Application Report

Understanding Thermal Capabilities of Automotive Class-D Amplifiers

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ABSTRACT

Class-D audio amplifiers have been replacing Class-AB audio amplifiers in many applications. While higher efficiencies are achieved, power dissipated from the amplifier still needs a thermal path to displace the heat generated. This document will go over the basic thermal model, how to calculate Class-D amplifier's thermal capabilities in different thermal solutions, as well as how to design a realistic thermal test for automotive audio applications. This document will then test the TPA6304-Q1 under common thermal test conditions used across the automotive industry. While the TPA6304-Q1 is used as an example, the materials covered in this document are relevant for all Class-D amplifiers in testing and determining their thermal limits.

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Trademarks

1 Introduction

In semiconductors, power losses are the result of inherent impedances in the device. These power losses are converted into heat and cannot be ignored. The same is true for integrated Class-D amplifiers. To remove this heat either the PCB or a top-mounted heatsink attached to the device. If the thermal solution is not properly designed for the required conditions, the audio amplifier can experience reduced performance and potentially trigger the thermal protection.

2 Understanding the Thermal Flow

The equation used for calculating the thermal dissipation of a system is shown in Equation 1:

$$\theta_{JA} = (T_J - T_A)/P_D \tag{1}$$

Where:

- θ_{JA} = thermal resistance
- T_J = junction temperature
- T_A = ambient temperature
- P_D = power dissipation

θ_{JA} represents the thermal resistance path(s) where the heat will flow out of the amplifier to relatively cooler surroundings. There are two paths where the heat generated from the device can go. As seen in Figure 2-1, for top-mounted heatsinks, heat can escape from the junction to the thermal pad (case), then to the thermal interface material. From the thermal interface material the heat goes to the heatsink, then through the heatsink to the surrounding air. The second path is from the junction to the board, then from the board to surrounding air.

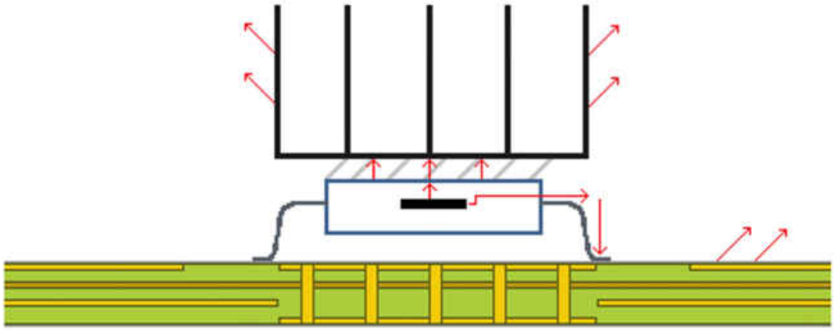


Figure 2-1. Thermal Model

Using thermal dissipation equations, the thermal model seen in Figure 2-1 can be represented as shown in Figure 2-2 where:

- θ_{JC} = thermal resistance of the device from the junction to the case
- θ_{CH} = thermal resistance of the interface compound
- θ_{HA} = thermal resistance of the heatsink
- θ_{JB} = thermal resistance of the device from the junction to the board
- θ_{BA} = thermal resistance of the board

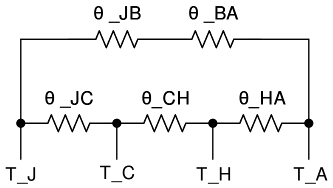


Figure 2-2. Thermal Resistance Model

This can be simplified as the majority of the heat from the device will be going through the case into the heatsink rather than from the package to the board as θ_{JC}, θ_{CH}, and θ_{HA} have a much lower combined thermal resistance to that of θ_{JB} and θ_{BA}. The simplified thermal resistance model is shown in Figure 2-3.

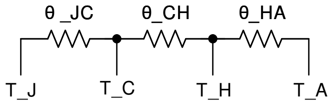


Figure 2-3. Simplified Thermal Resistance Model

With the simplified thermal resistance model, the thermal dissipation equation can be written as:

$$\theta_{JA} = \theta_{JC} + \theta_{CH} + \theta_{HA} \quad (2)$$

Since θ_{JC} represents the intrinsic thermal properties between the junction and case of the device, it cannot be changed. θ_{CH} and θ_{HA} will vary greatly from system to system depending on the materials chosen for the heatsink, weight and shape of the heatsink, thickness of the thermal gap filler, and the thermal resistance of the thermal gap filler.

3 Understanding the Test and System Conditions

3.1 Device Efficiency

Before designing the thermal solution, its critical to understand what the expected power losses will be from the amplifier. As seen in Figure 3-1 and Figure 3-2, the TPA6304-Q1 is efficient at higher power levels, but the power dissipation is not negligible. More details on the test conditions for these efficiency and power dissipation plots can be found in the TPA6304-Q1 data sheet.

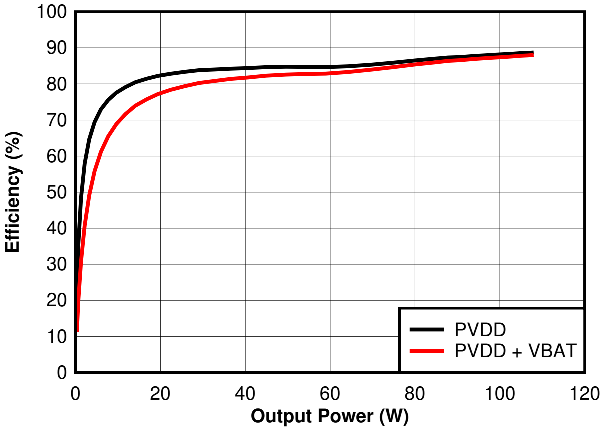


Figure 3-1. TPA6304-Q1 Efficiency vs Output Power - 4 Ω

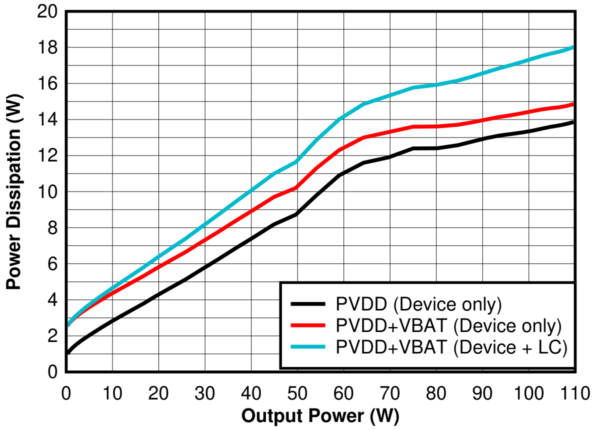


Figure 3-2. Power Dissipation vs Output Power - 4 Ω

Figure 3-2 shows how PVDD, VBAT, and the LC filters change the total power dissipation of the system. For calculating the thermal dissipation into the heatsink, the power loss from the LC filter should be ignored as most systems will have the inductors dissipate their generated heat into the PCB rather than into the heatsink. All of the calculations shown in the rest of this document will be assuming that the heat generated by the inductors will not be dissipated by the heatsink.

3.2 Test Signals

When testing an audio amplifier's thermal performance, there are three common types of signals used; sinusoidal, pink noise, and music.

3.2.1 Sinusoidal Signal

The most commonly seen input signal used for thermal tests are sinusoidal signals, usually running continuously at 100Hz or 1kHz. Sinusoidal signals have an advantage for testing since it's easy to track what the output power coming out of the amplifier is due to its continuous nature.

With a truly continuous output power rather than an average continuous power, sinusoidal signals make for a more strenuous tests compared to the other common signals. This also makes it the least representable to what most people will be using their audio systems.

3.2.2 Pink Noise

Pink noise is another commonly seen input signal used for thermal tests. Pink noise is a type of noise signal where each octave interval carries an equal amount of energy. One advantage of using pink noise is that it better simulates the various levels of dynamic range in music signals as well as testing the device across different frequencies.

Pink noise, unlike sinusoidal signals, can have a varying crest factor. The crest factor is the difference between the peak value to the RMS value in the waveform.

3.2.3 Music File

The final common signal used for thermal tests are specific music files, usually played on a continuous loop for a set amount of time.

Due to the unstandardized nature of music, this type of test signal was not used in the thermal tests.

