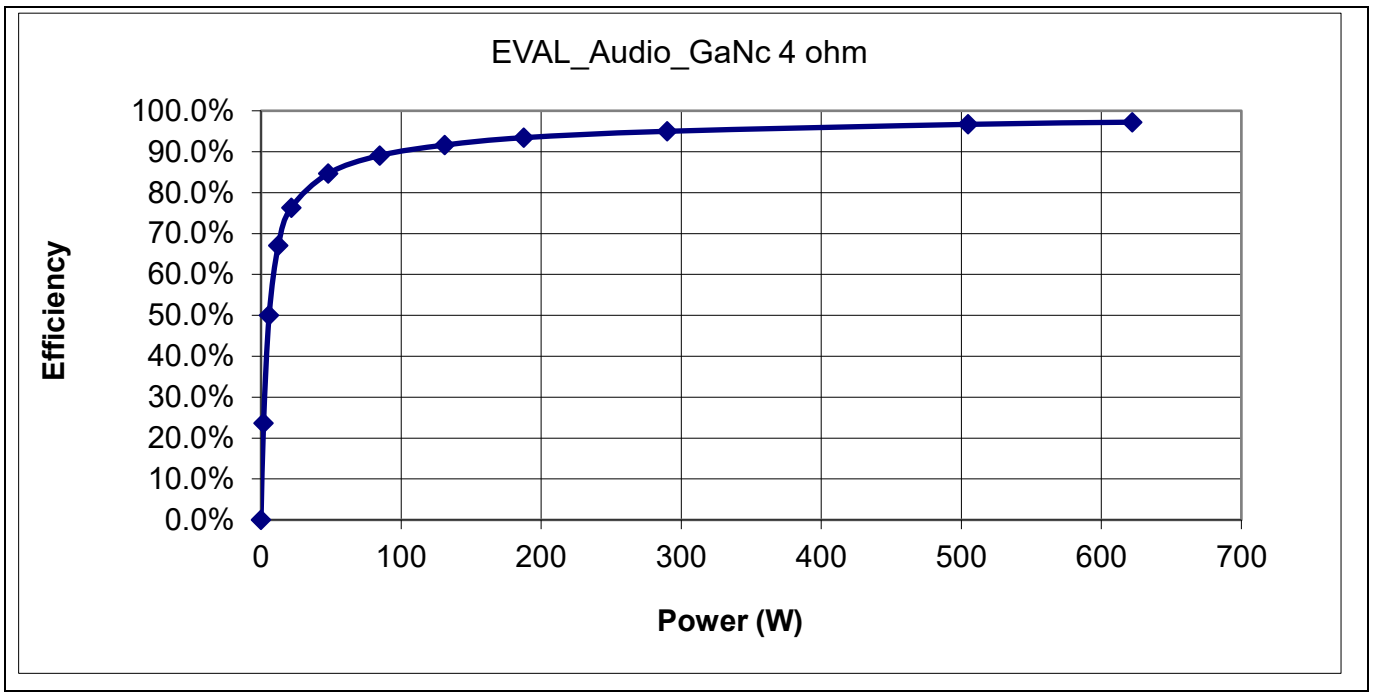

Figure 18 Total channel power efficiency 4 Ω load

Efficiency

Test conditions:

- V_{bus} ±70 V
- Input Signal = 1 kHz
- Load impedance = 8 Ω SE
- F_{PWM} = 450 kHz

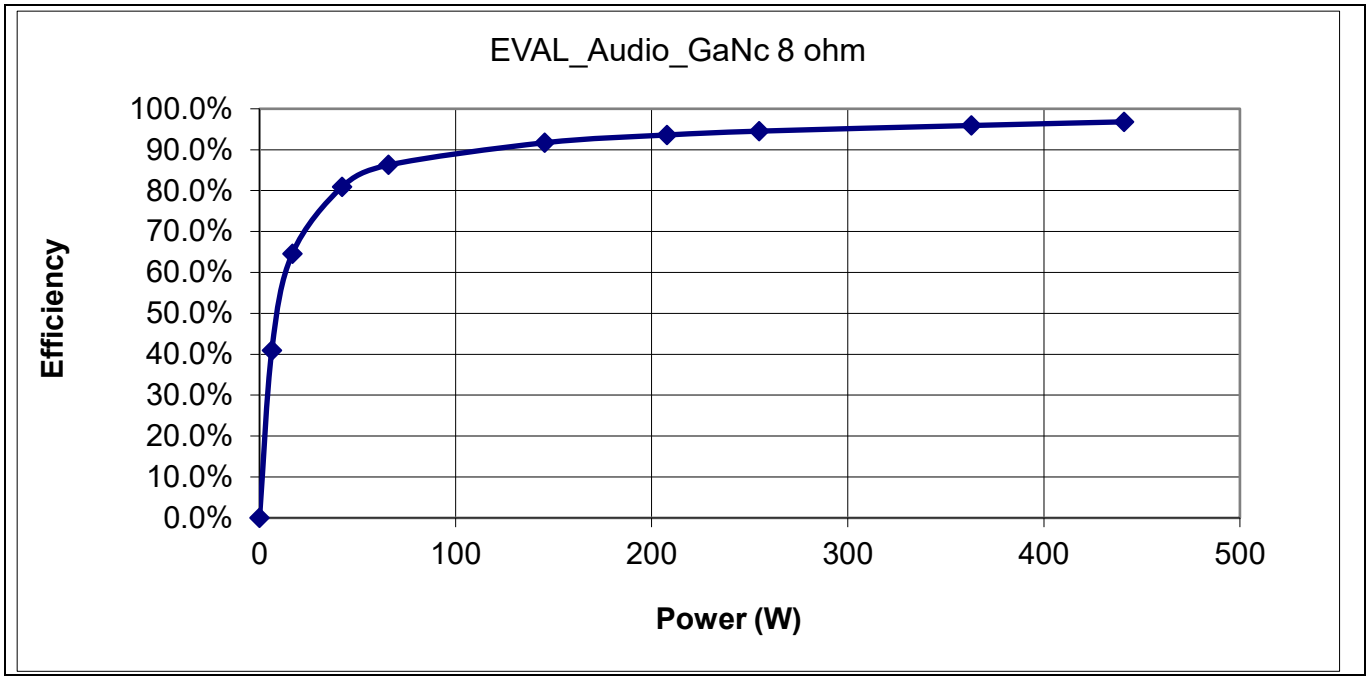

Figure 19 Total channel power efficiency 8 Ω load

7 Thermal information

7.1 Thermal performance

Test conditions:

- Input signal = 1 kHz
- Load = Single Ended (SE)
- F_{PWM} = 450 kHz

Table 5 Peak power without heatsink

Load	±V_{bus}	10% THD+N power	T_{case} Max	Duration (minutes)
4 Ω	63 V	600 W	82°C	>1 min no thermal shutdown <150°C

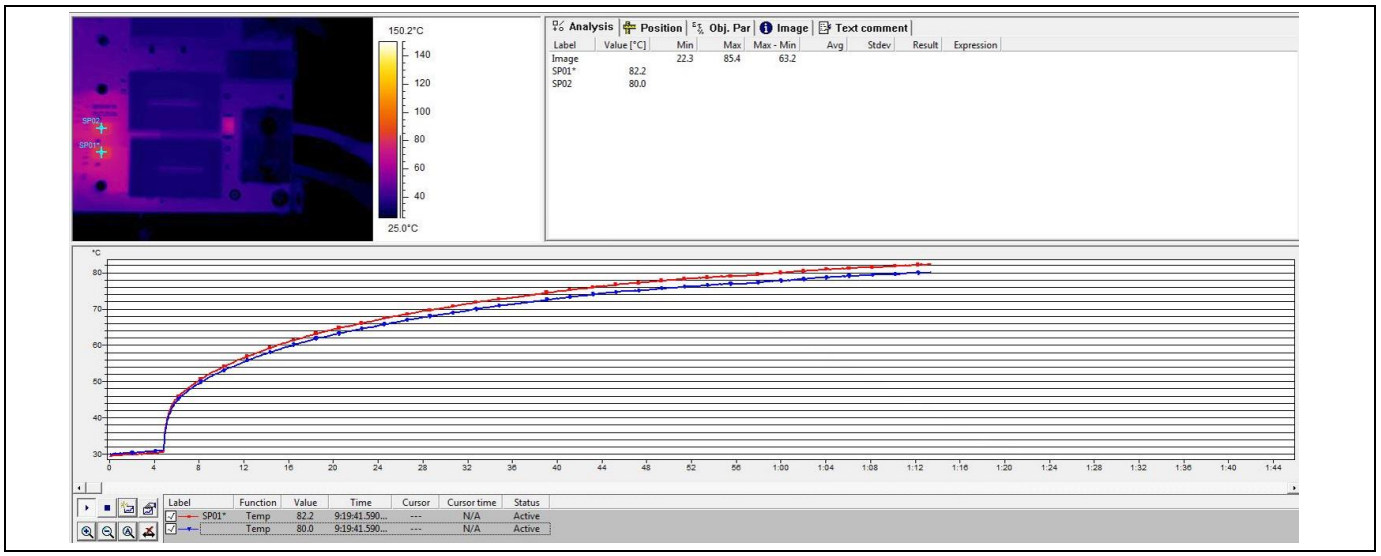

Figure 20 Peak power Pout = 600 W with 4 Ω load, ±63 V

Table 6 1/8 power without heatsink

Load	±V_{bus}	1/8 Power	T_{pcb} Max rise	Duration (minutes)
8 Ω	70 V	39 W	56°C	30 minutes ≤60°C PCB temperature rise
4 Ω	63 V	75 W	60°C	30 minutes ≤60°C PCB temperature rise

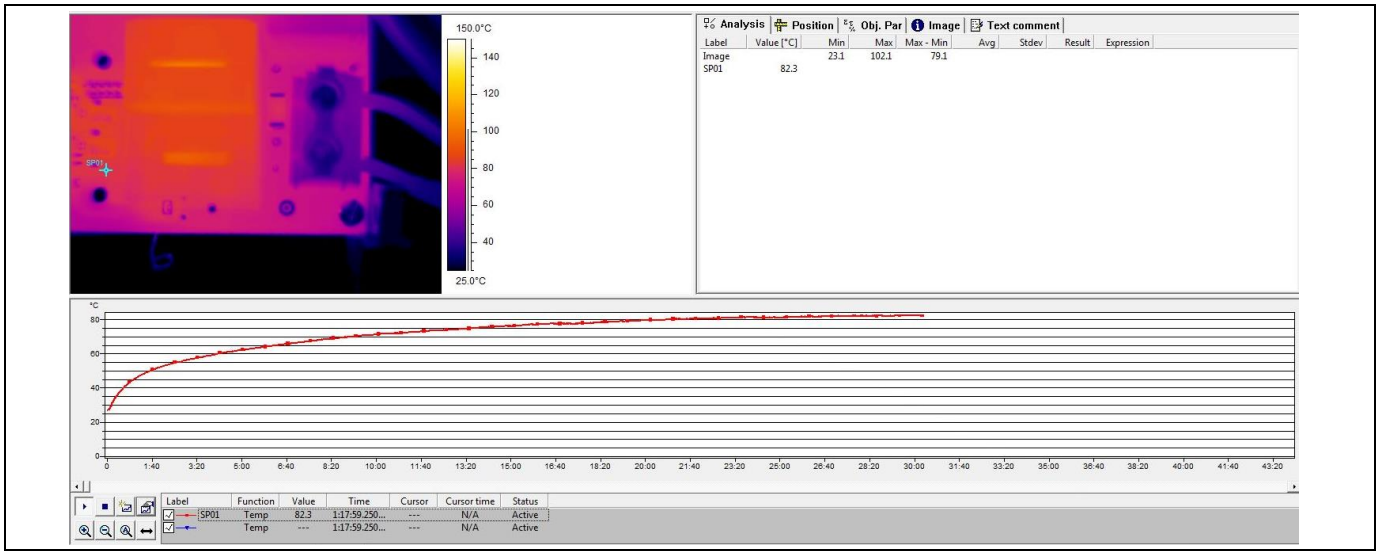

Figure 21 1/8 Power Pout = 39 W with 8 Ω load, ±70 V

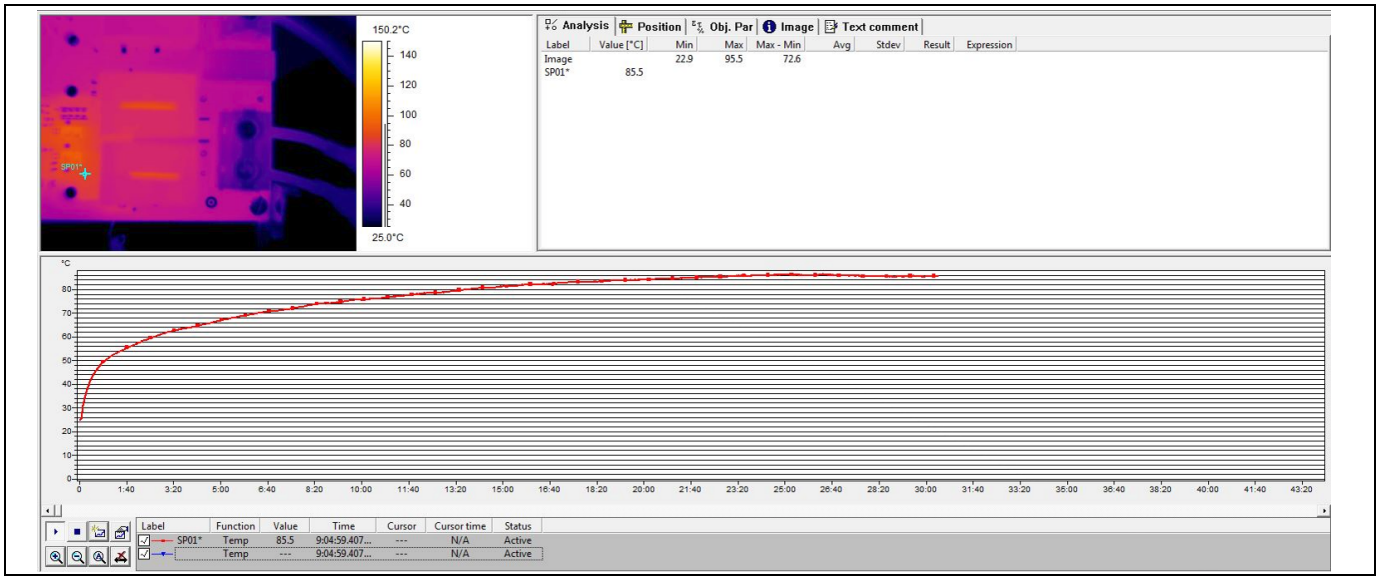

Figure 22 1/8 Power Pout = 75 W with 4 Ω load, ±63 V

8 1 MHz - 768 kHz variant of Ref_Audio_GaNc_1200W

The Ref_Audio_GaNc_1200W reference design is optimized for a 450 kHz switching frequency by default, which prioritizes efficiency and lower switching losses. For applications that prioritize higher switching frequencies, a 1 MHz or 768 kHz variant can be implemented with component value changes.

