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TDA856x and TDA8571J power amplifiers

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Application note

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Contact information

For additional information, please visit: <http://www.semiconductors.philips.com>

For sales office addresses, please send an email to: sales.addresses@www.semiconductors.philips.com

1. Introduction

1.1 Amplifier overview

This document describes the application specific subjects of the following audio power amplifiers : TDA856x family and TDA8571J.

These amplifiers, which are made in a bipolar process, are mainly used in automotive applications such as car radios, boosters and multimedia applications. The differences between the types are mainly the number of output channels, different load values and output power. The following matrix shows an overview of the mentioned amplifiers and their properties.

Table 1: Amplifier Overview

* DDD = Dynamic Distortion Detection

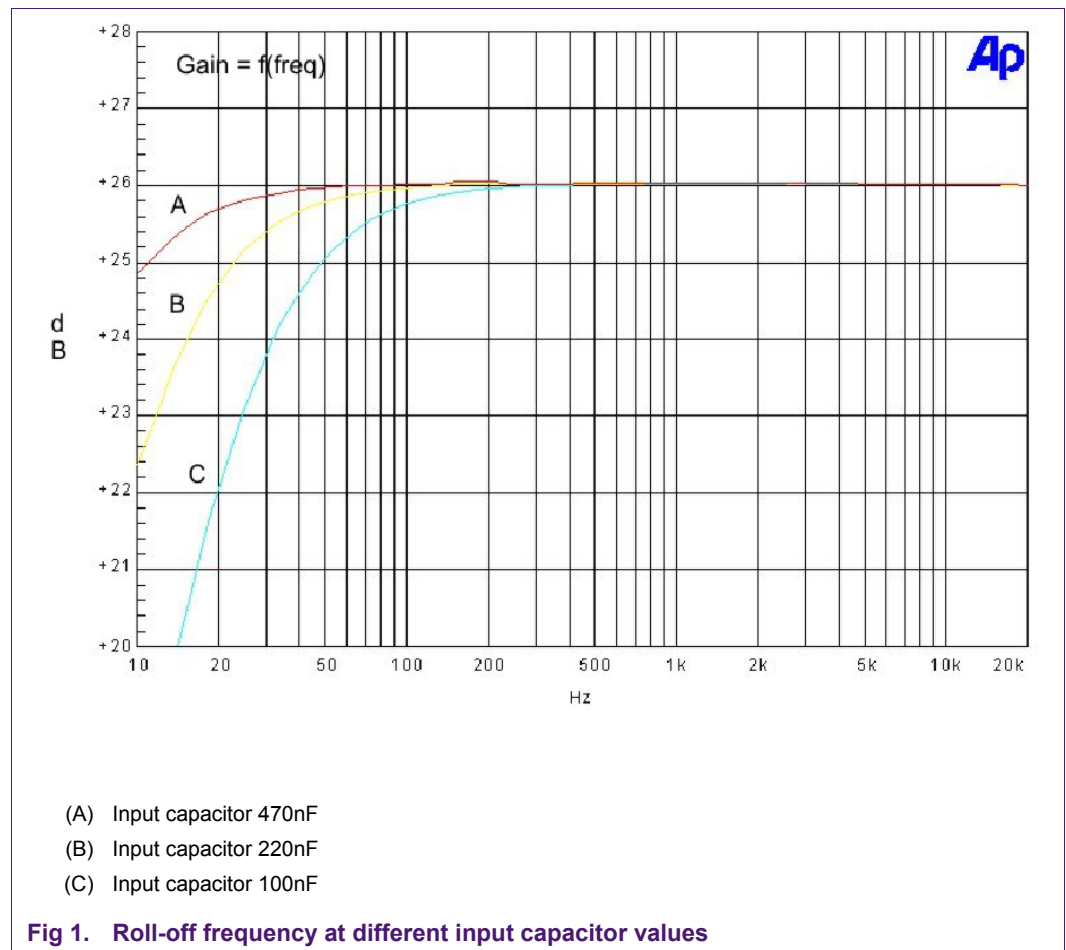
	Channels	Gain [dB]	Load [Ohm]	Inputs	Output power [W]	DDD* [%]	Package
TDA8560Q	2 x BTL	40	2	2 x SE	2 X 40	10	DBS13P
TDA8562Q	4 x SE	20	4	4 x SE	4 x 12	10	DBS17P
TDA8563Q	2 x BTL	20	2	2 x SE	2 x 40	10	DBS13P
TDA8563AQ	2 x BTL	20	2	2 x SE	2 x 40	2.2	DBS13P
TDA8566Q	2 x BTL	26	2	2 x diff.	2 x 40	7.5	DBS17P
TDA8566TH	2 x BTL	26	2	2 x diff.	2 x 40	10	HSOP20
TDA8567Q	4 x BTL	26	4	4 x SE	4 x 25	10	DBS23P
TDA8568Q	4 x BTL	40	4	4 x SE	4 x 25	10	DBS23P
TDA8569Q	4 x BTL	26	2	4 X SE	4 x 40	10	DBS23P
TDA8571J	4 x BTL	34	4	4 x SE	4 x 26	10	DBS23P

2. Application Information

2.1 Input capacitors

The amplifiers need capacitors on the inputs to get a DC decoupling of the input source (pre-amplifier stage). The impedance of the input stage together with the input capacitors, create a low frequency roll-off point. A larger input capacitor means a lower frequency roll-off point. The values that should be used are mentioned in the datasheet of the amplifier type.

The following figure shows the influence of the input capacitors on the frequency roll-off point for the TDA8566TH.



