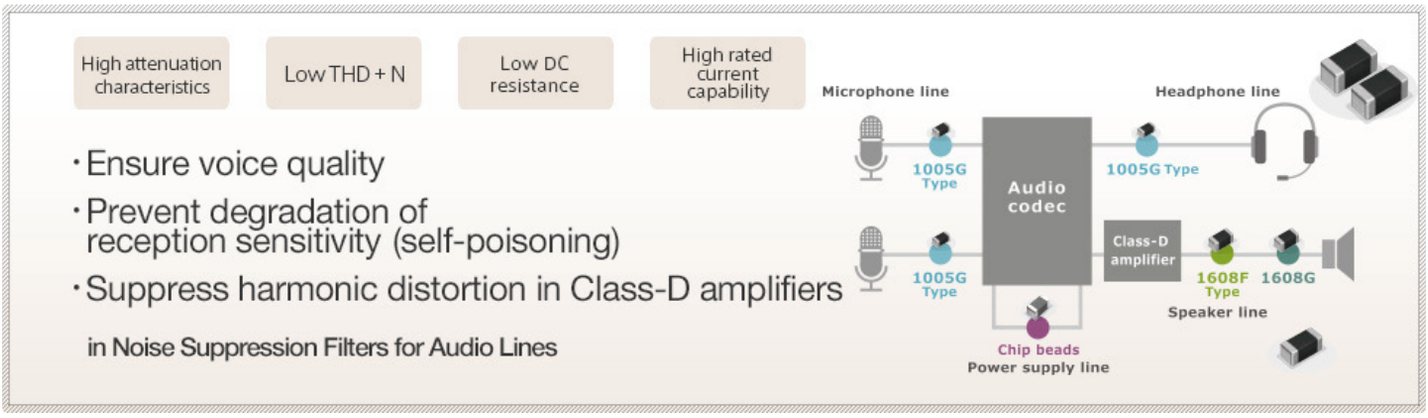


Solution guide to the use of noise suppression filters in audio lines – Outline

In the absence of any measures, electromagnetic noise is emitted from the wiring in smartphone speakers as well as the audio lines of headphones. Since this noise interferes with the built-in antenna and causes a drop in reception sensitivity, generally chip beads are inserted as a noise suppression measure. However, even though chip beads are effective for noise suppression, they also have a problem because they cause voice distortion when used for audio lines. As a solution for this problem, TDK has developed the MAF series of noise suppression filters for audio lines using a new product concept. Since these filters have an excellent noise attenuation effect in the cellular band, use of these filters results in great improvement in reception sensitivity, and solves the problem of degradation in noise quality found in the parts which have been used so far for noise suppression. They are extremely effective in reducing harmonic distortion in Class-D amplifiers which are being used in smartphones.

Background of the development of the MAF series of noise suppression filters for audio lines

In the existing chip beads manufactured using ferrite, it is difficult to eliminate noise and simultaneously minimize the voice distortion. It is necessary to find solutions to the problems of degradation of reception sensitivity and voice distortion in audio lines.

Noise suppression filter manufactured using TDK's proprietary low distortion ferrite material

TDK newly developed a new ferrite material which achieves low distortion while retaining its noise elimination characteristics.

Guide for application to the audio lines

Solution ①
Improvement in reception sensitivity and improvement in THD+N characteristics

Solution ②
Application of 1608F to the speaker line

Solution ③
Application to headphone lines

Please see here for the summary of "Solution guide for the audio lines."