3.3 Ambient Temperature

The temperatures in a car can fluctuate drastically depending on the time of the year, geographical location the car is, and the location of the amplifier in the vehicle. This is why automotive devices need to be able to operate within a larger range of temperatures. While 25°C is a commonly used ambient temperature, in automotive, 75°C-85°C is typically the ambient temperature for thermal tests. This creates a more streneous test condition as the ambient is closer to the maximum operating junction temperature of the amplifier.

3.4 Junction Temperature

When designing a thermal solution, it is important to consider what the maximum temperature the device/ junction is allowed to reach. It is recommended to choose one of the overtemperature warnings (OTW) as the maximum temperature threshold rather than the overtemperature shutdown (OTSD) threshold. Any OTSD event will prevent customers from listening to their audio. By choosing an OTW point, the device will not have to shutdown from reaching the OTSD temperature.

3.5 Thermal Interface Material and Heatsink

The final factor for determining the device's thermal capabilities within a system is the materials used for the thermal dissipation path. This path consists of the thermal interface material and the heatsink. The thermal resistive properties of these materials will have a direct result on the maximum output power the amplifier can drive without shutting down.

An easy way to determine what the maximum thermal resistance allowed from θ_{CH} and θ_{HA} is by looking at Equation 1 and Equation 2. Merging both equations gives the following:

$$(T_J - T_A)/P_D = \theta_{JC} + \theta_{CH} + \theta_{HA} \tag{3}$$

Simplifying it further by having $\theta_{CA} = \theta_{CH} + \theta_{HA}$ gives the following equation:

$$(T_J - T_A)/P_D = \theta_{JC} + \theta_{CA} \tag{4}$$

Using this formula in an example where the total output power desired is 80W into 4Ω loads with an ambient temperature set at 75°C. At 80W output power, the power dissipation will be approximately 13.6W. Using θ_{JC} = 0.6 °C/W and deciding that the junction temperature should never rise above 130°C , θ_{CA} can be found by:

$$(130 - 75)/13.6 = 0.6 + \theta_{CA}$$

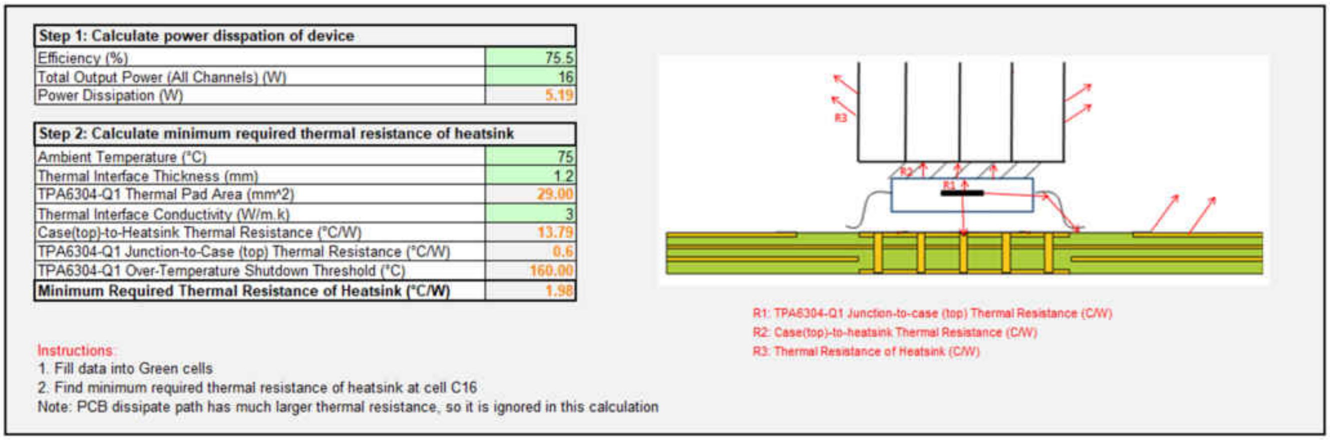
$$\theta_{CA} = 3.44°C/W$$

Thus, the total thermal resistance of the thermal solution cannot be higher than 3.44°C/W.

4 Calculating Dynamic Thermal Dissipation

The *TPA6304-Q1 Thermal Design* is an easy to use tool that was created to help design a thermal solution. There are two tabs in the excel document.

The first tab, as seen in Figure 4-1, is called the *Calculate Minimum Resistance of Heatsink*. As the name implies, this tool is used to help determine what the minimum thermal resistance of the heatsink is needed for specific output power, ambient temperature, and thermal interface.



Step 1: Calculate power disspation of device	
Efficiency (%)	75.5
Total Output Power (All Channels) (W)	16
Power Dissipation (W)	5.19

Step 2: Calculate minimum required thermal resistance of heatsink	
Ambient Temperature (°C)	75
Thermal Interface Thickness (mm)	1.2
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	3
Case(top)-to-Heatsink Thermal Resistance (°C/W)	13.79
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.6
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Minimum Required Thermal Resistance of Heatsink (°C/W)	1.98

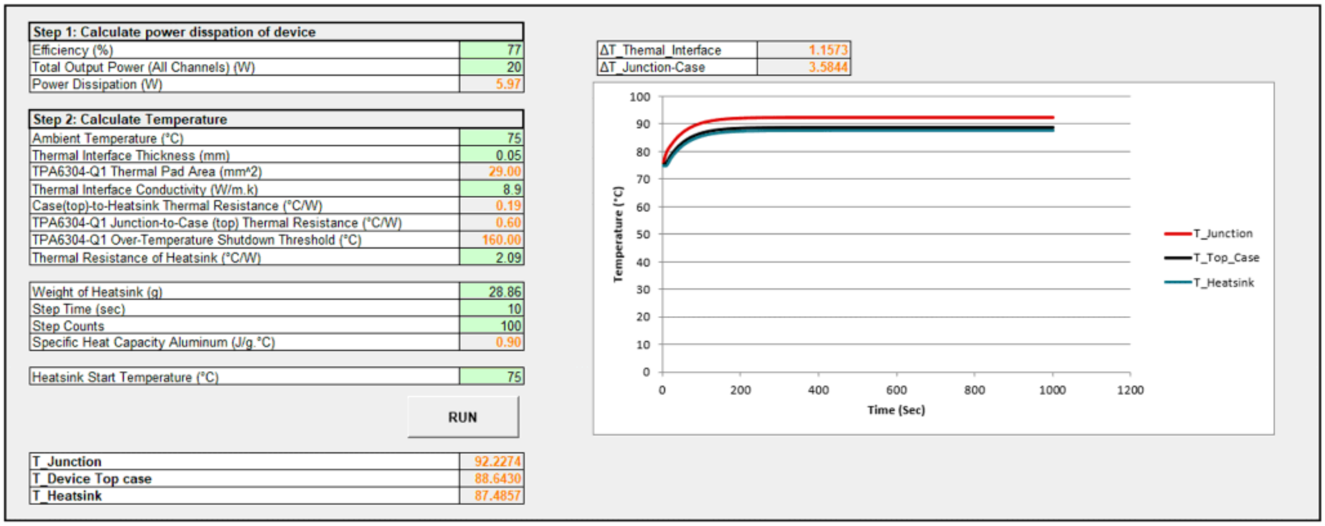
Instructions:
1. Fill data into Green cells
2. Find minimum required thermal resistance of heatsink at cell C16
Note: PCB dissipate path has much larger thermal resistance, so it is ignored in this calculation

R1: TPA6304-Q1 Junction-to-case (top) Thermal Resistance (C/W)
R2: Case(top)-to-heatsink Thermal Resistance (C/W)
R3: Thermal Resistance of Heatsink (C/W)

Figure 4-1. Display of the Calculate Minimum Resistance of Heatsink Tab

This tool is very helpful for quickly determining how variables such as thickness of a thermal interface, thermal interface conductivity, ambient temperature, and output power affect the needed thermal resistance of the heatsink.

The second tab, called *Calculate Temperature*, calculates the temperatures over time of the junction, case, and heatsink when running the TPA6304-Q1 under specific test conditions. The user interface is shown in Figure 4-2.