The low frequency roll-off point can easily be calculated :

$$f_{low_3dB} = \frac{1}{2 \cdot \pi \cdot Z_{in} \cdot C_{in_tot}}$$

For example the low frequency roll-off point for the TDA8566TH, when using 220nF input capacitors, equals :

$$f_{low_{-3dB}} = \frac{1}{2 \cdot \pi \cdot 120 \cdot 10^3 \cdot 110 \cdot 10^{-9}} = 12Hz$$

In this case the total input capacitance is halved since the input source is “seeing” the input capacitors in series. This is due to the differential input configuration which is drawn in the next figure.

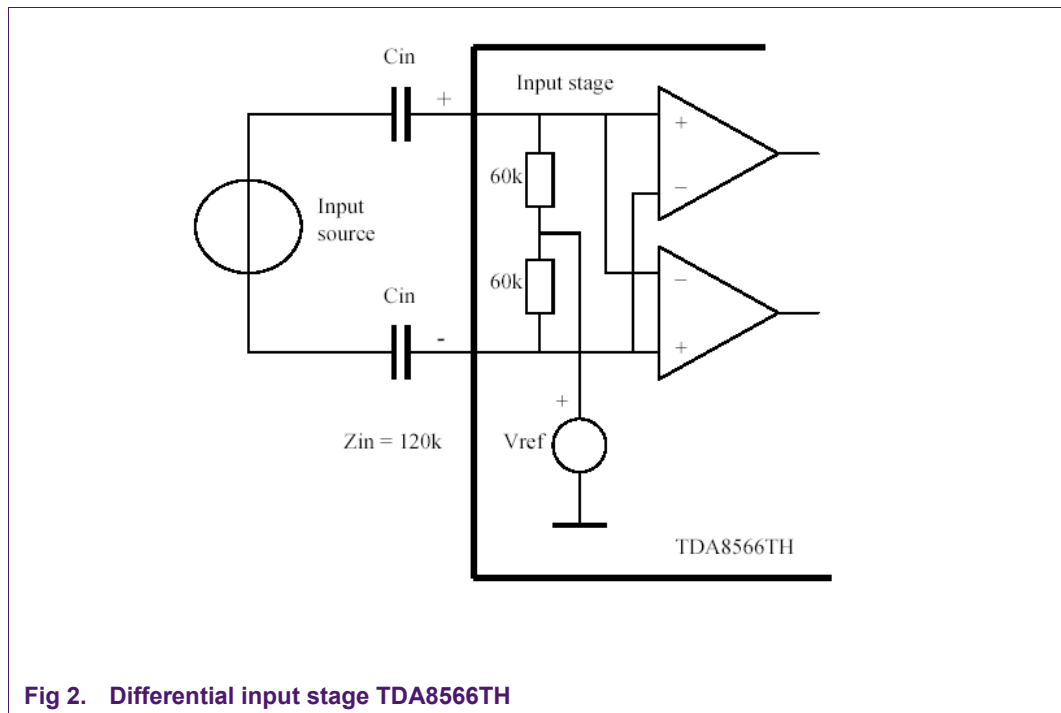


Fig 2. Differential input stage TDA8566TH

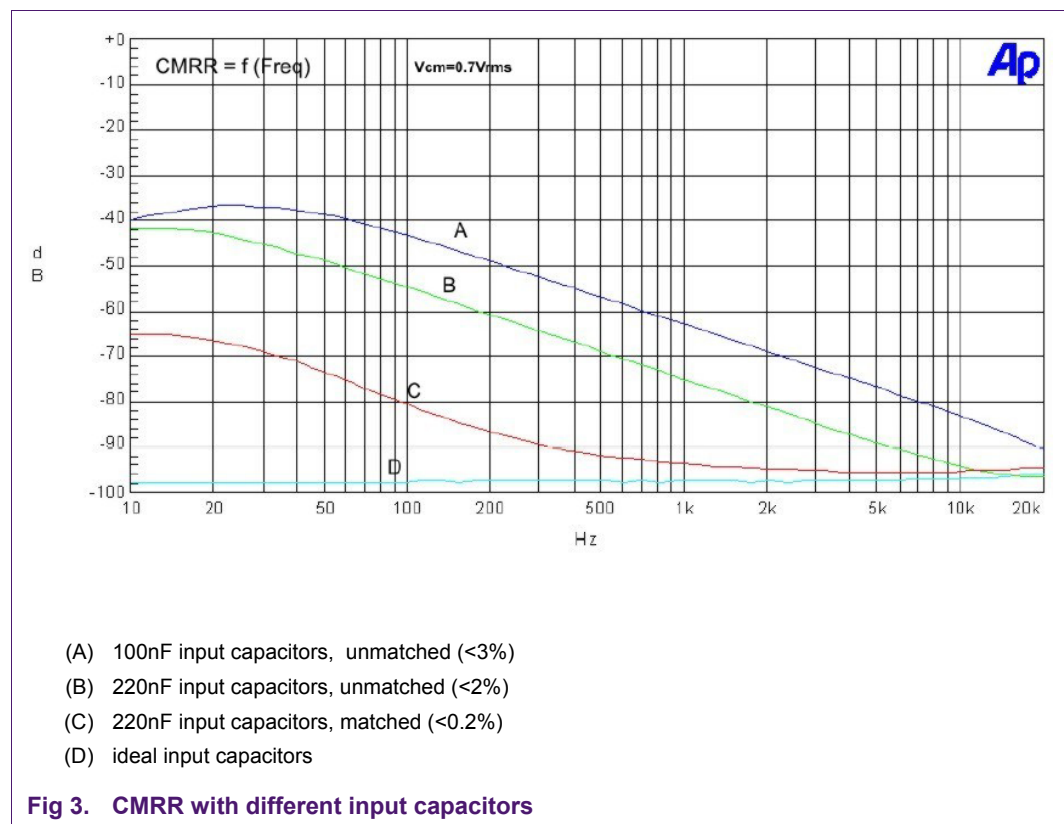
Furthermore it is recommended to use input capacitors with a low DC leakage (film capacitors), since any DC leakage at the inputs will result in a DC offset at the outputs. Electrolytic capacitors usually have a relatively high DC leakage and should therefore not be used.

