REF_MA5332BTLSPS

MA5332M reference board

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About this document

Scope and purpose

The REF_MA5332BTLSPS reference board is a single BTL channel, 200 W/ch (4 Ω at 40 V) class D audio power amplifier for home audio systems. This reference board demonstrates how to use the MA5332M IC with a single power supply and design an optimum PCB layout using an Infineon integrated class D IC. This reference design does not require additional heatsink or fan cooling for normal operation (one-eighth of continuous rated power). The reference design provides all the required housekeeping power supplies for ease of use.

Applications

- Smart speakers
- Sound bars
- Sub-woofers
- Powered speakers
- Musical instrument amplifiers
- Car audio amplifiers

Features

- Output power:
  - 200 W x 1 channels (10 percent THD+N, 4 Ω at 40 V)
- Multiple protection features:
  - Overcurrent protection (OCP), high-side and low-side
  - Overtemperature protection (OTP)
- Pulse width modulator (PWM):
  - Self-oscillating half-bridge topology with optional clock synchronization

Table of contents

1 Specifications

Table 1 General test conditions

Condition		Notes/conditions
Supply voltage	+40 V	Unipolar power supply
Rated load impedance	4 Ω	Resistive load
Self-oscillating frequency	400 kHz	No input signal, adjustable
Voltage gain	23 dB	1 V_{RMS} input yields rated power

Table 2 Electrical data

Data	Typical	Notes/conditions
Infineon devices	MA5332 integrated class D IC	
Modulator	Self-oscillating, second-order sigma-delta modulation, analog input	
Output power (1 percent THD+N)	150 W	1 kHz, RL = 4 Ω
Output power (10 percent THD+N)	200 W	1 kHz, RL = 4 Ω
Rated load impedance	4 Ω	Resistive load
Idling supply current	+75 mA	No input signal, +40 V
Signal-to-noise ratio (SNR)	96 dB	Filter: A-weighting (12017), 20 kHz SPCL Gain setting: 23 dB
Residual noise	140 µV	Filter: A-weighting (12017), 20 kHz SPCL Gain setting: 23 dB
Channel efficiency	90 percent	Single-channel driven, 200 W, class D stage

2 REF_MA5332BTLSPS overview

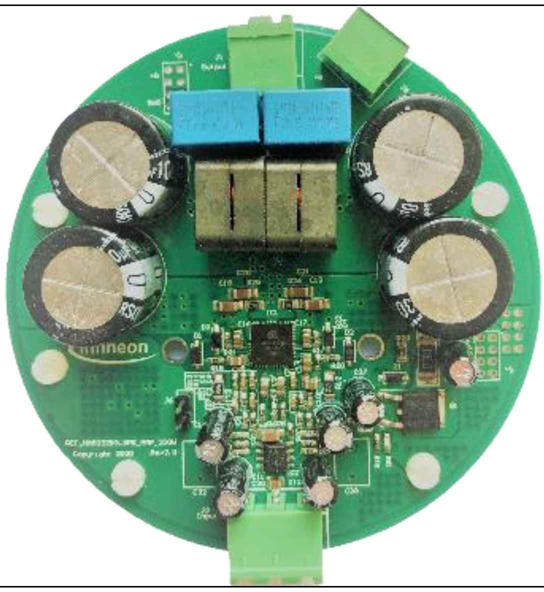

Figure 1 REF_MA5332BTLSPS board

The REF_MA5332BTLSPS features a single BTL channel self-oscillating type PWM for the lowest component count, convenient single power supply and highest performance and robust design. This topology represents an analog version of a second-order sigma-delta modulation, with the 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 nature of its operation. Also, sigma-delta modulation enables the designer to apply sufficient error correction.

The REF_MA5332BTLSPS self-oscillating topology consists of the following essential functional blocks:

- Front-end integrator
- PWM comparator
- Level shifters
- Integrated gate drivers and MOSFETs
- Output LPF