Guide to the MAF series of noise suppression filters for audio lines

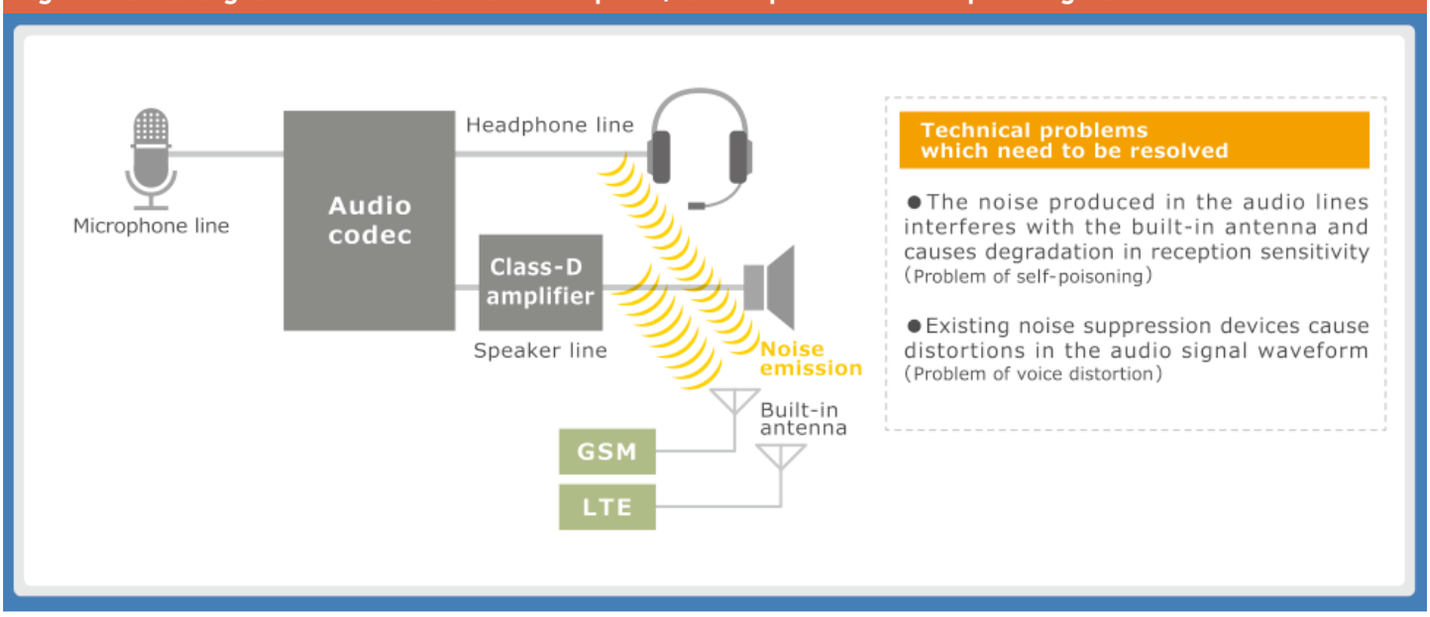
Type \ Size L × W mm	1005mm(0402inch)	1608mm(0603inch)
G type (to ensure cellular reception sensitivity)	**MAF1005G**	**MAF1608G**
F type (to suppress harmonic distortion in Class-D amplifiers)	—	**MAF1608F**

1. Background of the development of the MAF series of noise suppression filters for audio lines

Why is noise suppression important for audio lines?

Figure 1 shows a block diagram of the audio lines in a smartphone. In a smartphone, a Class-D amplifier, which is a digital amplifier, is used as the power amplifier for the speakers. A Class-D amplifier is also known as a switching amplifier, and it is a system that uses PWM (pulse width modulation) technology using switching elements (MOSFET, etc.) to convert audio input signals into pulse signals, and after amplifying them, reconverts them to analog signals and sends the output to the speakers. However, since pulse signals have many harmonic distortion components, in the absence of corrective measures, the wiring connecting the Class-D amplifier and the speakers becomes an antenna, causing electromagnetic noise emission, which interferes with the built-in antenna, and leads to degradation of reception sensitivity. In other words, it is the problem of "self-poisoning". A Class-D amplifier is compact and has excellent power efficiency, and it is used to improve the time for which the battery lasts, even if it is by a small amount, in multi-functional devices with high power consumption such as smartphones. This problem of degradation of reception sensitivity also arises due to noise from the headphone line.
Further, noise suppression measures used so far in audio lines resulted in the problem of voice distortion caused by distortion in the audio signal waveform. With increasing interest in Hi-Fi audio available in smartphones and headphones supporting "Hi-Res", it has become necessary to find solutions to the problems of degradation of reception sensitivity and voice distortion in audio lines.

Figure 1: Block diagram of the audio lines in a smartphone, and the problems of "self-poisoning" and voice distortion