2.2 Differential inputs

The TDA8566 is provided with differential input circuits. This has the advantage that disturbances on the inputs, with relation to ground, are greatly eliminated.

However, if there's a mismatch of the input capacitors, the common mode rejection ratio (CMRR) decreases for low frequencies, since the impedance of the input capacitors will increase then.

The next figure shows the CMRR of the different input capacitor configurations :



It may be clear that using matched input capacitors give the best CMRR results (line C).

So, in order to take optimum advantage of the differential inputs, the input capacitors should be equal (matched) and have a low tolerance. Also, when a very high CMRR is required it is therefore best to use input capacitors with a high capacitance.

When only a pre-amplifier *without* differential outputs is available, the TDA8566 can also be driven single ended. In this way one of the inputs should be tied to signal ground via the capacitor, while the other input is driven.

Since this is a compromise, one must consider that the CMRR ratio will get worse.

2.3 Loss of ground

The definition of a loss of ground with a power amplifier can be described as following :

The ground of the power supply (car-battery) is connected to the output of the amplifier, instead of to the amplifier-ground, after which the amplifier is switched on.

In a practical situation a loss of ground condition could occur during assembly in the factory, the car manufacturer (OEM) or in the case of an aftersales customer.

The following picture shows a loss of ground condition

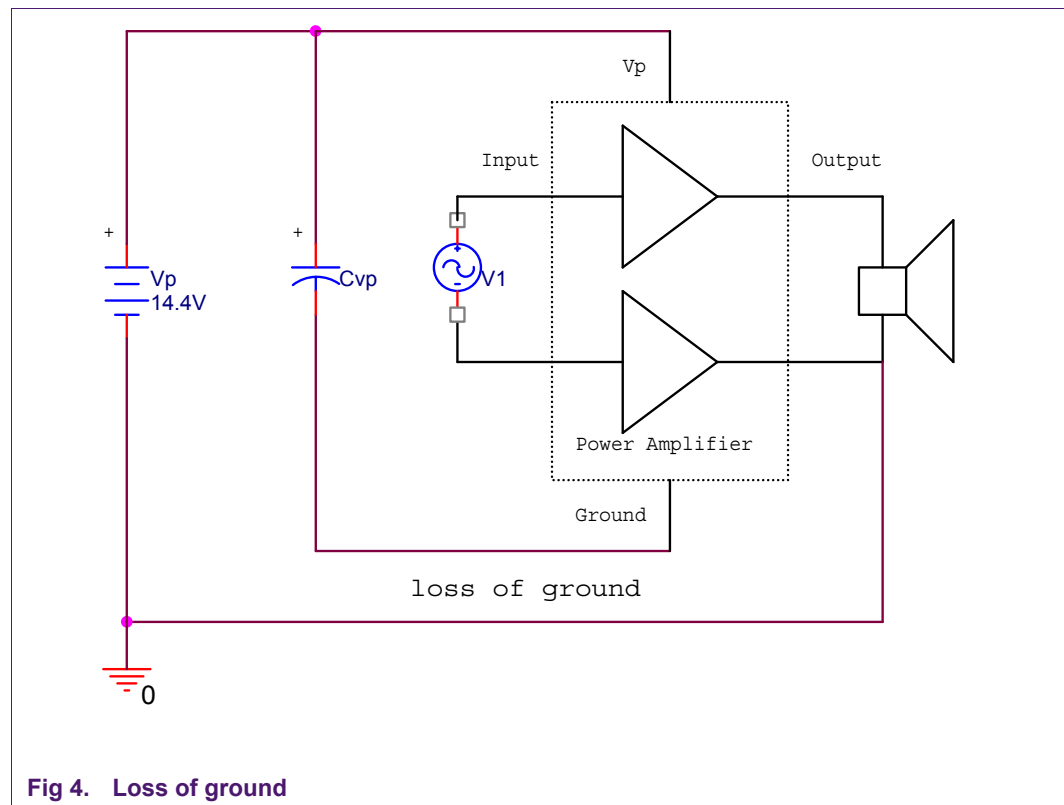


Fig 4. Loss of ground

According to figure 4, during a LOG, the peak current which charges the buffer capacitor Cvp, will flow from Cvp into the amplifier ground pin and can destroy the amplifier.

