TECHNICAL PAPER

Analysis of the DC Blocking Capacitor for Stereo High-Fidelity Audio

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Abstract

The representation of audio signals in analog and digital electronics can take many forms. Still, they must ultimately be converted back to their mechanical origins as the motion of air molecules propagating as waves. These waves are generated by moving a mass, often the cone of a speaker, back and forth around a neutral position.

ANALYSIS OF THE DC BLOCKING CAPACITOR FOR STEREO HIGH-FIDELITY AUDIO

APPLICATION BACKGROUND

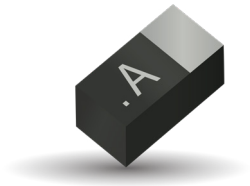
The representation of audio signals in analog and digital electronics can take many forms. Still, they must ultimately be converted back to their mechanical origins as the motion of air molecules propagating as waves. These waves are generated by moving a mass, often the cone of a speaker, back and forth around a neutral position. As such, any fixed offset in the audio signal, represented by a DC bias, is simply a waste of energy and possibly a source of imbalance in the resulting sound wave. Series blocking capacitors are generally used for each audio channel to eliminate the potential of any DC component.

While most capacitors will adequately remove the DC component from the output, each of the many varieties will also alter the actual audio signal to varying degrees. For high-fidelity applications, proper selection of these blocking capacitors can be a critical performance factor.

CAPACITOR SELECTION

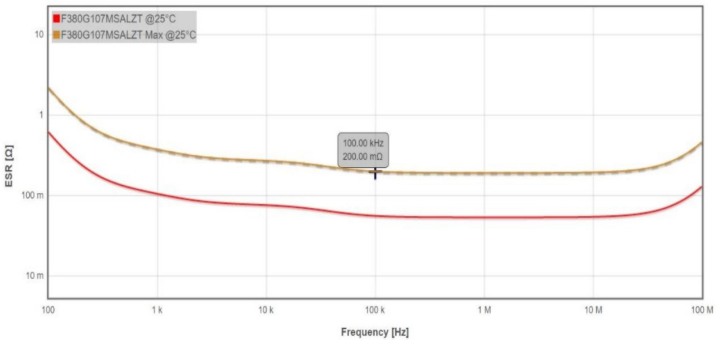
For mobile and wearable applications, volumetric and height restrictions limit the available choices for capacitors with high capacitance-voltage (CV) characteristics. Multilayer ceramics (MLCC) cannot be used because of piezo noise and capacitance reduction at high voltage.

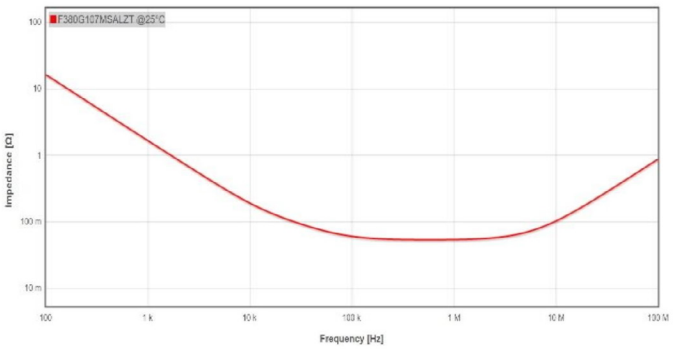
The only feasible devices to fit within an 0805 package and provide 100 uF of capacitance at a minimum are of the Tantalum MnO_2 and Tantalum polymer varieties. Two candidate capacitors from KYOCERA AVX were selected and are compared in the following tables:



F380G107MSALZT

CAP	TOL	RV	DCL	DF	ESR	ESL
100uF	20%	4V	80µA	10%	200mΩ	1.4nH



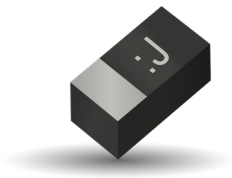


Tables 1 and 2

CAPACITOR SELECTION

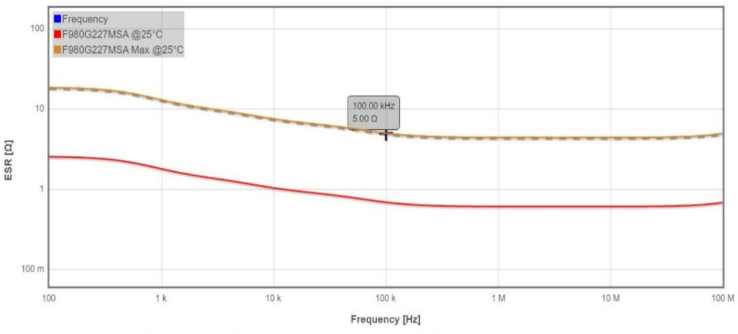
The Tantalum MnO_2 (F98 series) offers high CV, while the Tantalum polymer (F38 series) offers comparable CV along with extremely low series resistance (ESR).

