AN4233
Application note

Sound Terminal®: a method for measuring the total thermal resistance (R_{th}) in the final application

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Introduction

The purpose of this document is to provide a methodology for measuring the total thermal resistance junction-to-ambient ($R_{th\ j\text{-}a}$) of a Sound Terminal® amplifier in a final application. The methodology allows identifying R_{th}, considering the effect of the PCB and in particular the influence of the GND plane, the number of layers of the board, and the copper connective paths.

Contents

1 Description

As mentioned, this test methodology allows measuring with high accuracy $R_{th\ j\text{-}a}$ of the Sound Terminal® amplifier when it is assembled in a PCB.

To perform the test it is not necessary to modify the hardware in the final application although some registers must be configured in order to have the appropriate setup of the device.

Setting the registers to have ternary modulation and with no input signal (or amplitude < –60 dBFs), each output of the power stage will be set to GND. Connecting the output to a positive source and with a resistor connected in series to limit the current, it is possible to sink a DC current from the output. A reliable and cheap method to measure the output current is to convert the current to voltage using a high-precision sense resistor (for instance 0.1 Ω) connected in series to each output. Using a voltmeter it is possible to also measure the voltage level on the output of each bridge and this information, along with the current level, allows calculating with high accurancy the RDSon of each power output (only for the low-side portion of the output bridge).

1.1 Equipment needed and HW and SW configuration

To perform the measurement, the equipment and the settings are summarized as follows:

- **Register setting**: the device must be set to have TERNARY modulation scheme.
- **Output loads**: four dummy resistors must be connected to each bridge output and connected to a positive supply voltage (Vdd or Vcc).
- **Input signal**: it must be null or < –60 dBFs.
- **High precision resistor (R_{sense})**: four sense resistors with very low resistive value (for instance 0.1 Ω) must be connected in series between each output and the load. These will be used to read the current ($I_{out} = V_{Rsense}/R_{sense}$)
- **Current meter (DC)**: a current meter must be inserted in series to each supply sources; specifically Vdd (+3.3 V) and Vcc must be monitored. The series resistance of this equipment must be very low to avoid adding any unwanted voltage drop.
- **Voltmeters (DC)**: a voltmeter will be used to measure both Vdd and Vcc after the current meter and to measure the voltage across each sense resistor. The accuracy of this equipment must be precise enough to measure the low voltage levels present across each sense resistor. This equipment will be used to measure V_{Rsense} and V_{out}.
- **Thermal camera**: a thermal camera must be used to measure the device temperature. Care must be taken to avoid any possible mistake during the temperature measurement; it is mandatory to define the right emission coefficient and to avoid reflection from the device package (special paint could be used or a small portion of non-reflective tape could be applied on top of the case). It is mandatory to use a thermal camera with a resolution high enough to discriminate the surface of the device. It is not recommended to use an IR thermometer because with this tool it is not possible to measure with sufficient precision the device due to the optical angle and also the position of the beam.

From the description above it is clear that all the measurements have been performed in the DC domain. This aspect is very important because whatever parasitic effects due to the PWM switching signal will be cancelled as well as the losses in the snubber networks, output dumping network and in the magnetic materials, all of which are usually difficult to estimate.

1.2 Test procedure

The steps to perform the test are as follows:

1. Connect the board to the supply generators (Vcc, Vdd; Vdd could be provided by the APWlink if this board is connected to the DUT)
2. Connect the outputs to the series made by the sense resistors and limiter resistors to a positive supply source. The voltage source could be the same used to supply the device (Vcc), in this manner simplifying the connections and the number of PSUs. The limiter resistor must be selected to reach the target current to sink from each output.
3. Set the digital input to have no audio input signal.
4. Turn on the PSUs.
5. Set the device register to have a TERNARY modulation. This action could be executed using an APWlink board and the APWorkbench software.
6. Measure using the voltmeter each supply voltage and adjust the level if it is too low due to the additional voltage drop caused by the current meter internal resistance.
7. Read the current sunk from each supply source.
8. With a voltmeter, for each output measure the voltage across the sense resistor (this level allows knowing the output current) and the voltage between the output pin and GND. This last measurement allows measuring the voltage drop inside the device due to RDSon. The measurement must be carried out, positioning the voltage probe as close as possible to the output pin or output ball to avoid any voltage drop due to the copper track.
9. With the thermal camera measure the device temperature. It is mandatory to wait to have a stable measurement and then save the thermal picture.