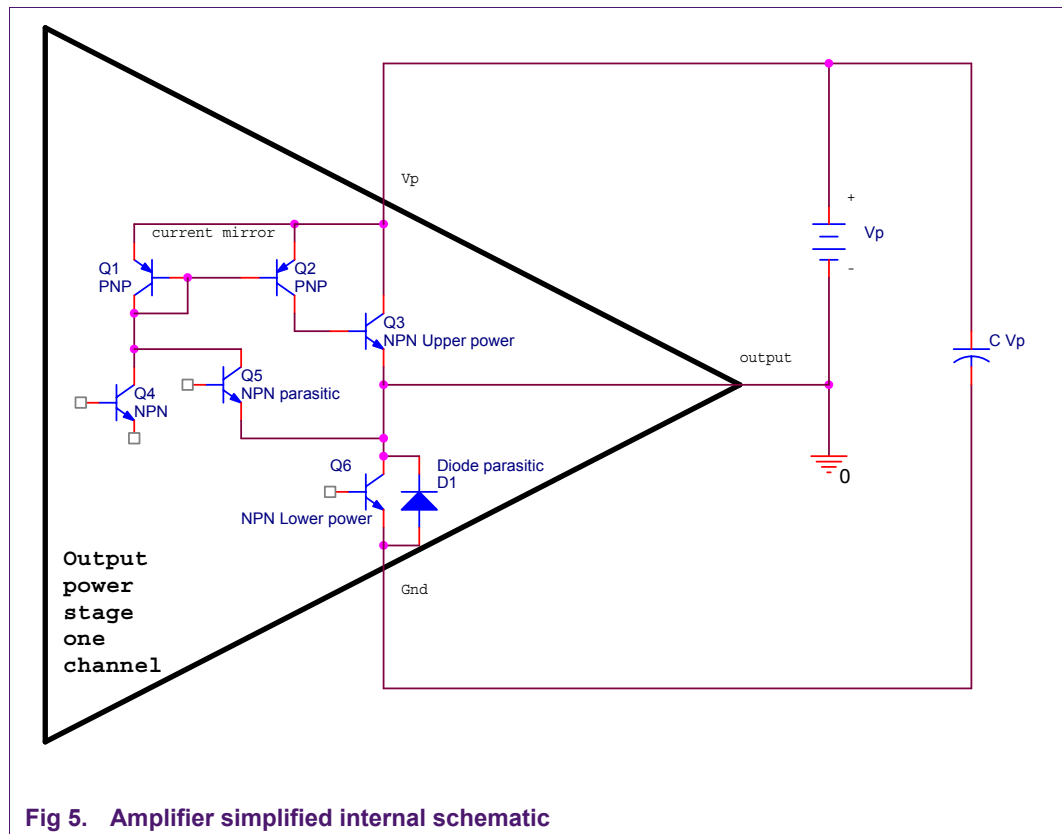


Fig 5. Amplifier simplified internal schematic

According to the internal schematic of the amplifier, the failure mechanism is described step by step.

During a Loss of ground, when the amplifier is turned on :

1. The buffer capacitor C_{vp} is charged and the current flows from C_{vp} to the amplifier ground pin via the parasitic diode D1 to ground
2. Since D1 is conducting, the voltage on the collector of the lower power Q6 equals $-0.7V$ (under substrate level)
3. This causes a turn-on of a parasitic NPN Q5
4. The current mirror is 'activated' and pulls a current
5. Then the upper power Q3 will be turned on and a very large current will flow, since the full V_p is across it
6. This will destroy the upper power transistor

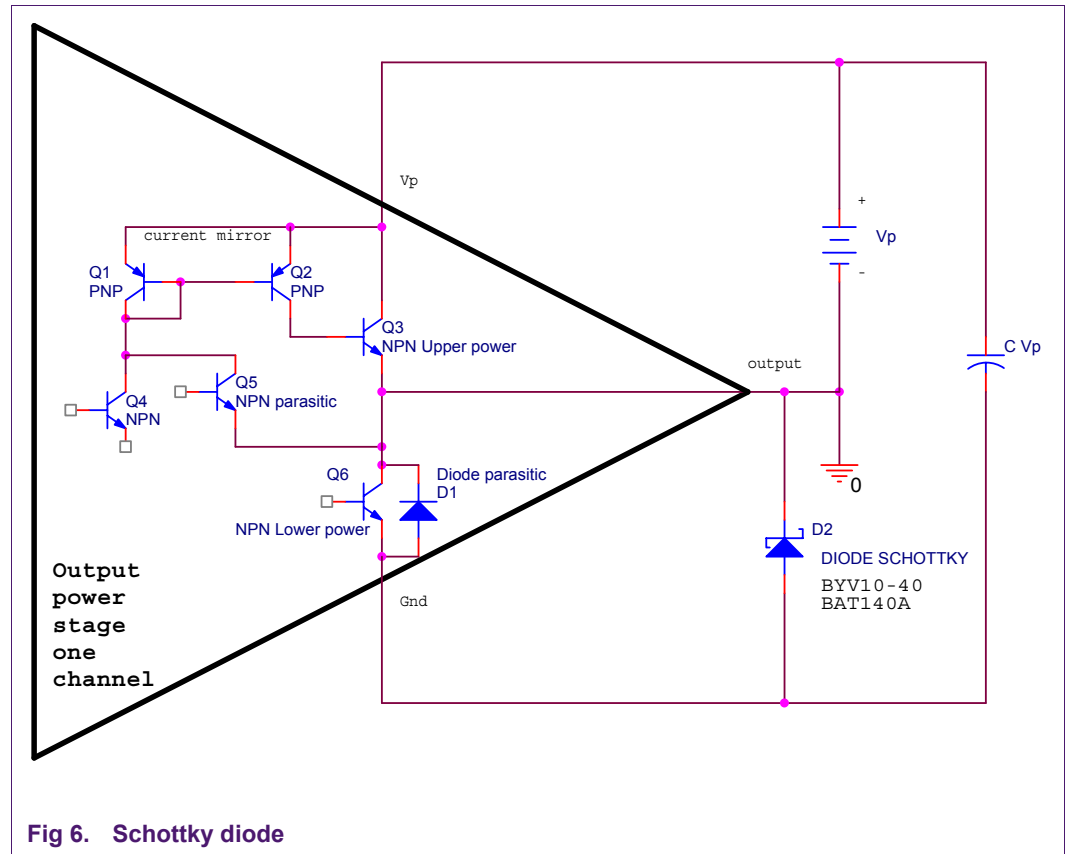
In order to withstand the LOG it has to be prevented that the upper power is conducting. The root cause is the conduction of the parasitic diode D1, which causes a substrate level of $-0.7V$.

To prevent the conduction of D1 it is advised to use a schottky diode between each of the outputs and ground, according to figure 6. (So for a 4 channel BTL amplifier 8 schottky diodes are to be used)

Since the schottky diode has a lower treshold (0.1 .. 0.3V) it will prevent a current flow through D1 and so the turn-on of the upper power.