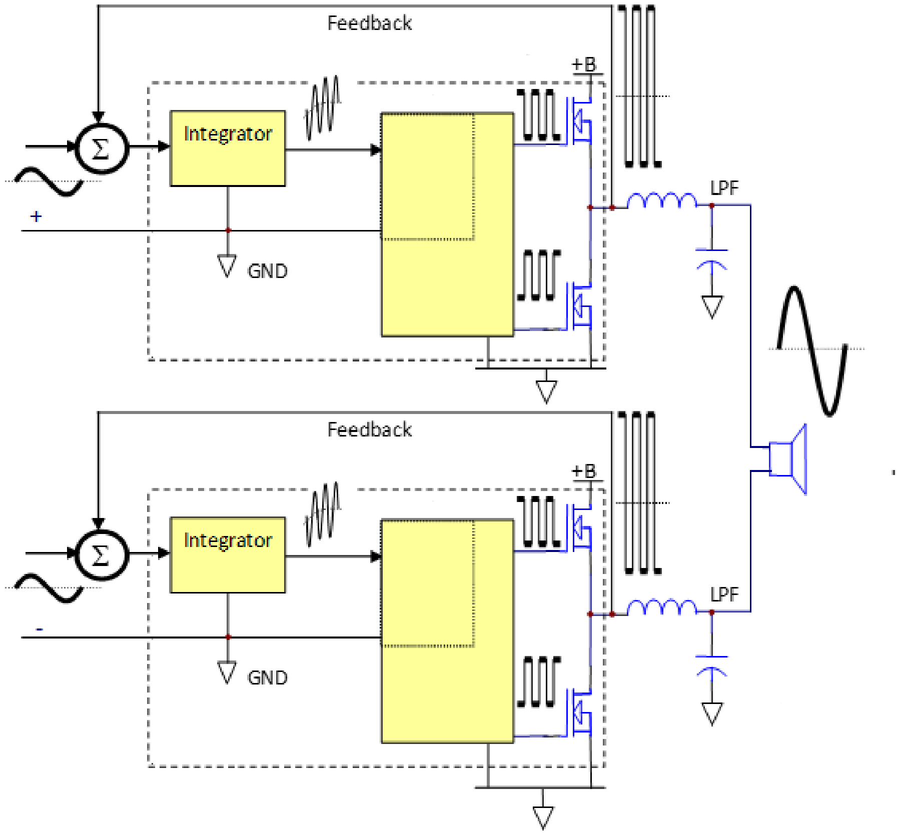

Figure 2 **Simplified block diagram of the class D amplifier**

3 Setup guide

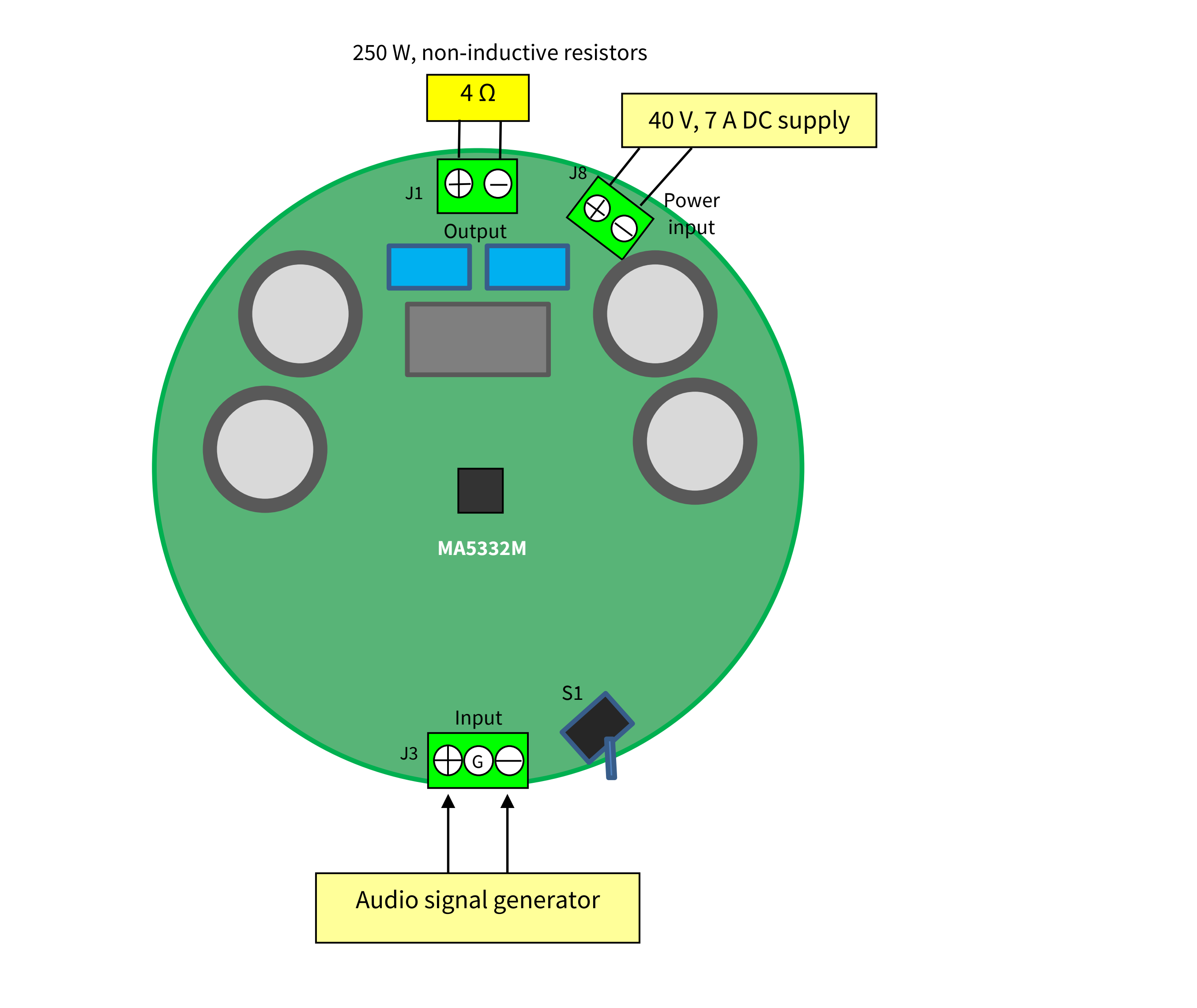

Figure 3 Typical connectors

Table 3 Connector descriptions

Analog input	J3	Analog balanced input
Output	J1	Analog output
Power	J8	Single power supply

4 Audio analyzer setup

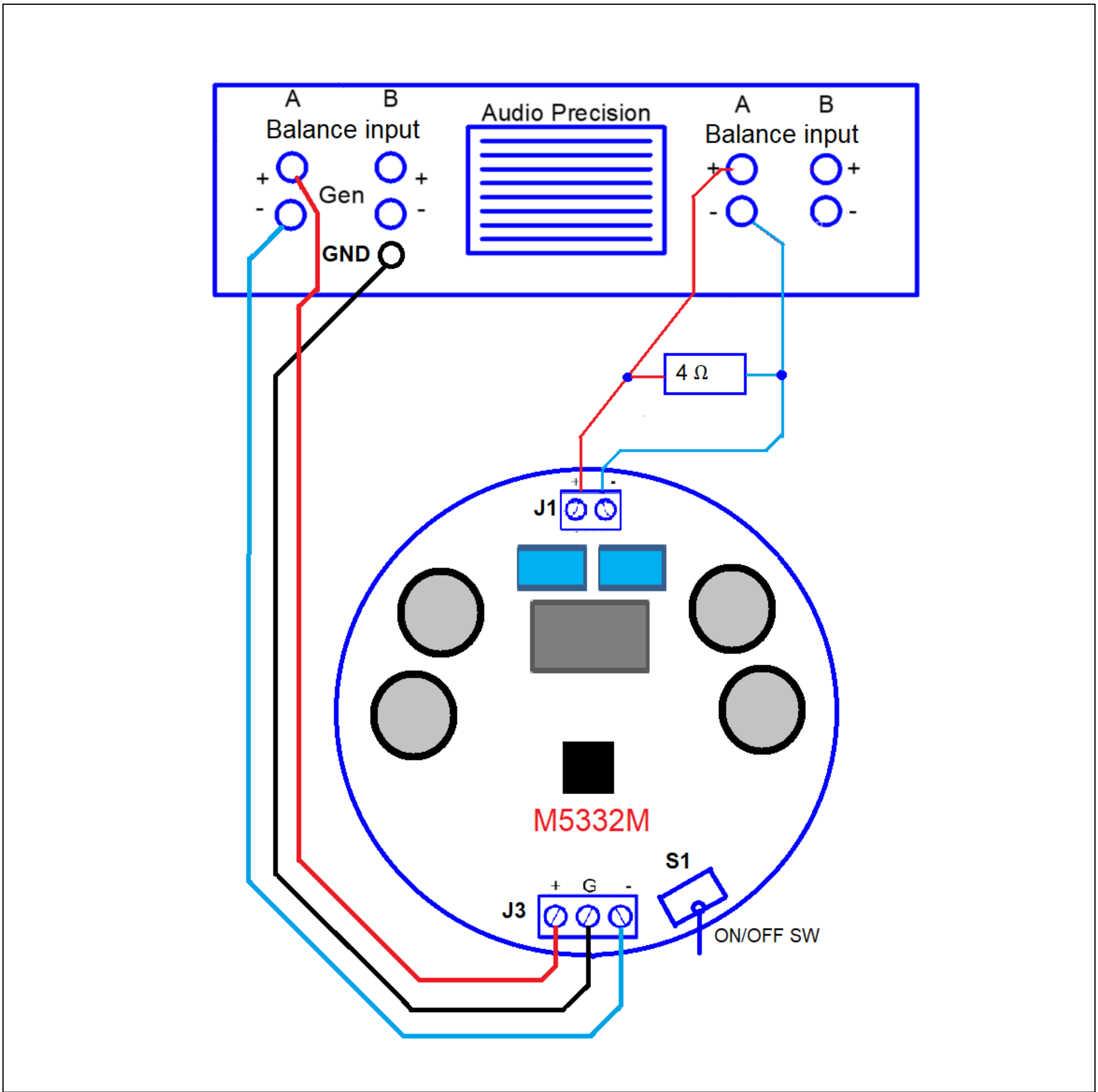

Figure 4 Audio analyzer connections

5 Operating the board

5.1 Test setup

1. Connect 4 Ω 250 W dummy loads to output connector (J1 as shown in **Figure 3**) and parallel it with the input of the audio precision (AP) analyzer.
2. Connect the audio signal generator (ASG) to J3 for analog signal respectively (AP).
3. Set up the power supply with voltages of 40 V; set the current limit to 7 A.
4. Turn off the power supply before connecting to “on” of the unit under test (UUT).
5. Connect the power supply to J8, as shown in **Figure 3**.

5.2 Power-up sequence

6. Turn on the power supply.
7. Quiescent current for the supply should be 75 mA ±10 mA at 40 V.
8. Turn on the switch S1 (middle position).

5.3 Audio functionality tests

8. Set the AP’s analog analyzer to 20 kHz AES17 filter.
9. Connect the audio signal from the AP to J3.
10. Sweep the audio signal voltage from 15 mV_{RMS} to 1.5 V_{RMS}.
11. Run the AP test as shown in Figures 5 to 12, below.