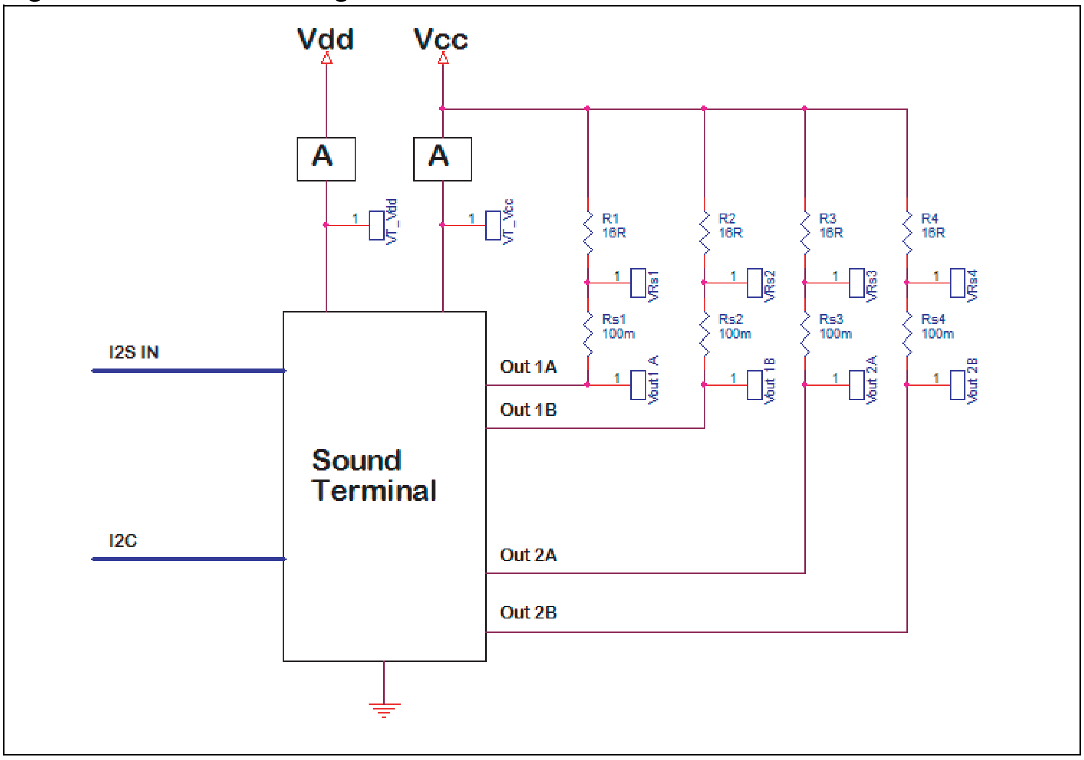
The above sequence can be repeated, setting some output current levels and modifying the Vcc supply level.

2 Schematic diagram

Figure 1 shows the schematic diagram which indicates the current meters connected in series to Vdd and Vcc and the 8 test points dedicated to measure V_R_{sense} and the Vout level for each channel.

Rs1 through Rs4 are the sense resistors and R1 through R4 are the resistors used to limit the current flowing from Vcc to the output.

Figure 1. Schematic diagram



3 Test results with the STA333IS and 2- or 4-layer PCB

The following examples show the results achieved when testing the STA333IS device assembled in two different boards, the first one has 2 layers while the second one has 4 layers. The test has also been performed with two different output current levels (500 mA and 1000 mA) for each board.