Step 1: Calculate power disspation of device	
Efficiency (%)	77
Total Output Power (All Channels) (W)	20
Power Dissipation (W)	5.97

Step 2: Calculate Temperature	
Ambient Temperature (°C)	75
Thermal Interface Thickness (mm)	0.05
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	8.9
Case(top)-to-Heatsink Thermal Resistance (°C/W)	0.19
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.60
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Thermal Resistance of Heatsink (°C/W)	2.09

Weight of Heatsink (g)	28.86
Step Time (sec)	10
Step Counts	100
Specific Heat Capacity Aluminum (J/g.°C)	0.90

Heatsink Start Temperature (°C)	75

T_Junction	92.2274
T_Device Top case	88.6430
T_Heatsink	87.4857

ΔT_Thermal_Interface	1.1573
ΔT_Junction-Case	3.5844

Figure 4-2. Display of the Calculate Temperature Tab

To run the dynamic calculation model, the following variables are needed:

- Efficiency
- Total Output Power (all four channels)
- Ambient Temperature
- Thermal Interface Thickness
- Thermal Interface Conductivity
- Thermal Resistance of the Heatsink
- Weight of the Heatsink
- Heatsink Start Temperature

Once those values are inserted, press the *Run* button for the calculations to run. When completed, the graph will update with the new temperature over time curves.

5 Designing a Realistic Thermal Test

When determining how to design a thermal test, the first thing to consider is how most users will use the device. In most situations the end user will run music and voice signals through the audio amplifiers. Music and voice audio signals are not at a single continuous power level, these signals are dynamically changing. Creating a realistic and challenging thermal test, should be designed not for continuous peak power but rather the expected average power, or slightly above it. For most audio systems in cars, this average output power per channel is between 4W to 10W into a 4Ω speaker.

Looking for θ_{CA} with 4W per channel, 4Ω loads, the total power dissipation in the TPA6304-Q1 will be about 5.19W. Assuming the junction temperature and ambient temperature is 130°C and 75°C, respectively:

$$\theta_{CA} = (130 - 75)/5.19 - 0.6 = 10°C/W$$

Now to find θ_{CA} for the same conditions except for 10W per channel and 9W of power dissipated:

$$\theta_{CA} = (130 - 75)/9 - 0.6 = 5.5°C/W$$

The maximum allowed thermal resistance of the thermal dissipation material nearly doubles when going from 10W per channel to 4W per channel. Designing for 10W per channel continuous output power will require a more thermally conductive solution than one used for the 4W per channel.

6 Thermal Tests

6.1 Test Setup

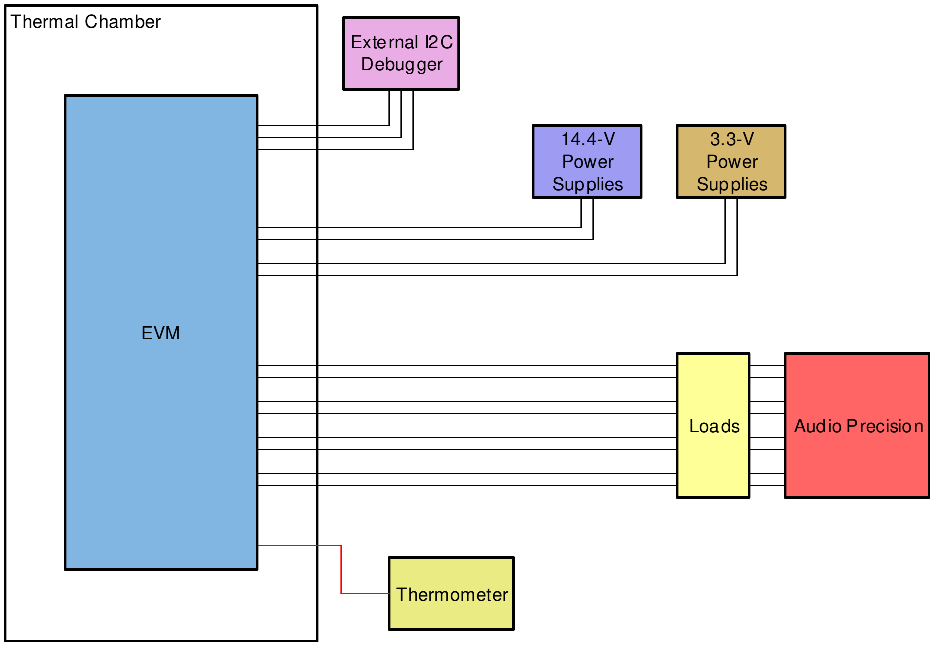


Figure 6-1. Block Diagram of Setup

For each thermal test, the TPA6304Q1EVM was used with the default heatsink (θ_{HA} = 2.09°C/W) and Arctic Silver 5 (θ_{CH} = 0.19°C/W) is used as the thermal interface.

There were several modifications done to the TPA6304Q1EVM before testing. Referencing to Figure 6-2, Figure 6-3, and Figure 6-4 the LM1086IT-3.3 was bypassed by removing L11 and plugging in a separate 3.3V supplies. The XMOS controller was disabled using S2 and removing the jumper on J3. This was done to remove any additional heat that would have been generated from those devices and could distort the thermal measurements of the audio amplifier.

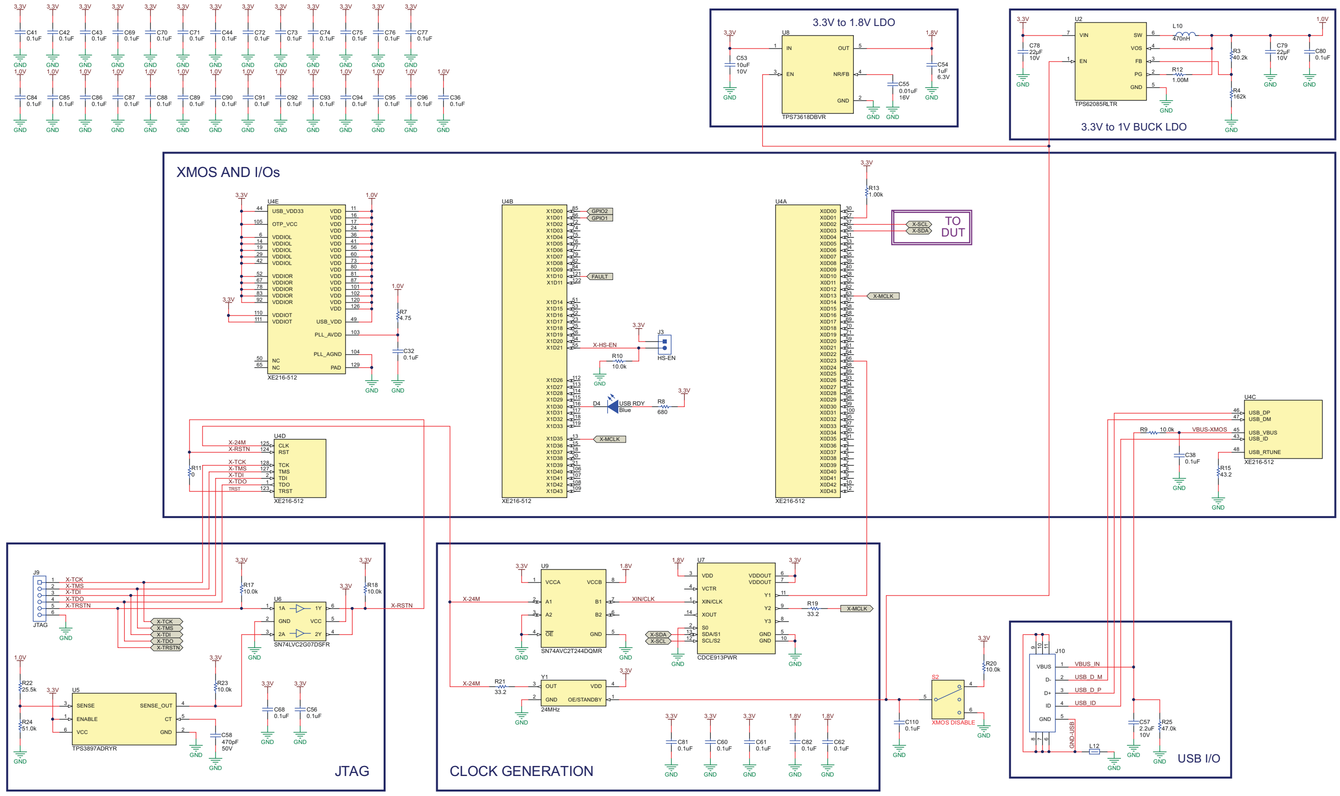


Figure 6-2. TPA6304Q1EVM Schematic (Page 1)