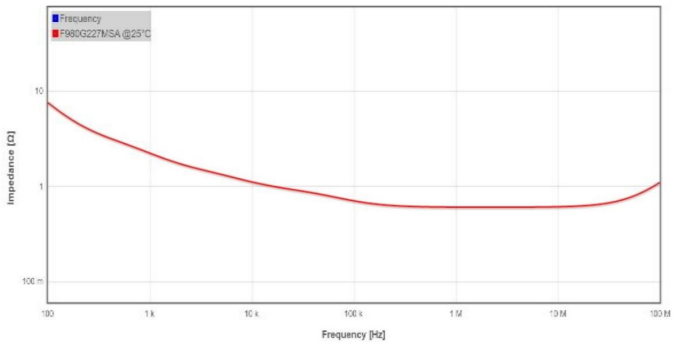
Therefore, one must evaluate the effect of ESR on the audio performance of the circuit, including balance, frequency response, and dynamic range.



F980G227MSA

CAP	TOL	RV	DCL	DF	ESR	ESL
220uF	20%	4V	132µA	80%	5Ωmax	1.4nH





Tables 3 and 4

FREQUENCY RESPONSE

The frequency response of the F380G107MSALZT and F980G227MSA for left and right channels were tested, as shown in Figure 1. Two characteristics are worth noting in this data: the F38 exhibits greater attenuation than the F98 below 100Hz, and the difference between the left and right channel is worse for the F38 even beyond 1kHz.

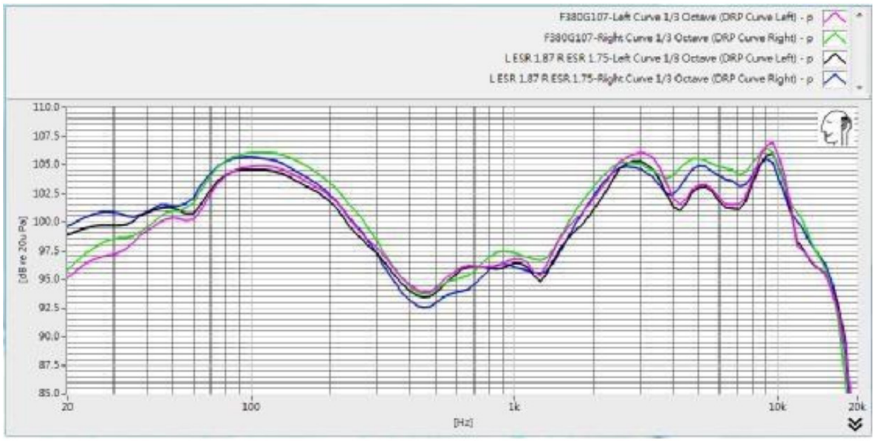


Figure 1 - Frequency response curve for F380G107MSALZT

FREQUENCY RESPONSE

Given the superior frequency performance of the F98 series capacitors, the effect of ESR on the left and right channels can then be analyzed. The worst- and best-case combinations are shown in Figure 2, with the worst (4.5 dB drop) ESR of 4.83Ω and 0.25Ω shown in green and red, and the best (2.5 dB drop) ESR of 1.87Ω and 0.35Ω shown in blue and black. From 50 Hz to approximately 4 kHz, the difference between right and left channels was maintained within 3 dB.