The 768 kHz switching frequency has been selected as it is an integer multiple of common digital audio sampling rates (e.g., 48 kHz x 16), enabling clean synchronization with DSP systems, and minimizing jitter and aliasing artifacts. This section details typical performance and the necessary component changes to configure the board for stable and reliable operation at 768 kHz.

8.1 Board specifications

Table 6 General specifications

Condition	Value	Notes
Supply voltaqges	± 42 V ~ ± 70 V	Bipolar power supply
Rated load impedance	4 Ω to 8 Ω	Resistive load
Self-oscillating frequency	768 kHz or 1 MHz	No input signal, adjustable
Voltage gain	17 – 41 dB	Class D fixed at 17.5 dB
Number of audio channels	2 x Single ended or 1 x BTL	–
Audio input format	Analog	–

Table 7 Electrical specifications

Condition	Typ.	Note
768 kHz		
Output power (1% THD+N) Single Ended	300 W x 2ch	1 kHz, RL = 8 Ω, ±70 V
	330 W x 2ch	1 kHz, RL = 4 Ω, ±52 V
Output power (10% THD+N) Single Ended	380 W x 2ch	1 kHz, RL = 8 Ω, ±70 V
	400 W x 2ch	1 kHz, RL = 4 Ω, ±52 V
Output power (1% THD+N) BTL	660 W x 1ch	1 kHz, RL = 8 Ω, ±52 V
Output power (10% THD+N) BTL	800 W x 1ch	1 kHz, RL = 8 Ω, ±52 V
Idling supply current	+100 mA -120 mA	No input signal ±52 V, ±10 mA
Channel efficiency	96%	Single-channel driven, 400 W 4 Ω, class D stage
1 MHz		
Output power (1% THD+N) Single Ended	190 W x 2ch	1 kHz, RL = 8 Ω, ±55 V
	245 W x 2ch	1 kHz, RL = 4 Ω, ±45 V
Output power (10% THD+N) Single Ended	230 W x 2ch	1 kHz, RL = 8 Ω, ±55 V
	300 W x 2ch	1 kHz, RL = 4 Ω, ±45 V
Output power (1% THD+N) BTL	490 W x 1ch	1 kHz, RL = 8 Ω, ±45 V
Output power (10% THD+N) BTL	600 W x 1ch	1 kHz, RL = 8 Ω, ±45 V

Condition	Typ.	Note
	768 kHz	
Idling supply current	+100 mA -120 mA	No input signal ±45 V, ±10 mA
Channel efficiency	96%	Single-channel driven, 300 W Ω, class D stage ±45 V

Table 8 Audio performance

Parameter	Value	Notes
Signal-to-noise Ratio (SNR)	120 dB	Filter: A-weighting(12017), 20 kHz SPCL, ±45 V, 1 MHz
Residual noise	<40 µV	Filter: A-weighting(12017), 20 kHz SPCL, ±45 V, 1 MHz

8.2 Rework instructions for 768 kHz and 1 MHz

Table 7 Electrical specifications

Designator	Change to	Manufacturers P/N	Function
R36	100k (0603)	Yageo: RC0603FR-07100KL or equivalent	Clock Sync to 500 kHz – 1 MHz
C33A, C33B,	Place 100 nF (0603)	AVX: 06035C104KAT4A or equivalent	PWM
R95A, R95B	Place 47r (0402)	Vishay: CRCW040247R0FKED or equivalent	PWM
C26A, C26B, C27A, C27B	560 pF (0603)	Yageo: CC0603KRX7R9BB561 or equivalent	PWM
R42A, R42B	200r (0603)	Vishay: CRCW0603200RFKEA or equivalent	PWM
C70A, C70B	330 nF	KEMET: R71XF333050H0K or equivalent	Output capacitor

8.3 Test setup

1. For SE, connect 4 Ω > 400 W capable dummy loads according to Figure 5
2. For BTL connect 8 Ω > 800 W capable dummy load according to Figure 6
3. Connect audio analyzer according to Figure 5 for SE or 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 **±52 V** ; set current limit to 15 A
   a) ±45 V for 1 MHz variant
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 the mute position
9. Set gain potentiometer R54 counterclockwise to the maximum limit
10. Connect the dual power supply to X4 as shown in Figure 5

8.4 Frequency adjustment

1. Monitor VS1 and VS2 switching frequency with oscilloscope (Figure 9)
2. Adjust R44A and R44B setting VS1 and VS2 to 768 kHz or 1 MHz

8.5 Total Harmoic Distortion - THD+N

Test conditions:

- V_{bus} ±52 V
- Input signal = 1 kHz
- Load impedance = 4 Ω SE
- FPWM = 768 kHz

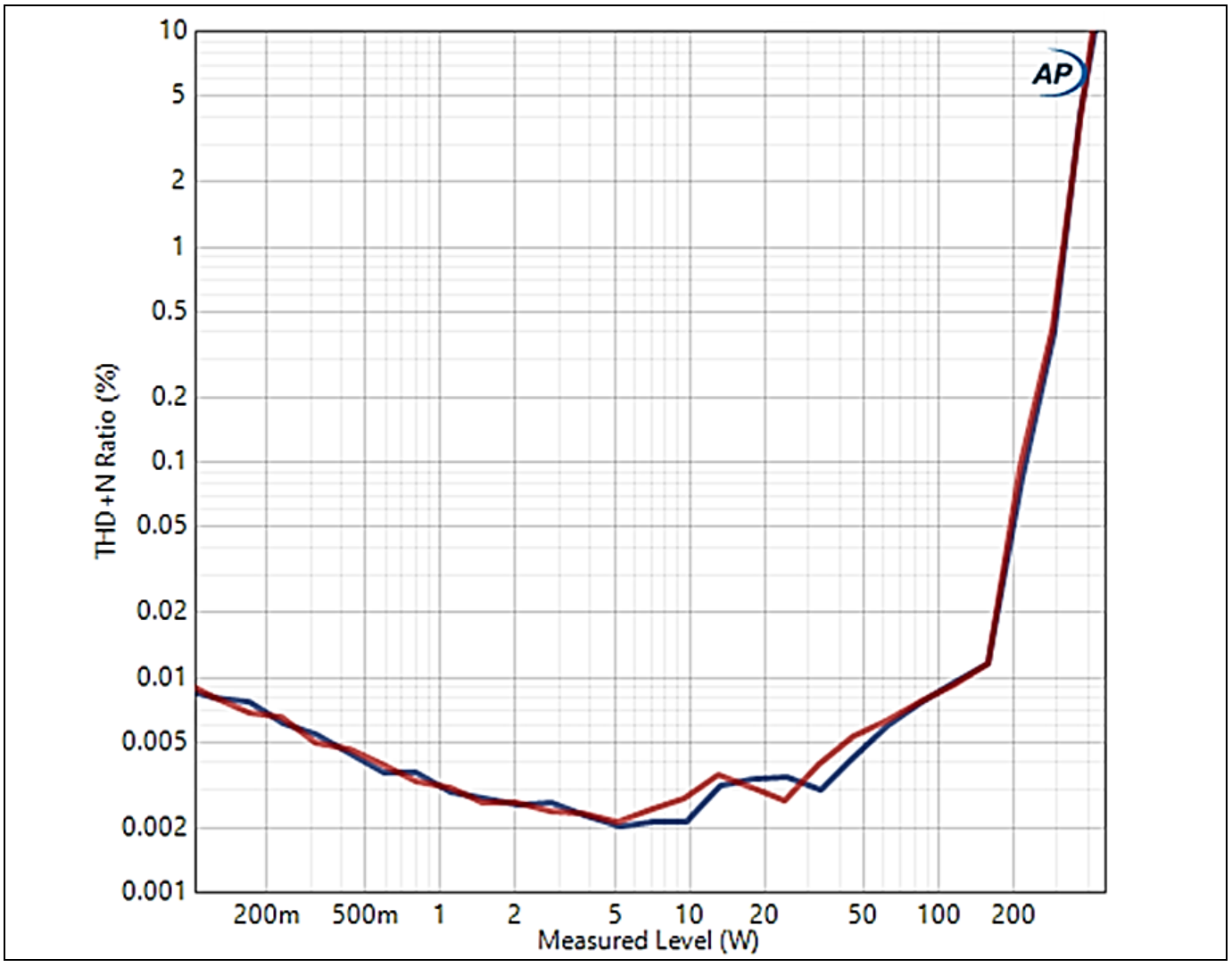

Figure 23 Power vs. THD+N 4 Ω load 768 kHz

Test conditions:

- V_{bus} ±45 V
- Input signal = 1 kHz
- Load impedance = 4 Ω SE
- FPWM = 1 MHz

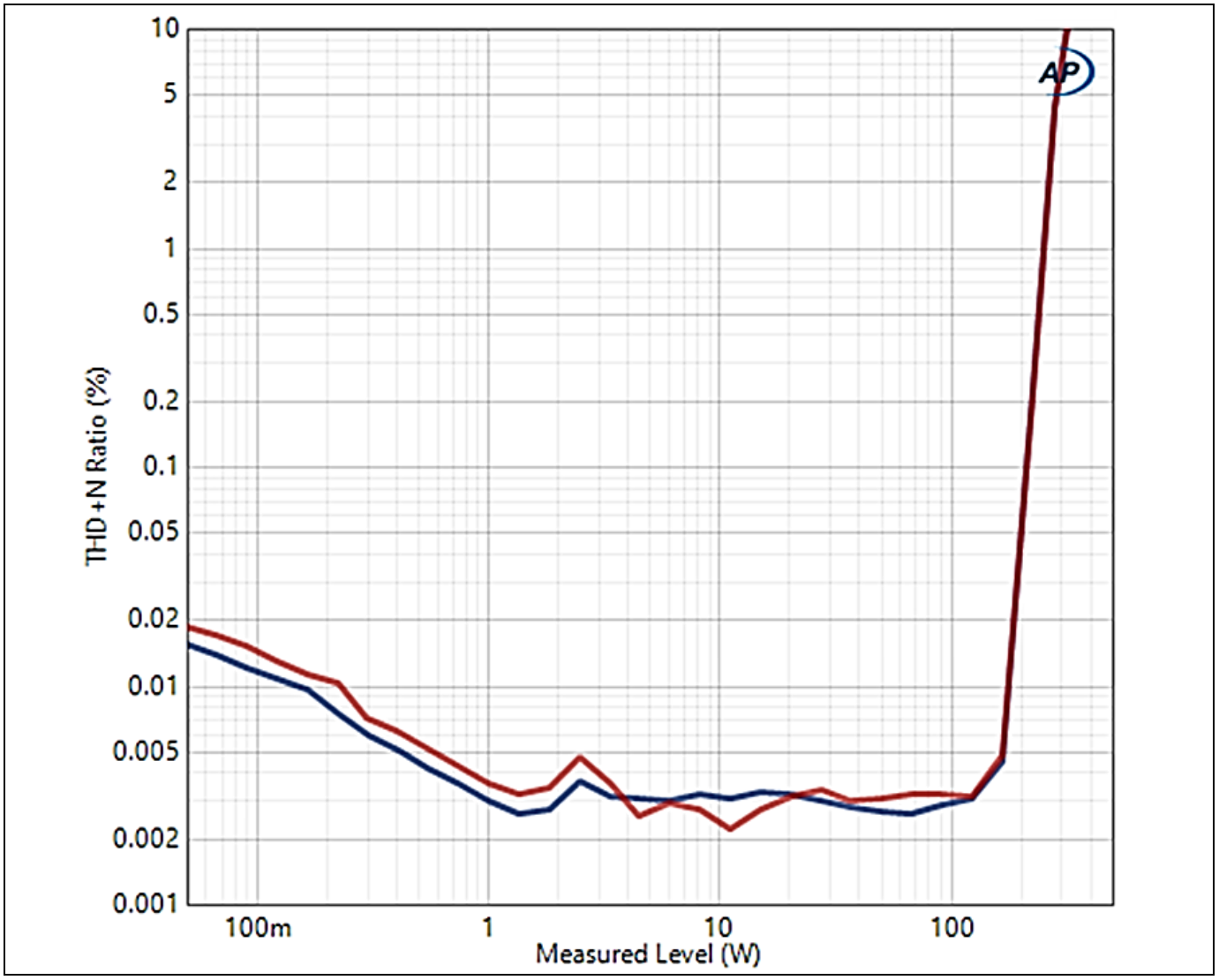

Figure 24 Power vs. THD+N 4 Ω load 1 MHz

Test conditions:

- V_{bus} ±70 V
- Input signal = 1 kHz
- Load impedance = 8 Ω SE
- F_{PWM} = 768 kHz

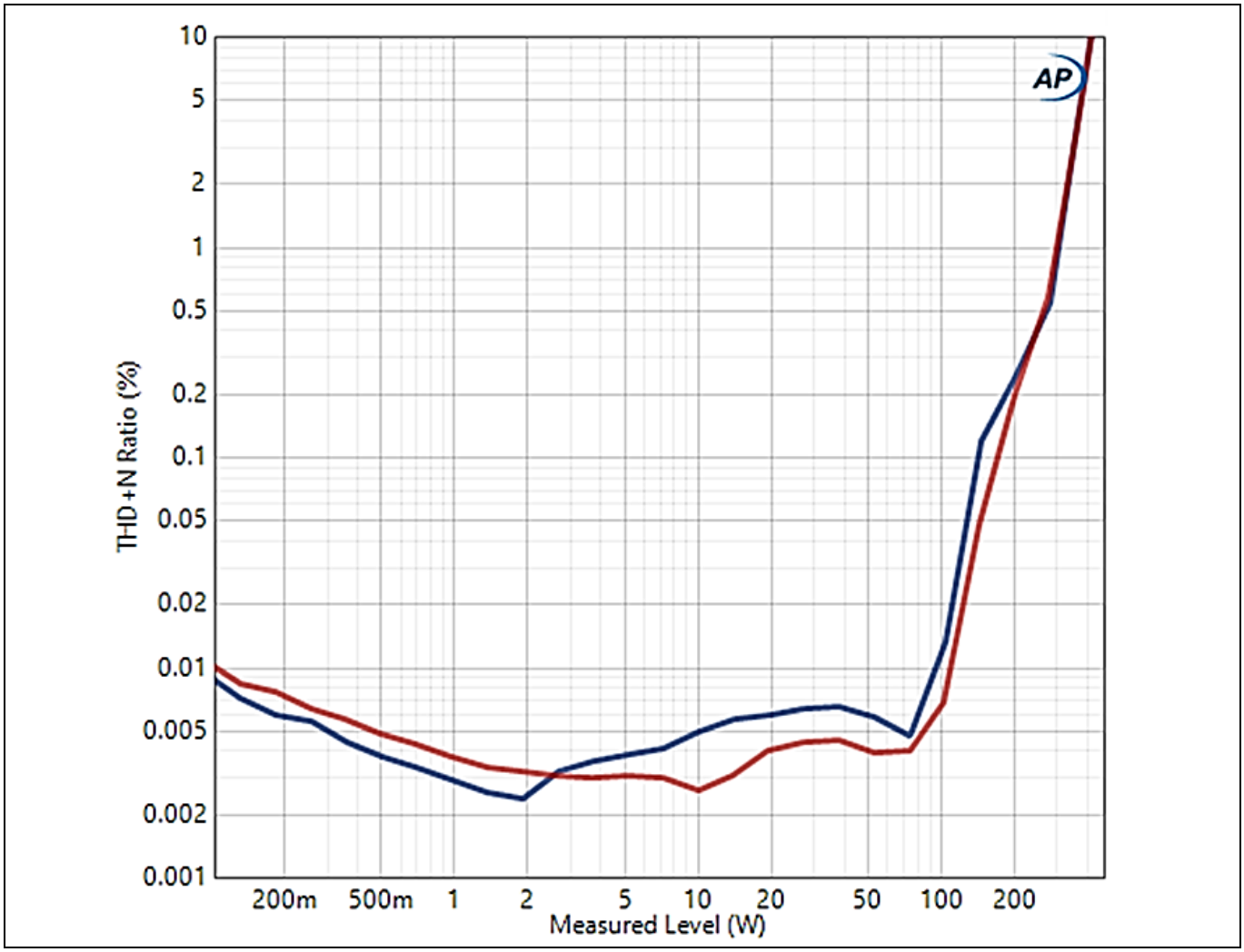

Figure 25 Power vs. THD+N 8 Ω load 768 kHz

Test conditions:

- V_{bus} ±55 V
- Input signal = 1 kHz
- Load impedance = 8 Ω SE
- F_{PWM} = 1 MHz

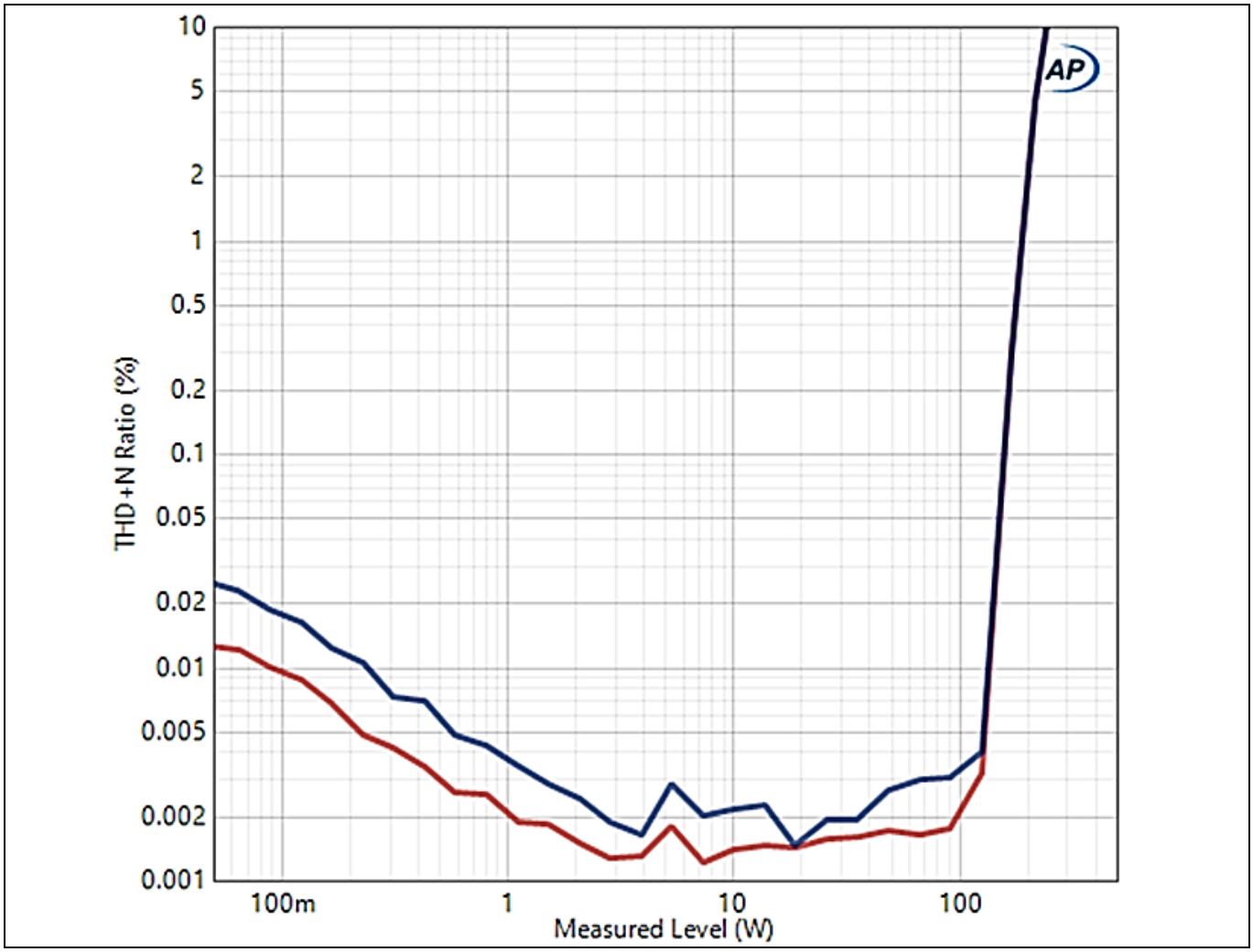

Figure 26 Power vs. THD+N 8 Ω load 1 MHz

8.6 Frequency response

Test conditions:

- V_{bus} ±52 V
- Output power = 1 W
- Load impedance = 4 Ω SE
- F_{PWM} = 768 kHz

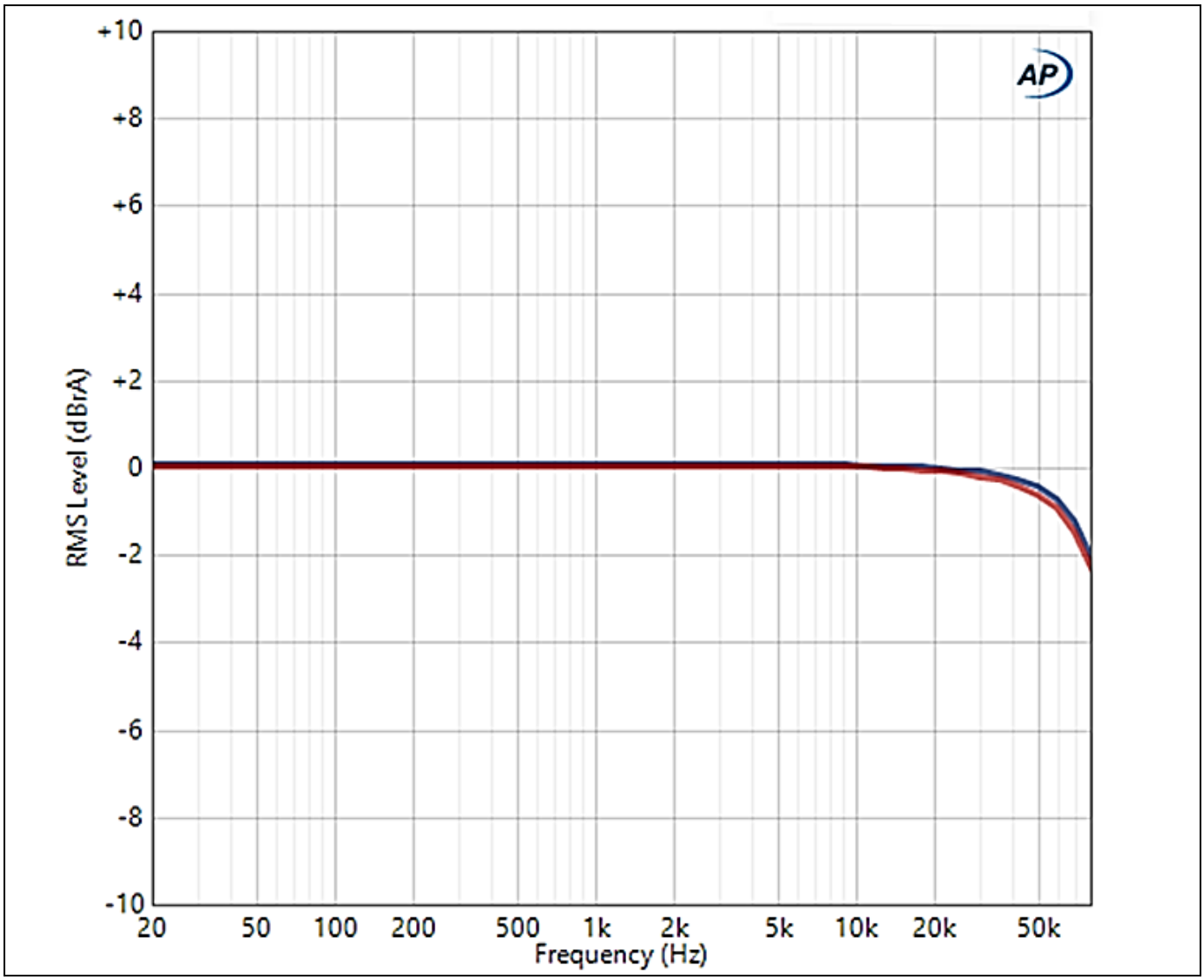

Figure 27 Frequency response 4 Ω load 768 kHz

Test conditions:

- V_{bus} ±45 V
- Output power = 1 W
- Load impedance = 4 Ω SE
- F_{PWM} = 1 MHz

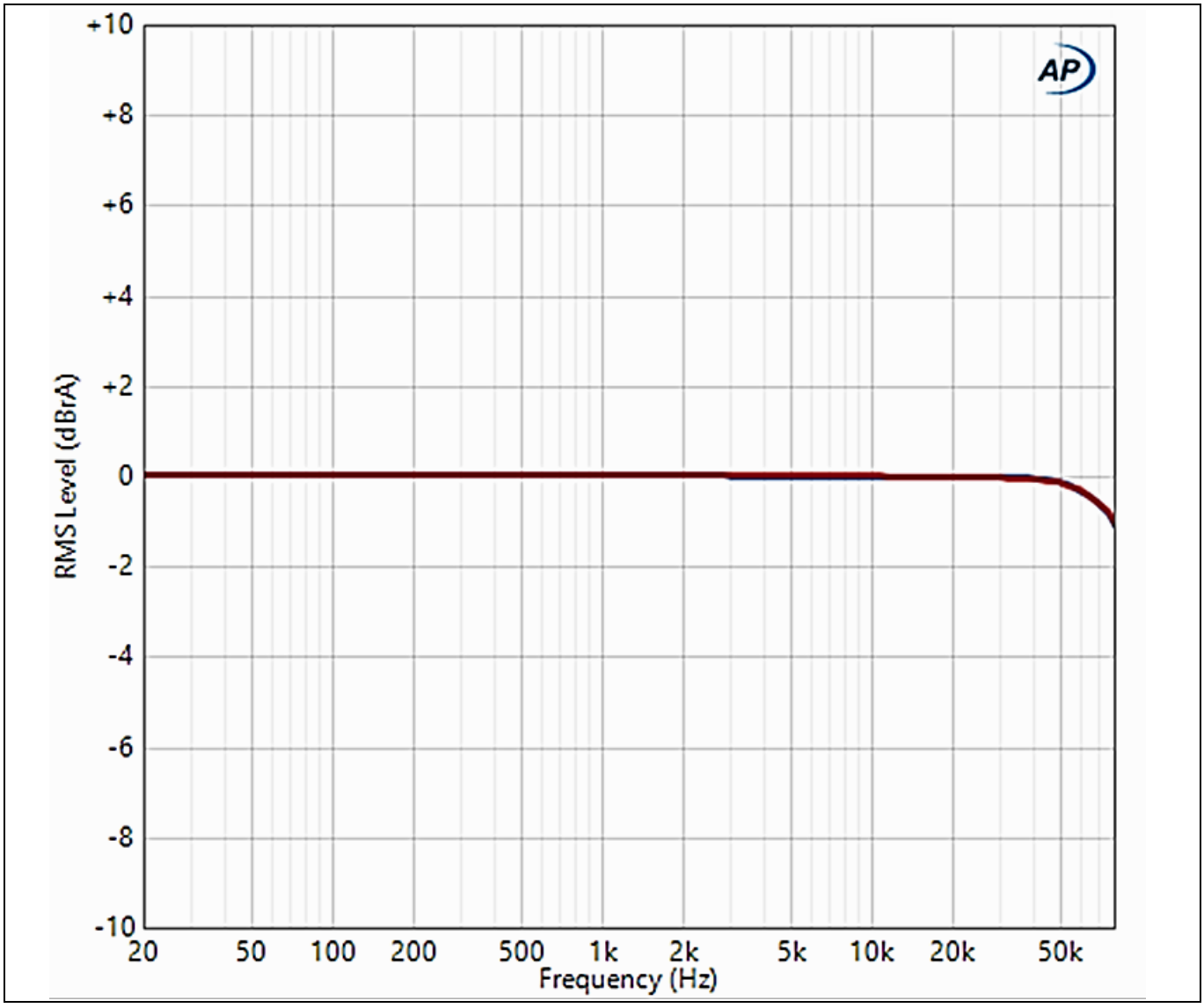

Figure 28 Frequency response 4 Ω load 1 MHz

8.7 Efficiency

Test conditions:

- V_{bus} ±52 V
- Input signal = 1 kHz
- Load impedance = 4 Ω SE
- F_{PWM} = 768 kHz

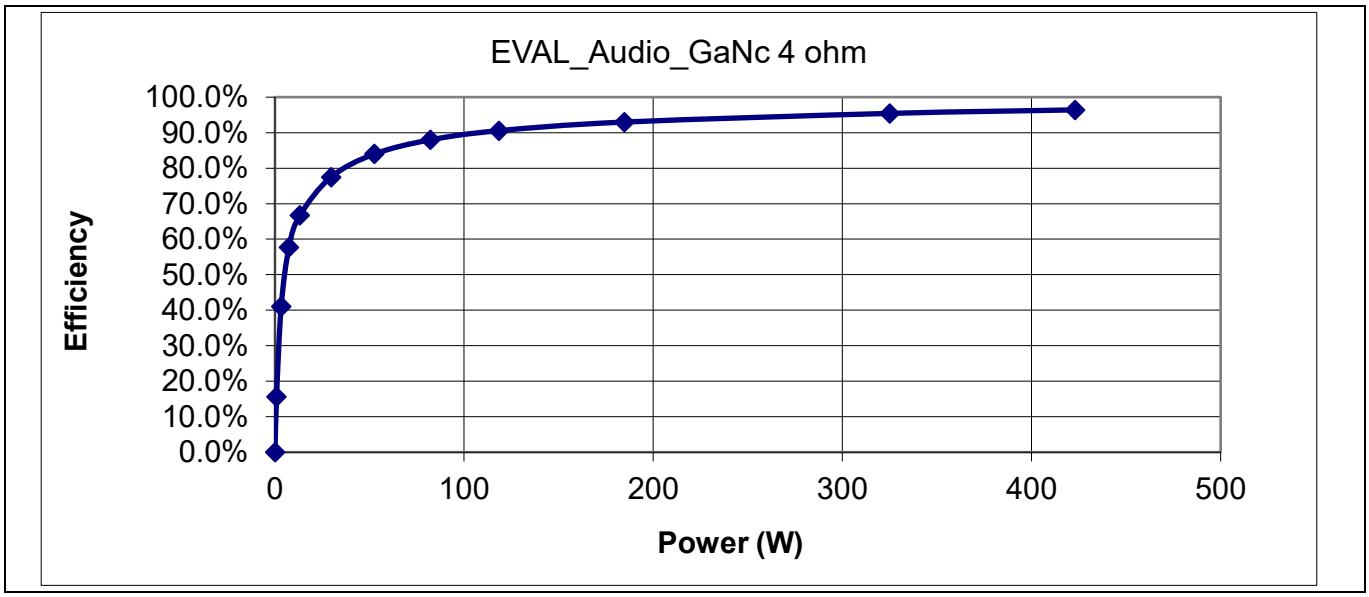

Figure 29 Total channel power efficiency 4 Ω load 768 kHz

8.8 Thermal performance

Test conditions:

- Input signal = 1 kHz
- F_{PWM} = 768 kHz

Table 8 Peak power with no heatsink

Load	$\pm V_{bus}$	10% THD+N power	T_{case} Max	Duration (minutes)
4 Ω	52 V	400 W	74°C	>1 min no thermal shutdown <150°C

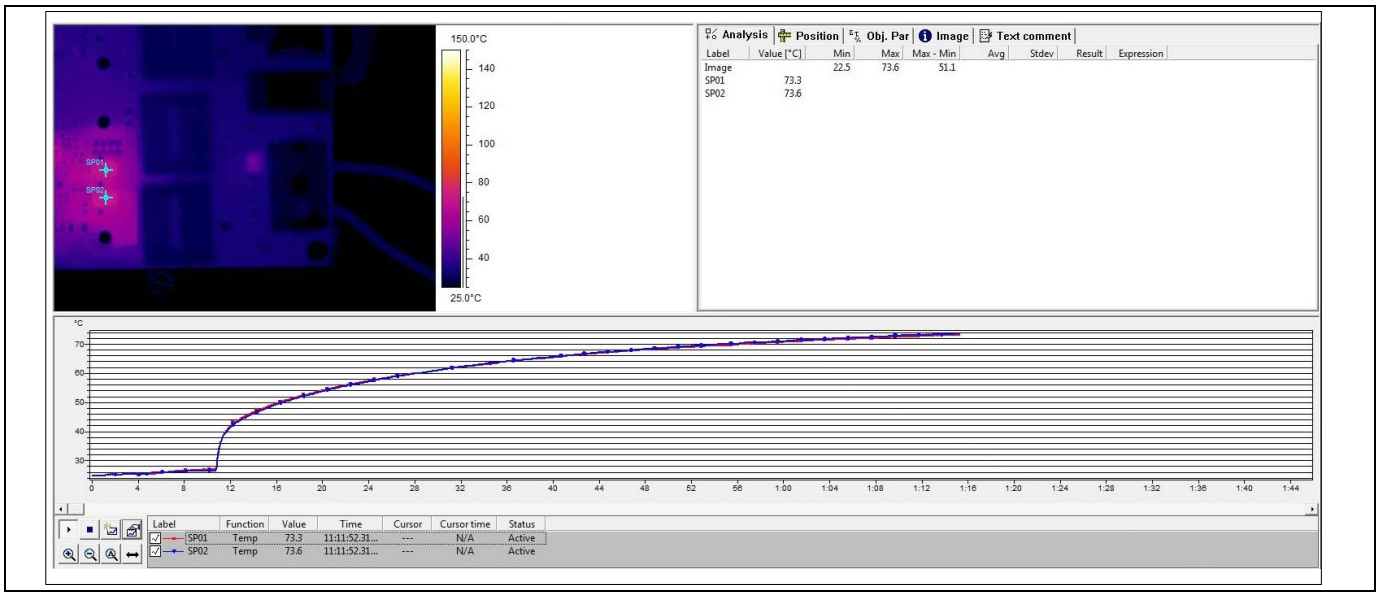

Figure 30 Peak Power Pout = 400 W with 4 Ω load, ±52 V

Table 9 1/8 power without heatsink

Load	$\pm V_{bus}$	1/8 Power	T_{pcb} Max rise	Duration (minutes)
4 Ω	52 V	50 W	57°C	30 minutes ≤ 60°C pcb temperature rise