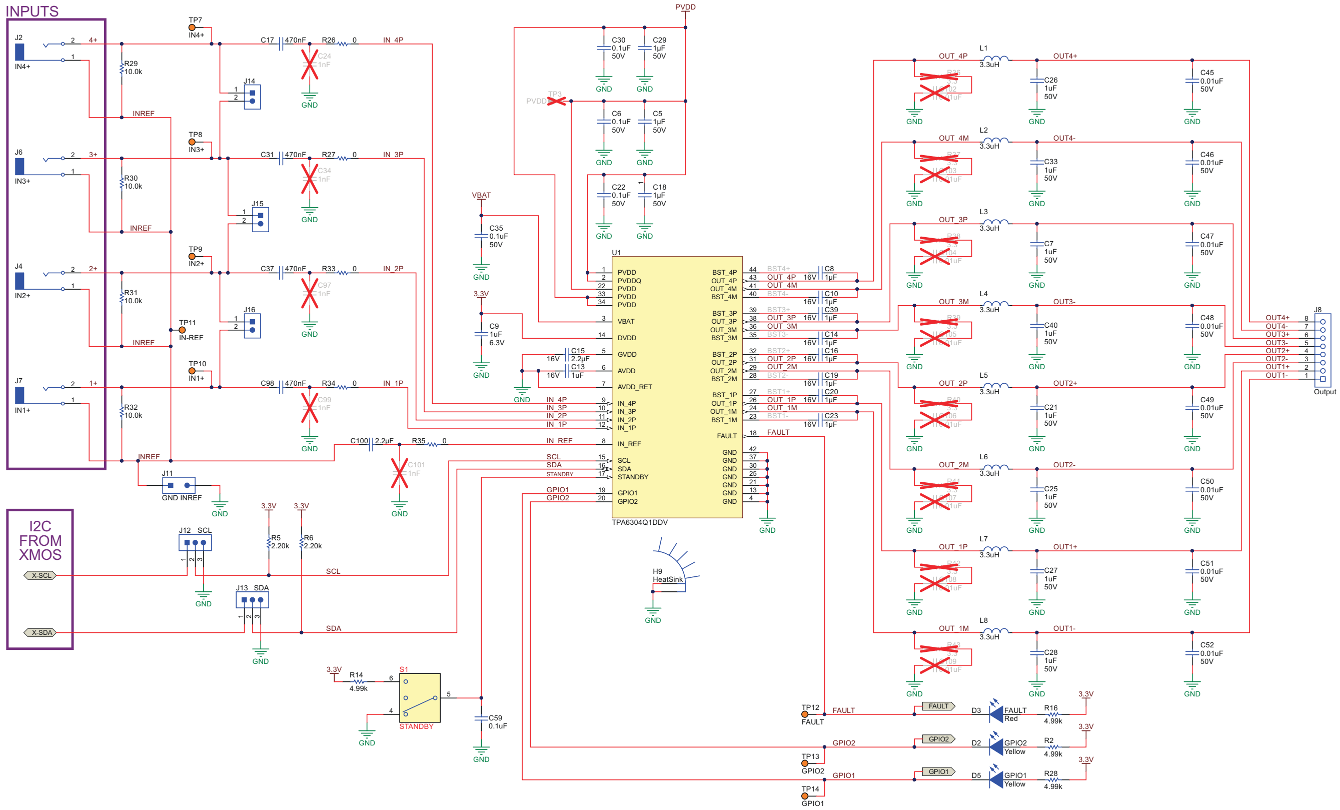


Figure 6-3. TPA6304Q1EVM Schematic (Page 2)

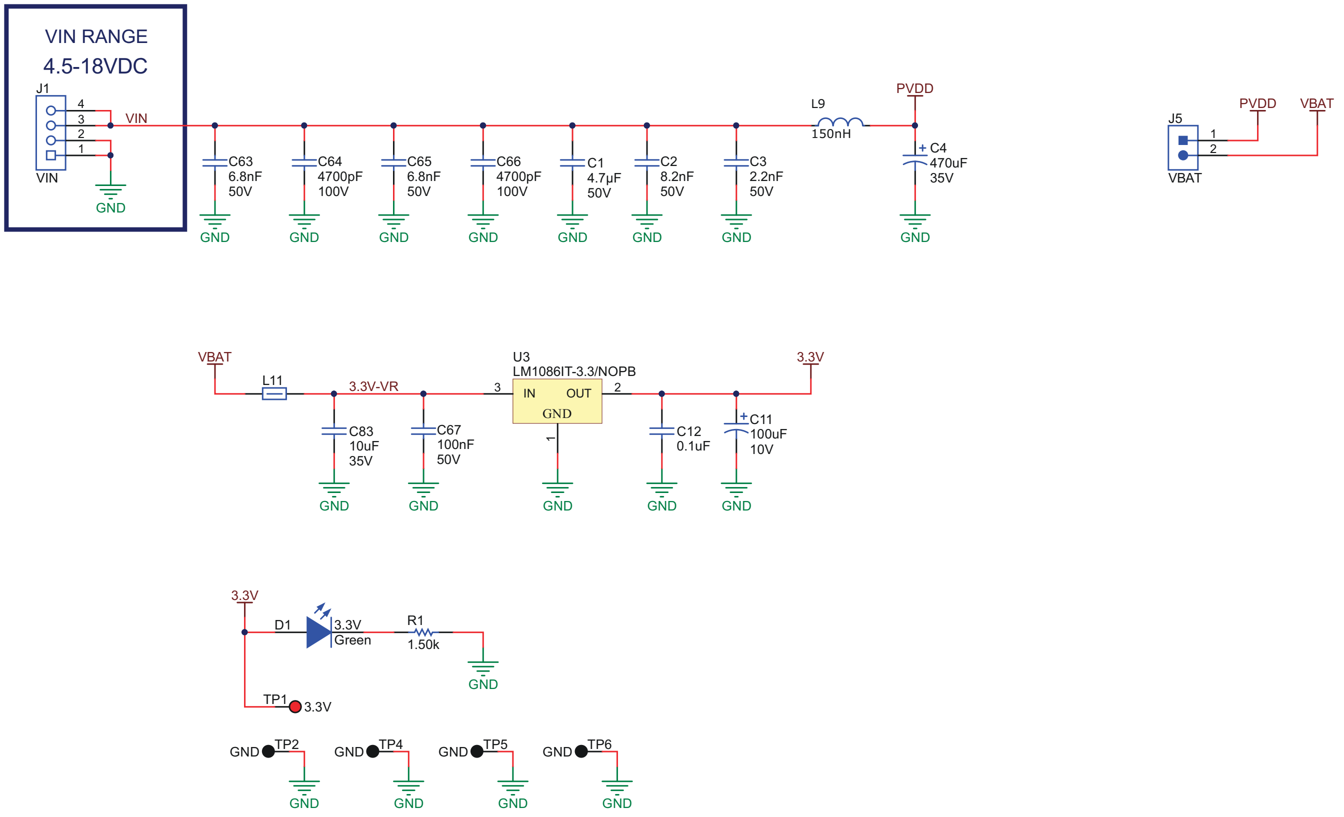


Figure 6-4. TPA6304Q1EVM Schematic (Page 3)

To monitor the temperature of the device case, a hole was drilled in the center of the heatsink large enough to place a thermocouple sensor, as seen in Figure 6-5. This thermocouple checks the temperature of the case's thermal pad over the course of the test and determines when the device reaches thermal equilibrium.