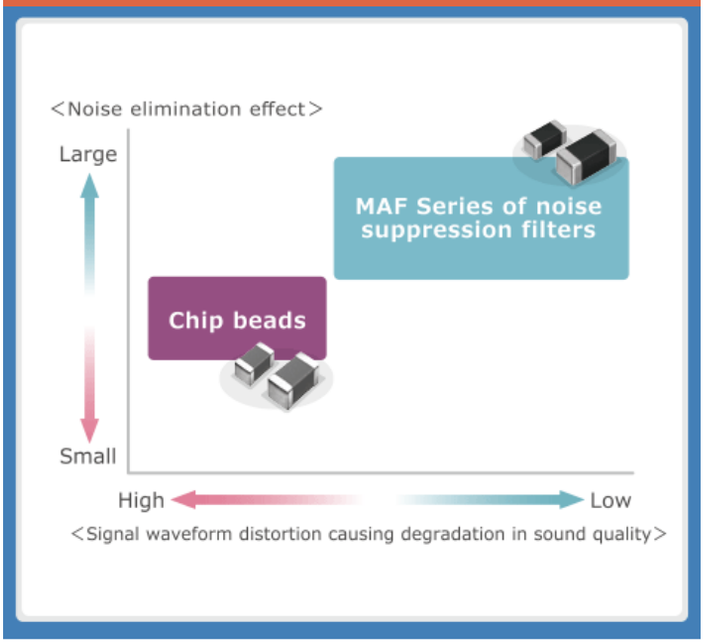


Problems when chip beads are used for noise suppression

In order to suppress the noise emitted from audio lines, chip beads are generally inserted in the output stage of Class-D amplifiers. These are chip components consisting of a coil inserted into a ferrite body using a lamination process. Chip bead impedance is expressed as the reactance component and AC resistance component of the coil. In the low frequency region, it is mainly the reactance component which functions to reflect noise, and in the high frequency region, it is mainly the AC resistance component which functions to absorb noise and convert it into heat. It is the ferrite which largely determines the characteristics of the chip beads. In the power supply system through which large current flows, chip beads with a large AC resistance component are used. Relatively large current also flows through the speaker lines in a smartphone. However, for chip beads which have a large AC resistance component, the voice distortion tends to increase, and in the existing chip beads manufactured using ferrite, it was difficult to eliminate noise and simultaneously minimize the voice distortion.

Noise suppression filter manufactured using TDK's proprietary low distortion ferrite material

Figure 2: Comparison of the characteristics of the MAF series of noise suppression filters with chip beads



In order to overcome the problems which are difficult to resolve when chip beads are used, we at TDK have used our accumulated material design technology to develop a new ferrite material which achieves low distortion while retaining its noise elimination characteristics. And, based on a new product concept, we have created multilayer chip components exclusively for noise suppression in the audio lines of devices such as smartphones. This is how the MAF series of noise suppression filters for audio lines was born. Incidentally, the name MAF is an acronym formed from the 3 words M (Multilayer), A (Hi-Fi Audio), and F (Noise suppression Filter).
Figure 2 shows a comparison of the characteristics of the MAF series of noise suppression filters with chip beads. From this comparison, it is clear that the MAF series of noise suppression filters is a uniquely positioned product which combines the characteristics of excellent noise elimination and low distortion.

Product range consisting of the G type and F type optimized for various applications

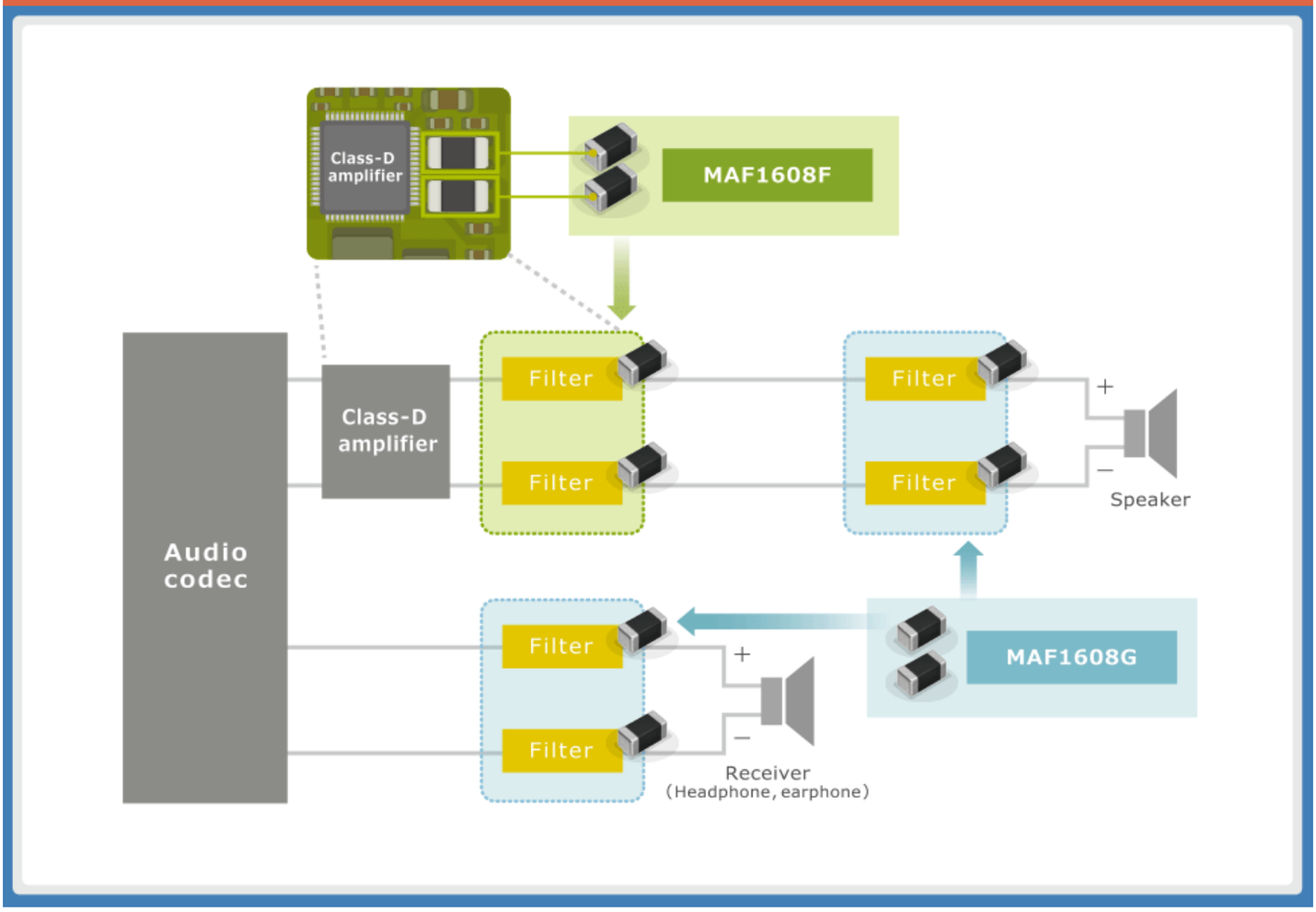
The MAF series of noise suppression filters for audio lines from TDK is commercially available with the following options: G type and F type in the 1608 size (L1.6 x W0.8 mm), and the G type in the 1005 size (L1.0 x W0.5 mm) (as of August 2016). The G type is a product having high attenuation characteristics in major cellular bands (700MHz to 2GHz) such as LTE, and by inserting it into the speaker line and headphone line, the reception sensitivity can be considerably improved. The F type is for the speaker line, and when it is inserted in the output stage of a Class-D amplifier, it proves to be extremely effective in elimination of harmonic noise.

