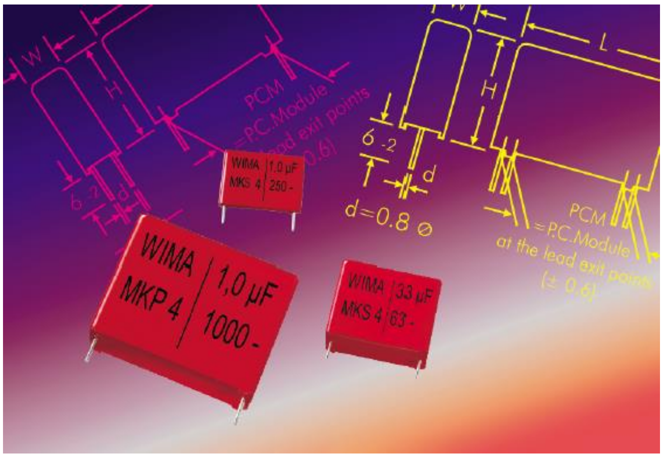
WIMA: The Capacitors for High End Audio Applications



Top of the range audio equipment has developed unto a small but pricey specialist field of home audio electronics. Qualified manufacturers are constantly endeavouring to meet the ever-growing demands of audio enthusiasts for sound enjoyment and prestige value. Passive components such as capacitors for example, may not be at the centre of public interest as compared to active components, they form an indispensible parts of the overall result.

Only the best is good enough.

Test reports in HiFi/High End magazines concentrate mainly on topics from the active sector but exclude that a first-class passive component in the form of a tight tolerance long-time stable precision capacitors also belongs to this high precision component. In some cases of high-class audio manufacturer the PC boards carried out 100% by **WIMA** capacitors.

Why **WIMA** capacitors are to be found in part or, often, as “monocultures” in almost all their equipment ?

What are the reason for the international popularity of **WIMA** capacitors in High End audio equipment? For sure, these components provide a welcome optical improvement of the PC-board layout, due to the precise geometry of the casing combined with the attractive red colour and imprint. Especially with equipment which has tube amplifiers and/or where it is possible to see the inner working through a perspex lid, these components, both the smaller and the larger types have an undeniable aesthetic charm. Nevertheless, an agreeable appearance alone, is not a sufficient reason. The inner working of these capacitors, i.e. their performance also have to satisfy the high demands of the leading manufacturers and fulfil their special requirements. Just to produce quality, which all component manufacturers claim to do, is not enough in this case. **WIMA** must therefore have succeeded in keeping well ahead of the others as in regards to the performance of their capacitors.

It is strange, that even in the normally matter-of-fact world of technology, top products, both as a whole as well as in their individual parts, often hold a unique fascination for those interested. In extreme cases, this sometimes even leads to an almost mystical way of looking at things in which even the word “wonder” has its place. Some fanatics or engineers, for example, use the **“WIMA therapy”** which just means, they believe that simply by replacing the actual capacitor with **WIMA** capacitors an improved sound effect can be achieved.

In any case, it is a fact that responsible engineers are keen to get the best possible results and cannot make any compromises when choosing film capacitors. A top product is only really top if, in its entirety, it is made up of top individual parts and materials.

Perhaps **WIMA's** success lies in the fact that, due to the choice of material, the principle of construction and their first-class processing know-how, their capacitors come closest to the goal for the ideal capacitor, This theme will be dealt with in detail in the following text, on the basis of the technical facts.

Applications

In the audio transmission chain in each individual pieces of equipment starting with CD player, tape deck and tuner, through transducer and pre-amplifier to power amplifier and finally in the crossover of the loudspeaker, capacitors with an almost endless variety of different capacitance and voltages are used. The majority of the applications are directly in the signal path and can have a direct influence on the audio signal. Great care should consequently be taken in the choice of suitable capacitors.

Audio applications can be grouped into three basic fields:

1. Applications in the signal path.
2. Functional tasks.
3. Use in voltage and support.

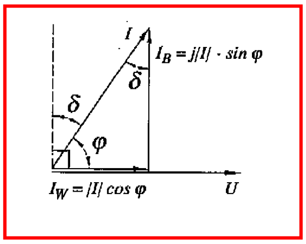
By using optimal capacitors versions in all three fields of application, distinct improvements in the tone can be achieved, or, to be correct, the sound will be less affected.