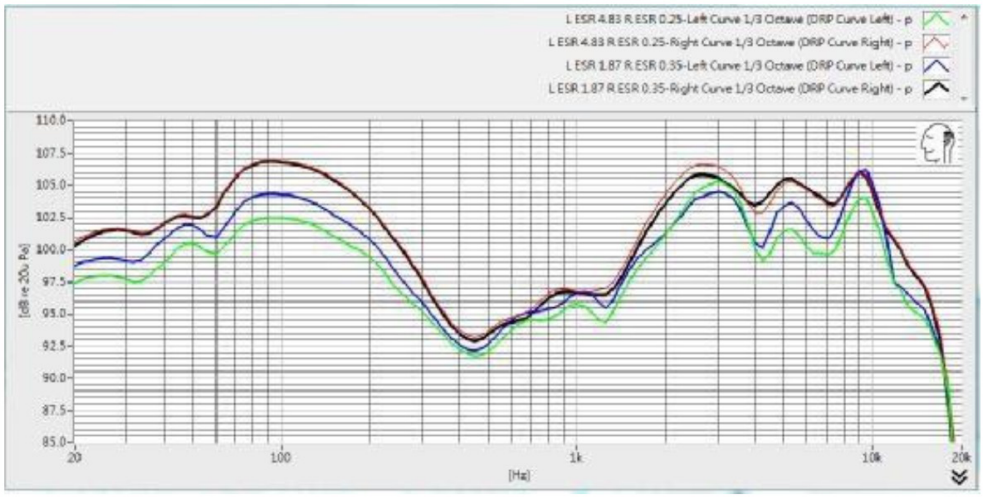


Figure 2 - Frequency response curve for F980G227MSA

DYNAMIC RANGE AND ESR

Measuring twenty F98 capacitors yielded a range of results for capacitance and ESR in the range of interest, as shown in Figure 3.

Several different combinations of ESR values were chosen and tested for the left and right audio channels. Figure 4 (next page) shows the black trace with ESR of 1.87Ω and 1.75Ω produced the optimal results for minimizing channel difference.

Tantalum Capacitor
F980G227MSA

No.	Sample	Cap (uF) at 120Hz	ESR (Ω) at 100kHz
1		207.2	0.25
2		204.4	0.35
3		202.7	0.53
4		195.1	0.64
5		203.1	0.73
6		203.1	0.93
7		185.6	1.03
8		200.8	1.15
9		202.1	1.27
10		205.0	1.40
11		198.6	1.50
12		198.9	1.66
13		190.6	1.75
14		190.6	1.87
15		195.2	2.26
16		196.2	2.34
17		201.4	2.45
18		188.9	3.21
19		193.2	3.68
20		194.5	4.83

Figure 3 - ESR and capacitance measurements for a set of F98 devices

DYNAMIC RANGE AND ESR

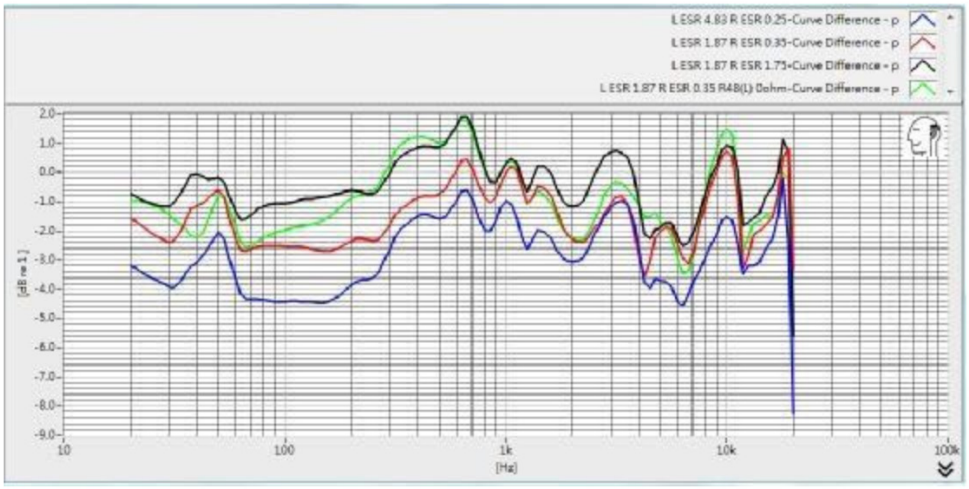


Figure 4 - Dynamic range tests for left and right channels with varying ESR combinations

STEPPED FREQUENCY SWEEP

Four groups of F980G227MSA were selected with different ranges of values for ESR. Stepped frequency response tests were conducted for each group, as shown in the following figures. The first and second groups have similar ESR values. The third and fourth groups have larger differences in ESR values.

The closer ESR values result in closer RMS values between the left and right channels. Conversely, a greater ESR difference resulted in an RMS difference between the left and right channels of around 1 dB at low frequencies.