2. Guide for application to an audio line

1 Solution ①
Improvement in reception sensitivity and improvement in THD+N characteristics

The excellent features of the MAF series of noise suppression filters for audio lines are explained below with specific examples of their application. Figure 3 is a block diagram showing the use of MAF1608F and MAF1608G in the speaker line, and the use of MAF1608G in the receiver (headphone/earphone) line.

Figure 3: Example of the use of /1608F in MAF1608G of the audio line in a smartphone



First, the effect of using MAF1608G, which has high attenuation characteristics in the cellular band, is shown in Figure 4. The figure shows the reception sensitivity - frequency characteristics:

◆When there is no filter

●When MAF1608G is inserted.

This is a measurement example of the 900MHz band. Compared to the case when there is no filter, the measurement reading shows an improvement which is as high as 8dB when using MAF1608G. This is because, as you can clearly see from the insertion loss - frequency characteristics in Figure 5, the design has been optimized so that in this frequency band, there is large insertion loss (= high impedance).

Figure 4: Result of insertion of MAF1608G into the speaker line (improvement in reception sensitivity) (1)
Reception sensitivity – Frequency characteristics

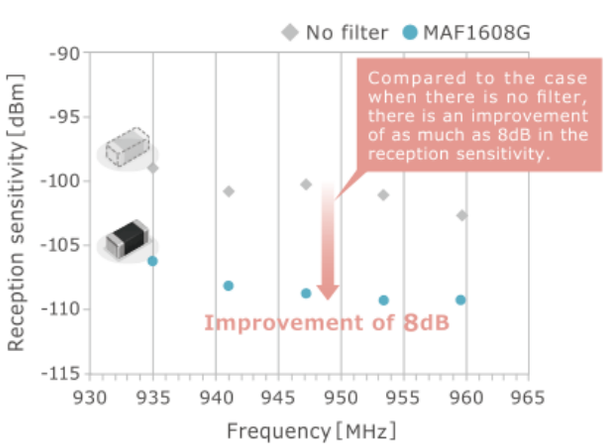
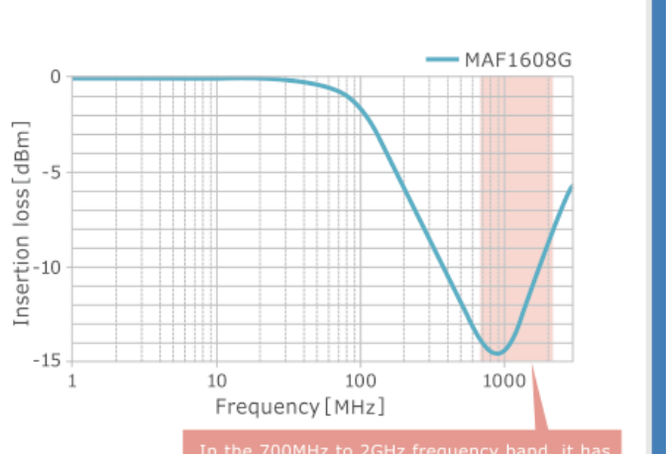


Figure 5: Result of insertion of MAF1608G into the speaker line (improvement in reception sensitivity) (2)
Insertion loss – Frequency characteristics



Thus, it can be seen that the application of MAF1608G to audio lines is extremely effective as a solution to the problem of degradation of reception sensitivity in smartphones. But what about the problem of voice distortion caused by insertion?
Voice distortion in audio lines is generally expressed as a numeric value represented by THD+N (Total Harmonic Distortion + Noise). This is a ratio (Unit: [%]) representing the share of harmonic distortion and other noise components (Total Harmonic Distortion + Noise) in the source signal component, and the lower this number, the better is the sound quality.

