

CS4525 Power Calculator

1. OVERVIEW

The CS4525 Power Calculator provides many important application-specific performance numbers for the CS4525 based on user-supplied design parameters. The Power Calculator uses first-order approximations to serve as a guideline in designing new applications featuring the CS4525. The Power Calculator assumes that all applications follow Cirrus Logic's recommended layout considerations and guidelines for the CS4525. It is important to note that deviation from these recommendations in an application may result in a discrepancy between the calculator's predictions and the application's results.

In particular, the thermal performance calculations are based off specific printed circuit board (or "PCB") models using standard a Flame Resistant 4 ("FR-4") laminate, plated vias, and a minimum PCB area of 4 square inches.

For Cirrus Logic's recommended layout considerations for the CS4525, please refer to the CS4525 data sheet. For examples of Cirrus Logic's recommended layouts, please refer to the CRD4525-D1 and CRD4525-Q1 datasheets. For Cirrus Logic's guidelines concerning the thermal considerations of QFN packages, please refer to Cirrus Logic application note AN315.

2. DESIGN PARAMETERS

The first window of the CS4525 Power Calculator contains the Design Parameters fields. These fields characterize the application. A default value for each parameter is shown in the orange box. Alternatively, the user can enter in their own value in the adjacent yellow box to override that value. Some fields will only accept certain values as inputs. If the user enters an invalid value, they will be prompted and forced to either enter in a valid value or erase their entry to revert back to the default value.

Design Parameters	Value		Unit	Description
	Default	Override		
VP Supply Voltage	16.5	15	Volts	High-power supply to the amplifier
Load Impedance	8		Ohms	Nominal impedance of the output loads
Amplifier Configuration	Full-bridge			Output channel configuration of the CS4525
Number of PCB Layers	4	2		Number of layers on the CS4525's PCB
Copper Thickness	1		Ounces	Thickness of each copper layer of PCB
PCB Material	FR4			Insulative material of PCB
Ambient Temperature	25	35	°C	Ambient temperature surrounding the CS4525
Rated Output Power	100%		%	Rated output power relative to 10% THD power

Figure 1. Example Usage of the Design Parameters Window

2.1 Application Design Parameters

The VP Supply Voltage, Load Impedance, and Amplifier Configuration characterize the amplifier's electrical operating conditions. These parameters will directly affect the audio performance.

2.1.1 VP Supply Voltage

This is the voltage applied to the VP pins. The calculator assumes the VP source to have minimal series resistance; if the series resistance is high, it can cause a significant DC voltage drop. The calculator does not account for supply tolerance or ripple.

2.1.2 Load Impedance

This is the nominal impedance of the load. It is recommended to use a standard value of either 4 Ω , 6 Ω , or 8 Ω here. However, the calculator will function with any value. The calculator assumes this load is purely resistive.

2.1.3 Amplifier Configuration

This is the amplifier configuration. There are three possible amplifier configurations to choose from: half-bridge, full-bridge, and parallel full-bridge. For more details about each of these configurations and the amplifier's capabilities, please refer to the CS4525's data sheet.

2.2 PCB Design Parameters

The Copper Thickness, PCB Material, Ambient Temperature, and Rated Output Power characterize the Printed Circuit Board (PCB). These parameters will directly affect the thermal performance of the design.

2.2.1 Copper Thickness

This is the thickness of the copper layers of the PCB. The unit of measurement is in ounces. One ounce is equivalent to 0.0014 inches (or 0.03556 mm) of thickness on each layer.

2.2.2 PCB Material

This is the insulating material used for laminate in the PCB. This tool assumes a laminate of FR-4 material or equivalent. Any other input for this field is considered invalid.

2.2.3 Ambient Temperature

This is the ambient temperature of the air surrounding the PCB of the CS4525. The calculator assumes the ambient air to be an infinite mass of uniform temperature.

2.2.4 Rated Output Power

This field is the ratio of rated output power to the maximum output power at 10% Total Harmonic Distortion (THD). The rated output power is used in the thermal calculations and is assumed to be a constant RMS power. By default this ratio is 100%, but it can be changed if the thermal characterization of the application is desired for a sustained output power less than the maximum output power, for example at 40% of the rated output power. Alternatively, this field can also be used to account for features that prevent the amplifier from achieving the maximum 10% THD output power, such as limiting.