The capacitors in the signal path certainly have the most direct influence on the audio signal. Consequently real improvements in the sound can be achieved just by exchanging inferior quality capacitors.

Another very important criterion is the functional capacitors, which can be the cause of signal distortions. For example, in CD players, D/A-A/D transducers and pre-amplifiers.

Capacitors for voltage support have less influence on the precise re-production of the music, providing they have sufficiently large capacitance. However, they should not be disregarded in genuine High End equipment. With qualified optimisation in this field too, ultimate refinements in the conception of the equipment can be achieved.

Film capacitors – the optimum solution



Basically film capacitors offer the optimum solution to problems in all areas of application. Only the position of the energy storage/smoothing capacitor is to be covered by electrolytic capacitors, due to the limited capacitance with C_{max} → 220 µF for film capacitors. In all other positions, plastic film capacitors are far superior to other technologies both in performance and reliability.

Plastic film capacitors are offered by **WIMA** in many different versions. The dielectric used certainly constitutes the main distinguished criterion:

- Polyester (Mylar) MKS/FKS versions*
- Polypropylene MKP/FKP versions*
- Mixed dielectric MKM/FKM versions*

*WIMA-types

Dissipation factor

In AC voltage operations a continuous change of polarity of the capacitor electrodes and consequently of the dielectric takes place. The resulting friction in the molecular structure is converted into

heat. The losses incurred in this polarity change are dependent on frequency and also on the applied voltage.
Furthers losses are the so-called heat losses. They stem from the resistive component of the current carrying parts of the capacitors: leads, schoopage and capacitor electrodes.

From the equivalent circuit diagram of the technical capacitor

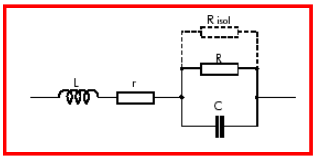


Figure 1: Equivalent circuit diagram

Results the calculation of the dissipation factor in accordance with the vector diagram.

Figure 2: Vector diagram phase displacement

$Q_{\varepsilon} = \tan \delta$ $\qquad \delta = 90° \varphi$

$$\tan \delta = \frac{1}{Q_{\varepsilon}} = \frac{Rs}{Xc} = Rs \times W \times C$$

Due to the phase displacement between voltage and current in the technical capacitor which is less than the theoretical value

$\varphi = 90°$

because of the dissipation factor, undesirable phase displacements of the audio signal occur in proportion to the rate of the dissipation factor.

Consequently capacitors with the lowest dissipation factors show the least signal distortions. Especially if polypropylene capacitors are used, the remaining dissipation factor is so small that noticeable displacements no longer occur.

Polypropylene – the ultimate solution

For applications in the audio field, polypropylene versions are, in principle, the most suitable as they have the lowest dissipation factor. Polypropylene capacitors are therefore available in both metallized and film/foil technology. The capacitance ranges from

C = 100 pf to C = 33 µF

Thus, almost all fields of applications can be completely covered by polypropylene capacitors.
In some cases applications, as for example, in loudspeaker crossover networks higher capacitance values are required. In these cases, as an exception, it is possible to us polyester capacitors which are manufactured as special versions with a capacitance value up to

C = 220 µF.

The dissipation factor of polyester is considerable higher than that of polypropylene, but it is 20 times lower than comparable audio frequency electrolytic capacitors.

Dielectric absorption

A further important criterion in the field of audio applications is the dielectric absorption. Like the dissipation factor, it is a basic physical property of the dielectric.

The dielectric residual recharging described as dielectric absorption can be observed in all capacitor technologies. In a charged capacitors which has been discharged by a bridge, a slight development of voltage with the original polarity can be observed after a short time.

The dielectric absorption can be attributed to the polarisation processes/memory effects of the respective dielectric; it is, to a large extend, independent of the capacitance value and the thickness of the dielectric. Figure 4 demonstrates the lowest ratings for polypropylene.