Figure 6: THD+N characteristics for MAF1608G

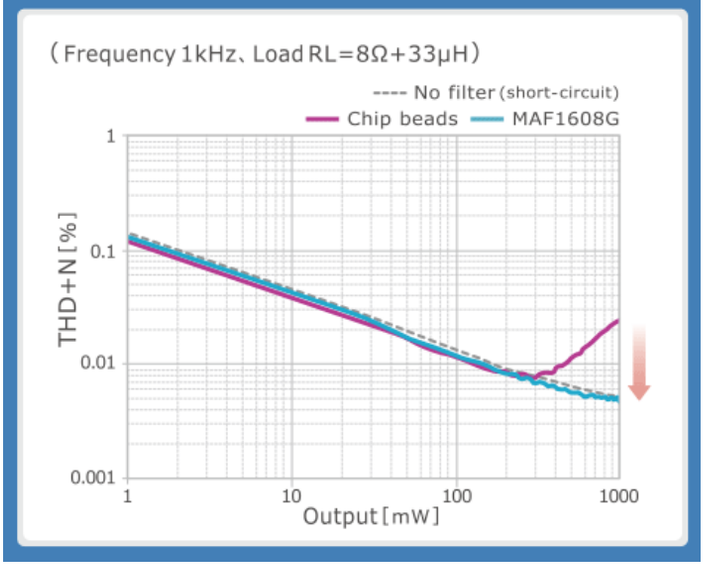


Figure 6 is a graph which compares the THD+N characteristics versus the output of chip beads (TDK MPZ1608D) and MAF1068G (Measured at a frequency of 1kHz, and load of RL=8Ω+33μF). Since the output with chip beads is around 200mW, the THD+N value suddenly increases. On the other hand, even at an output of 1000mW, MAF1608G has almost the same characteristics as when there is no filter. This means that even when it is inserted in the speaker line, it will not cause voice distortions which is a problem in the case of chip beads. Also, the rated current of MAF1608G is as large as 1.6A, and it is ideal for speaker lines which require large current.

The DC resistance (RDC) is also an important characteristic. This is because, if the DC resistance is high, the power consumption increases, and the signal level also drops. MAF1608G has achieved a low resistance of 0.06Ω (typical value). As a result, the drop in sound volume due to insertion is small, and it also contributes to a longer time for which the battery lasts.

2 Solution ②
Application of MAF1608F to the speaker line

MAF1608F has even more striking THD+N characteristics. Figure 7 is a graph which compares the THD+N characteristics versus the output of chip beads (TDK MPZ1608S) and MAF1068F (measured at a frequency of 1kHz, and load of RL=8Ω+33μF).
In case of the MPZ1608S chip beads, the THD+N value is stable at approximately 1[%], while the MAF1608F retains excellent characteristics until it approaches around 1000mW.
In MPZ1608S, S represents the ferrite material used, and S material is the standard type of material having frequency - impedance characteristics similar to ordinary ferrite.
The newly-developed low-distortion ferrite material used in the MAF series has contributed to extremely low THD+N characteristics, as can be seen in the graph.
Figure 8 shows the suppression effect of the noise emission from a Class-D amplifier by using MAF1608F. Since MAF1608F has been designed to show a high impedance value in the 100 to 400MHz frequency band, it is extremely effective in noise suppression in this frequency band.

Figure 7: Result of insertion of MAF1608F into the speaker line (1) Comparison of the THD + N characteristics versus output

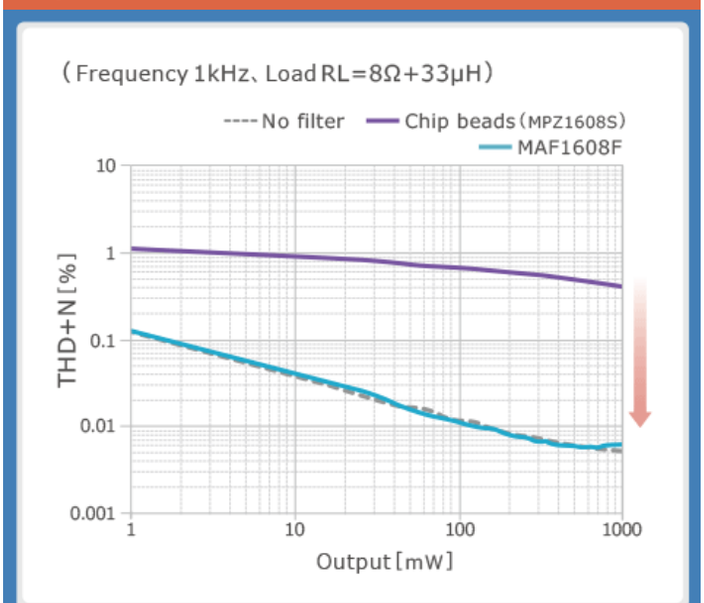
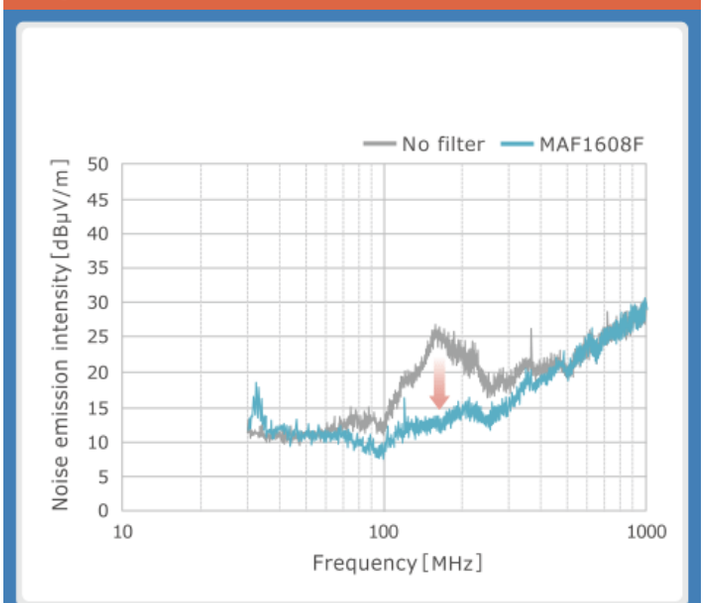