3. AUDIO PERFORMANCE

These parameters characterize the output performance at the load. These values are calculated from the Application Design parameters. The results are displayed in blue boxes.

Audio Performance	Value	Unit	Description
Output Power (<1%THD)	8.4	Watts	Power at <1%THD (0dB FS) per channel
Output Power (7%THD)	11.7	Watts	Power at 7% THD (Clipped) per channel
Output Power (10%THD)	12.7	Watts	Power at 10% THD (Clipped) per channel
Peak Load Voltage	11.6	Volts	Peak voltage across the output load
Peak Load Current	1.5	Amps	Peak current through the output load

Figure 2. Example Usage of the Audio Performance Window

3.1 Output Power

This shows the RMS output power across the load at < 1%, 7%, and 10% Total Harmonic Distortion (THD). These results assume the audio signal is not being attenuated by an internal feature such as the limiter or the thermal foldback.

3.2 Peak Voltage and Peak Current

This shows the peak (instantaneous) voltage and peak current across the load at full power. These numbers are the same for < 1% THD, 7% THD, and 10% THD output power. Note that, although in each of these cases the RMS levels for these different powers vary, the peak levels are the same. This is due to the fact that the signal is clipped.

3.3 Audio Warning Window

This display indicates any potential audio design issues. If no text is displayed in this window, no audio design issues are detected. Please note that these warnings are based off the output power at 10% THD and do not take in to consideration any limiting of the audio signal.

3.3.1 ***“Warning: Peak load current is too high”***

This warning message is displayed if the peak current through the individual output pins is calculated to be too high. This means that the over-current protection may engage while at high power, causing interruption of the audio. To solve this issue, it is recommended to either increase the load impedance or decrease the output power. In cases where the amplifier configuration is set for full-bridge, this issue can also be solved by changing the configuration from full-bridge to parallel full-bridge.

3.3.2 ***“Warning: Supply voltage exceeds recommended operating conditions”***

This warning message is displayed whenever the VP supply voltage exceeds the recommended supply voltage. It is not advised to design for supply voltages outside the recommended range. Because supply ripple and switching noise will inevitably cause a large amount of noise on the VP pins, there must be a comfortable margin between this value and the absolute maximum voltage rating.

3.3.3 ***“Warning: Maximum output power exceeds rated power”***

This warning message is displayed whenever the output power at 10% THD exceeds the amplifier’s rating, even though the supply voltage and the peak current are within acceptable limits. If this condition oc-

curs, then either the maximum output level should be decreased or the audio signal should be limited to ensure the amplifier's output power stays within its intended range.

4. EFFICIENCY

These parameters characterize the electrical efficiency and thermal performance of the amplifier. These values are calculated from the PCB Design parameters and Audio Performance results. The results are displayed in blue boxes.

Efficiency	Value	Unit	Description
Rated Power / Channel	12.7	Watts	Rated output power per channel
Supply Current / Channel	0.9	Amps	Supply current per channel at rated power
Estimated Total Supply / IC	1.9	Amps	Total current from the high-power supply
Heat Generated / Channel	1.4	Watts	Heat generated by the CS4525 per channel
Estimated Total Heat / IC	2.9	Watts	Total heat generated by the CS4525
Amplifier Efficiency	89.9%	%	Amplifier power output vs power input

Figure 3. Example Usage of the Efficiency Window

4.1 Rated Power / Channel

This is the effective rated output power as calculated from the Rated Output Power input field and the Output Power (10% THD) result.

4.2 Supply Current

This is the current from the supply at the rated power. The calculator will also estimate the total supply for the amplifier by multiplying this number by either four (for half-bridge), two (for full-bridge), or one (for parallel full-bridge). If the amplifier employs a combination of different output-configurations and/or loads, such as in a 2.1-channel application, then this approximation will not be accurate. For these scenarios, the user should configure the Power Calculator for each different channel configuration and calculate the total supply current manually by adding the supply current per channel for each channel.

4.3 Heat

This is the heat generated in the amplifier from the power dissipated by the MOSFET's $R_{ds(on)}$ at the rated output power. The calculator will also estimate the total heat for the amplifier by multiplying this number by either four (for half-bridge), two (for full-bridge), or one (for parallel full-bridge). If the amplifier employs a combination of different output-configurations and/or loads, such as in a 2.1-channel application, then this approximation will not be accurate. For these scenarios, the user should configure the Power Calculator for each different channel configuration and calculate the total heat manually by adding the heat generated per channel for each channel.