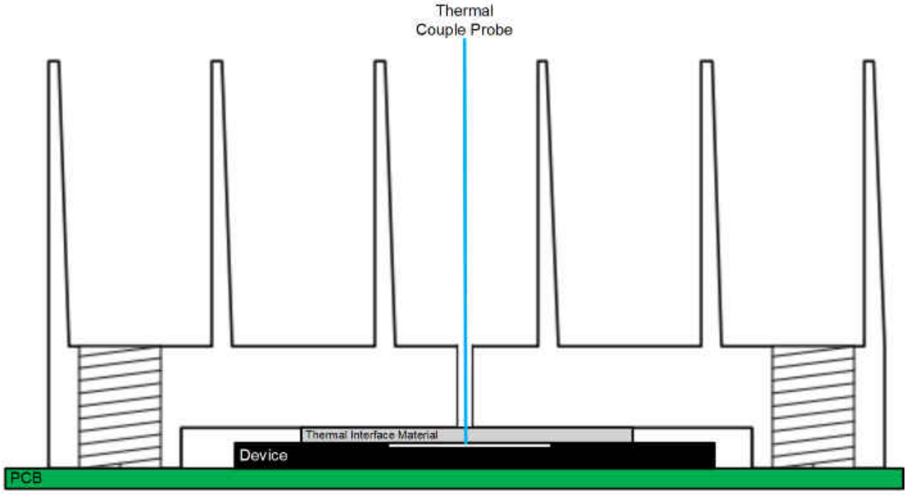


Figure 6-5. Cross-Sectional View of the System

The test will run until the system reaches thermal equilibrium. Thermal equilibrium was defined in these tests as a temperature change of less than 1°C after 10 minutes.

To ensure that the ambient temperature on the heatsink remained consistent, the test was taken in a thermal chamber.

6.2 5W 1kHz Sine Wave Test

Conditions:

- PVDD Voltage: 14.4V
- Load: 4Ω
- All Channels in PLAY Mode
- Input Signal: 1kHz Sine Wave
- Ambient Temperature: 75°C
- Continuous Output Power: 5W
- Thermal Gain Foldback: Disabled

6.2.1 Calculations

Rearrange Equation 4 to find T_J:

$$T_J = (\theta_{JC} + \theta_{CA}) \times P_D + T_A = (0.6 + 2.28) \times 5.97 + 75 = 92.2°C$$

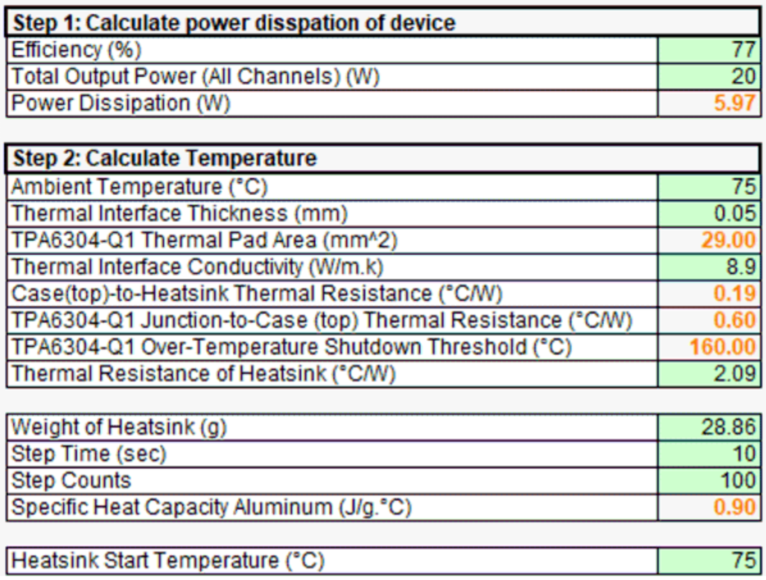
With T_J found, T_C can be found using Equation 1 but with θ_{JC} instead of θ_{JA}:

$$T_C = T_J - \theta_{JC} \times P_D = 92.2 - 0.6 \times 5.97 = 88.6°C$$

The expected value of T_J and T_C are 92.2°C and 88.6°C respectively.

6.2.2 Dynamic Calculation Results

The *TPA6304-Q1 Thermal Design* is used to calculate the dynamic thermal performance of the system.



Step 1: Calculate power disspation of device	
Efficiency (%)	77
Total Output Power (All Channels) (W)	20
Power Dissipation (W)	5.97
Step 2: Calculate Temperature	
Ambient Temperature (°C)	75
Thermal Interface Thickness (mm)	0.05
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	8.9
Case(top)-to-Heatsink Thermal Resistance (°C/W)	0.19
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.60
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Thermal Resistance of Heatsink (°C/W)	2.09
Weight of Heatsink (g)	28.86
Step Time (sec)	10
Step Counts	100
Specific Heat Capacity Aluminum (J/g.°C)	0.90
Heatsink Start Temperature (°C)	75

Figure 6-6. Dynamic Calculation Table

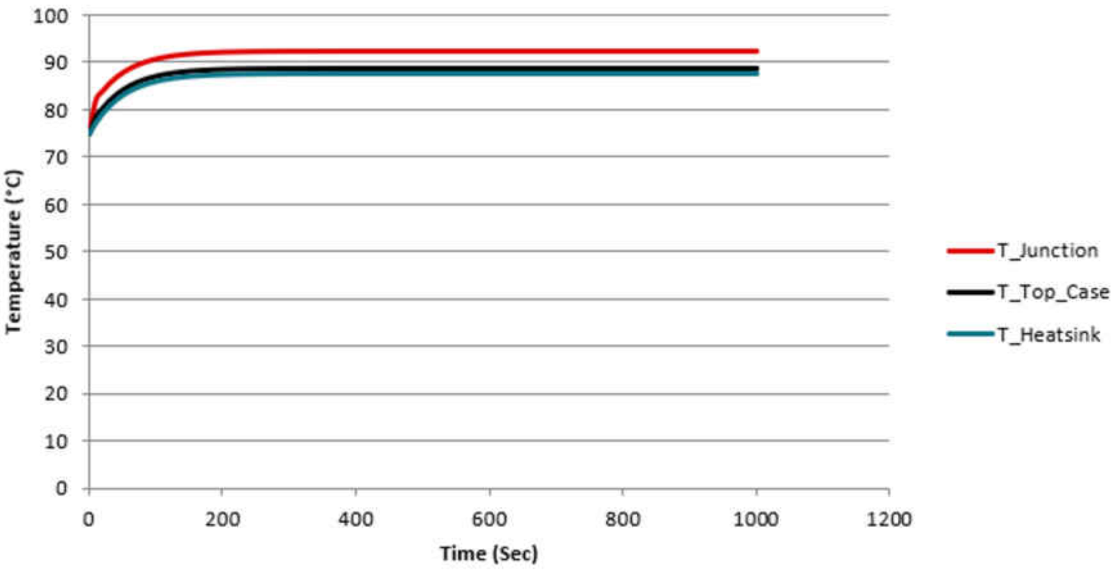


Figure 6-7. Dynamic Calculation Results: 5W 1kHz Sine Wave Temperature Over Time

Temperatures at thermal equilibrium:

- Junction Temperature = 92.2°C
- Case Temperature = 88.6°C
- Heatsink Temperature = 87.5°C

6.2.3 Tested Results

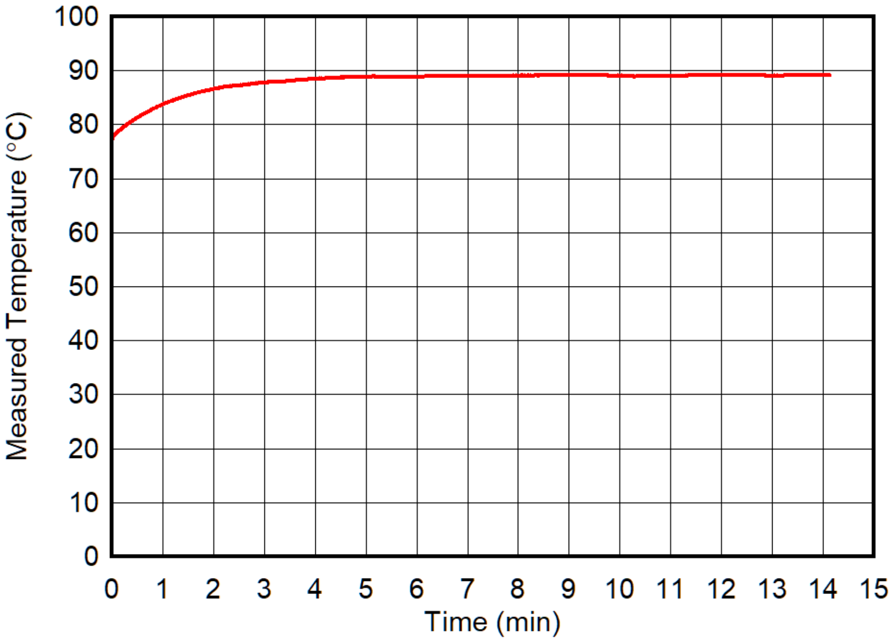


Figure 6-8. Tested Results: 5W 1kHz Sine Wave Case Temperature Over Time

6.2.4 Summary of Results

In the real world test, the case temperature settled at about 89.1°C. The case temperature tracked very closely with the calculation and dynamic calculation results, with both calculation data being about 3.1°C degrees hotter.