5.4 Power-down sequence

12. Turn off the switch S1 (side position).
13. Turn off power supply.
14. All LEDs turn off when housekeeping power supplies are off.

6 Audio performance

6.1 Power vs. THD+N

Test conditions:

V_{bus} = 40 V

Input signal = 1 kHz

Load impedance = 4 Ω

F_{PWM} = 400 kHz

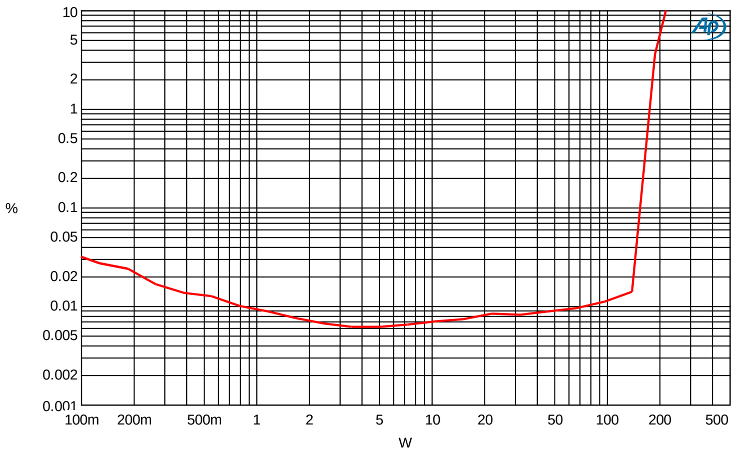

Figure 5 Power vs. THD+N 4 Ω load

6.2 Frequency response

Test conditions:

V_{bus} = 40 V

Output power = 1 W

Load impedance = 4 Ω

F_{PWM} = 400 kHz

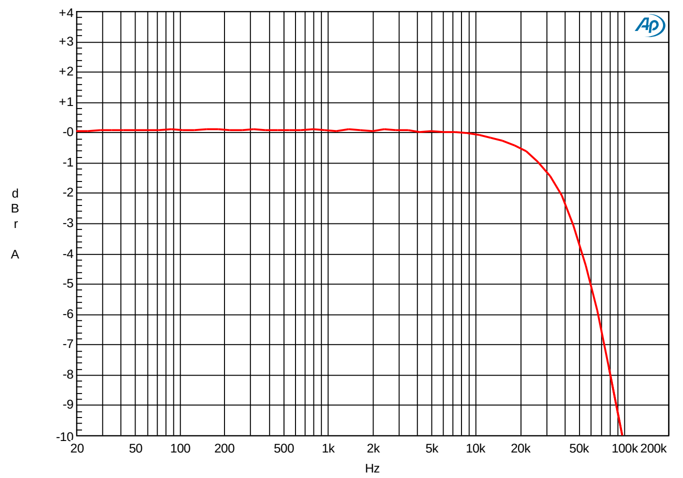

Figure 6 Frequency response 4 Ω load

6.3 Noise floor

Test conditions:

V_{bus} = 40 V

No input signal

Load impedance = 4 Ω

F_{PWM} = 400 kHz

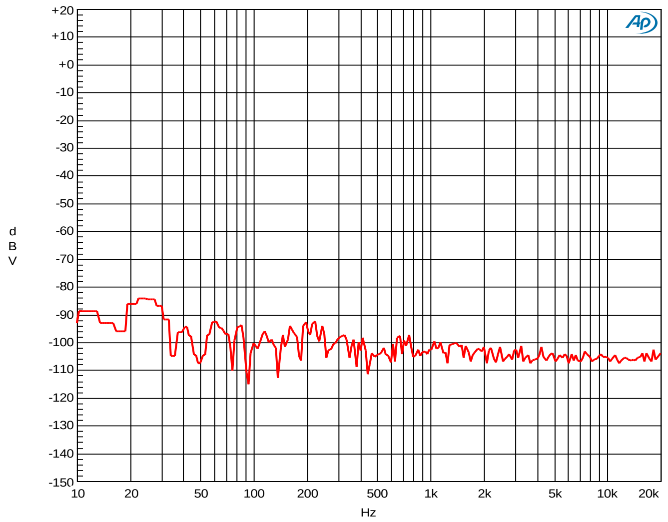

Figure 7 Noise floor 4 Ω load

6.4 Noise floor with 1 V_{RMS} output

Test conditions:

V_{bus} = 40 V

Output = 1 V_{RMS} at 1 kHz

Load impedance = 4 Ω

F_{PWM} = 400 kHz

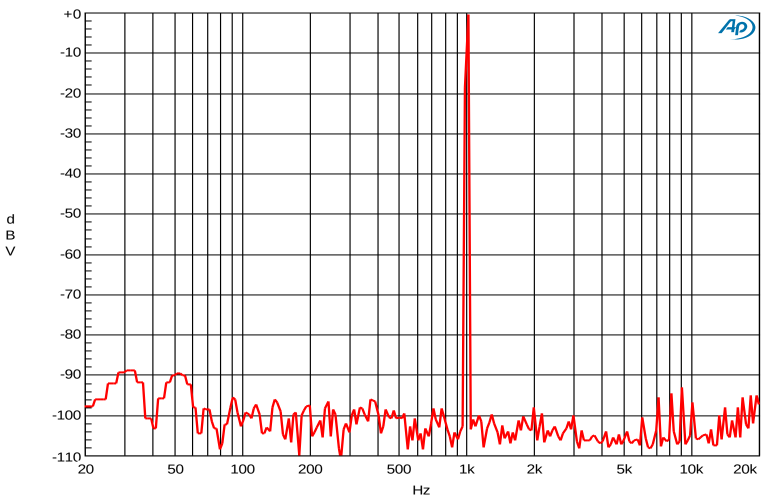

Figure 8 Noise floor with 1 V_{RMS} output 4 Ω load

7 Efficiency

Test conditions:

V_{bus} = 40 V

Output = 1 V_{RMS} at 1 kHz

Load impedance = 4 Ω

F_{PWM} = 400 kHz

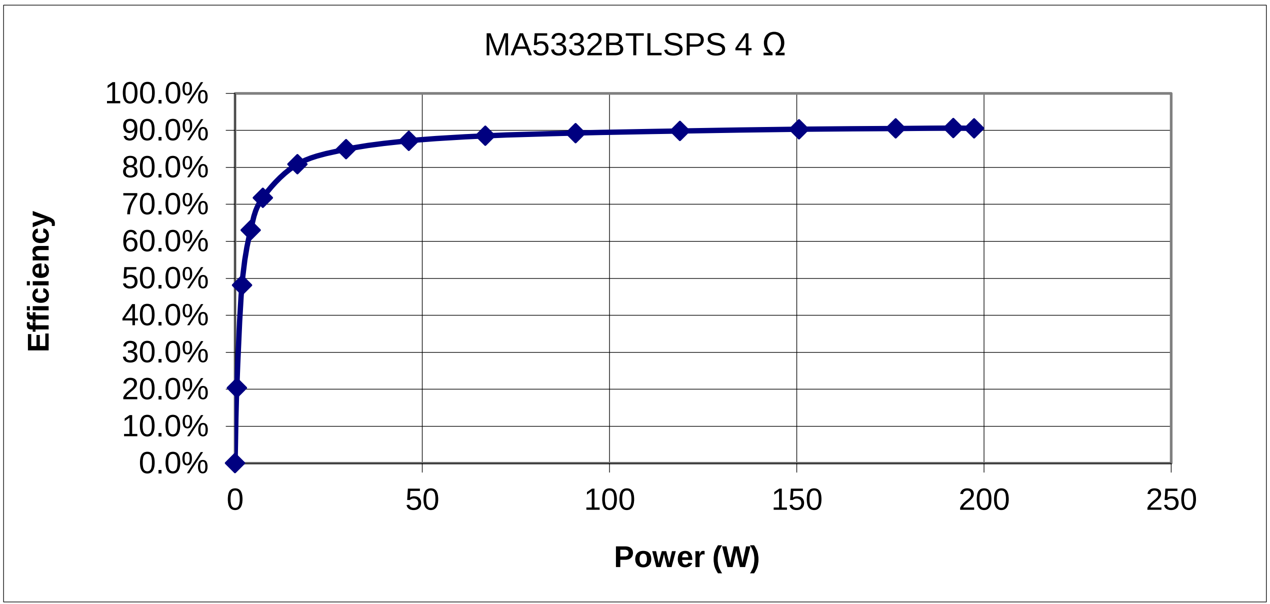

Figure 9 REF_MA5332BTLSPS 4 Ω load stereo, Vbus = 40 V

8 Thermal information

Test conditions:

V_{bus} = 40 V

Input signal = 1 kHz

Both channels driven

F_{PWM} = 400 kHz

Load = 4 Ω

8.1 Thermal performance

Table 4 Thermal performance (with heatsink)

Output power(W)	Temperature (°C)	Record time (minutes)
18.75	71.4	30
200	109	1
200	144	5

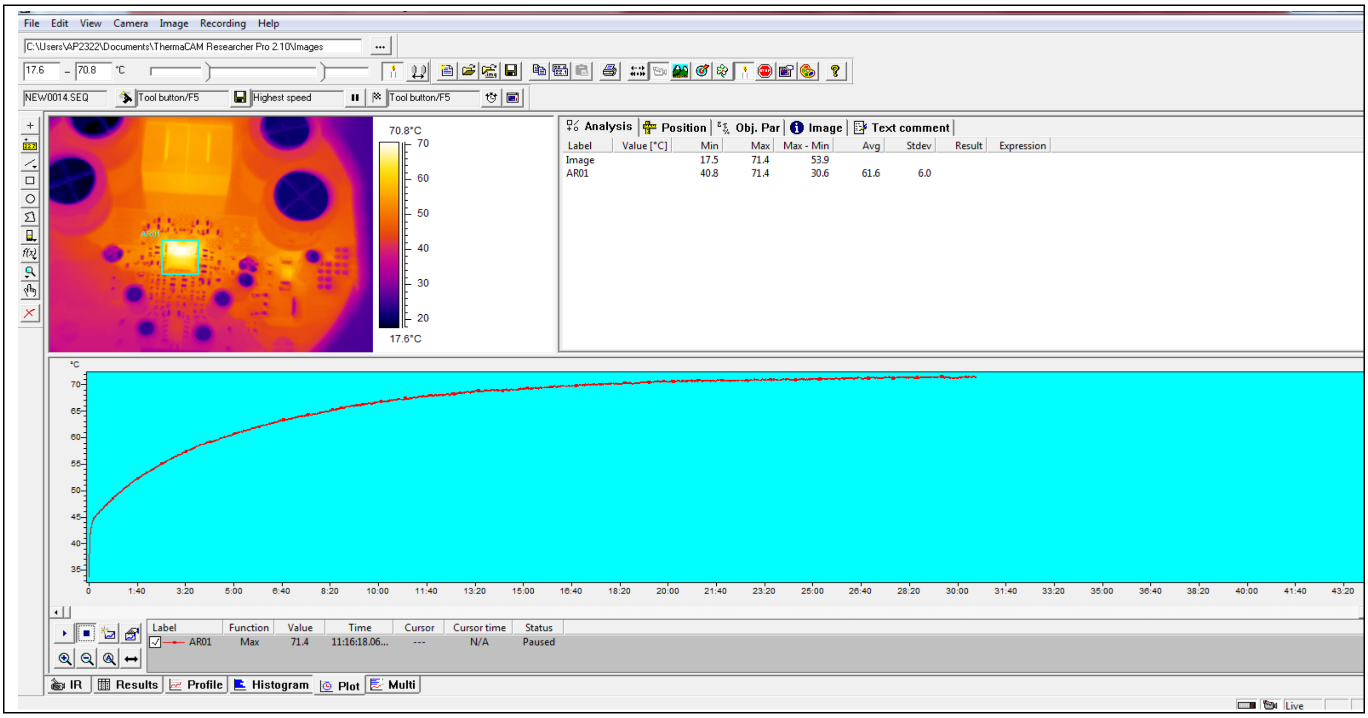

Figure 10 1/8 P_{out} = 18.75 W with 4 Ω load 40 V with heatsink

Note: Temperature saturated at 71.4°C after 30 minutes.