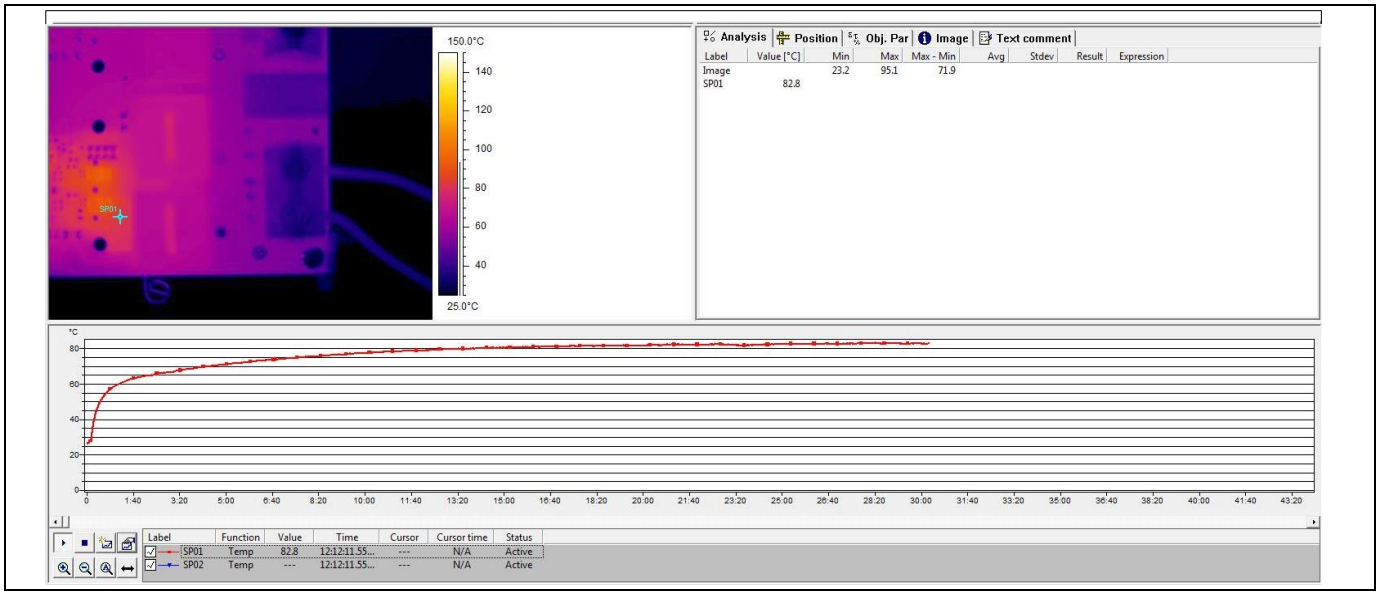

Figure 31 1/8 Peak Power Pout = 50 W with 4 Ω load, ±52 V

9 Schematic

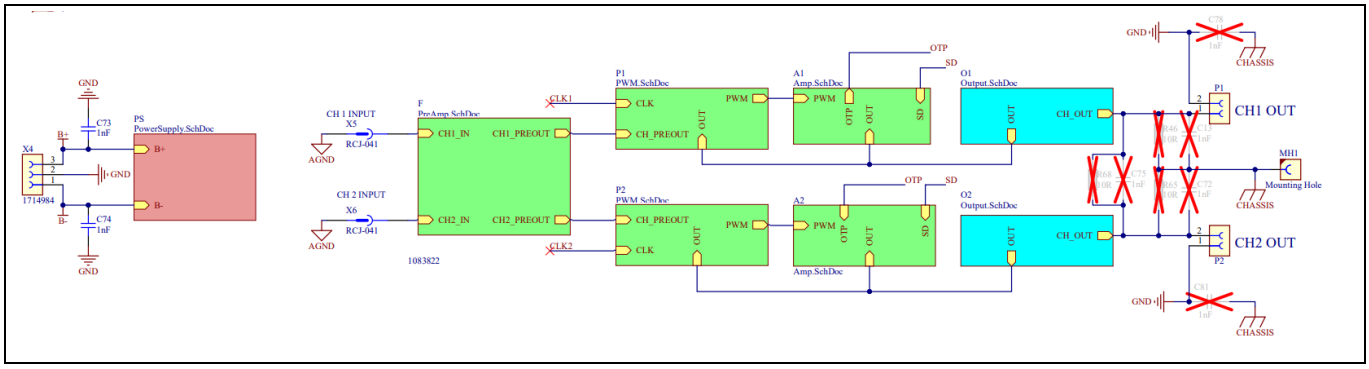

Figure 32 Signal chain

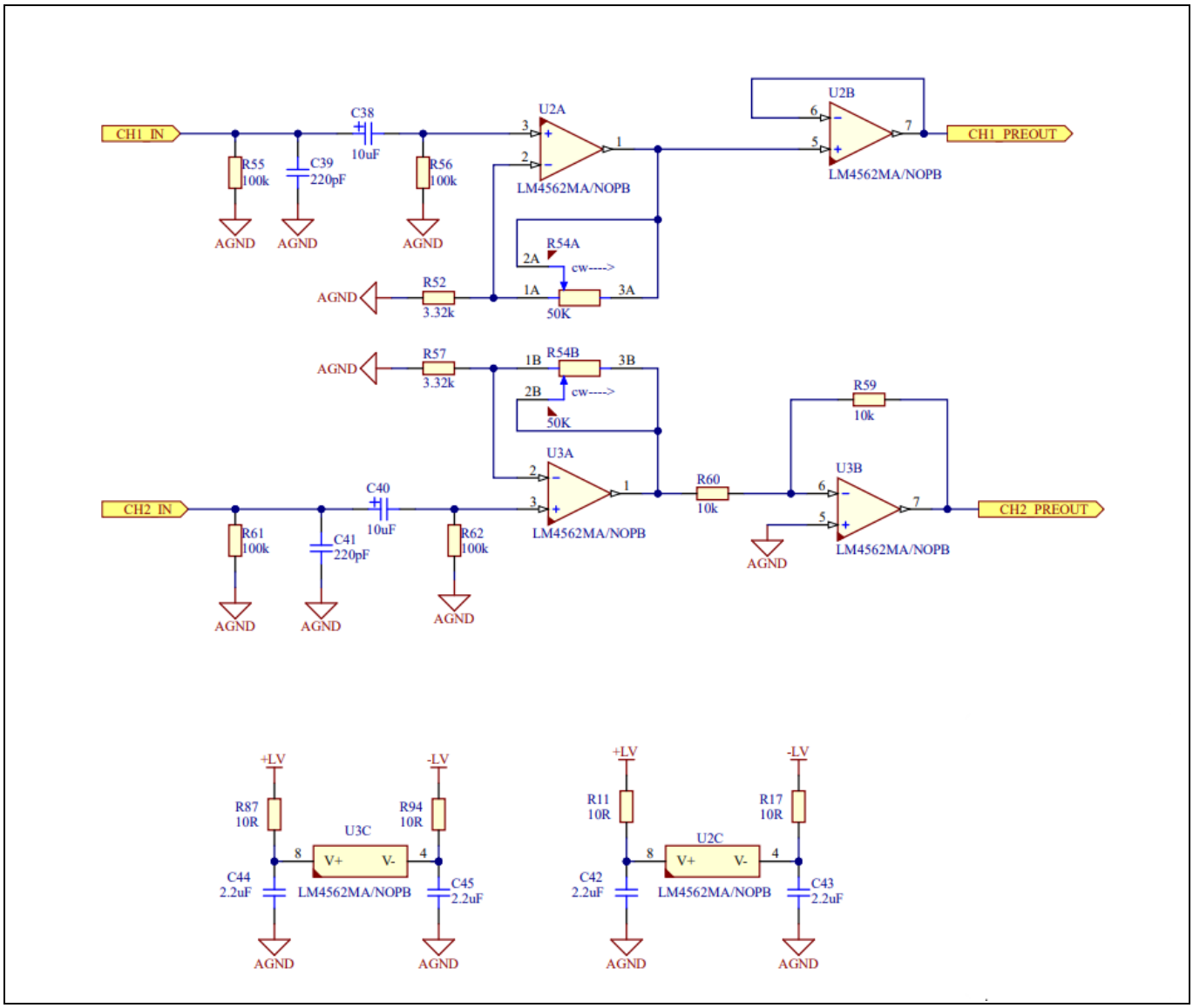

Figure 33 Preamplifier

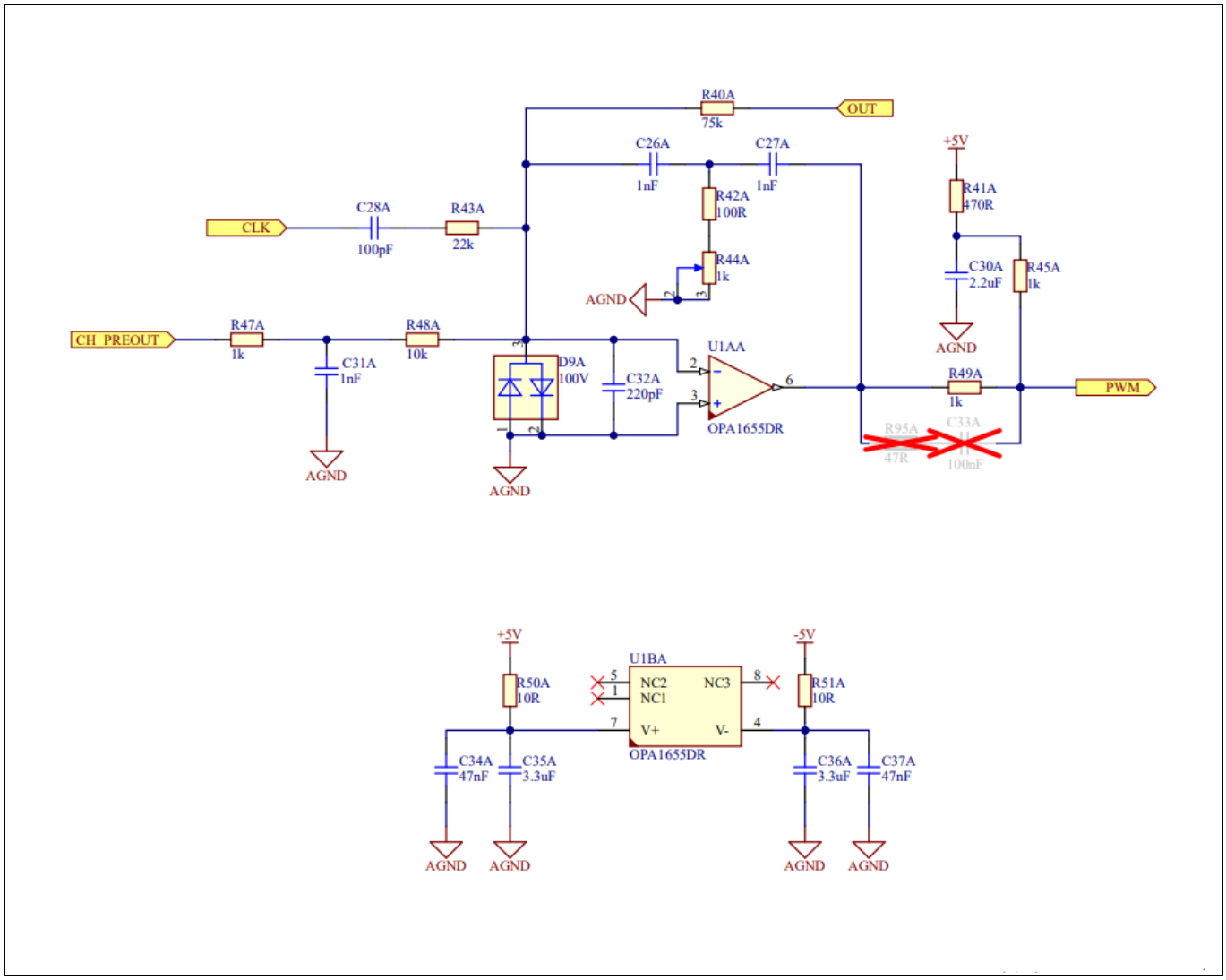

Figure 34 Self-oscillating PWM modulator

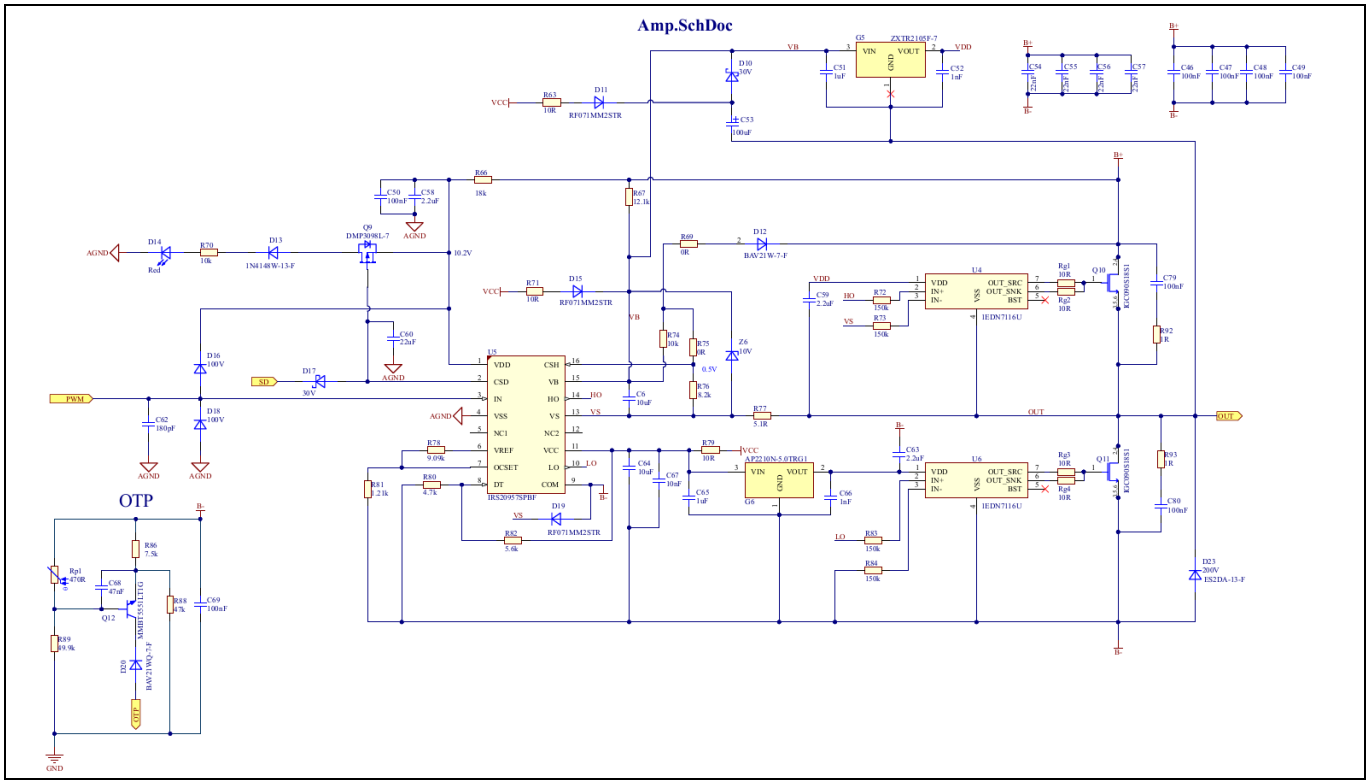

Figure 35 Class D amplifier stage

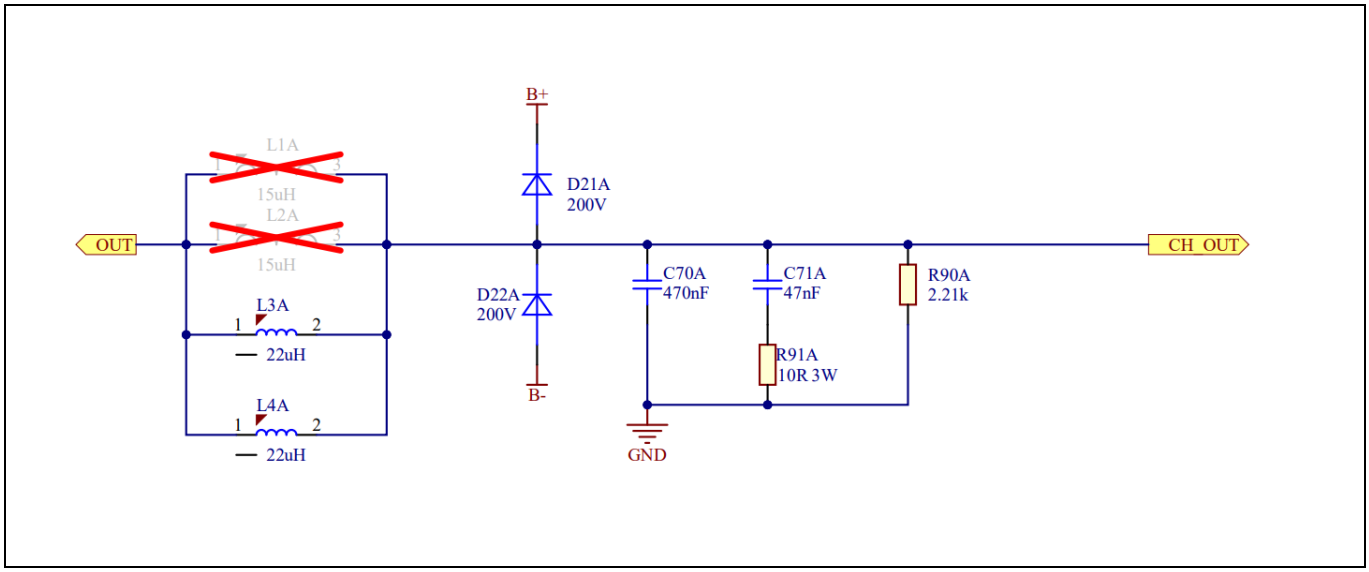

Figure 36 Class D output stage