6.3 10W 1kHz Sine Wave Test

Conditions:

- PVDD Voltage: 14.4V
- Load: 4Ω
- All Channels in PLAY Mode
- Input Signal: 1kHz Sine Wave
- Ambient Temperature: 75°C
- Continuous Output Power: 10W
- Thermal Gain Foldback: Disabled

6.3.1 Calculations

Rearrange Equation 4 to find T_J:

$$T_J = (\theta_{JC} + \theta_{CA}) \times P_D + T_A = (0.6 + 2.28) \times 8.96 + 75 = 100.8°C$$

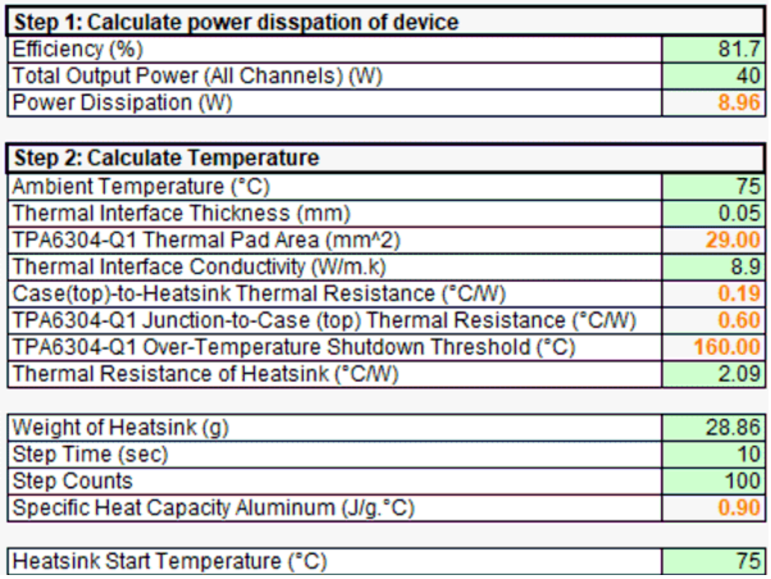
With T_J found, T_C can be found using Equation 1 but with θ_{JC} instead of θ_{JA}:

$$T_C = T_J - \theta_{JC} \times P_D = 100.8 - 0.6 \times 8.96 = 95.4°C$$

So the expected value of T_J and T_C are 100.8°C and 95.4°C respectively.

6.3.2 Dynamic Calculation Results

The *TPA6304-Q1 Thermal Design* is used to calculate the dynamic thermal performance of the system.



Step 1: Calculate power disspation of device	
Efficiency (%)	81.7
Total Output Power (All Channels) (W)	40
Power Dissipation (W)	8.96

Step 2: Calculate Temperature	
Ambient Temperature (°C)	75
Thermal Interface Thickness (mm)	0.05
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	8.9
Case(top)-to-Heatsink Thermal Resistance (°C/W)	0.19
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.60
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Thermal Resistance of Heatsink (°C/W)	2.09

Weight of Heatsink (g)	28.86
Step Time (sec)	10
Step Counts	100
Specific Heat Capacity Aluminum (J/g.°C)	0.90

Heatsink Start Temperature (°C)	75

Figure 6-9. Dynamic Calculation Table

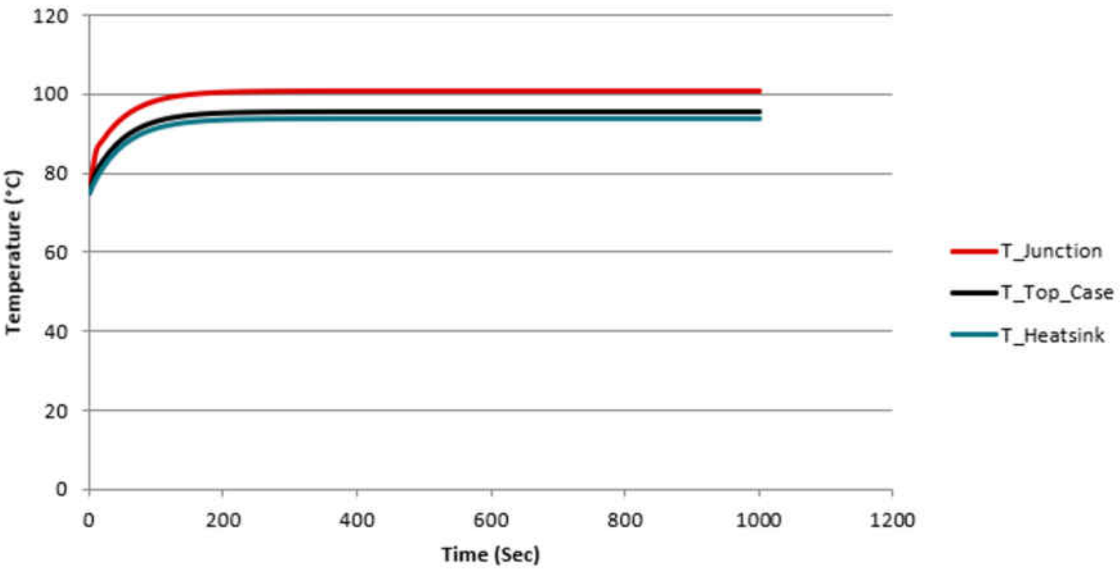


Figure 6-10. Dynamic Calculation Results: 10W 1kHz Sine Wave Temperature Over Time

Temperatures at thermal equilibrium:

- Junction Temperature = 100.8°C
- Case Temperature = 95.5°C
- Heatsink Temperature = 93.7°C

6.3.3 Tested Results

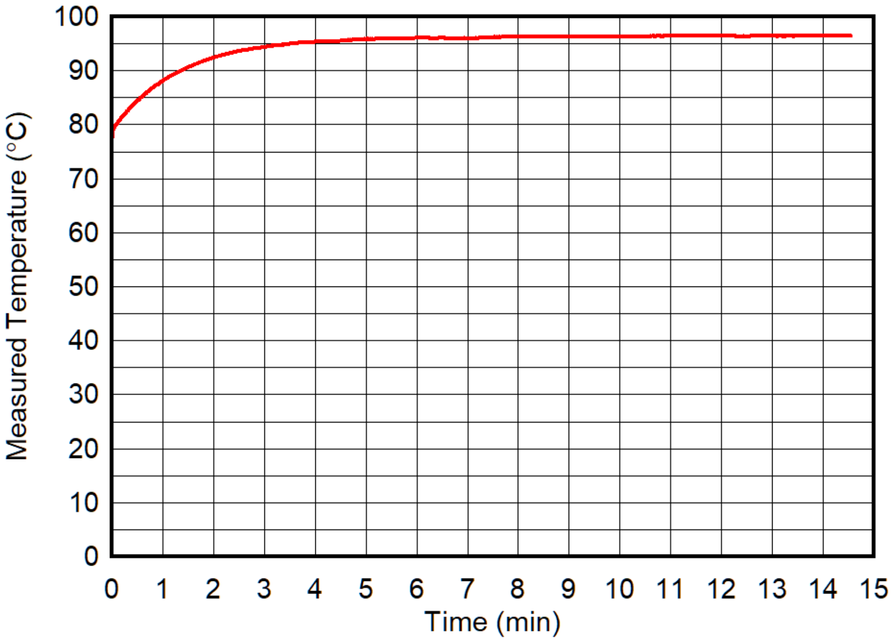


Figure 6-11. Tested Results: 10W 1kHz Sine Wave Case Temperature Over Time

6.3.4 Summary of Results

In the real world test, the case temperature settled at about 96.4°C, which was about a degree off compared to the calculation and dynamic calculation results. As expected, the case temperature rose higher than in the 5W test since there's a higher amount of power being dissipated.

