WAN_0176

A.C. Coupling Capacitor Selection

INTRODUCTION

This application note discusses the various capacitor types available which are suitable for a.c. coupling of audio signals in and out of Wolfson CODECs. The choice is becoming more difficult as parts are getting smaller. A good choice will avoid signal attenuation or distortion.

REQUIREMENTS

In many audio circuits the input or output has a d.c. bias on it. To connect this to another circuit, which may have a different bias voltage, a capacitor is used. This capacitor blocks the d.c. path, but passes the a.c. audio signal. This capacitor is required with Wolfson ADC inputs, DAC outputs and usually headphone drivers.

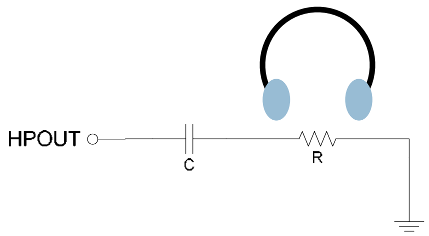

Figure 1 High-pass Network Formed by a.c. Coupling

The value of capacitance required depends on the source/load impedance and the frequency range. In the a.c. coupling situation the capacitor will form part of a high-pass filter, so it is the bass cut-off frequency that is important. If the capacitance is too small, bass response is made worse. The cut-off frequency, at which the signal is attenuated by 3dB, is defined by the following equation:

$$f_{-3dB} = \frac{1}{2\pi RC}$$

The table below shows the main two applications. For DAC line outputs, the load impedance may be the traditional 47kΩ, or it may be around 10kΩ (like SCART). For ADC line inputs, the impedance may also go below 10kΩ, depending on the ADC amplifier gain selected. These issues affect the choice of coupling capacitor, depending on the acceptable cut-off frequency.

APPLICATION	LOAD IMPEDANCE	COUPLING CAPACITOR	-3DB CUT-OFF FREQUENCY
Line In/Out	10kΩ	10µF	1.6Hz
	47kΩ	1µF	3.4Hz
Headphone	16Ω	220µF	45Hz
	32Ω	220µF	23Hz

Table 1 Cut-off Frequencies

CAPACITOR DIELECTRICS

It is important to understand about the dielectric (the insulator between the metal plates of the capacitor) and how its behaviour deviates from ideal. If the capacitance is not stable, it can lead to signal distortion.

CERAMIC

Ceramic capacitors are by far the most popular type of capacitor as they are available in small surface-mount packages at low cost. They are most commonly used for decoupling ICs, but are also used in RF applications and some audio applications.

Ceramic capacitors are available in a number of dielectrics. The most common dielectrics are C0G (same as NP0), X7R and Y5V.

C0G gives a very stable capacitance value with varying temperature and voltage. Unfortunately it is only available in smaller values. It is good for the signal path.

X7R is not so stable, but is available in much higher values. Its capacitance varies a little with temperature and d.c. voltage.

Y5V is a poor choice. The temperature range is smaller and it has huge variations of capacitance with voltage.

U2J is a newer dielectric which is nearly as good as C0G, with narrower temperature range, but is available in higher capacitance values. It is primarily applicable in audio low-pass filters.

X5R is a newer dielectric, replacing Y5V with better performance. It is essentially the same as X7R but with reduced temperature range and more d.c.-voltage dependency.

DIELECTRIC	C0G	U2J	X7R	X5R	Y5V
Capacitance range	0.5pF to 0.1µF	3pF to 0.1µF	1nF to 22µF	0.1µF to 100µF	0.1µF to 100µF
Initial tolerance	±0.25pF to ±5%	±10% or ±20%	±10% or ±20%	±10% or ±20%	+80 to -20%
Temperature range	-55 to +125°C	-55 to +85°C	-55 to +125°C	-55 to +85°C	-30 to +85°C
Capacitance change with temperature	0±30ppm/°C	-750±120ppm/°C	±15%	±15%	+22 to -82%
Capacitance change with d.c. voltage	Not Significant	Not Significant	Significant – see individual part graph	Significant – see individual part graph	Very bad – do not use for a.c. coupling