Figure 8: Result of insertion of MAF1608F into the speaker line (2) Effect of suppression of noise emission in Class-D amplifiers by using MAF1608F



3 Solution ③
Application to headphone lines

Figure 9 is an example of the application of MAF1005G for headphone lines. Figure 10 shows the comparison of the reception sensitivity with the case when there is no filter in the 900MHz band (The last three digits in the product code represent the impedance). Compared to the case when there is no filter, there is an improvement of 6dB in the reception sensitivity.

Figure 9: Result of insertion of MAF1005G into the headphone line (1)

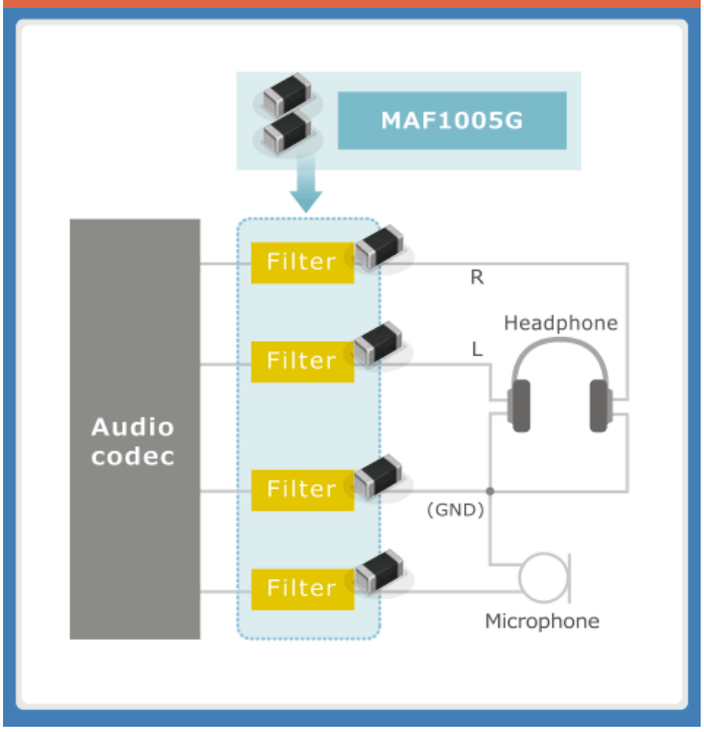


Figure 10: Result of insertion of MAF1005G into the headphone line (2) Reception sensitivity – frequency characteristics