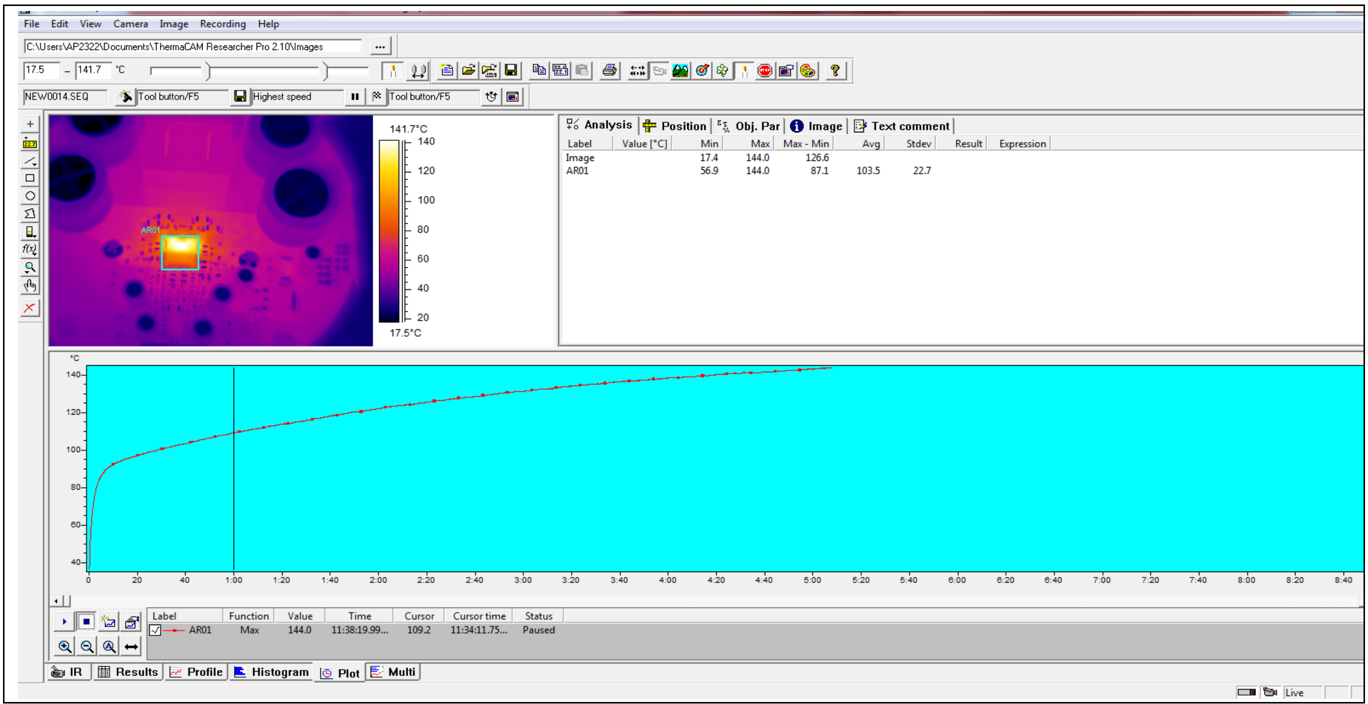

Figure 11 **Peak power P_{out} = 200 W with 4 Ω load 40 V with heatsink**

Note: *Maximum temperature 109.2°C at 1 minute and 144°C at 5 minutes.*

8.2 Heatsink

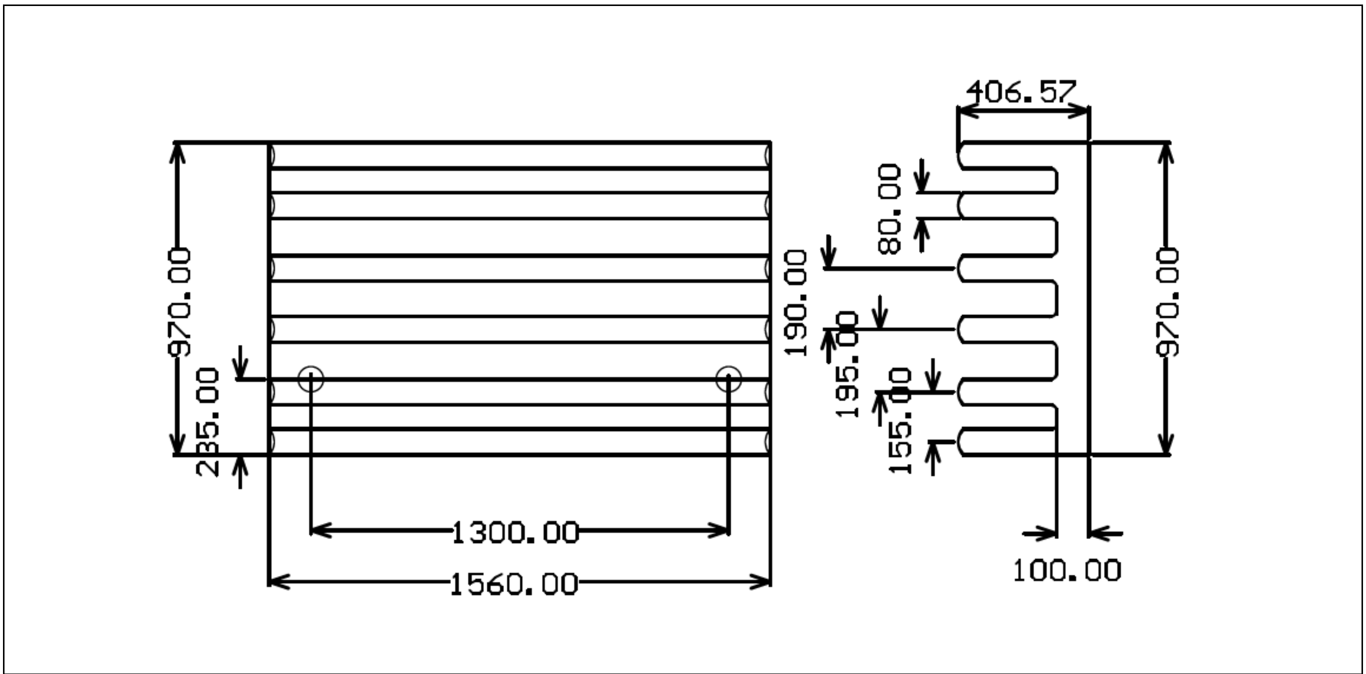

Figure 12 **Heatsink dimensions**

9 Gain setting

The REF_MA5332BTLSPS reference board has two gain settings for the single power supply application, which is different from the split power supplies application. The AC gain setting (red path in **Figure 13**) is the same as the normal gain setting, and the ratio of RFB and R_{in} is the AC gain. The DC gain setting (blue path in **Figure 13**) depends on the desired bus voltage and rated output power.

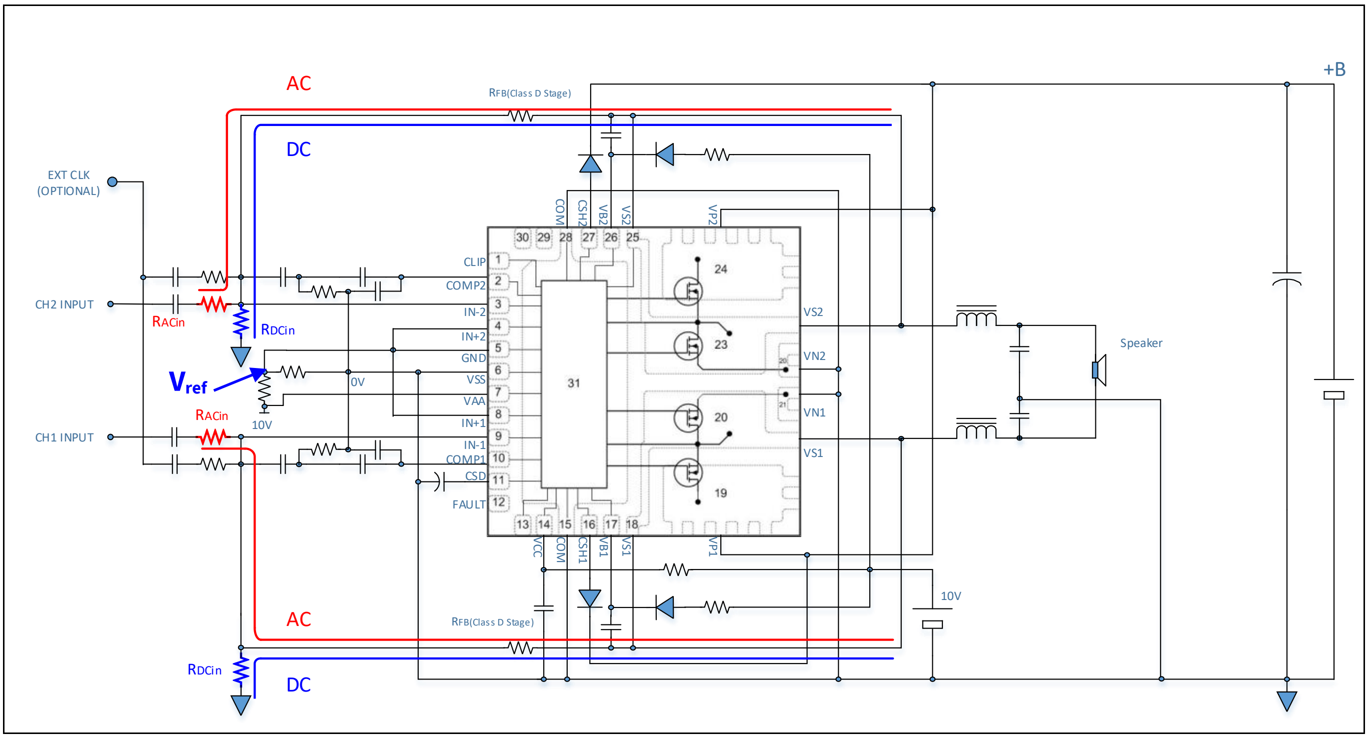

Figure 13 AC and DC path

9.1 Gain design flow

The gain design flow is shown below.