During turn-on of the amplifier, the capacitor will be charged via the schottky diode instead of via D1.

For the schottky D2 it is recommended to use a Philips type BYV10-40 or a double SMD type BAT140A.



2.4 Critical conditions

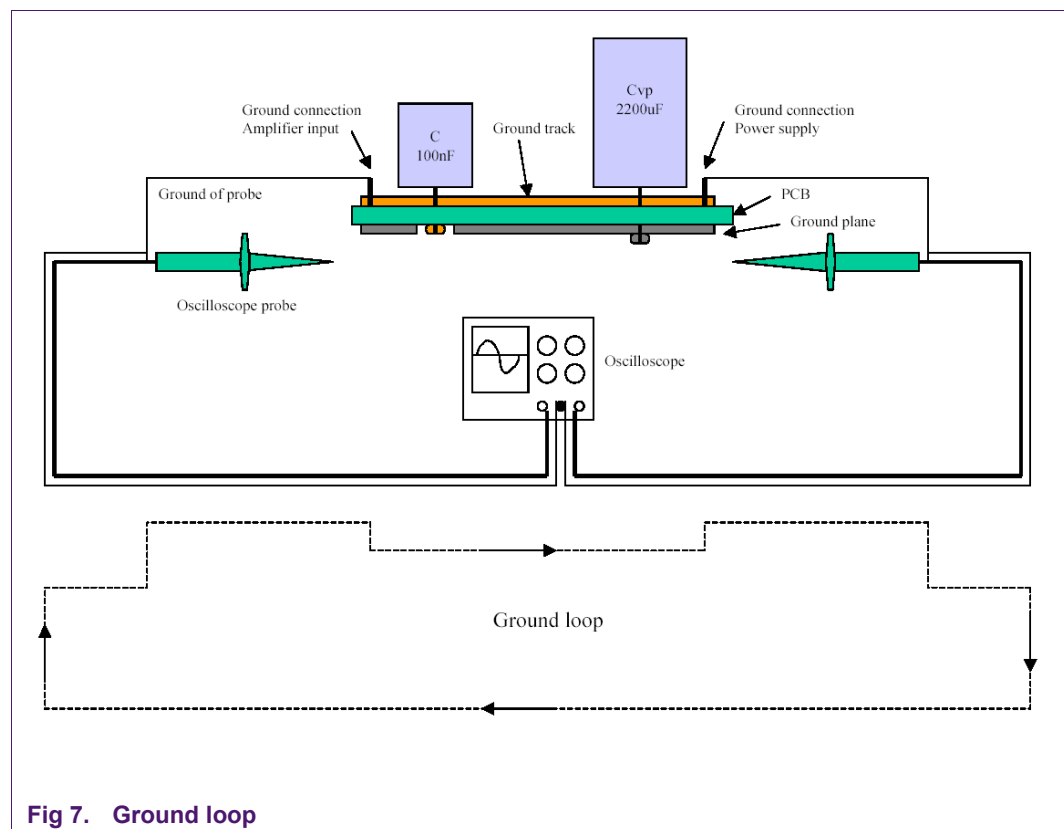
2.4.1 Stability

When using capacitors from the outputs to ground (EMC) one must consider that the TDA856x / TDA8571 is stable for capacitances smaller than 2.2nF and larger than 100nF. So, when capacitors are used outside of this range, boucherot filters at the outputs could be necessary.

2.4.2 Ground loops

Ground loops are unwanted signal paths that can occur during measurements of the power amplifier, which can result in a higher THD performance of the amplifier. A many seen fault is after connecting two ground connectors of an oscilloscope probe : one at the signal ground of the input of the amplifier and one on the ground of the power supply. The same condition holds when connecting an audio analyser (Audio Precision). In this case when the ground connector (cable shield) is connected to the amplifier input signal ground and when the output is measured, while its ground connector (cable shield) is connected to the power supply ground.

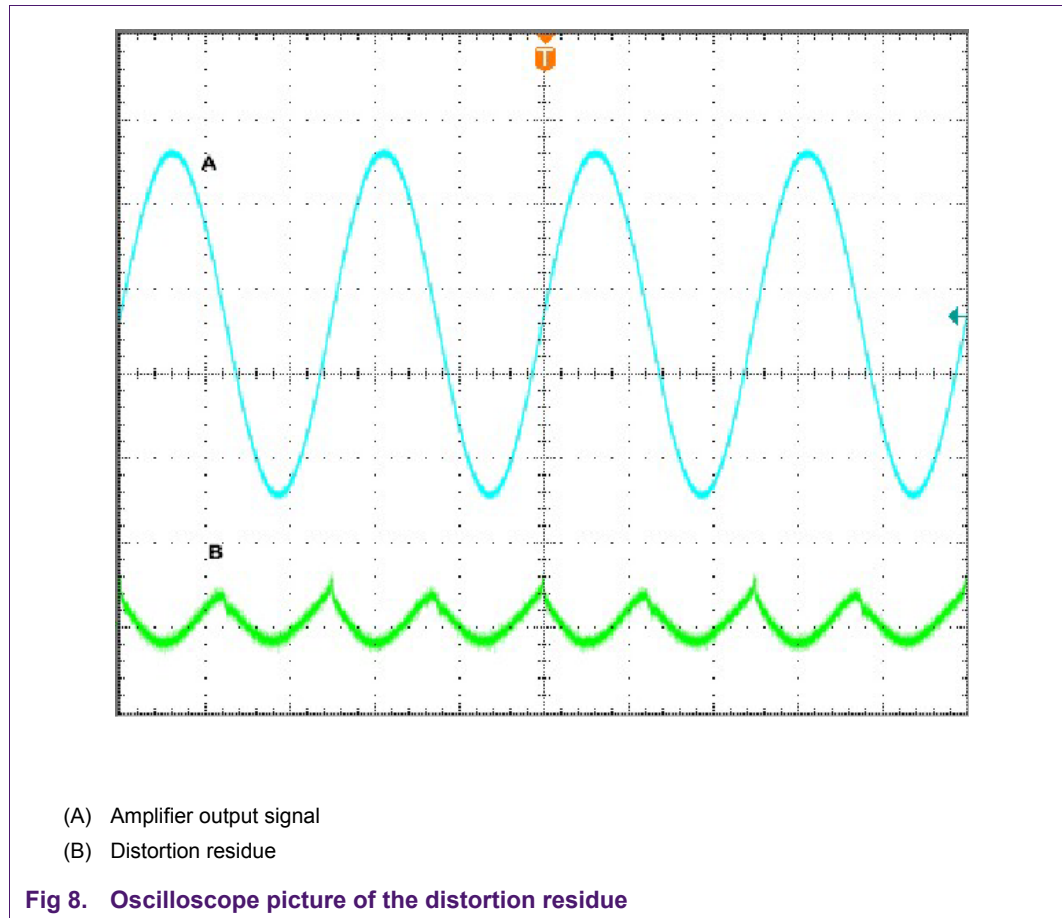
The following drawing shows such a ground loop condition