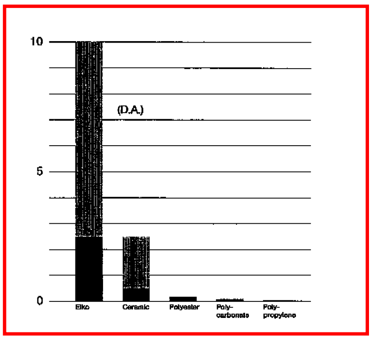


Figure 3: Dielectric absorption

Electrolytic and ceramic capacitors have a residual recharging effect which is 10-100 times higher and which leads to lack of clarity the treble tone reproduction in the audio signal path. Dielectric absorption is also an important feature in the field of D/A-A/D transducers in CD players or DAT recorders. Because of the low signal level, recharging effects can lead to quantization failure of the transducers and thus distort the conversion of the audio signal.

In these cases renowned High End manufacturers as well as industrial converter manufacturers employ exclusively **WIMA FKP** versions.

Structural characteristics

To achieve a faithful musical reproduction every designer has the intention of using electrically ideal component in the development of High End equipment. However, ideal components only exist in theoretical physics. With every technical /real component as in the case of the capacitors, further possible disruptive influences occur and above the real function. The actual behaviour of a real capacitor can be derived from the equipment circuit diagram of the capacitor. The equivalent circuit diagram shown at the top of the figure 1 demonstrates parasitic components characteristics such as

L = self inductance
r = ohmic resistance
R = polarisation losses in the dielectric
R_{isol} = insulation resistance/residual current

By means of suitable structural measures minimising the parasitic components, **WIMA** has come very close to obtain an ideal capacitor.

The polarisation losses referred to as R can, as has already been discussed, be reduced to a minimum by using polypropylene.

Due to the very good insulation properties of almost all plastic film in the region of specific volume resistance > 10^{18} Ω x cm the insulation resistance parameter may be disregarded. This parameter is more critical in the field of electrolytic capacitors which work expressedly with the term of residual current. Here the values are 100-1000 times higher than in plastic film capacitors.

The structural features we are mainly concerned with are therefore self-inductance L and ohmic resistance r.

Self-inductance

In the field of audio application, very precise pulse reproduction is called for, which is assessed in the pulse behaviour criteria. In particular in the case of the audio signal dynamic jumps of up to 100 dB occur. This means a voltage of

100 dB → U_1 = 1 : 100000.

Both the parasitic self-inductance and the ohmic resistance of the capacitor have a de-emphasising effect on such voltage changes. Furthermore such voltage curves are made up of a high proportion of harmonics of fundamental oscillation. The frequency spectrum thus transmitted, exceeds the audible range of f = 20Hz to 20 kHz considerable. In this case the transmitting frequency is up to f = 100 kHz.

Modern **WIMA** high-performance capacitors are produced as radial components with end surface contacts. In comparison to conventionally manufactured axial wire contact versions, parasitic self-inductance is reduced to a minimum in modern plastic film capacitors.

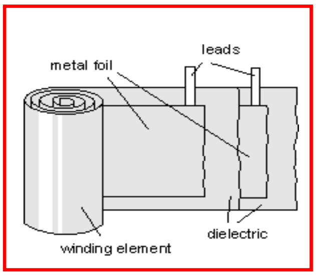


Figure 4: Old type with high self-inductance

The tape length of the winding element determines the value of the self-inductance.

WIMA plastic film capacitors are nowadays contacted over the surface of the whole tape length. The self inductance of the winding element is thus short-circuited.

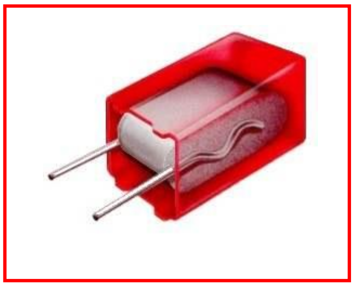


Figure 5: Modern low-inductive WIMA type

The remaining self-inductance is reduced to the smallest sized resulting conductor loop possible, which is made up of the

- width of the winding element
- remaining length of the leads

Values for practical purposes: L= 1 nH/mm

Example: lead length 2 x 3 mm
PCM 5 mm
$L_{self} \approx 11nH$

Modern radial capacitor technology complies with the efforts being made in audio applications to keep the signal paths as short as possible.

The old types of axial designs often still offered as special audio capacitors, hate the striking disadvantage of unnecessarily lengthening the conduction paths on the PC-boards and, because of the larger structure and longer remaining length of the leads, they have considerable higher self-inductance.