3.1 STA333IS: 500 mA output current and 2-layer PCB

Table 1. STA333IS: 500 mA output current and 2-layer PCB - current measurement

	R_{sense} [mΩ]	V_R_{sense} [mV]	I_Channel [A]	V_{RDS} [mV]	P_{RDS} [mW]	RDS [mΩ]	Vcc [V]	I_Vcc [mA]	Vdd [V]	I_Vdd [mA]
Out 1A	100	51.53	0.5153	65.88	33.947964	127.84786	8.4	19.6	3.3	31
Out 1B	100	51.53	0.5153	72.89	37.560217	141.45158				
Out 2A	100	51.42	0.5142	73.43	37.757706	142.80436				
Out 2B	100	51.65	0.5165	67.28	34.75012	130.26137				

Table 2. STA333IS: 500 mA output current and 2-layer PCB - power dissipation

Power_Output [W]	0.14402	W
Power_Vdd [W]	0.1023	W
Power_Vcc [W]	0.16464	W

Figure 2. STA333IS: 500 mA output current and 2-layer PCB - thermal measurement

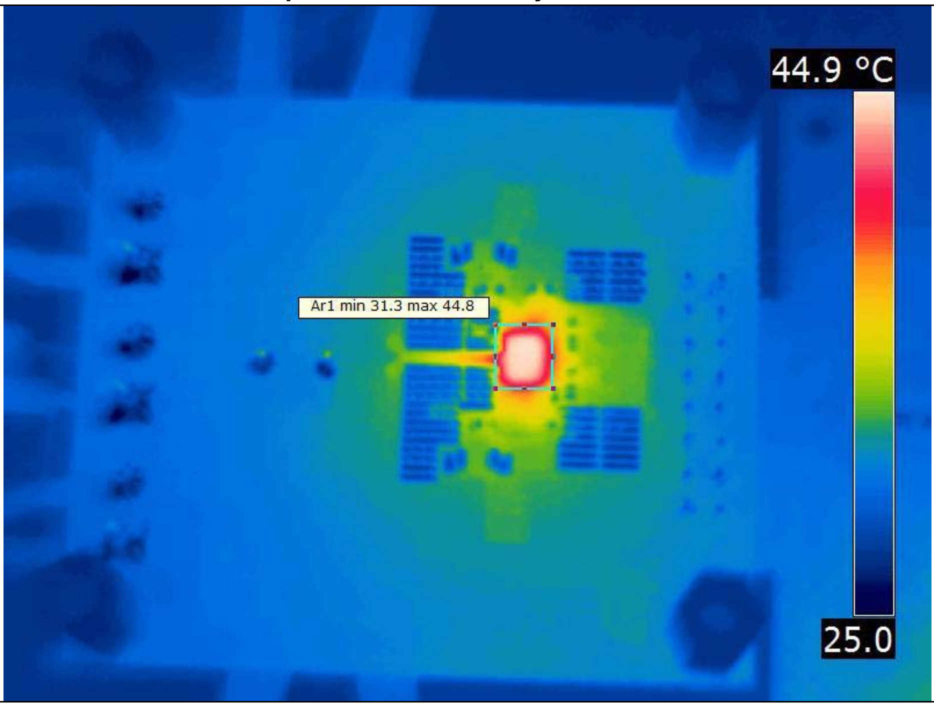


Table 3. STA333IS: 500 mA output current and 2-layer PCB - summary table

Total power [W]	0.41096	W
Temperature (case) [°C]	44.8	°C
Temperature (ambient) [°C]	26	°C
R_{th} [k/W]	45.747	°C/W

3.2 STA333IS: 1000 mA output current and 2-layer PCB

Table 4. STA333IS: 1000 mA output current and 2-layer PCB - current measurement

	R_{sense} [mΩ]	V_R_{sense} [mV]	I_Channel [A]	V_{RDS} [mV]	P_{RDS} [mW]	RDS [mΩ]	Vcc [V]	I_Vcc [mA]	Vdd [V]	I_Vdd [mA]
Out 1A	100	102.8	1.028	147.7	151.8356	143.67704	17.05	19.87	3.3	32
Out 1B	100	103.9	1.039	162.63	168.97257	156.52551				
Out 2A	100	103.7	1.037	163.1	169.1347	157.28062				
Out 2B	100	104.24	1.0424	149.63	155.97431	143.54375				