In practice one should always try various ground connections when measuring THD. However, in many cases it is advised to use only one ground connection from the measuring device to the power amplifier board.

To check if a ground loop is present, measure the distortion residue on an oscilloscope together with the output signals of the amplifier. The distortion residue is usually a monitor output on an audio analyser, eg. Audio Precision System Two, which shows the difference between the shape of the original waveform that is put on the input of the power amplifier and the waveform that is present on the output. (be aware of that the Audio Precision System Two does not scale this distortion residue !)

The distortion residue shows a groundloop; the waveform shows **the rectified frequency** of the signal that is put on the amplifier inputs. The following picture shows an example of a ground loop.

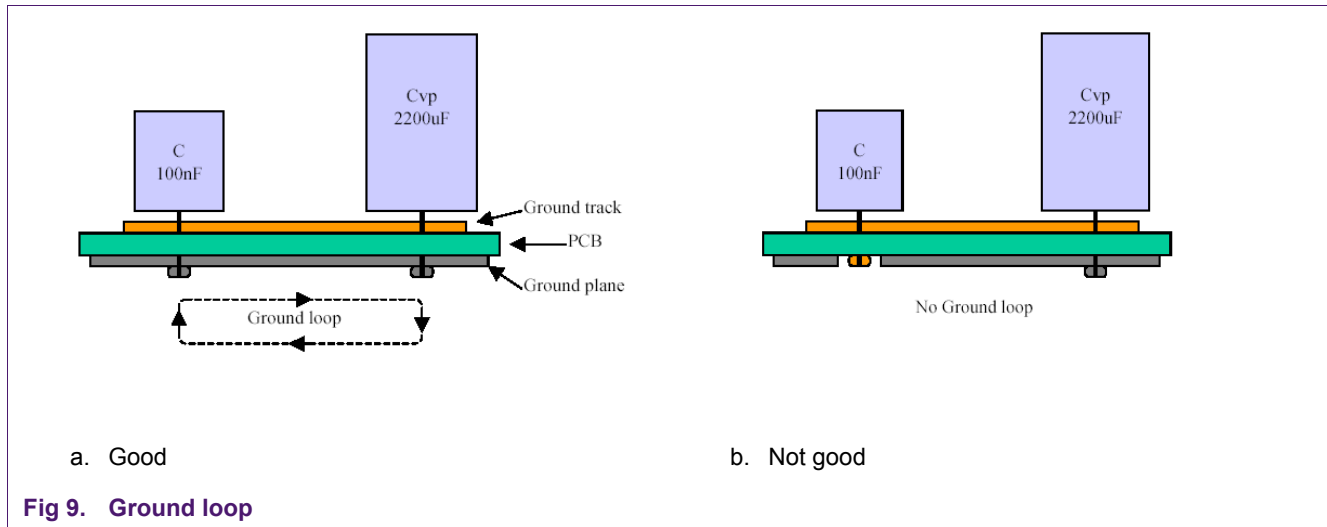


2.5 PCB Layout recommendations

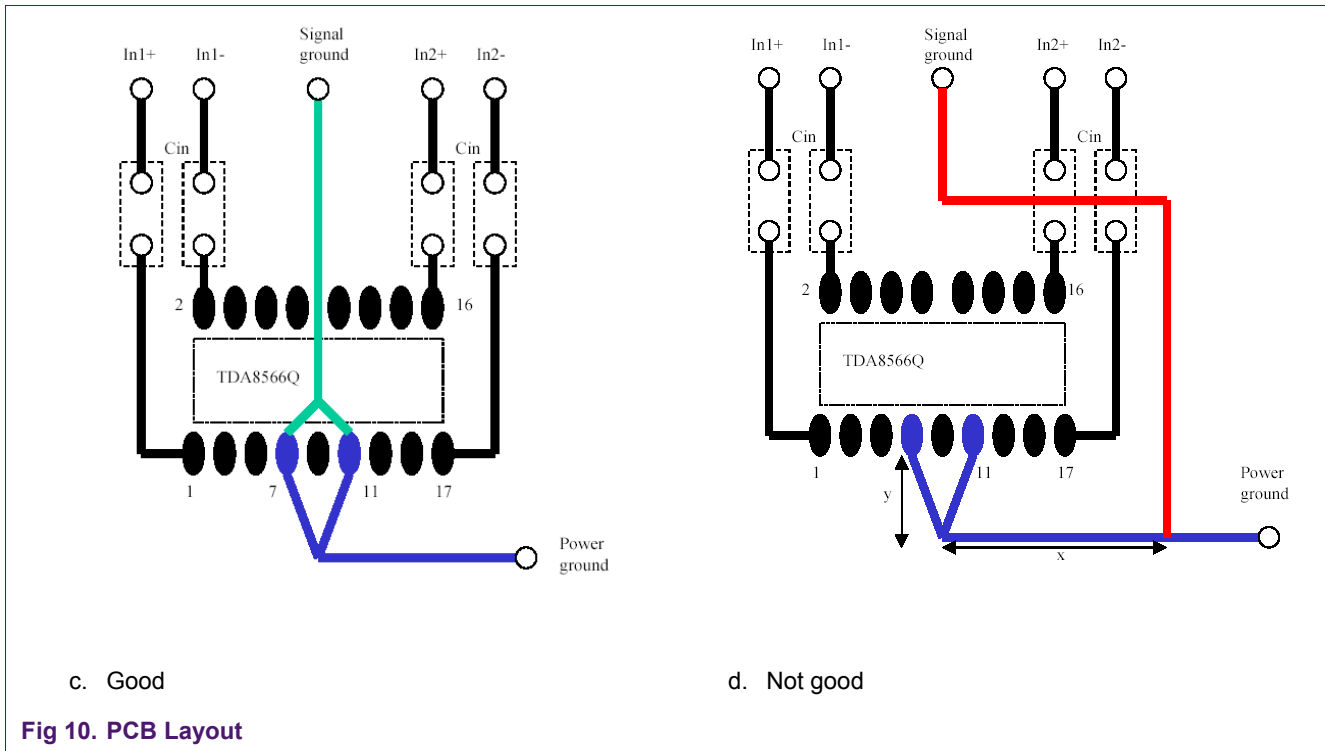
The following recommendations can be given when designing a PCB

- Don't situate input tracks nearby output tracks to prevent interference
- Use a HF decoupling capacitor of about 100nF .. 220nF nearby the device, between each Vp and power ground pin
- When for the HF decoupling capacitors SMD components are used, be aware of differences in behaviour w.r.t. the capacitor material. Good results are found with NPO capacitors which have a low ESR (electrical series resistance), next are X7R capacitors and last are Y5V capacitors which have a considerable ESR
- In order to minimize the losses in the tracks for Vp and power ground during high output power, use 75um or thicker copper layer and use a track-width of at least 5mm

When using a ground plane, prevent ground loops which have a negative effect on the THD performance. Use only one connection from the ground plane to ground, eg at the buffer capacitor of Vp. The following drawing shows an example of a proper grounding and a poor grounding.