Table 2 Ceramic Dielectric Properties

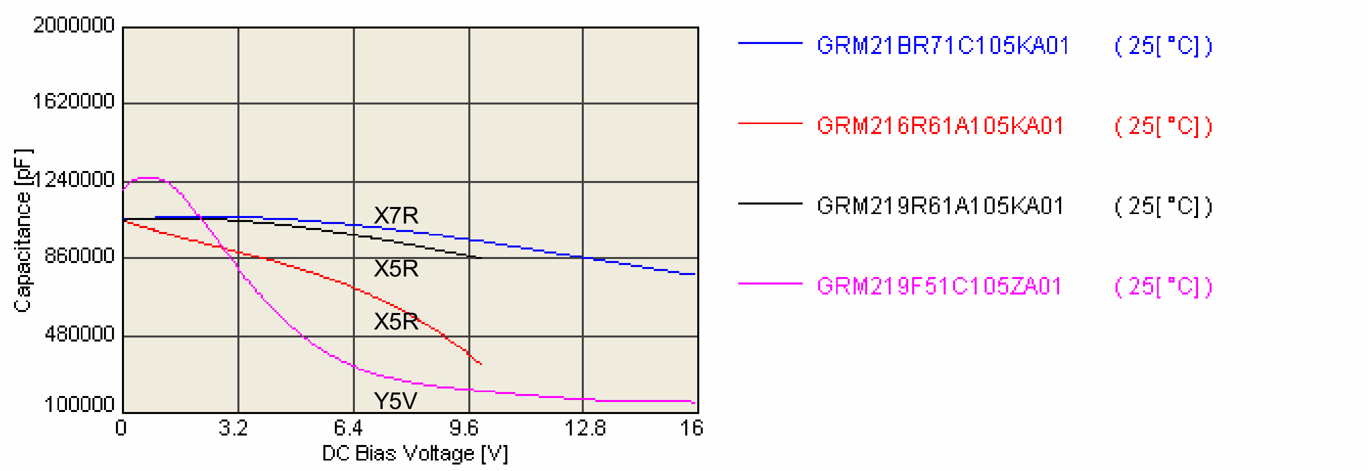

Figure 2 Ceramic Capacitance vs. d.c. Bias Voltage

Figure 2 shows 1µF 16V 0805 capacitors and how their capacitances vary with voltage. The first (blue) is X7R, second (red) is X5R, third (black) is thicker X5R, fourth (magenta) is Y5V. As you can see, the Y5V capacitance changes greatly with voltage and is only suitable for decoupling low fixed voltages like VMID on our CODECs. X5R shows a big difference between parts and the right one must be chosen for best performance. X7R is the most stable and best choice for performance.

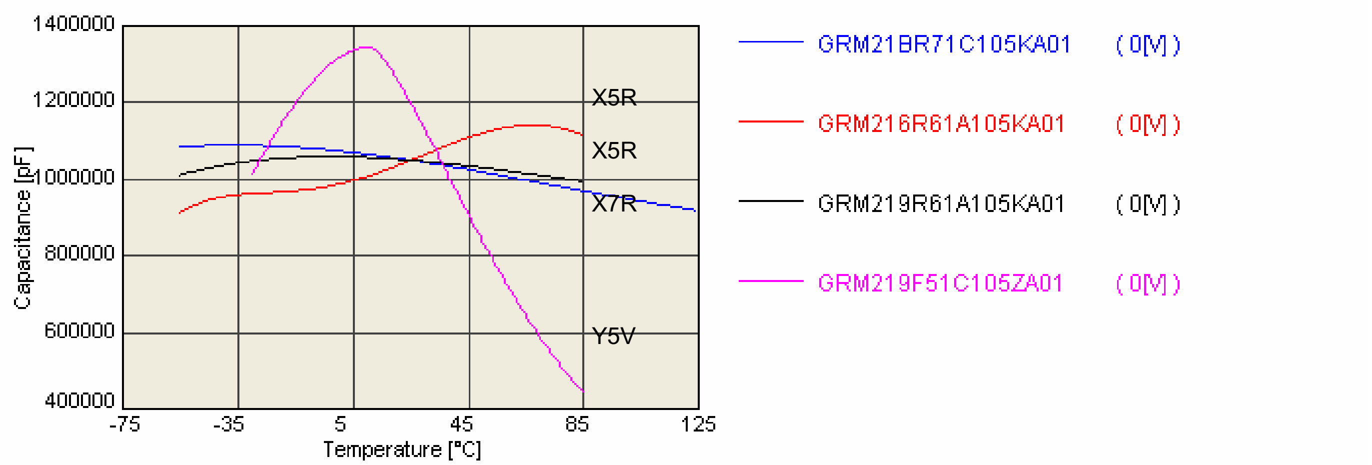

Figure 3 Ceramic Capacitance vs. Temperature

Figure 3 shows the same 1µF 16V capacitors and how their capacitances vary with temperature. As you can see the Y5V capacitance changes greatly with temperature. In a product with elevated temperatures, the cut-off frequency could be adversely affected.

TANTALUM ELECTROLYTIC

Tantalum capacitors are available in a number of variants. They are generally more expensive than ceramic capacitors but offer greater stability at higher capacitance values, albeit with higher ESR (Equivalent Series Resistance). These features make them preferable over ceramic types in most cases.