Table 5. STA333IS: 1000 mA output current and 2-layer PCB - power dissipation

Power_Output [W]	0.64592	W
Power_Vdd [W]	0.1056	W
Power_Vcc [W]	0.33878	W

Figure 3. STA333IS: 1000 mA output current and 2-layer PCB 2 - thermal measurement

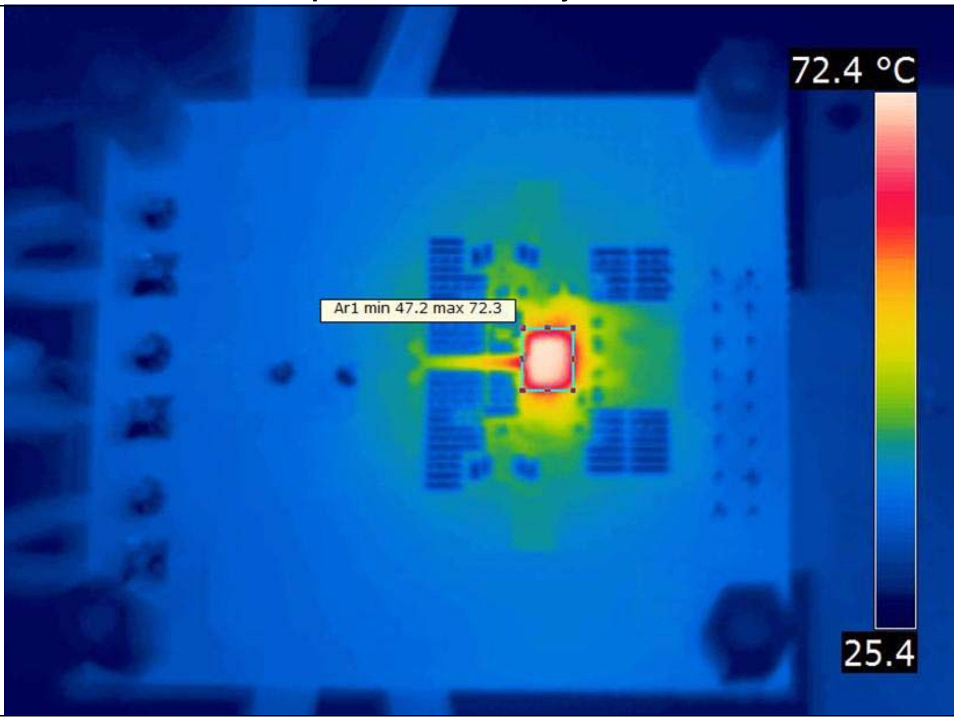


Table 6. STA333IS: 1000 mA output current and 2-layer PCB - summary table

Total power [W]	1.0903	W
Temperature (case) [°C]	72.3	°C
Temperature (ambient) [°C]	24	°C
R_{th} [k/W]	44.300	°C/W

3.3 STA333IS: 500 mA output current and 4-layer PCB

Table 7. STA333IS: 500 mA output current and 4-layer PCB - current measurement

	R_{sense} [mΩ]	V_R_{sense} [mV]	I_Channel [A]	V_{RDS} [mV]	P_{RDS} [mW]	RDS [mΩ]	Vcc [V]	I_Vcc [mA]	Vdd [V]	I_Vdd [mA]
Out 1A	100	51.1	0.511	65.15	33.29165	127.49511	8.36	19.21	3.3	32
Out 1B	100	50.46	0.5046	69.55	35.09493	137.83195				
Out 2A	100	50.94	0.5094	69.9	35.60706	137.22026				
Out 2B	100	51.1	0.511	64.8	33.1128	126.81018				

Table 8. STA333IS: 500 mA output current and 4-layer PCB - power dissipation

Power_Output [W]	0.13711	W
Power_Vdd [W]	0.1056	W
Power_Vcc [W]	0.1606	W

Figure 4. STA333IS: 500 mA output current and 4-layer PCB - thermal measurement

Table 9. STA333IS: 500 mA output current and 4-layer PCB - summary table

Total power [W]	0.4033	W
Temperature (case) [°C]	42	°C
Temperature (ambient) [°C]	26	°C
R_{th} [k/W]	39.672	°C/W