- In spite of the fact that amplifiers with differential (balanced) inputs perform a lot better on ground noise than an amplifier with unbalanced inputs, it is recommended to separate the small signal ground connection from the power ground connection that leads to the power supply (car battery), to prevent possible interference of any disturbances that come from the power supply
- The ground references of the amplifier should all have the same potential. This is to prevent dc shifts between the different grounds. In practice this can be done by choosing a star ground connection between power ground and signal ground (DC voltage shifts could otherwise occur through the large currents that flow through the power ground tracks) The next drawing shows an example between a proper lay-out and a poor one



As can be seen in picture 10c is that the signal ground potential of the ground pin (7,11) is equal to the potential of the signal groundconnector of the input signal. In picture 10d the potential between pin 7, 11 and the signal ground connector is unequal, depending on the current-flow through the track, x+y.

Suppose that, at a certain output power, the current through the x+y ground track equals 3A , while the resistance of the track x+y equals 100mOhm, then the voltage across x+y equals 0.3V and will increase with increasing output power

2.6 Heatsink calculation

2.6.1 Power dissipation

As an example, the heatsink for a TDA8566Q is calculated.

When designing a heatsink, the amount of dissipated power must be calculated first.

For one channel of a conventional class B, BTL amplifier, the dissipated power equals :

$$P_{diss} = P_{supply} - P_{out} = V_p \cdot \frac{2}{\pi} \cdot \sqrt{\frac{2 \cdot P_{out}}{R_{load}}} - P_{out}$$

For a stereo amplifier this means :

$$P_{diss} = V_p \cdot \frac{4}{\pi} \cdot \sqrt{\frac{2 \cdot P_{out}}{R_{load}}} - 2 \cdot P_{out}$$

According a rule of thumb the following can be assumed : the power dissipation of a *music signal* is about *half* of the worst case dissipation of a sine wave signal.

$$P_{diss_music} = V_p \cdot \frac{2}{\pi} \cdot \sqrt{\frac{2 \cdot P_{out}}{R_{load}}} - P_{out}$$

This means that when :

$$V_p = 14.4V$$

$$P_{out} = 2x5W$$

$$R_{load} = 4\Omega$$

The dissipated power for music signals equals :

$$P_{diss_music} = V_p \cdot \frac{2}{\pi} \cdot \sqrt{\frac{2 \cdot 2 \cdot 5}{4}} - 10 = 10.5W$$