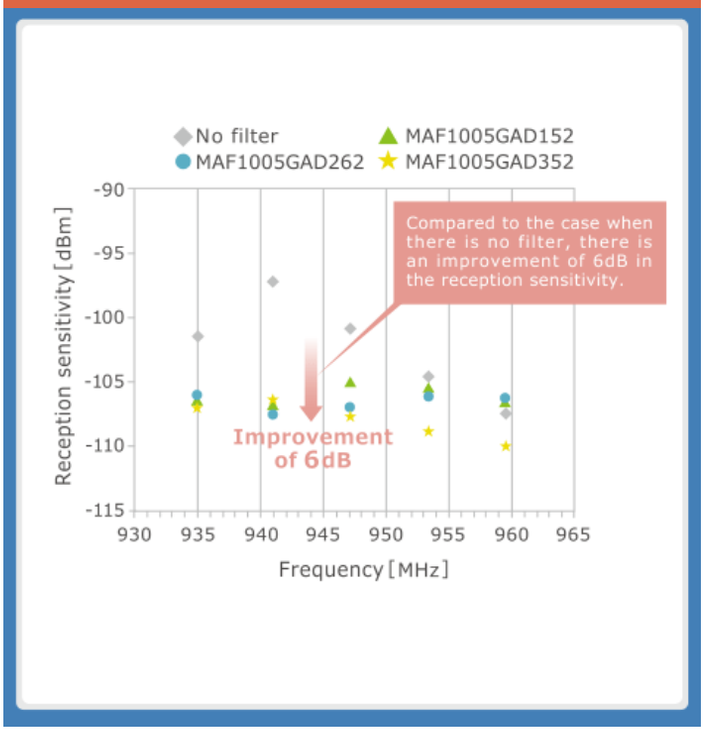


Figure 11 shows the THD+N value versus the output for the 1005 size (L1.0 x W0.5 mm) when compared to chip beads of the same size (TDK MMZ1005A). For chip beads, 0.2mW is the limit, and increasing the output beyond this limit leads to a sharp increase in the THD+N value. In other words, degradation of noise quality cannot be avoided at high sound volume. On the other hand, MAF1005G has the same characteristics as when there is no filter even at a large output of several tens of mW.
Figure 12 shows the FFT spectrum analysis of the THD+N characteristics versus output. In case of chip beads, the harmonic distortion rises significantly at integral multiples of the measurement frequency (1kHz), and its THD+N value reaches 0.035%. On the other hand, in MAF1005G, the harmonic distortion is considerably suppressed, and the THD+N value is 0.00022%, which is almost zero.

Figure 11: THD+N characteristics for MAF1005G (1)
Comparison of the THD + N characteristics versus output

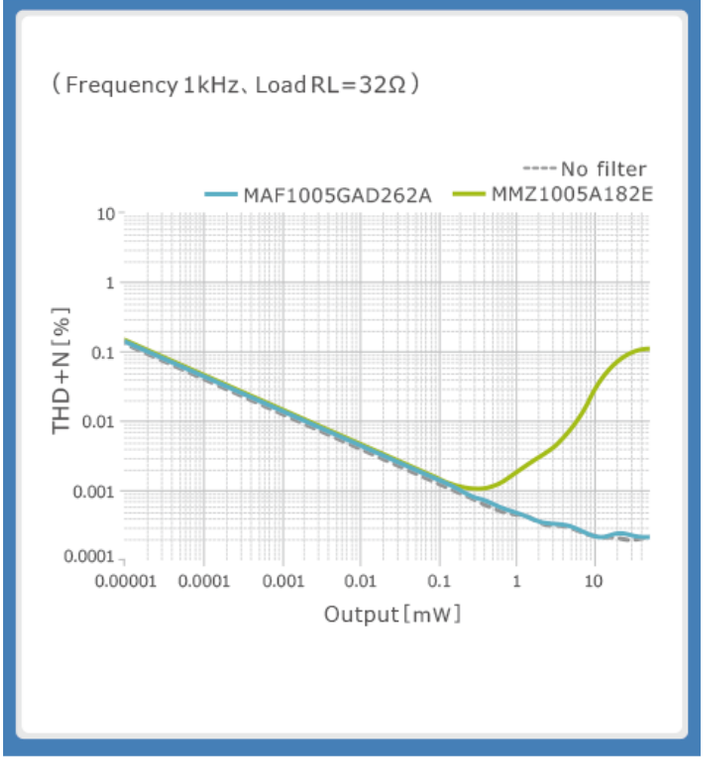
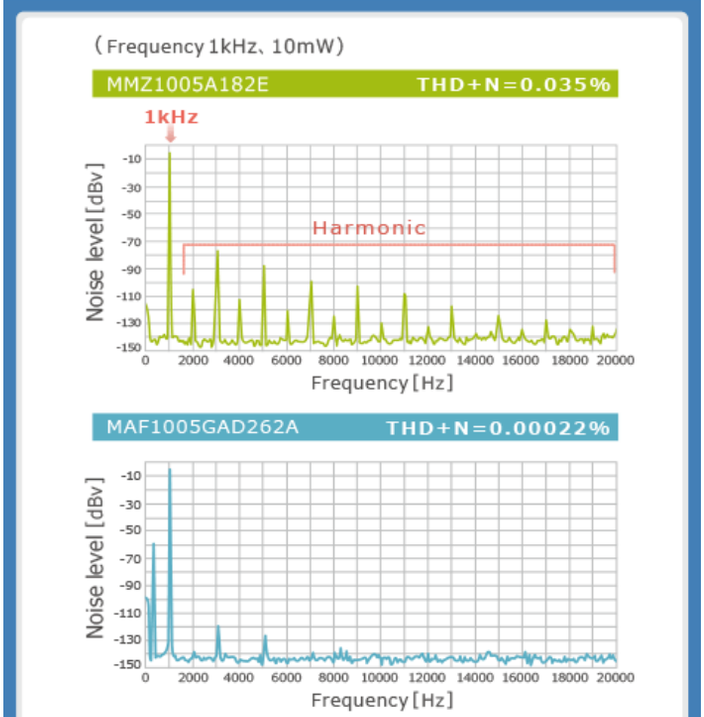