3.4 STA333IS: 1000 mA output current and 4-layer PCB

Table 10. STA333IS: 1000 mA output current and 4-layer PCB - current measurement

	R_{sense} [mΩ]	V_R_{sense} [mV]	I_Channel [A]	V_{RDS} [mV]	P_{RDS} [mW]	RDS [mΩ]	Vcc [V]	I_Vcc [mA]	Vdd [V]	I_Vdd [mA]
Out 1A	100	101.8	1.018	137	139.466	134.5776	16.58	19.5	3.3	32
Out 1B	100	100.5	1.005	146.5	147.2325	145.77114				
Out 2A	100	101.4	1.014	147.5	149.565	145.46351				
Out 2B	100	101.9	1.019	137	139.603	134.44553				

Table 11. STA333IS: 1000 mA output current and 4-layer PCB - power dissipation

Power_Output [W]	0.57587	W
Power_Vdd [W]	0.1056	W
Power_Vcc [W]	0.32331	W

Figure 5. STA333IS: 1000 mA output current and 4-layer PCB - thermal measurement

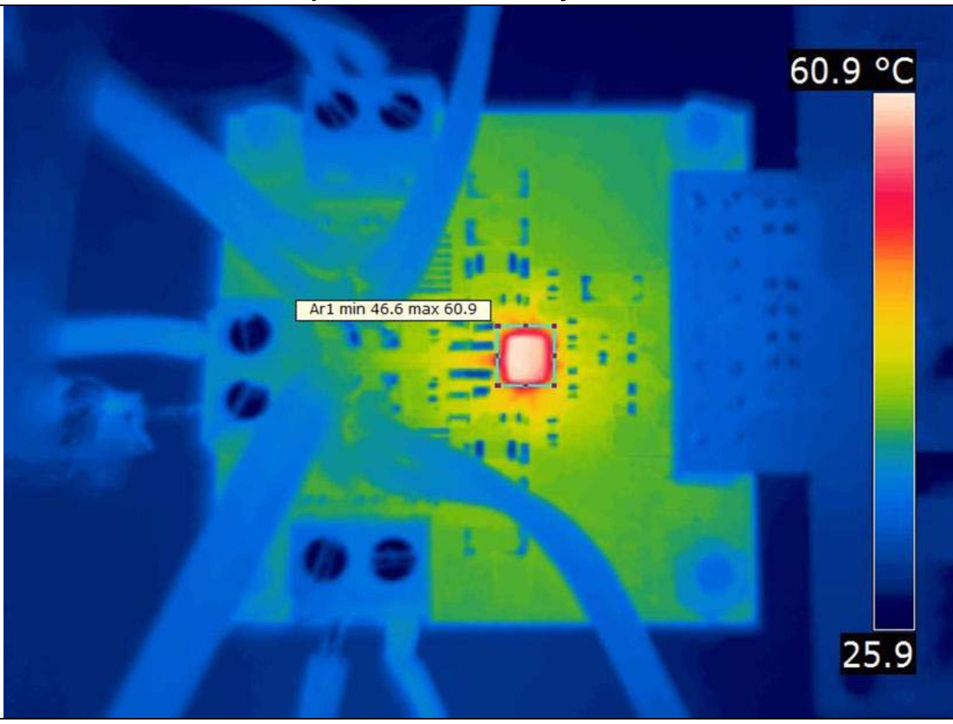


Table 12. STA333IS: 1000 mA output current and 4-layer PCB - summary table

Total power [W]	1.00478	W
Temperature (case) [°C]	60.9	°C
Temperature (ambient) [°C]	26	°C
R_{th} [k/W]	34.734	°C/W

4 Conclusion

This methodology is very simple to implement because it measures only DC current and voltage levels. The result achieved is very reliable.

The flexibility and the easy configurability of the external components allow implementing tests with any output current level, estimating the thermal behavior with the operating condition using the same PCB used in the final application.

Another positive aspect is that this methodology provides an estimation of the combination of RDSon + output PCB tracks. This data is useful for evaluating the proper connection of the output pads or balls.

5 Revision history

Table 13. Document revision history

Date	Revision	Changes
16-Jan-2013	1	Initial release.