2.6.2 Thermal resistance

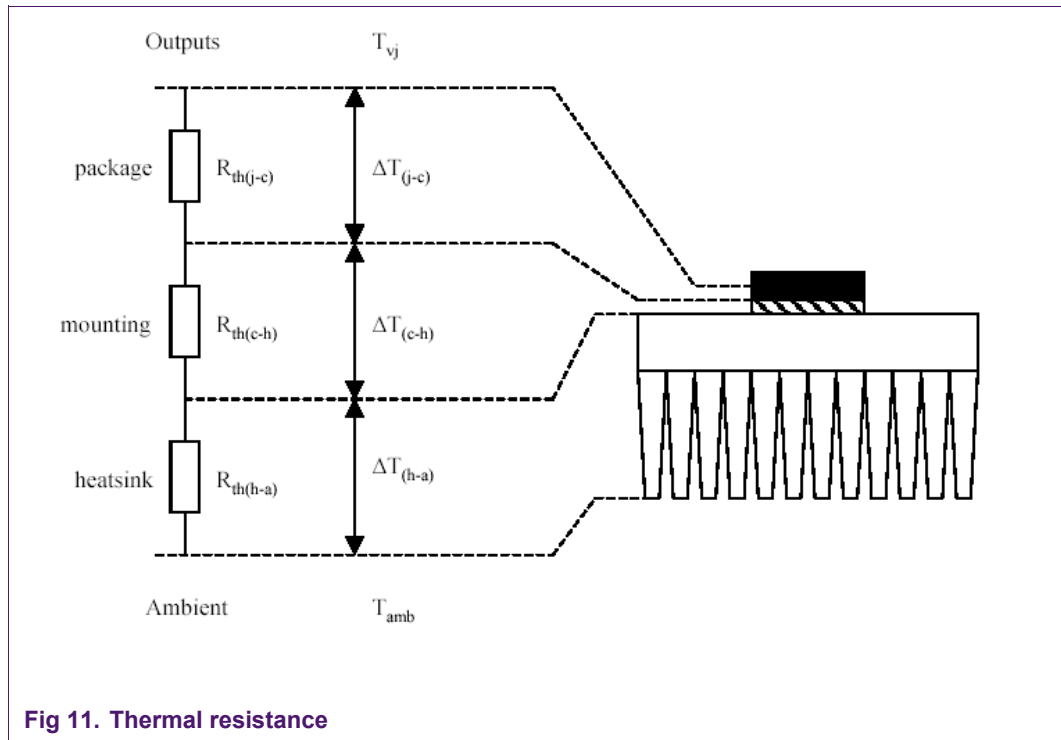
The equation for the thermal resistance [R_{th}] equals Ohms law, when temperature [T] is substituted for voltage and power [P] is substituted for current :

$$R_{th} = \frac{T}{P}$$

In fact, T is the temperature difference across the thermal resistance while P is the dissipated power of the amplifier, so :

$$R_{th} = \frac{\Delta T}{P_{diss}}$$

When looking at the next drawing it may be clear that the total thermal resistance is the sum of the thermal resistances from the junction (outputs) of the amplifier to the ambient, while the temperature difference is the difference between the junction temperature of the amplifier and the ambient temperature.



So this means that the equation can be extended to :

$$R_{th(j-c)} + R_{th(c-h)} + R_{th(h-a)} = \frac{T_{vj} - T_{amb}}{P_{diss}}$$

When the value of the heatsink is determined for *music signals*, the equation leads to :

$$R_{th(h-a)} = \frac{T_{vj} - T_{amb}}{P_{diss_music}} - R_{th(j-c)} - R_{th(c-h)}$$

The thermal resistance from the junction to case (package) is usually drawn like three (stereo amplifier) or five (quad amplifier) thermal resistances, but can be translated (according to Ohms law) to one thermal resistance, according to the next figure.

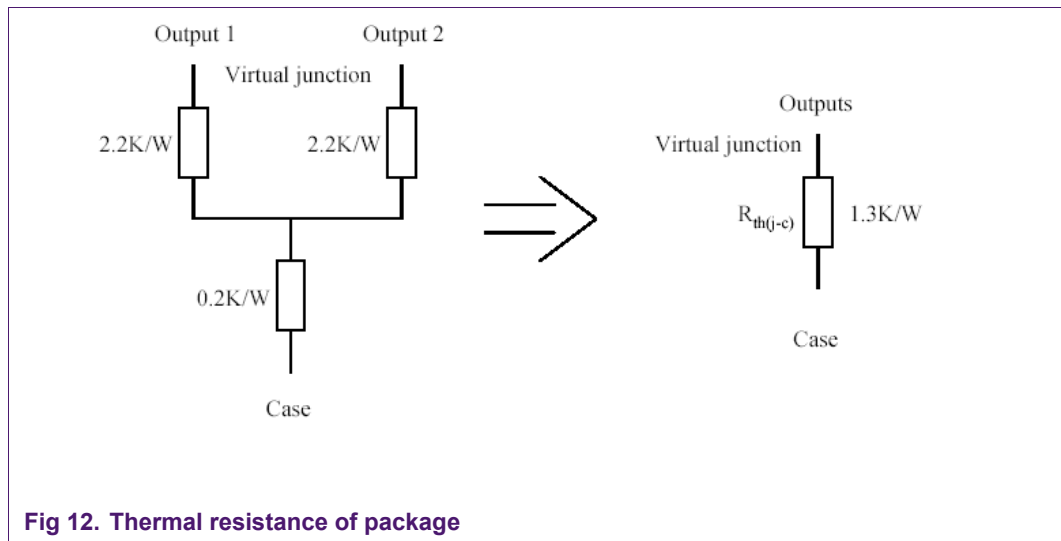


Fig 12. Thermal resistance of package

Finally, when :

$T_{vj} = 150^{\circ}C$ the absolute maximum junction temperature at which the amplifier does not breakdown (value mentioned in datasheet)

$T_{amb} = 70^{\circ}C$ the ambient temperature in which the amplifier is used, ie. In the dashboard of a car

$P_{diss_music} = 10.5W$ the dissipated power for music signals

$R_{th(j-c)} = 1.3K/W$ the thermal resistance of the amplifier according to the datasheet

$R_{th(c-h)} = 0.1K/W$ the thermal resistance of thermal paste

The thermal resistance of the required heatsink equals :

$$R_{th(h-a)} = \frac{150 - 70}{10.5} - 1.3 - 0.1 = 6.2K/W$$

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