6.4 5W Pink Noise Test

Conditions:

- PVDD Voltage: 14.4V
- Load: 4Ω
- All Channels in PLAY Mode
- Input Signal: Pink Noise
- Ambient Temperature: 75°C
- Average Output Power: 5WCrest Factor: 6dB
- Thermal Gain Foldback: Disabled

6.4.1 Calculations

In the previous tests, the calculations used the average output power of a 1kHz sine wave. This will be the same for pink noise calculations. Rearrange Equation 4 to find T_J:

$$T_J = (\theta_{JC} + \theta_{CA}) \times P_D + T_A = (0.6 + 2.28) \times 5.97 + 75 = 92.2°C$$

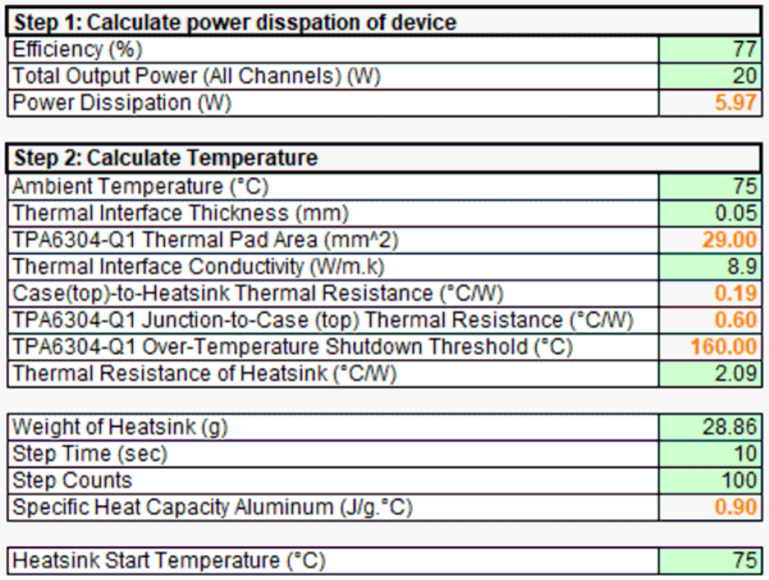
With T_J found, T_C is found using Equation 1 but with θ_{JC} instead of θ_{JA}:

$$T_C = T_J - \theta_{JC} \times P_D = 92.2 - 0.6 \times 5.97 = 88.6°C$$

So the expected value of T_J and T_C are 92.2°C and 88.6°C respectively.

6.4.2 Dynamic Calculation Results

The *TPA6304-Q1 Thermal Design* is used to calculate the dynamic thermal performance of the system. For the total output power calculation, the average output power (5W per channel) is used.



Step 1: Calculate power disspation of device	
Efficiency (%)	77
Total Output Power (All Channels) (W)	20
Power Dissipation (W)	5.97

Step 2: Calculate Temperature	
Ambient Temperature (°C)	75
Thermal Interface Thickness (mm)	0.05
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	8.9
Case(top)-to-Heatsink Thermal Resistance (°C/W)	0.19
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.60
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Thermal Resistance of Heatsink (°C/W)	2.09

Weight of Heatsink (g)	28.86
Step Time (sec)	10
Step Counts	100
Specific Heat Capacity Aluminum (J/g.°C)	0.90

Heatsink Start Temperature (°C)	75

Figure 6-12. Dynamic Calculation Table

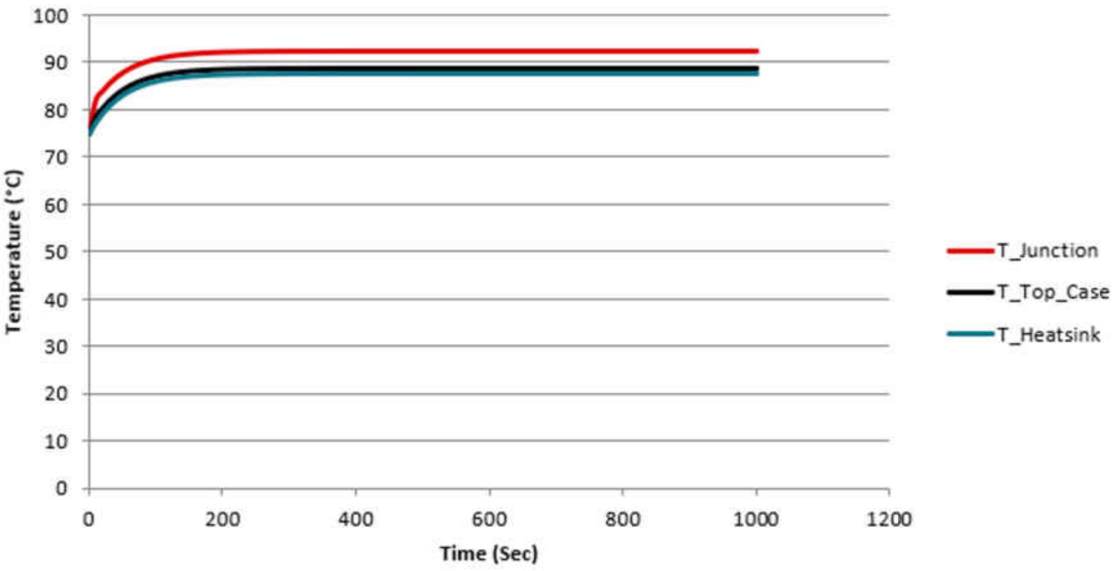


Figure 6-13. Dynamic Calculation Results: 5W Pink Noise Temperature Over Time

Temperatures at thermal equilibrium:

- Junction Temperature = 92.2°C
- Case Temperature = 88.6°C
- Heatsink Temperature = 87.5°C

6.4.3 Tested Results

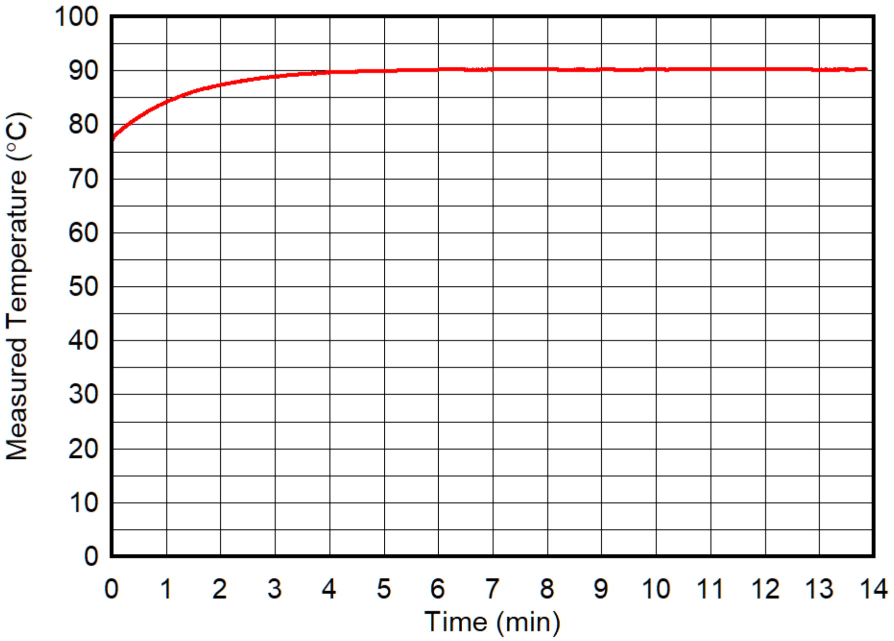


Figure 6-14. Tested Results: 5W Pink Noise Case Temperature Over Time

6.4.4 Summary of Results

The real world test results for 5W peak noise came out to be similar to the 5W sine wave test. The case temperature reached about 90.1°C, a degree hotter than the 5W sine wave test.