4.4 Efficiency

This is the efficiency of the amplifier. This number is calculated as

$$\text{Efficiency} = P_{OUT} / (VP * IP)$$

where,

Efficiency = The efficiency of the amplifier

P_{OUT} = RMS output power of the amplifier (per channel)

VP = DC voltage of the VP supply

IP = RMS input current from the VP supply to the amplifier (per channel)

4.5 Thermal Advisory Window

This window advises the user of potential thermal issues based on the PCB characteristics and the rated output power. This advice assumes the application adheres to Cirrus Logic’s layout recommendations for optimal thermal performance. If no message is displayed, then the estimated thermal junction temperature has a safe margin from the point of thermal shutdown. If a message of “PCB layout will be critical to maintain rated output power” is displayed, then the estimated junction temperature is relatively close to the thermal shutdown temperature. Failure to follow the recommended layout practices closely in this condition may result in the amplifier thermally shutting down at the rated output power. If a message of “An external heat sink may be required” is displayed, then there is not enough margin on the estimated junction temperature, even when using recommended layout practices. For this condition, the PCB’s parameters should be modified to decrease its thermal resistance, the amplifier’s power output requirements should be reduced, or an external heat sink should be added to the system.

5. QUALIFICATION

The Power Calculator is based on upon two mathematical components: an electrical model and thermal model. The electrical model is used to calculate the values for Output Power, Peak Load Current, Peak Load Voltage, Heat Generated, and Amplifier Efficiency. The thermal model is used to make any necessary recommendations in the Thermal Advisory Window. To ensure the accuracy of each of these models, both were correlated to Cirrus Logic CS4525 reference designs.

5.1 Qualification of Electrical Model

The electrical model of the CS4525 is mathematically equivalent to that of an analog amplifier. In this model, the source amplitude is equivalent to the PWM modulator’s output multiplied by the applied VP voltage and the series resistance is equivalent to the $R_{ds_{on}}$ of the MOSFETs plus the series resistance of the PCB, including the series resistance of the passive filter components. This model is illustrated in [Figure 4](#).

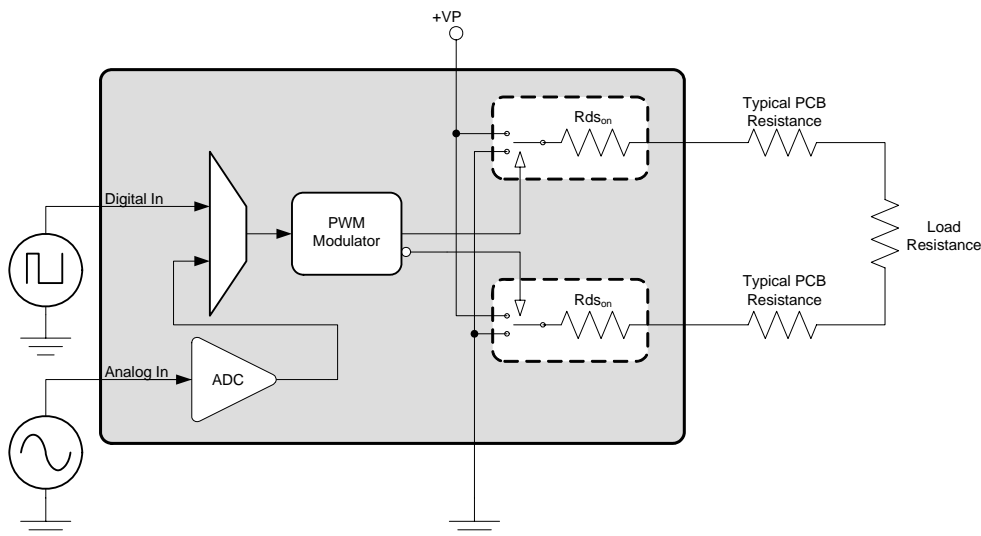


Figure 4. Mathematical Model of the CS4525

Based on this model, each element was empirically characterized and used to construct the equations used in the Power Calculator that calculate Output Power, Peak Load Current, Peak Load Voltage, Heat Generated, and Amplifier Efficiency. These equations were correlated to the measured results from a typical CRD4525-Q1 reference design for all valid integer-value voltages and for the two standard load values that are supported by the CS4525’s full-bridge configuration (8 Ω and 6 Ω).