Figure 6 shows the different self-inductance of axial / radial construction.

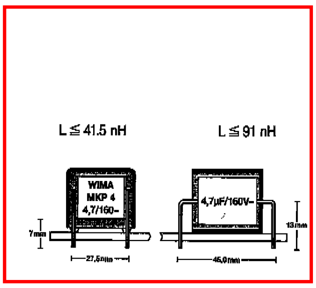


Figure 6: Comparison self-inductance axial vs, radial

The pulse behaviour of axial constructions is therefore always much worse than that of modern radial ones.

The old axial versions may just offer slight advantages in the installation of crossover networks in outdoor wiring. For such applications, however, radial **WIMA** components are also available with long leads.

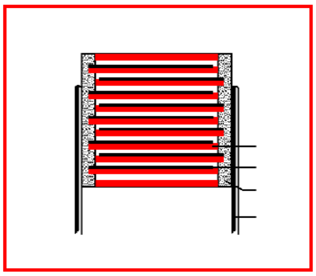
Further advantage: Low ohmic re-sistance

The large surface contact over the whole length of the winding element represents a further advantage of modern **WIMA** capa-citor technology. With contact over a schoopage layer, the technically largest possible area of the winding element is contacted and this inevitable results in the lowest ESR.

The structure form of the capacitors electrode also influence the dissipation factor/phase angle and pulse accuracy. In general there are three different constructions which are available for use in audio applications.

Single-sided metallized versions

One of the most widespread capacitor versions is the single sided metallized structure shown in figure 7. Such a capacitor consists of two layers of film metallized on one side with aluminium. Contacts to the leads is made through a schoopage layer.



Vacuum-deposited plastic film dielectric
aluminium electrodes
Metal contact

Figure 7: Cross section of WIMA MKP 4

This construction has the advantage of being the best C/V product i.e. the smallest possible box size at a given capacity. Thus, high capacitance values can be produced, as required in crossover networks, for example, or decoupling of the final power amplifier.

However, these types have the disadvantage that the capacitor current is only conducted by the thin aluminium metallization, In comparison with the double-sided metallized and film/foil version described in the following section, the above construction are the least favourable pulse behaviour. In absolutely High End equipment such capacitors should therefore only be used when the required capacitance values are not available in the higher rated versions.

Double-sided metallized versions

To cover positions with high capacitance values in audio applications the principle of the double-sided metallized construction used in the **WIMA MKP 10** series and shown in figure 7, is the most suitable.

Here the capacitor electrode is made of film metallized on both sides. The capacitor is produced with 4 layers of film. Such a construction has a 5-10 times greater pulse rise time and a much better pulse behaviour due to the double contact of the metallization and also the improved toothed attachment of the schoopage due to the enlarged spaces in the winding element.

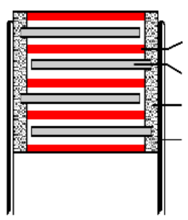


Figure 8: Cross section of WIMA MKP 10

The good contact to the capacitor electrode also has a favourable effect on the dissipation factor. Types which are metallized on both sides have a 30-50% lower dissipation factor than comparable versions metallized on one side only.

Film/foil versions

With regard to audio applications, **WIMA** film/foil capacitors with polypropylene dielectric represent the non plus-ultra.

In figure 9 the capacitor electrode is shown as a massive tin foil.

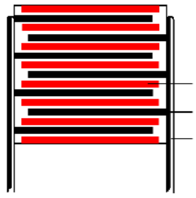


Figure 9: Cross section of WIMA FKP 3

Due to the very good contact of the capacitor electrodes at the end surfaces to the Leads –"direct bonding", as well as the large cross-section of the electrode foil, such versions, for example

WIMA FKP 02 (PCM 2.5 mm)
WIMA FKP 2 (PCM 5 mm)
WIMA FKP 3 (PCM 7.5 + 10 + 15 mm)

have exceptional pulse behaviour. Film/foil constructions cause pr ... no
attenuation of the audio ... nd
therefore provide abso ... se
accurate reproduction.