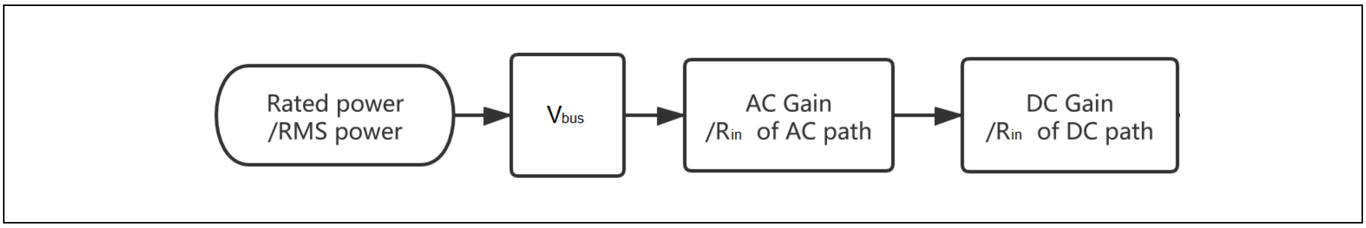

Figure 14 Gain design flow

1. Set target rated power and load impedance.

2. Calculate V_{bus} based on rated power and load impedance.

3. Calculate required AC gain and R_{ACin}.

4. Calculate R_{DCin}.

9.2 V_{bus} calculation

V_{bus} is calculated by the load impedance and clipping power (normally 75 percent of RMS power).

V_{bus} = (2*$P_{clipping}$*R_{load})^(1/2)/M

M is maximum modulation index, normally M = 90 percent

V_{bus} = (2*200*75%*4)^(1/2)*90%

= 38.5 V

Use 40 V as V_{bus} in this design.

9.3 AC gain setting

AC gain is the mean ratio of the signal amplitude at the output to the amplitude at the input.

In the REF_MA5332BTLSPS design, assume the maximum input signal is up to 5 $V_{p\text{-}p}$ balanced input.

Set the gain when input is 5 $V_{p\text{-}p}$ and the clipping voltage is 74 Vp-p (93 percent of V_{bus}*2 = 40*2 V for BTL).

Desired total voltage gain = 74/5 = 14.8

Total voltage gain = gain (op-amp stage)*gain (class D stage)

Set op-amp gain to maximum to have the minimum noise floor. Set the op-amp gain based on the supply of the op-amp, which is 10 V in this design. The maximum output of the op-amp is 9.9 V, which is decided by the parameters of the op-amp.

So the maximum op-amp voltage gain is 9.9/(1.414*2) = 3.5.

Gain (class D stage) = total voltage gain/gain (op-amp stage)

= 14.8/3.5

= 4.3

In the current design preset values below:

$R_{FB(OPAMP\ stage)}$ = R30 = 34.8 kΩ

$R_{in(OPAMP\ stage)}$ = R15 = 10 kΩ

$R_{FB(class\ D\ stage)}$ = R135 = 47.5 kΩ (recommended to fix the value as 47.5 kΩ)

$R_{in(class\ D\ stage)}$ = R31+R3 = (3.3+8.2) kΩ

Total voltage gain = gain (op-amp stage)*gain (class D stage)

= [$R_{FB(OPAMP\ stage)}$/$R_{in(OPAMP\ stage)}$]*[$R_{FB(class\ D\ stage)}$/$R_{in(class\ D\ stage)}$]

= (R30/R15)*(R13/(R31+R3))

= (34.8/10)*(47.5/(3.3+8.2))

= 3.48*4.13

= 14.37 (close to 14.8)

Gain (dB) = 20*log (14.37) = 23.15 dB

9.4 DC gain setting

DC gain is to set the output DC operation point at half of the V_{bus}.

Output DC operation point = $½*V_{bus} = V_{ref}*$DC gain

$V_{ref} = ½*$of V_{AA}

DC gain = $½*V_{bus}/V_{ref}$

$= (R_{FB(class\ D\ stage)} + R_{DCin})/R_{DCin}$

With $R_{FB(class\ D\ stage)} = 47.5\ k\Omega$

$R_{FB(class\ D\ stage)}/R_{DCin} = (½*V_{bus}/2-V_{ref})/V_{ref}$

⇨ $R_{DCin} = R_{FB(class\ D\ stage)}*V_{ref}/(½*V_{bus}-V_{ref})$

R7 == R8 = R30*5/(V_{bus}/2-5) = 47.5*5/(40/2-5) = 15.8 kΩ

10 Schematic

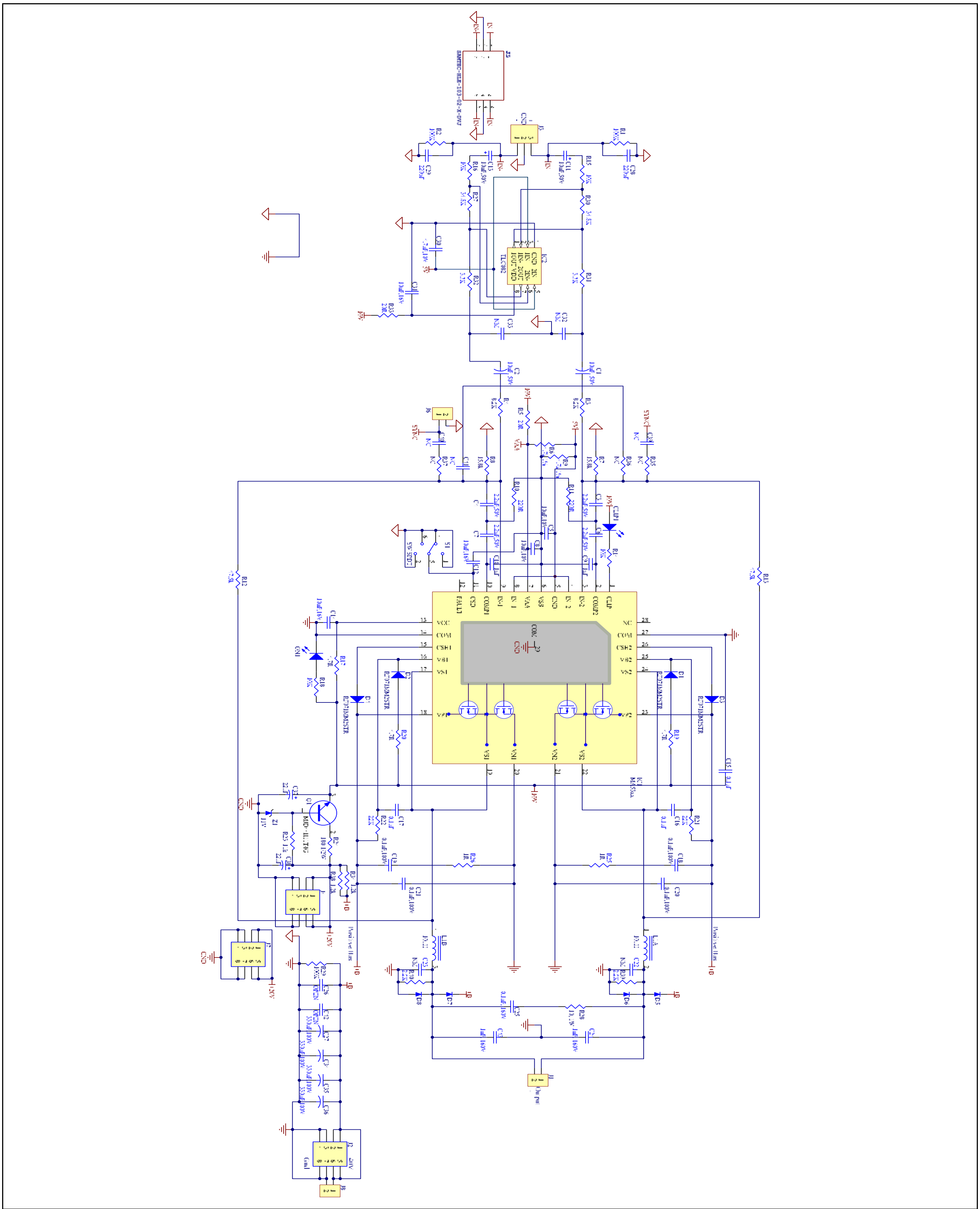

Figure 15 Schematic

11 PCB

11.1 PCB specifications

- Two-layer SMT PCB with through-holes
- 1/16 thickness
- 2/0 oz. copper
- FR4 material
- 10 mil lines and spaces
- Solder mask to be green enamel EMP110 DBG (carapace) or Enthone endplate DSR-3241 or equivalent
- Silkscreen to be white epoxy non-conductive per IPC–RB 276 standard
- All exposed copper must be finished with tin-lead Sn 60 or 63 for 100 µ inches thick
- Tolerance of PCB size shall be 0.010 to 0.000 inches
- Tolerance of all holes is ±0.003 inches
- PCB acceptance criteria as defined for class II PCB standards