Figure 12: THD+N characteristics for MAF1005G (2)
Frequency spectrum analysis by an FFT analyzer

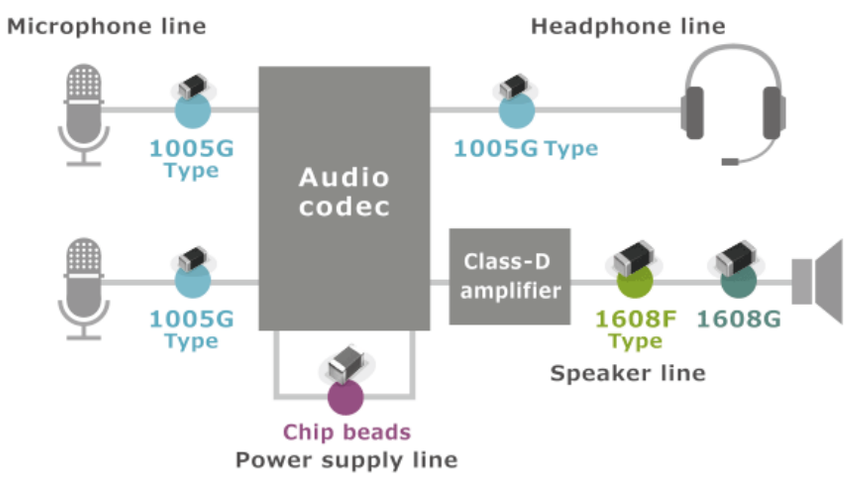


Summary

In mobile devices with communication functions such as smartphones and tablets, noise suppression components inserted into the audio lines of speakers, headphones/earphones, and microphones must improve reception sensitivity (by suppressing noise which is the cause of a drop in reception sensitivity) with minimal impact on the sound quality. The MAF series of noise suppression filters for audio lines, which is a new product line from TDK, has high attenuation characteristics in the cellular band, and inserting it results in significant improvement in the reception sensitivity. And, by using TDK's proprietary ferrite material with low distortion, THD+N (Total harmonic distortion + Noise) , which is an indicator of voice distortion, is suppressed in the actual usage bandwidth until it is extremely close to zero, and this makes it an ideal noise suppression component for devices requiring high sound quality. They are also highly effective in reducing harmonic distortion in Class-D amplifiers which are being used in smartphones.

Thus, while the MAF series has excellent characteristics which cannot be implemented using chip beads, there are also some points which can be handled using chip beads in audio lines. By appropriately using the MAF series of components in combination with chip beads, a variety of excellent solutions are offered not only for smartphones and tablets, but even for the audio lines of portable game consoles (Figure 13).

Figure 13: Recommended application of noise suppression components in a Hi-Fi audio line



Line	Sound quality assurance
Headphone	Required
Speaker	Required
Microphone	Required
Power supply	Not required

《Main features and applications of the MAF series of noise suppression filters for audio lines》

【Main features】

- Compact noise suppression filters for audio lines and support large current
- By using newly developed low distortion ferrite material, there is considerable reduction in voice distortion during insertion into audio lines
- Since the resistance is low, drop in sound volume is small, and since they are able to suppress voice distortions, these filters are ideal for devices which require high sound quality
- Due to their high attenuation characteristics, they have proved to be highly effective in suppressing degradation of reception sensitivity in the cellular band

【Main applications】

- Audio lines of smartphones and tablets (Speakers, headphones, microphone)
- Audio lines for portable game consoles
- Others

【MAF series of noise suppression filters for audio lines】 Product Information and Sample Purchase

* Please select the type/Part No. suitable for your applications to improve the reliability of your products.

Figure 13: Recommended application of noise suppression components in a Hi-Fi audio line

Part No.	Size [mm]	Impedance at 900MHz[Ω] typ.	DC resistance[Ω] typ.	Rated current [A]	THD+N[1W,1KHz] Resistor:8ohm	catalog
MAF1608GAD471C	1608	470	0.06	1.6	-86dB/0.005%	[157KB]

Part No.	Size [mm]	Impedance at 900MHz[Ω] typ.	DC resistance[Ω] typ.	Rated current [mA]	THD+N[10mW,1KHz] Resistor:32ohm	catalog
MAF1005GAD152A	1005	1500	0.55	400	-114dB/0.0002%	[178KB]
MAF1005GAD262A	1005	2600	1.00	300	-114dB/0.0002%	
MAF1005GAD352A	1005	3500	1.30	270	-114dB/0.0002%	

Part No.	Size [mm]	Impedance at 100MHz[Ω] typ.	DC resistance[Ω] typ.	Rated current [A]	THD+N[1W,1KHz] Resistor:8ohm	catalog
MAF1608FAD121C	1608	120	0.085	1.35	-86dB/0.005%	[168KB]
MAF1608FAD151C	1608	150	0.090	1.25	-84dB/0.006%	

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