Furthermore, **WIMA FKP** ... e
also available as a precisi ... n
a tolerance of up to

Plastic film dielectric Electrode carrier plastic film with vacuum-deposited on both sides
Metal contact layer
Terminating wire

Δ C/C = ± 2.5% (1% on

However because of the rapidly increasing box sizes, this film/foil technology can only be used in the capacitance range of

C = 100 pf ... C = 0.033 µF

Higher capacitance values are best covered by the metallized type on both sides in accordance with the preceding explanations.

Applications in the signal path

Efficient **WIMA** polypropylene capacitors are therefore available for all the fields of audio applications mentioned before.

The field of applications in the signal path covers the greatest capacitance range. Coupling capacitor of C = 100 pF are used, for example in transducers and pre-amplifiers, as well as values above C = 10 µF in crossover networks.

Based on the respective demands of the equipment manufacturers, from the point of view of what is technically possible, the following recommendation may be given for application:

WIMA FKP 02 C = 100 pF to C = 0.01 µF
WIMA FKP 2 C = 33 pF to C = 0.033 µF
WIMA FKP 3 C = 100 pf to C = 0.22 µF

WIMA MKP 4 C = 1000 pf to C = 33.0 µF
WIMA MKP 10 C = 1000 pf to C = 15.0 µF

Functional tasks

Functional capacitors are in general used in the field of small signal processing. Typical for this are applications in pre-amplifiers, D/A-A/D transducers, filters e.g. in tuners, CD-players. DAT recorders etc.. the capacitance values required here are in the lower capacitance range. Highly precise 1% versions are often demanded for filter, timer and integration application or as sample and hold capacitors in transducers.

For this purpose it is always suitable to use the **WIMA FKP 2** series which is also available on request with a nominal tolerance of Δ C/C = $\pm$ 1%. Furthermore film/foil capacitors show the best time constant. They therefore remain within the specified parameter even after many years of use.

Use in voltage support

Reservoir capacitors have the task of storing energy and passing it on again as quickly as possible when needed. They are directly connected to the voltage supply of the respective amplifier stage.

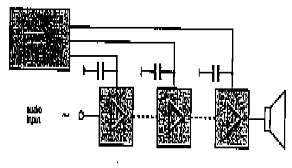


Figure 19: Application of voltage support capacitors

When high dynamic jumps occur in the audio reproduction, high power demands are suddenly made on the amplifiers, which cannot be provided directly from the central power supply with the electrolytic energy storage capacitor.
Such a power bounce would lead to a drop of the supply voltage and, inevitably, distorsions and unfavourable pulse behaviour.

To avoid this effect, capacitors in the capacitance range of

C = 0.1 µF ... 10µF

are connected against the ground directly at the feeding point of the voltage supply of the respective amplifier stage When power bounce occur, these capacitors provide the required energy as quickly as possible and effectively avoid voltage drops.

In the subsequent pulse pause the reservoir capacitors are recharged.

Since these capacitors are not used in the signal path, the use of polyester versions e.g.

WIMA MKS 02 PCM 2.5 mm C_{max} = 1µF
WIMA MKS 2 PCM 5 mm C_{max} = 10µF
WIMA MKS 4 ≥PCM 7.5 mm C_{max} = 220µF

is quite adequate. Furthermore, **WIMA MKS** capacitors have the advantage of very small box sizes, i.e. the designer is in a position to use the largest possible capacitance value within given space requirements.

Conclusion: WIMA, first choice in the High End audio sector

WIMA plastic film capacitors offer the best possible properties for all fields of audio application.

Special constructional features which are made-to-measure to suit each particular field of application, combined with an ultra modern, automated manufacturing process and a special quality assurance system WPCS (WIMA Process Control System) in accordance with ISO 9001/2000, form the basis of **WIMA's** position in the High End audio sector and their clear distinction from other firms.

As a world-wide leader in the specialist technological field of film capacitors,

WIMA now already produces day after day "real" capacitors which come close to being the ideal capacitor.

"Infinitive wonders" as promised by some third-class manufacturers who offer special audio capacitors at high prices, are not in demand. In the majority of cases the analysis of such construction confirms that these capacitors are often made in slipshod way and, furthermore, employ out-of-date technologies such as

- axial constructions
- thin/weak schoopage
- single point wire contacts
- one side metallized film
- use of standard film

If it's film capacitors for audio applications - then it's WIMA !

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