11.2 PCB layout

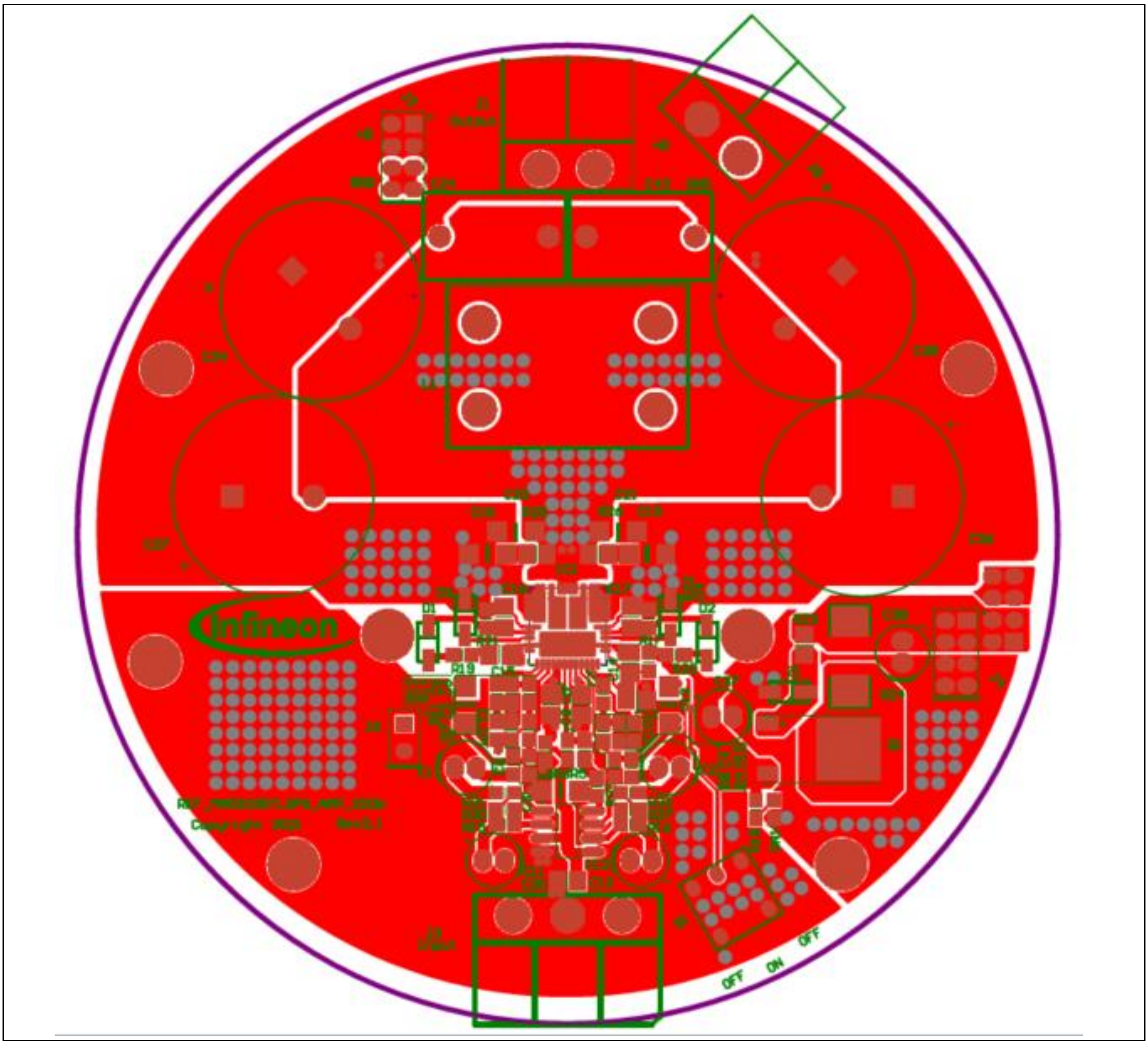

Figure 16 Board top view

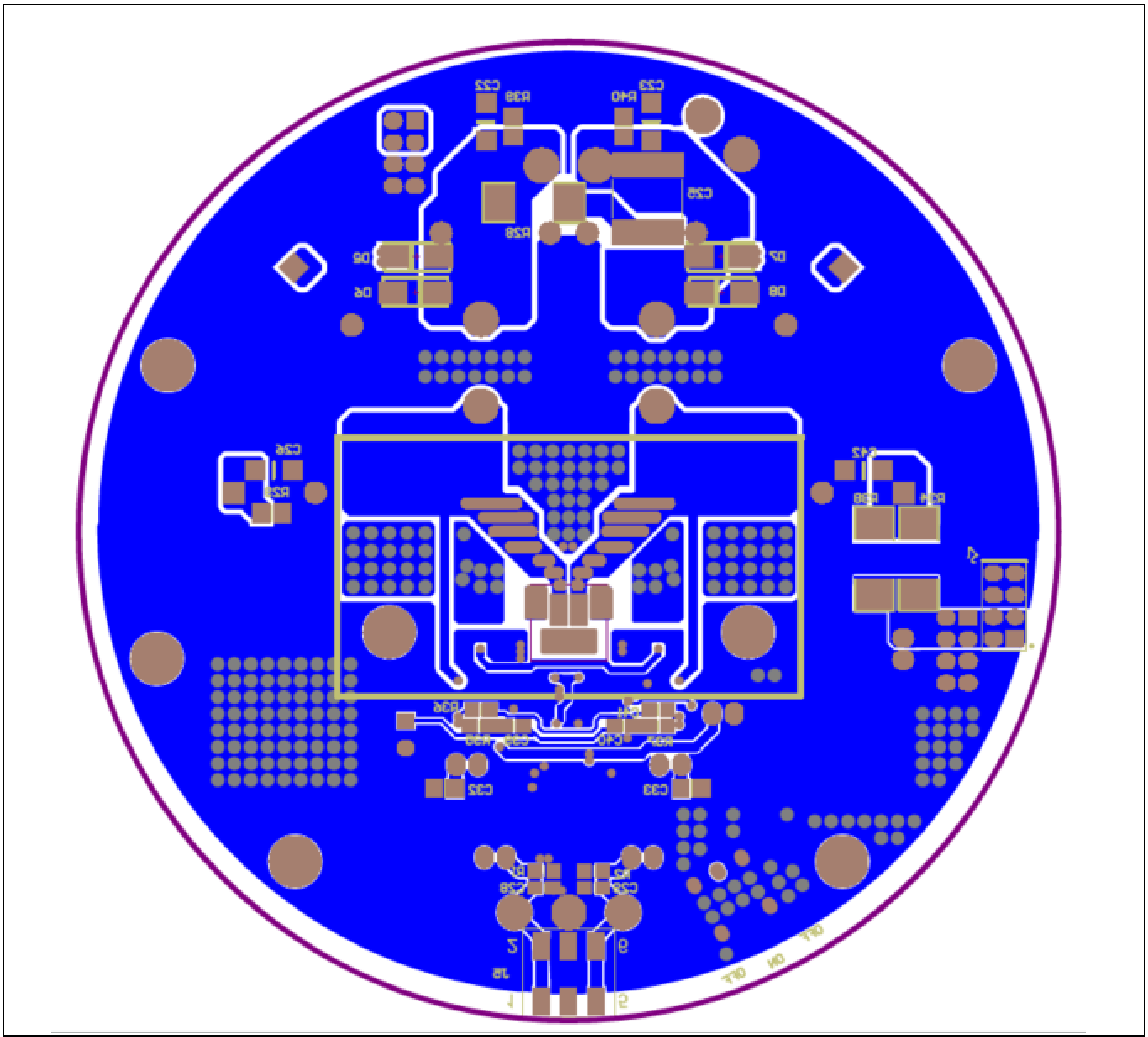

Figure 17 **Board bottom view**

12 Bill of materials (BOM)

Table 5 Board BOM

No.	Part number	Designator	Description	Quantity	Vendor
1	565-1106-ND	C1, C2,C11, C13	Aluminum capacitor 10 µF 20% 50 V radial	4	Digikey
2	490-1500-1-ND	C3, C4, C6, C7	Ceramic capacitor 2200 pF 50V 10% X7R 0603	4	Digikey
3	587-2668-1-ND	C5, C8	Ceramic capacitor 10 µF 10 V X7R 10% 0805	2	Digikey
4	399-1082-1-ND	C9, C10	Ceramic capacitor 1000 pF 50 V X7R 0603	2	Digikey
5	490-5519-1-ND	C12, C14	Ceramic capacitor 10 µF 16 V X6S 0805	2	Digikey
6	445-1418-1-ND	C15, C16, C17	Ceramic capacitor 0.10 µF 100 V X7R 10% 0805	3	Digikey
7	445-1377-1-ND	C18, C19, C20, C21	Ceramic capacitor 0.1 µF 100 V X7R 10% 1206	4	Digikey
8	495-4721-ND	C24, C43	Film capacitor 1 µF 10% 450 V DC radial	2	Digikey
9	1928-1956-1-ND	C25	Film capacitor 0.1 µF 20% 250 V DC 2824	1	Digikey
10	URS2A331MHD	C27, C34, C35, C36	Aluminum capacitor 330 µF 20% 100 V radial	4	Digikey
11	490-1483-1-ND	C28, C29	Ceramic capacitor 220 pF 50 V X7R 0603	2	Digikey
12	478-1429-1-ND	C30	Ceramic capacitor 4.7 µF 10 V Y5V 0805	1	Digikey
13	445-1601-1-ND	C31	Ceramic capacitor 10 µF 16 V X7R 1206	1	Digikey
14	565-1056-ND	C37, C38	Aluminum capacitor 22 µF 20% 25 V radial, 22 µF 25 V elect. VR radial	2	Digikey
15	160-1183-1-ND	CLIP1	LED green clear 0603 SMD	1	Digikey
16	RF071MM2SCT-ND	D1, D2, D3, D4	Switch diode 100 V 400 MW SOD123	4	Digikey
17	MURA120T3GOSCT-ND	D5, D6, D7, D8	General-purpose diode 200 V 2 A SMA	4	Digikey
18	**MA5332**	**IC1**	**2-channel integrated digital audio amplifier**	**1**	**Infineon**
19	296-2421-1-ND	IC2	IC op-amp GP 2 circuit 8SOIC	1	Digikey

No.	Part number	Designator	Description	Quantity	Vendor
20	ED2779-ND	J1', J8'	2-position terminal block plug	2	Digikey
21	ED2779-ND	J1', J8'	2-position terminal block plug	2	Digikey
22	A98249-ND	J3	Terminal block HDR 3POS 90-degree 5 mm	1	Digikey
23	A113286-ND	J3'	Terminal block plug 3POS STR 5 mm	1	Digikey
24	CPD1521C-100M	L1	2" 1 10 µH inductor	1	Codaca
25	160-1646-1-ND	ON1	LED 468 nm blue clear 0603 SMD	1	Digikey
26	MJD44H11T4GOSCT-ND	Q1	Transistor NPN Epitax 100 V 3 A TO-220	1	Digikey or Mouser