5.2 Qualification of Thermal Model

The thermal model of the CS4525 is based off the following first-order equation:

$$\theta_{CA} = [(T_J - T_A) / P_D] - \theta_{JC}$$

where,

θ_{CA} = Thermal resistance from the case to ambient air (a function of the PCB characteristics)

T_J = Junction temperature of the amplifier

T_A = Ambient temperature of the surrounding air

P_D = RMS power dissipation of the amplifier (also referred to as "Heat Generated")

θ_{JC} = Thermal resistance from the amplifier's junction to its case (typically 1°C/W for the CS4525)

Assuming that the user enters an appropriate T_A , that the Power Calculator can accurately predict P_D , and that the θ_{JC} and the maximum allowable T_J for the CS4525 are well known, the only unknown variable in this equation is θ_{CA} . The values of θ_{CA} used by the Power Calculator were derived from computer simulations. To validate the simulations' accuracy, their results were correlated to measured thermal characteristics from Cirrus Logic reference designs. After the simulation was correlated to the measured results, the simulator's calculated θ_{CA} values were incorporated into the Power Calculator.

To test the thermal characteristics of the reference designs, each board was setup to operate with constant gain in a closed environment with controlled ambient air temperature. In such an environment, a slight increase to the input level will cause a linear increase in power dissipation and a corresponding rise in the junction temperature. If the input level is regulated such that the junction temperature is just under point of thermal shutdown for a long period of time, then it is possible to reach a thermal steady state and deduce the thermal derating of the amplifier at that particular ambient temperature. Once this is done for several ambient temperatures and the power dissipation is well known for each of these data points, it is possible to derive the θ_{CA} of the system under test (i.e., of the PCB) based on the above formula.

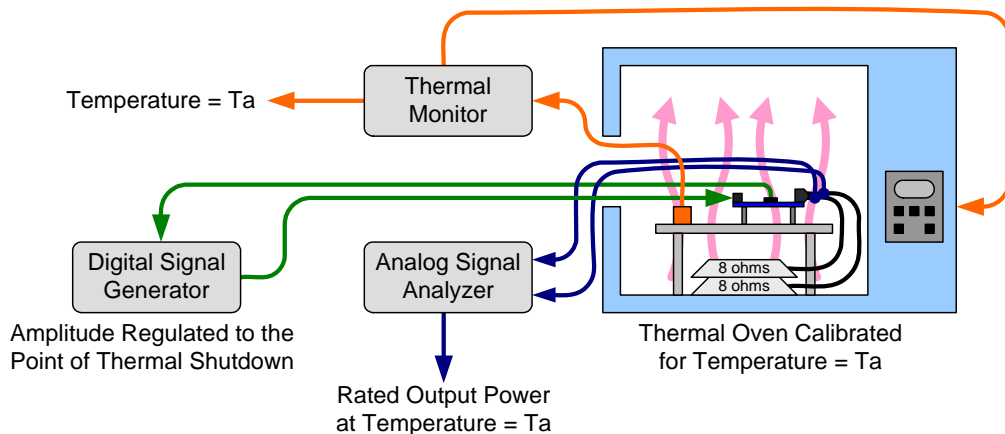


Figure 5. Illustration of the Thermal Derating Test

This procedure was repeated to measure the θ_{CA} for both the for the 4-layer CRD4525-Q1 "Quad" PCB and 2-layer CRD4525-D1 "Dual" PCB, which are Cirrus Logic reference designs for the CS4525. Both of these reference designs are 1 ounce copper with layout optimized for minimal thermal resistance. Once the measured θ_{CA} for these two designs correlated to computer simulations, additional simulations were used to calculate the θ_{CA} for similar PCBs with the same optimized layout but with different thicknesses of copper. These various θ_{CA} are stored in the Power Calculator. They are used by Efficiency Window along with the Ambient Temperature field and the calculated Heat Generated to approximate the junction temperature and make an appropriate design recommendation in the Thermal Advisory Window.

For details about how a PCB's copper thickness, routing, and number of layers affect thermal resistance, please refer to Cirrus Logic application note AN315.

Contacting Cirrus Logic Support

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