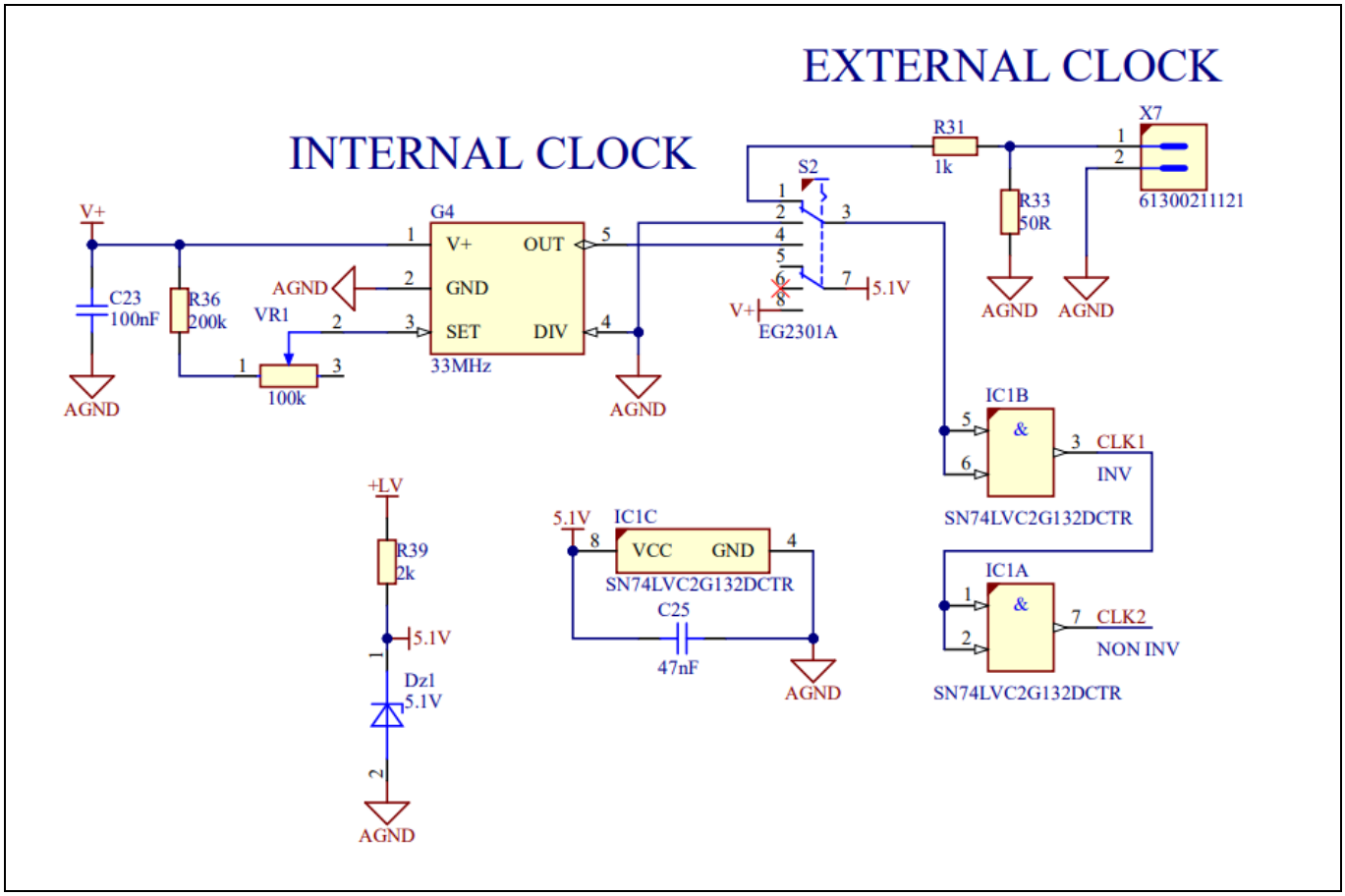

Figure 37 Channel Sync

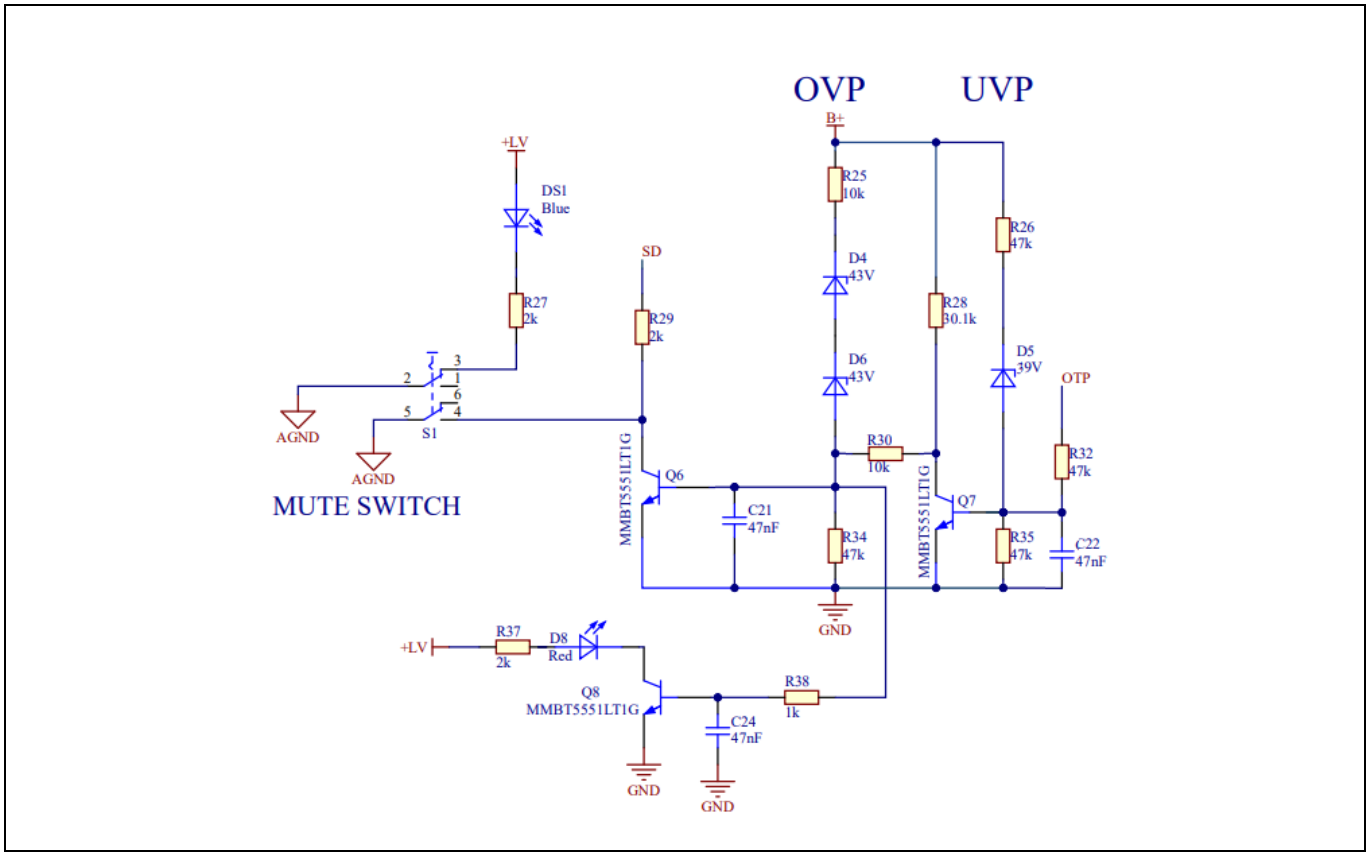

Figure 38 Over-/undervoltage protection

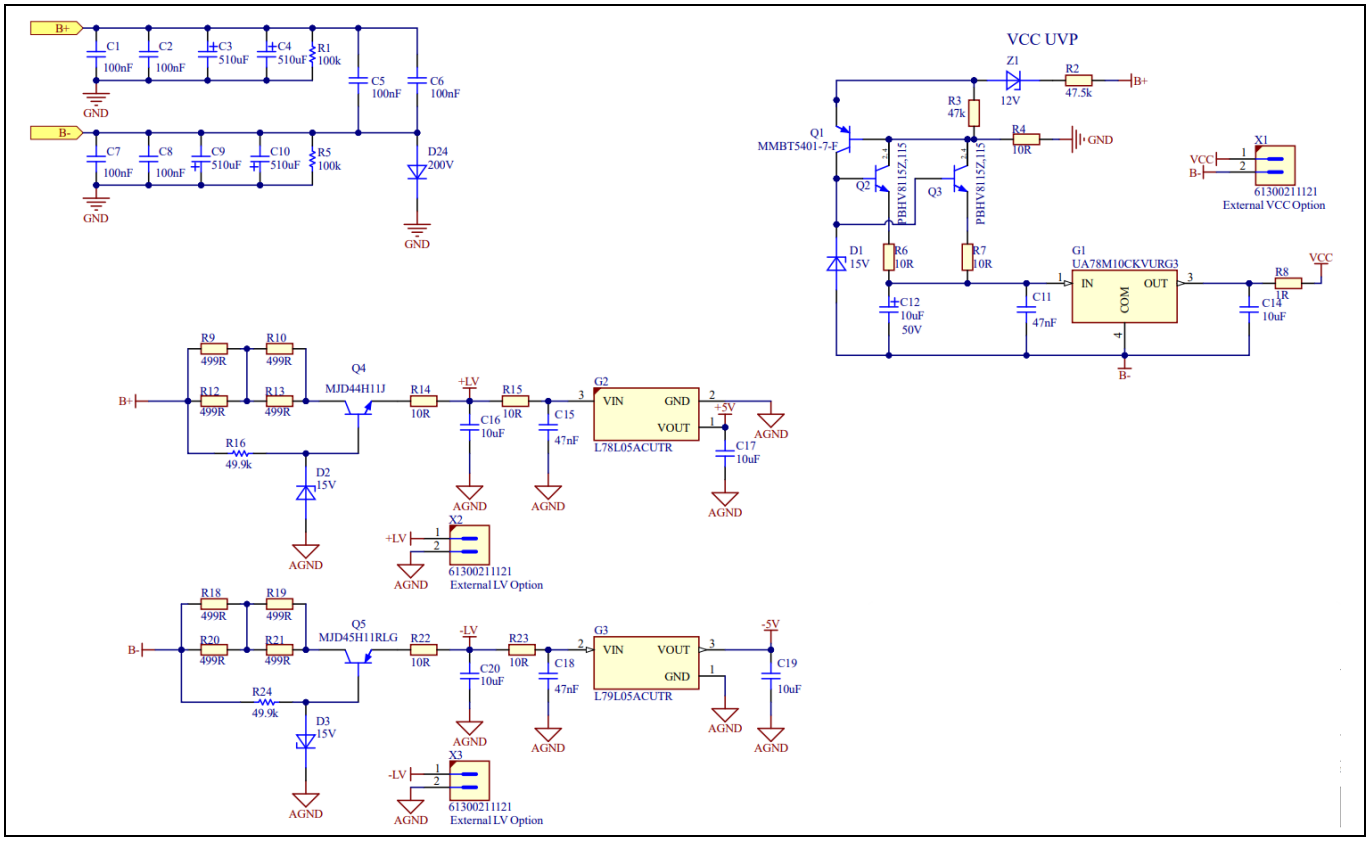

Figure 39 Housekeeping power supplies

10 PCB specification and layout

10.1 PCB specification

- Fabricate per ipc-601x series, class 2, and inspect per IPC-A-600 Class 2
- U.l. rating: 94v-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 the primary or secondary side, or both, using white non-conductive epoxy ink