27	RHM100KGCT-ND	R1, R2	Resistor SMD 100K Ω 5% 1/10 W 0603	2	Digikey
28	CR0603-FX-8201ELFCT-ND	R3, R4	Resistor SMD 8.2K Ω 1% 1/10 W 0603	2	Digikey
29	RMCF0603JT10R0CT-ND	R5, R33	Resistor 10 Ω 1/10 W 5% 0603 SMD	2	Digikey
30	311-4.70KHRCT-ND	R6, R9	Resistor SMD 4.7K Ω 1% 1/10 W 0603	2	Digikey
31	RMCF0603FT15K8CT-ND	R7, R8	Resistor 15.8K Ω 1% 1/10 W 0603	2	Digikey
32	YAG3652CT-ND	R10, R11	Resistor 220 Ω 1/10 W 5% 0603 SMD, resistor 620 Ω 1/10 W 5% 0603 SMD	2	Digikey
33	311-47.5KFRCT-ND	R12, R13	Resistor SMD 47.5K Ω 1% ¼ W 1206	2	Digikey
34	RHM10KGCT-ND	R14, R15, R16, R18	Resistor 10K Ω 1/10 W 5% 0603 SMD	4	Digikey
35	RMCF0603JT4R70CT-ND	R17, R19, R20	Resistor TF 1/10 W 4.7 Ω 5% 0603	3	Digikey
36	RMCF0603JT22K0CT-ND	R21, R22	Resistor 22K Ω 5% 1/10 W 0603	2	Digikey
37	RNCP0805FTD11K0CT-ND	R23	Resistor 11K Ω 1% ¼ W 0805	1	Digikey
38	RMCF2512JT180RCT-ND	R24	Axial resistor 1.0K Ω 1 W 5% metal oxide	1	Digikey
39	311-1.0ARCT-ND	R25, R26	Resistor 1.0 OHM 1/8W 5% 0805 SMD	2	Digikey
40	RMCF0603FT34K8CT-ND	R27, R30	Resistor 34.8K Ω 1% 1/10 W 0603	2	Digikey
41	PT10XCT-ND	R28	Resistor SMD 10 Ω 5% 1 W 2512	1	Digikey

No.	Part number	Designator	Description	Quantity	Vendor
42	311-100KCRCT-ND	R29	Resistor SMD 100K Ω 1% 1/8 W 0805	1	Digikey
43	RHM3.3KGCT-ND	R31, R32	Resistor SMD 3.3K Ω 5% 1/10 W 0603	2	Digikey
44	RMCF2512JT1K20CT-ND	R34, R38	Resistor 1.2K Ω 5% 1 W 2512	2	Digikey
45	RMCF0805JT2K20CT-ND	R39, R40	Resistor 2.2K Ω 5% 1/8 W 0805	2	Digikey
46	360-1768-ND	S1	Toggle switch SPDT 0.4 VA 28 V	1	Digikey
47	BZT52C11-FDICT-ND	Z1	Zener diode 11 V 500 MW SOD123	1	Digikey
48	8401K-ND	1/2" standoffs 4-40	Hexagonal standoff #4-40 aluminum 1/2"	5	Digikey
49	H724-ND	4-40 nut	Hexagonal nut 4-40 stainless steel	5	Digikey
50	H729-ND	No. 4 lock washer	Internal washer lock #4 SS	5	Digikey
51	Heatsink	Heatsink	1560*970*406.57 (mil)	1	–
52	BER161-ND	Thermal pad	Thermal pad	1/8	Digikey
53	Screws		Depends on holes on the heatsink	2	–

Note: **Heatsink is an option for AMP.*

Note: *25 to deliver higher power.*

Revision history

Document version	Date of release	Description of changes
V 1.0	2021-10-11	First release

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