6.5 10W 1kHz 85°C Test

Conditions:

- PVDD Voltage: 14.4V
- Load: 4Ω
- All Channels in PLAY Mode
- Input Signal: 1kHz Sine Wave
- Ambient Temperature: 85°C
- Continuous Output Power: 10W
- Thermal Gain Foldback: Disabled

6.5.1 Calculations

Rearrange Equation 4 to find T_J:

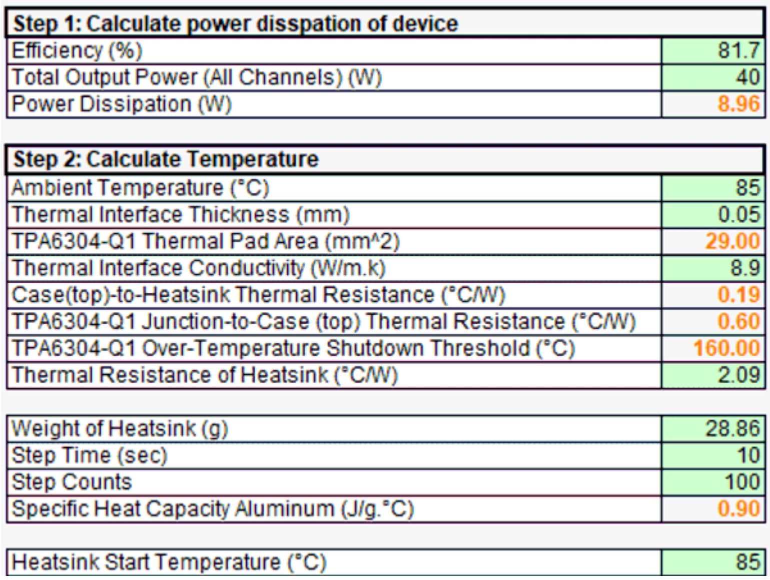
$$T_J = (\theta_{JC} + \theta_{CA}) \times P_D + T_A = (0.6 + 2.28) \times 9 + 85 = 110.9°C$$

With T_J found, T_C can be found using Equation 1 but with θ_{JC} instead of θ_{JA}:

$$T_C = T_J - \theta_{JC} \times P_D = 100.9 - 0.6 \times 9 = 105.5°C$$

The expected value of T_J and T_C are 110.9°C and 105.5°C respectively.

6.5.2 Dynamic Calculation Results



Step 1: Calculate power disspation of device	
Efficiency (%)	81.7
Total Output Power (All Channels) (W)	40
Power Dissipation (W)	8.96

Step 2: Calculate Temperature	
Ambient Temperature (°C)	85
Thermal Interface Thickness (mm)	0.05
TPA6304-Q1 Thermal Pad Area (mm^2)	29.00
Thermal Interface Conductivity (W/m.k)	8.9
Case(top)-to-Heatsink Thermal Resistance (°C/W)	0.19
TPA6304-Q1 Junction-to-Case (top) Thermal Resistance (°C/W)	0.60
TPA6304-Q1 Over-Temperature Shutdown Threshold (°C)	160.00
Thermal Resistance of Heatsink (°C/W)	2.09

Weight of Heatsink (g)	28.86
Step Time (sec)	10
Step Counts	100
Specific Heat Capacity Aluminum (J/g.°C)	0.90

Heatsink Start Temperature (°C)	85

Figure 6-15. Dynamic Calculation Table

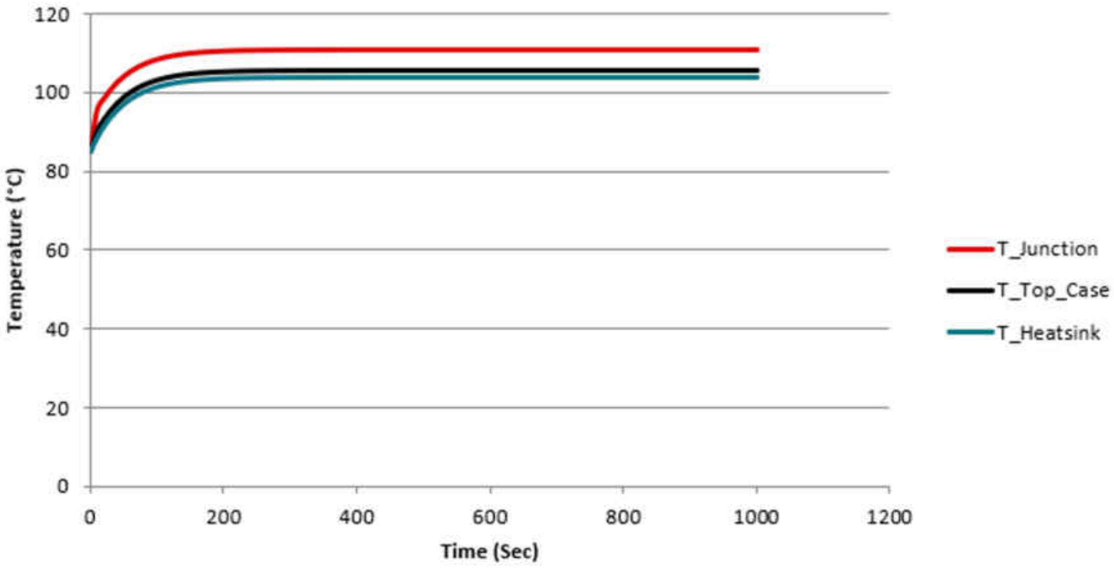


Figure 6-16. Dynamic Calculation Results: 10W 1kHz 85°C Temperature Over Time

Temperatures at thermal equilibrium:

- Junction Temperature = 110.8°C
- Case Temperature = 105.5°C
- Heatsink Temperature = 103.7°C

6.5.3 Tested Results

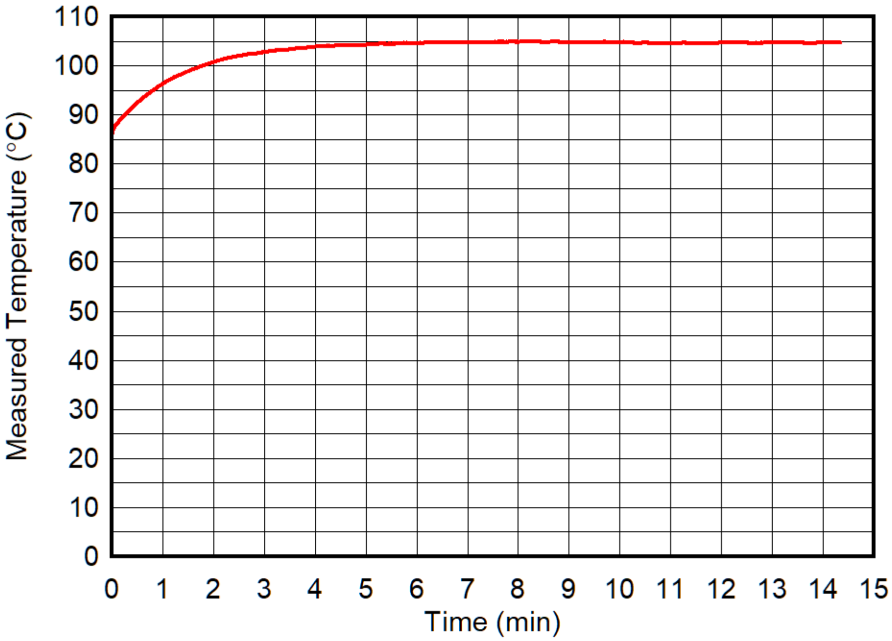


Figure 6-17. Tested Results: 10W 1kHz 85°C Case Temperature Over Time

6.5.4 Summary of Results

In the real world test, the case temperature reached 104.7°C at thermal equilibrium. This was less than a degree cooler from the case temperature found in both the calculation and dynamic calculation results. It was also 8 degrees hotter than the 10W per channel, 75°C ambient test, aligning closely to what is expected when starting 10 degrees hotter.

7 Overall Summary

The TPA6304-Q1 performed each test without reaching thermal shutdown. While successful here, if used in a system that cannot dissipate the heat quick enough, the device could enter shutdown, even under the same test conditions. This is why it is important to consider how the audio amplifier will be used and then design a thermal solution around it.

8 References

- Texas Instruments, *Semiconductor and IC Package Thermal Metrics* application report.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (June 2018) to Revision A (June 2021)	**Page**
• Corrected calculations	8

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