10.2 Layout

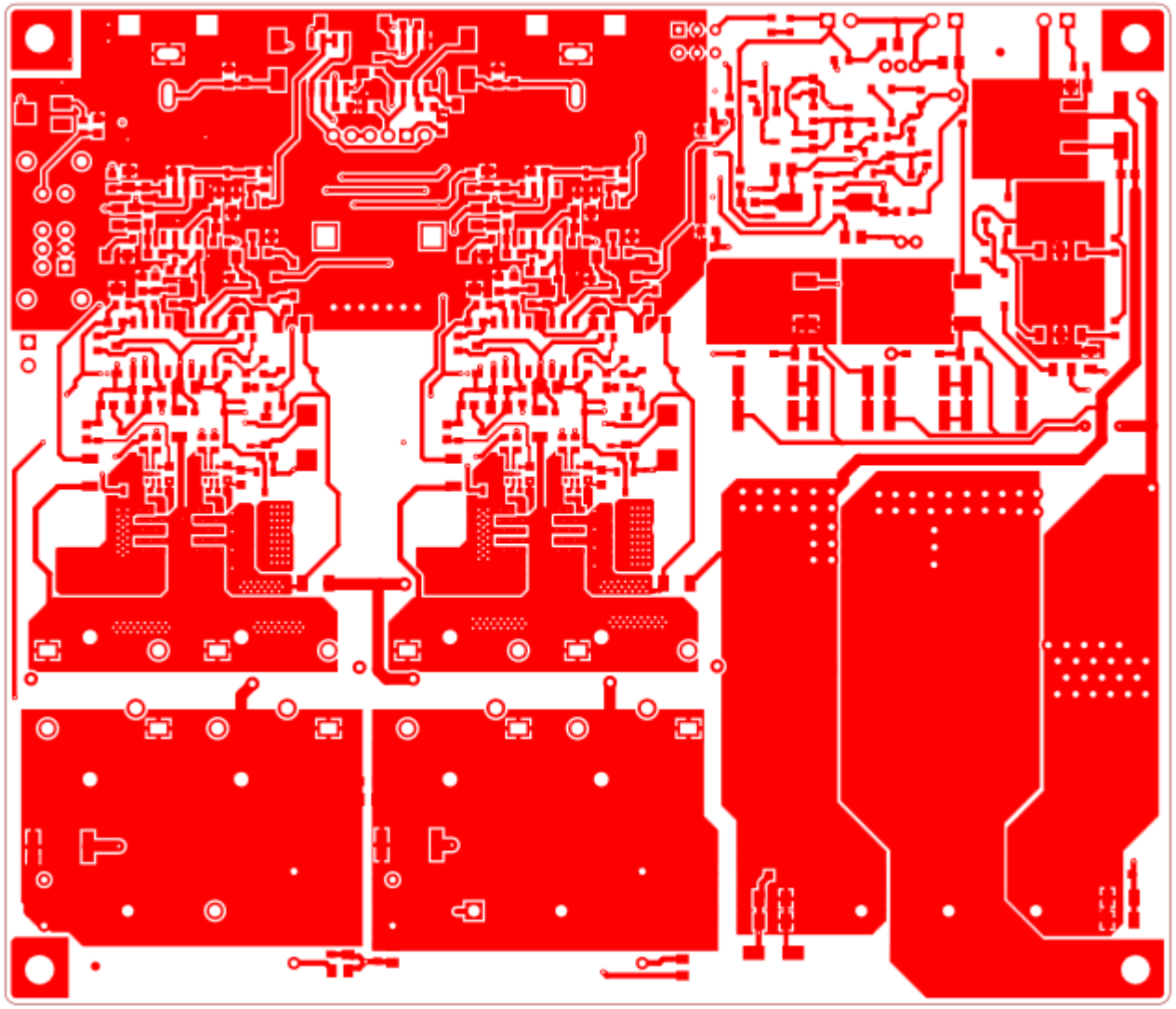

Figure 40 Layout layer 1

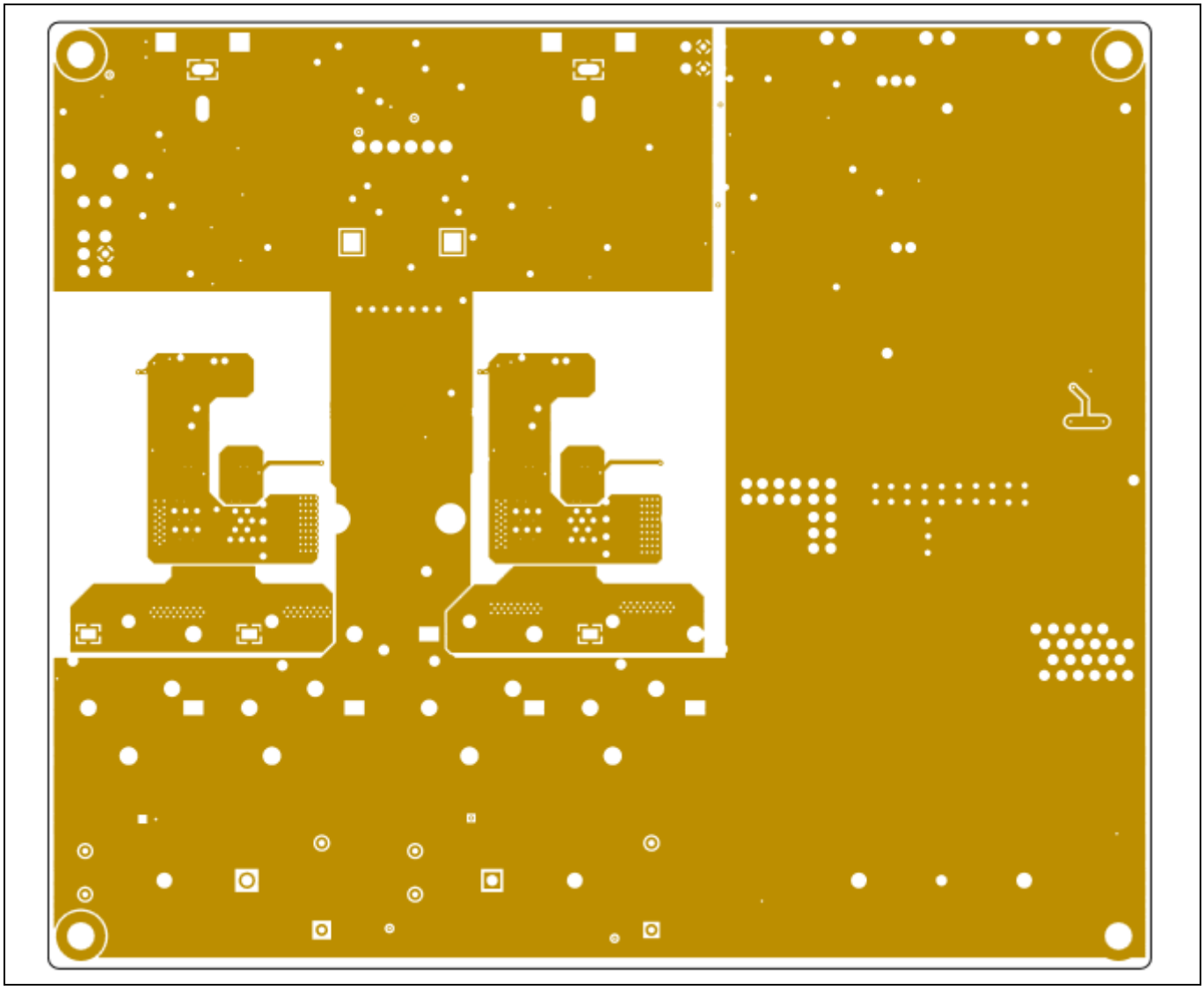

Figure 41 Layout layer 2

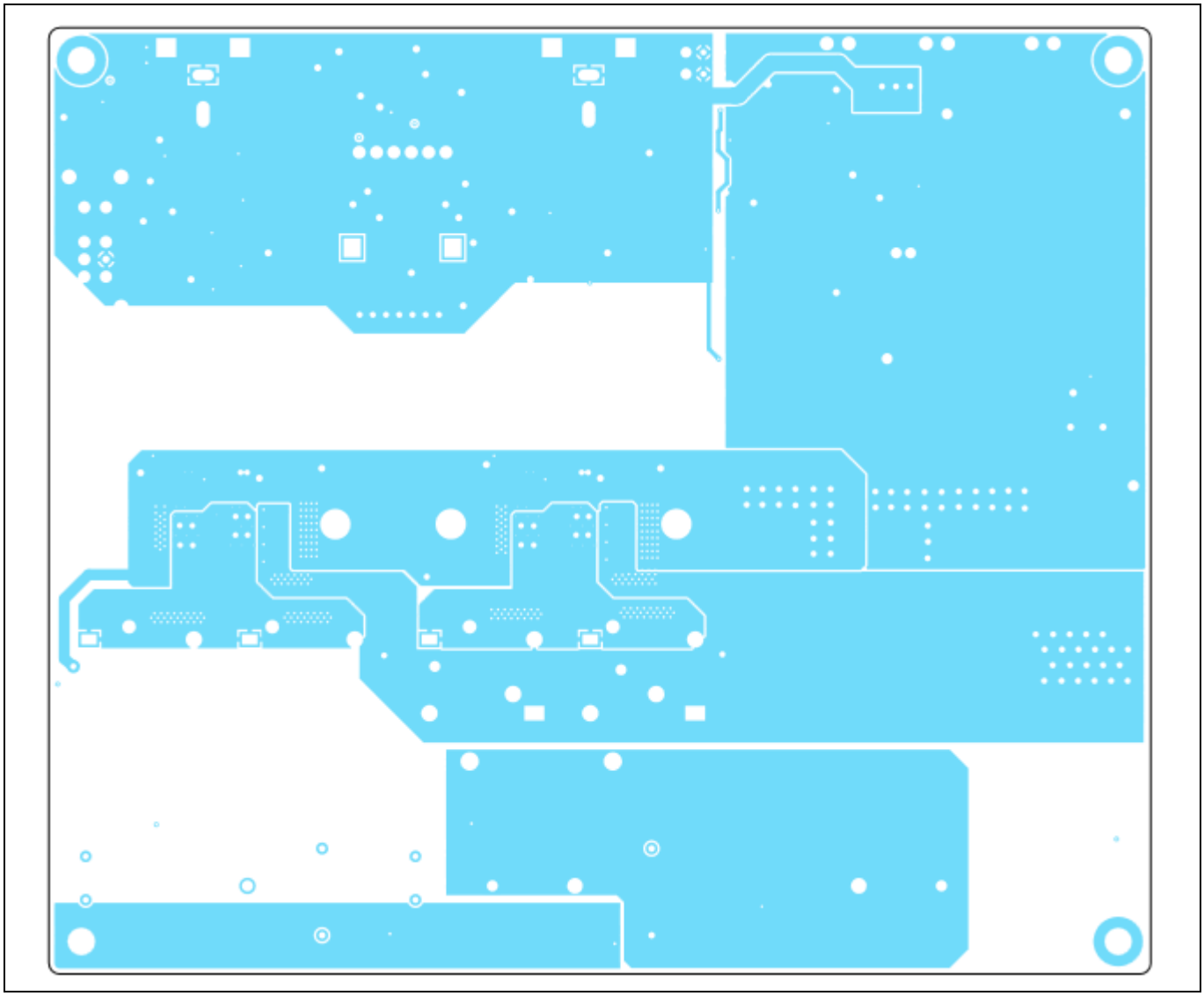

Figure 42 Layout layer 3

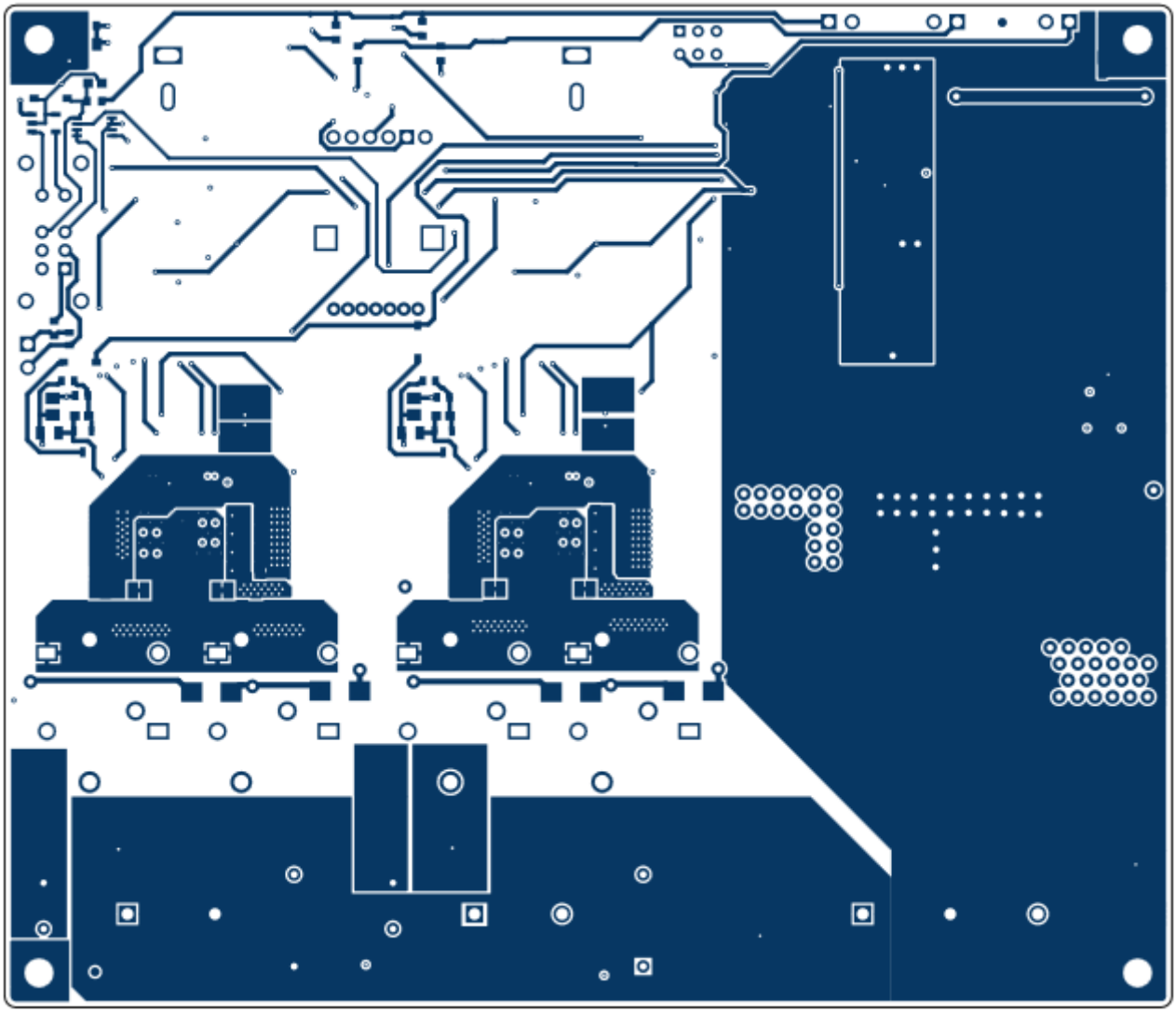

Figure 43 Layout layer 4

11 Bill of Materials

Table 9 Bill of Materials

Parameter	Part number	Designator	Description	Quantity	Vendor
1	P200KHCT-ND	R36	RES SMD 200K OHM 1% 1/10W 0603	1	DigiKey
2	UCM2A511MNS1MTR-ND	C3, C4, C9, C10	CAP ALUM 510uF 20% 100V SMD	4	DigiKey
3	445-173687-1-ND	C11, C15, C18, C21, C22, C24, C25, C34A, C34B, C37A, C37B, C68A, C68B	CAP CER 0.047UF 50V X7R 0603	13	DigiKey
4	P4.70KHCT-ND	R80A, R80B	RES SMD 4.7K OHM 1% 1/10W 0603	2	DigiKey
5	490-GRM21BZ71E106KE15LDKR-ND	C6A, C6B, C14, C16, C17, C19, C20, C64A, C64B	CAP CER 10UF 25V X7R 0805	9	Digikey
6	732-8451-1-ND	C12	CAP ALUM 10UF 20% 50V SMD	1	Digikey
7	445-5885-1-ND	C23, C50A, C50B	CAP CER 0.1UF 25V X8R 0603	3	Digikey
8	490-1451-1-ND	C26A, C26B, C27A, C27B, C31A, C31B, C52A, C52B, C66A, C66B, C76, C77	CAP CER 1000PF 50V C0G/NP0 0603	12	Digikey
9	399-C0805C101J1GACTUDKR-ND	C28A, C28B	CAP CER 100PF 100V C0G/NP0 0805	2	Digikey
10	490-4520-6-ND	C30A, C30B, C59A, C59B, C63A, C63B	CAP CER 2.2UF 10V X7R 0603	6	Digikey
11	311-3891-1-ND	C32A, C32B, C39, C41	CAP CER 220PF 50V C0G/NPO 0603	4	Digikey
12	445-7582-1-ND	C35A, C35B, C36A, C36B	CAP CER 3.3UF 16V X7R 0805	4	Digikey