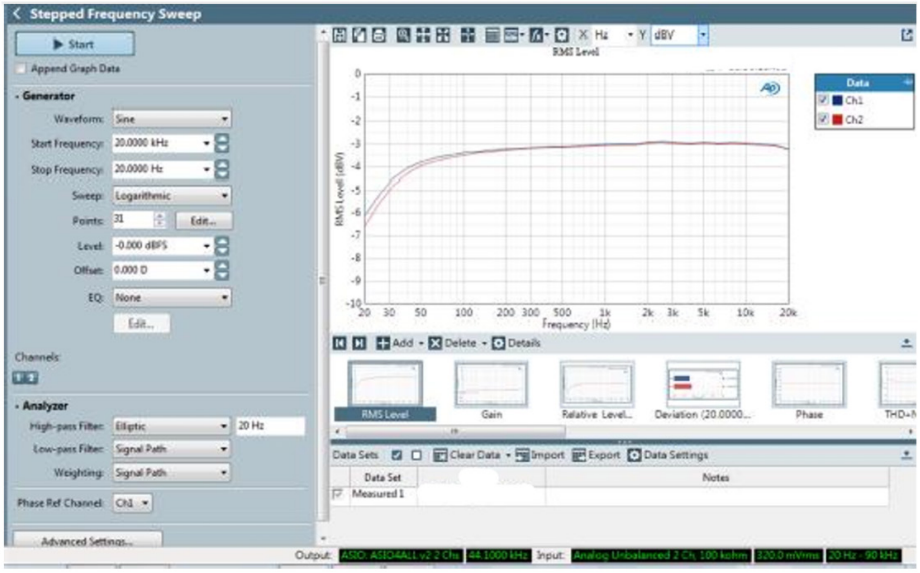


Figure 5 - Stepped frequency sweep testing sample #1

STEPPED FREQUENCY SWEEP

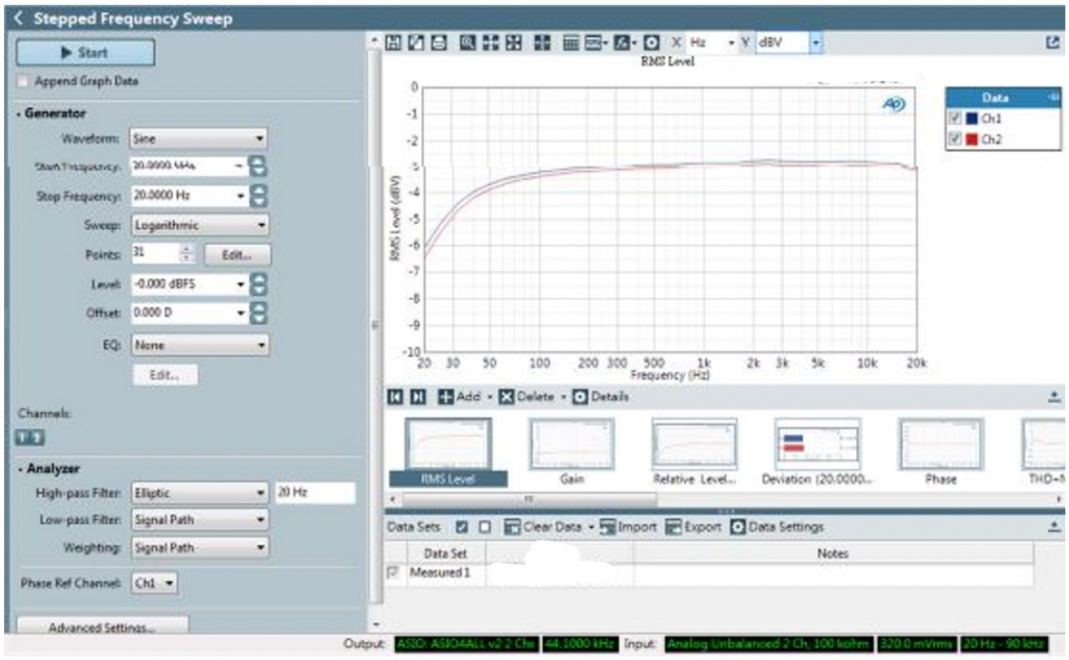


Figure 6 - Stepped frequency sweep testing sample #2

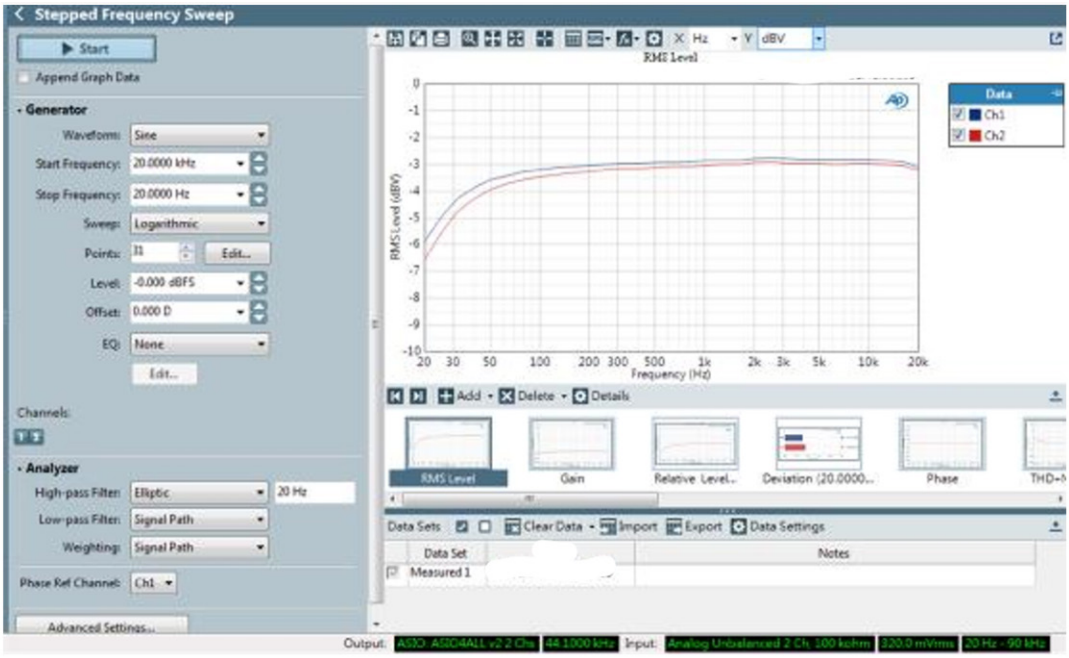


Figure 7 - Stepped frequency sweep testing sample #3

STEPPED FREQUENCY SWEEP

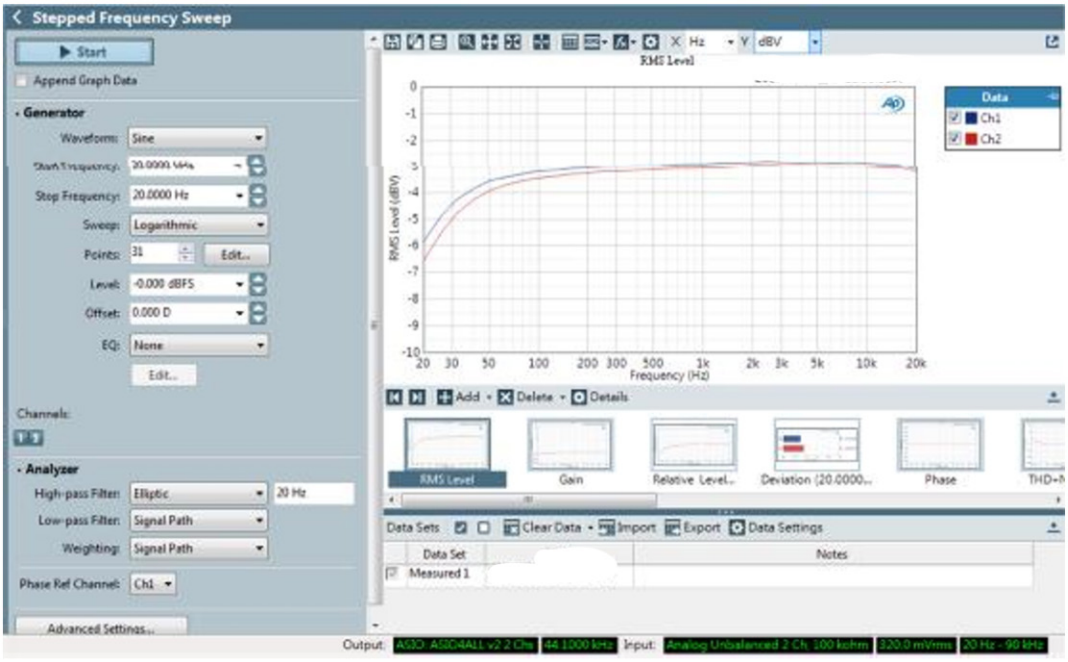


Figure 8 - Stepped frequency sweep testing sample #4

F98 SERIES FOR MAXIMIZED CAPACITANCE

Analyzing the effects of ESR and capacitance for DC blocking capacitors in audio signal paths demonstrates how critical they can be for high-fidelity applications. Unfortunately, optimal capacitor selection may not be possible when constrained by height, size, and cost. Therefore, it is recommended that the designer first maximize capacitance by using a Tantalum Polymer capacitor such as KYOCERA AVX's F98 series.

After this selection is made, designers can optimize the specific device for ESR to maximize audio performance across the dynamic range and frequency response.

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