TYPE	STANDARD	MICROCHIP
Capacitance range	0.1µF to 1500µF	0.47µF to 220µF
Initial tolerance	±10% or ±20%	±10% or ±20%
Temperature range	-55 to +125°C	-55 to +125°C
Capacitance change with temperature	-5 to +8%	-5 to +8%
Capacitance change with d.c. voltage	Not Significant	Not Significant

Table 3 Tantalum Electrolytic Properties

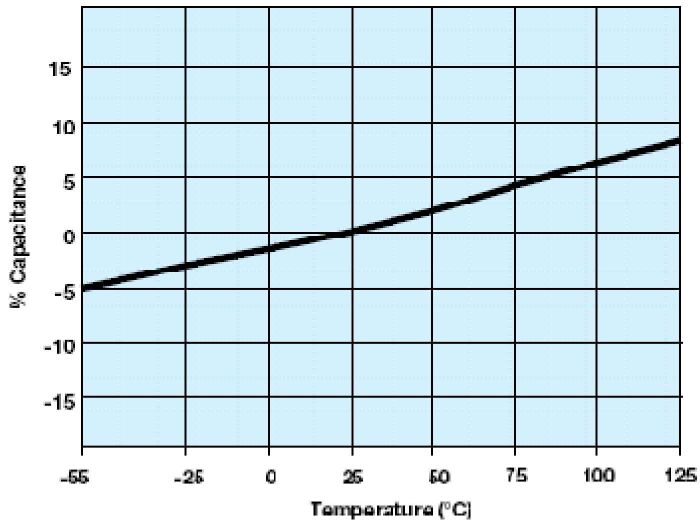

Figure 4 Tantalum Capacitance vs. Temperature

ALUMINIUM ELECTROLYTIC

Standard aluminium parts are much lower cost than tantalum, but are usually physically bigger. They offer good stability of capacitance with voltage and temperature and have similar ESR, so are recommended where there is enough space.

ALUMINIUM ORGANIC/POLYMER ELECTROLYTIC

These parts offer very good performance at a higher price. If the application permits, these are the preferred choice.

WHY IS THE CAPACITANCE CHANGE WITH D.C. VOLTAGE IMPORTANT?

If a large low-frequency signal is applied to the capacitor, it looks like a slowly-changing d.c. offset. Consider a 2Vrms DAC output at 50Hz. The typical d.c. offset will be 4.5V if the supply is 9V. When the DAC is producing a full-scale waveform, the output is going between 0 and 9V. This means the capacitor sees an effective change in d.c. bias from 0 to 9V. For a ceramic Y5V capacitor, the capacitance changes between 1.25µF and 0.22µF, which means that charge is stored and released in a non-linear fashion, causing signal distortion.

RECOMMENDATIONS

LINE INPUTS AND OUTPUTS

The load impedance is usually >1kΩ, so the higher ESR of electrolytic capacitors is not significant.

To achieve good frequency response with 47kΩ load, 1µF is a minimum requirement. For best performance choose tantalum or aluminium electrolytic. Where space is limited and high performance is not required, use X7R ceramic.

To achieve good frequency response with 10kΩ load, 1µF is a minimum requirement, but 10µF would be better for higher-quality applications. For best performance choose tantalum or aluminium electrolytic. Where space is limited and high performance is not required, use X7R ceramic. For lowest cost, use X5R ceramic, but THD at low frequencies will be worse.

HEADPHONE OUTPUTS

The load impedance is usually 16-32Ω, so the higher ESR of tantalum capacitors is significant for power loss. To achieve good frequency response, 100µF is a minimum requirement, 220µF better. For best performance choose low-ESR tantalum or aluminium electrolytic. ESR under 1Ω would be best for power efficiency. Where space is limited, use microchip tantalum. For lowest cost, use X5R ceramic, but THD at low frequencies will be worse.

TYPE	LINE IN/OUT	LINE IN/OUT	HEADPHONE
Capacitance	1µF	10µF	220µF
High performance	Sanyo OSCON 30SC1M	Sanyo OSCON 16SC10M	Sanyo OSCON 10SA220M
Medium performance	AVX tantalum TAJA105M020	AVX tantalum TAJA106M010	AVX tantalum TAJD227M006
Medium performance Small Size	X7R Murata GRM21BR71C105KA01	Tantalum Microchip AVX TACH106M010	Tantalum Microchip AVX TLCT227M004
Low cost	X5R Murata GRM219R61A105KA01	X7R Murata GRM32DR71C106KA01	Standard aluminium
Low cost Small Size	X5R Murata GRM188R61C105KA93	X5R Murata GRM21BR60J106KE15	X5R (100µF) Murata GRM32ER60J107ME20

Table 4 Recommended Components

CONCLUSION

There are a variety of capacitors available for audio applications. With careful choice, the cost can be optimised for the appropriate size and performance level.

APPLICATION SUPPORT

If you require more information or require technical support, please contact the Wolfson Microelectronics Applications group through the following channels:

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Mail: Applications Engineering at the address on the last page

or contact your local Wolfson representative.

Additional information may be made available on our web site at:

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