Bill of Materials

Parameter	Part number	Designator	Description	Quantity	Vendor
13	10-EEE-FN0J100RCT-ND	C38, C40	CAP ALUM 10UF 20% 6.3V SMD	2	Digikey
14	478-5719-6-ND	C42, C43, C44, C45, C58A, C58B	CAP CER 2.2UF 25V X7R 0805	6	Digikey
15	445-6931-2-ND	C51A, C51B, C65A, C65B	CAP CER 1UF 25V X7R 0603	4	Digikey
16	399-11392-1-ND	C53A, C53B	CAP TANT 100UF 10% 16V 2312	2	Digikey
17	399-16459-1-ND	C54A, C54B, C55A, C55B, C56A, C56B, C57A, C57B	CAP CER 0.022UF 250V X7R 0805	8	Digikey
18	1276-6780-1-ND	C60A, C60B	CAP CER 22UF 16V X5R 0805	2	Digikey
19	490-GCM1885G2A181JA16DCT-ND	C62A, C62B	CAP CER 180PF 100V X8G 0603	2	Digikey
20	399-12987-1-ND	C67A, C67B	CAP CER 10000PF 16V X7R 0603	2	Digikey
21	399-C0805X104K1RACTUCT-ND	C69A, C69B	CAP CER 0.1UF 100V X7R 0805	2	Digikey
22	399-R71XF347050H0M-ND	C70A, C70B	0.47 µF Film Capacitor 160V 450V Polypropylene (PP), Metallized Radial	2	Digikey
23	495-1190-ND	C71A, C71B	CAP FILM 0.047UF 5% 250VDC RAD	2	Digikey
24	478-6058-1-ND	C73, C74	CAP CER 1000PF 100V X7R 0603	2	Digikey
25	MMSZ5245BT1GOSTR-ND	D1, D2, D3	DIODE ZENER 15V 500MW SOD123	3	Digikey
26	MMSZ5259BT1GOSTR-ND	D5	DIODE ZENER 39V 500MW SOD123	2	Digikey

Bill of Materials

Parameter	Part number	Designator	Description	Quantity	Vendor
27	MMSZ5260BT1GOSCT-ND	D4, D6	DIODE ZENER 43V 500MW SOD123	1	Digikey
28	732-4984-1-ND	D8, D14A, D14B	LED RED CLEAR 0805 SMD	3	Digikey
29	MMBD4148SECT-ND	D9A, D9B	DIODE ARR GP 100V 200MA SOT23-3	2	Digikey
30	BAT5403WE6327HTSA1CT-ND	D10A, D10B	DIODE SCHOT 30V 200MA PGSOD3233D	2	Digikey
31	RF071MM2SCT-ND	D11A, D11B, D15A, D15B	DIODE STANDARD 200V 700MA PMDU	4	Digikey
32	BAV21W-FDIDKR-ND	D12A, D12B	DIODE STANDARD 200V 400MA SOD123	2	Digikey
33	1N4148W-13FDICT-ND	D13A, D13B, D16A, D16B, D18A, D18B	DIODE STANDARD 100V 300MA SOD123	6	Digikey
34	MMSD301T1GOSTR-ND	D17A, D17B	DIODE SCHOTTKY 30V 200MA SOD123	2	Digikey
35	31-BAV21WQ-7-FTR-ND	D20A, D20B	DIODE STANDARD 200V 400MA SOD123	2	Digikey
36	ES2DFSCT-ND	D21A, D21B, D22A, D22B	DIODE STANDARD 200V 2A DO214AA	4	Digikey
37	ES1DFSCT-ND	D24	DIODE STANDARD 200V 1A DO214AC	1	Digikey
38	475-LBQ39G-L2OO-35-1CT-ND	DS1	LED BLUE DIFFUSED 0603 SMD	1	Digikey

Bill of Materials

Parameter	Part number	Designator	Description	Quantity	Vendor
39	MMSZ5V1T1GOSCT-ND	Dz1	DIODE ZENER 5.1V 500MW SOD123	1	Digikey
40	296-19534-1-ND	G1	IC REG LINEAR 10V 500MA TO252-3	1	Digikey
41	497-1183-1-ND	G2	IC REG LINEAR 5V 100MA SOT89-3	1	Digikey
42	497-1219-1-ND	G3	IC REG LINEAR -5V 100MA SOT89-3	1	Digikey
43	505-LTC1799HS5#TRPBFCT-ND	G4	Oscillator, Silicon IC 1kHz ~ 33MHz TSOT-23-5	1	Digikey
44	ZXTR2105F-7DICT-ND	G5A, G5B	IC REG LINEAR 5V 89MA SOT23-3	2	Digikey
45	AP2210N-5.0TRG1DICT-ND	G6A, G6B	IC REG LINEAR 5V 300MA SOT23-3	2	Digikey
46	296-17056-1-ND	IC1	IC GATE NAND SCHMITT 2CH 2IN SM8	1	Digikey
47	4044-CPD2315-220M-ND	L3A, L3B, L4A, L4B	THT CLASS D IND FOR DIGITAL AMP	4	Digikey
48	277-1271-ND	P1, P2	TERM BLK 2P SIDE ENT 9.53MM PCB	2	Digikey
49	MMBT5401-FDICT-ND	Q1	TRANS PNP 150V 0.6A SOT-23-3	1	Digikey
50	1727-5425-1-ND	Q2, Q3	TRANS NPN 150V 1A SOT223	2	Digikey
51	1727-8673-1-ND	Q4	TRANS NPN 80V 8A DPAK	1	Digikey
52	MJD45H11RLGOSCT-ND	Q5	TRANS PNP 80V 8A DPAK	1	Digikey
53	MMBT5551LT1GOSDKR-ND	Q6, Q7, Q8, Q12A, Q12B	TRANS NPN 160V 0.6A SOT23-3	5	Digikey

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Parameter	Part number	Designator	Description	Quantity	Vendor
54	DMP3098LDICT-ND	Q9A, Q9B	MOSFET P-CH 30V 3.8A SOT23-3	2	Digikey
55	311-100KHRDKR-ND	R1, R5, R55, R56, R61, R62	RES 100K OHM 1% 1/10W 0603	6	Digikey
56	541-47.5KCCT-ND	R2	RES SMD 47.5K OHM 1% 1/8W 0805	1	Digikey
57	311-47.0KHRDKR-ND	R3, R26, R32, R34, R35, R88A, R88B	RES 47K OHM 1% 1/10W 0603	7	Digikey
58	311-10.0CRDKR-ND	R4	RES 10 OHM 1% 1/8W 0805	1	Digikey
59	P10.0HDKR-ND	R6, R7, R11, R14, R15, R17, R22, R23, R50A, R50B, R51A, R51B, R63A, R63B, R71A, R71B, R79A, R79B, R87, R94	RES SMD 10 OHM 1% 1/10W 0603	20	Digikey
60	541-1.00HCT-ND	R8, R64, R85	RES SMD 1 OHM 1% 1/10W 0603	3	Digikey
61	541-499AFCT-ND	R9, R10, R12, R13, R18, R19, R20, R21	RES SMD 499 OHM 1% 1W 2512	8	Digikey
62	P49.9KCDKR-ND	R16, R24, R89A, R89B	RES SMD 49.9K OHM 1% 1/8W 0805	4	Digikey
63	311-10.0KHRDKR-ND	R25, R30, R48A, R48B, R59, R60, R70A, R70B, R74A, R74B	RES 10K OHM 1% 1/10W 0603	10	Digikey
64	YAG3590CT-ND	R27, R29, R37, R39	RES SMD 2K OHM 1% 1/10W 0603	4	Digikey
65	541-30.1KHDKR-ND	R28	RES SMD 30.1K OHM 1% 1/10W 0603	1	Digikey
66	311-1.00KHRDKR-ND	R31, R38, R45A, R45B, R47A, R47B, R49A, R49B	RES 1K OHM 1% 1/10W 0603	8	Digikey

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Parameter	Part number	Designator	Description	Quantity	Vendor
67	541-3318-1-ND	R33	RES SMD 50 OHM 1% 1/10W 0603	1	Digikey
68	541-75.0KFCT-ND	R40A, R40B	RES SMD 75K OHM 1% 1/4W 1206	2	Digikey
69	P470HCT-ND	R41A, R41B	RES SMD 470 OHM 1% 1/10W 0603	2	Digikey
70	311-100HRDKR-ND	R42A, R42B	RES 100 OHM 1% 1/10W 0603	2	Digikey
71	311-22.0KCRDKR-ND	R43A, R43B	RES 22K OHM 1% 1/8W 0805	2	Digikey
72	490-8524-1-ND	R44A, R44B	TRIMMER 1K OHM 0.25W GW TOP ADJ	2	Digikey
73	541-3.32KHCT-ND	R52, R57	RES SMD 3.32K OHM 1% 1/10W 0603	2	Digikey
74	PTV112-4420A-A503-ND	R54	POT 50K OHM 1/20W CARBON LOG	1	Digikey
75	541-18.0KFCT-ND	R66A, R66B	RES SMD 18K OHM 1% 1/4W 1206	2	Digikey
76	541-12.1KAACT-ND	R67A, R67B	RES SMD 12.1K OHM 1% 1/2W 2010	2	Digikey
77	311-0.0GRTR-ND	R69A, R69B, R75A, R75B	RES 0 OHM JUMPER 1/10W 0603	4	Digikey
78	311-150KHRDKR-ND	R72A, R72B, R73A, R73B, R83A, R83B, R84A, R84B	RES 150K OHM 1% 1/10W 0603	8	Digikey
79	P17617DKR-ND	R77A, R77B	RES SMD 5.1 OHM 1% 1/2W 1206	2	Digikey
80	P9.09KHCT-ND	R78A, R78B	RES SMD 9.09K OHM 1% 1/10W 0603	2	Digikey
81	541-1.21KHCT-ND	R81A, R81B	RES SMD 1.21K OHM 1% 1/10W 0603	2	Digikey

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Parameter	Part number	Designator	Description	Quantity	Vendor
82	541-7.50KHDKR-ND	R86A, R86B	RES SMD 7.5K OHM 1% 1/10W 0603	2	Digikey
83	541-2.21KAFCT-ND	R90A, R90B	RES SMD 2.21K OHM 1% 1W 2512	2	Digikey
84	A121123CT-ND	R91A, R91B	RES SMD 10 OHM 1% 3W 2512	2	Digikey
85	P10.0LDKR-ND	Rg1A, Rg1B, Rg2A, Rg2B, Rg3A, Rg3B, Rg4A, Rg4B	RES SMD 10 OHM 1% 1/10W 0402	8	Digikey
86	490-6993-1-ND	Rp1A, Rp1B	SENSOR PTC 470OHM 50% 0805	2	Digikey
87	EG1908-ND	S1	SWITCH SLIDE DPDT 100MA 12V	1	Digikey
88	EG1944-ND	S2	SWITCH SLIDE DP3T 200MA 30V	1	Digikey
89	36-29311-ND	SC1, SC2, SC3, SC4	MACH SCREW PAN HEAD SLOTTED M3	4	Digikey
90	36-24435-ND	SO1, SO2, SO3, SO4	HEX STANDOFF M3 ALUMINUM 15MM	4	Digikey
91	296-OPA1655DRCT-ND	U1A, U1B	SOUNDPLUS ULTRA-LOW NOISE AND DI	2	Digikey
92	296-44416-5-ND	U2, U3	IC AUDIO 2 CIRCUIT 8SOIC	2	Digikey
93	448-1EDN7116UXTSA1CT-ND	U4A, U4B, U6A, U6B	High-Side or Low-Side Gate Driver IC	4	Digikey
94	IRS20957STRPBFCT-ND	U5A, U5B	IC AMP CLASS D MONO 16SOIC	2	Digikey
95	3314J-104ECT-ND	VR1	TRIMMER 100K OHM 0.25W J LEAD TOP	1	Digikey

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Parameter	Part number	Designator	Description	Quantity	Vendor
96	732-5315-ND	X1, X2, X3, X7	CONN HEADER VERT 2POS 2.54MM	4	Digikey
99	277-1272-ND	X4	TERM BLK 3P SIDE ENT 9.53MM PCB	1	Digikey
100	CP-1418-ND	X5, X6	CONN RCA JACK MONO 3.2MM R/A	2	Digikey
101	MMSZ5242BT1GOSTR-ND	Z1	DIODE ZENER 12V 500MW SOD123	1	Digikey
102	1727-1596-2-ND	Z6A, Z6B	DIODE ZENER 10V 375MW SOD123F	2	Digikey
103	IGC090S18S1	Q10A, Q10B, Q11A, Q11B	175 V CoolGaN™ e-mode transistor	4	Infineon

12 Summary

The REF_Audio_GaNc_1200W is a high-performance class D audio amplifier reference board developed by Infineon Technologies. It combines 175 V CoolGaN™ transistors (IGC090S18S1) 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 1200 W total output power at 4 Ω.

Key features include a self-oscillating PWM topology, comprehensive protection mechanisms (OCP, OVP, UVP, OTP), and support for both internal and external clock synchronization. The system operates at a typical 450 kHz switching frequency, with a 768 kHz variant available for applications that require synchronization with 48 kHz DSP systems.

The design offers over 120 dB signal-to-noise ratio, <60 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: *IGC090S18S1*; Available online

[2] Infineon Technologies AG: *IRS20957*; Available online

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

Revision history

Document revision	Date	Description of changes
V 1.0	2025-06-06	Initial release
V 2.0	2026-01-29	Changed Q10A, Q10B, Q11A, Q11B to IGC090S18S1
V 2.1	2026-03-10	Updated 768 kHz/1 MHz update instruction

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