Tantalum Capacitors Advanced to Mobile Phone Applications

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Abstract

Miniaturization and cost reduction put designers of mobile phones under pressure to compromise on performance features whilst not compromising the system function. Capacitors are continuing to be smaller to satisfy needs of space reduction in mobile phone applications. High capacitance of adequate rated voltage in small case sizes is the preference as regards suitability for a wide variety of mobile phone designs. PCBs are getting more populated with low profile chipsets. Therefore, the preference in all case sizes are low profile versions and small footprint capacitors. The miniaturization of capacitors has an impact on ESR increase therefore new techniques to recover this have had to be developed. However, low ESR is not always important in many mobile phone applications. The main intention of tantalum capacitors usage is in decoupling of the battery and power amplifier to secure of getting right amount of energy in pulse mode during transmission. The majority of mobile phones now have built-in audio features as a FM radio and or a MP3 player requiring high capacitance coupling capacitors on the analogue output to headphones. This paper will outline the main features and applicability of moulded tantalum capacitors suitable for today's mobile phones designs.

Introduction

Mobile phones have been achieving higher levels of audio and video fidelity requiring advanced passive components to facilitate such sophisticated functionality. Small case size capacitors with high capacitance and low rated voltage (up to 10V) are increasingly required. Tantalum capacitors are highly suitable for signal coupling in audio/video circuit functions. High capacitance tantalum coupling capacitors are able to cover the bass register of the sound, an important feature for better sound fidelity. Battery and power amplifier applications need a high capacitance capacitor used in decoupling mode for energy feed and battery backup. Tantalum capacitors are essential to such applications since this is the only technology allowing integration of high CV features into a small compact package. The capacitors allow clear noiseless coupling and decoupling functionality into the different mobile phone modules.

General Features of Tantalum Capacitors Applied to Mobile Phones

Mobile phone applications require high capacitance devices in a small package fitting into slim and highly integrated PCB layout design. The mostly preferred capacitors are in footprint range of up to 1210 with thickness below 1.5mm. Typically the required capacitance is in range of 10uF, 22uF, up to 150uF. Nowadays one of the most popular capacitors is 10uF/6.3V and 10uF/10V in an 0603 package with 1.0mm height limit. The ESR of such capacitors does not play as an important role as their capacitance since the capacitors are used in low power applications.

Influence of High Capacitance on Low Frequency Range in Audio Modules

Audio application (Figure 1) requires a coupling capacitor to avoid the appearance of a DC output voltage on the low contact resistance (8 – 32 Ohms) speakerphone. Therefore, a capacitor with great low frequency transmitting features is necessary to be put between the output of final amplifier and the loading made by a speakerphone. Capacitance value of the capacitor and resistance of the speakerphone determines low frequency cut off. The frequency point is calculated for -3dB attenuation based on the equation (1). High capacitance is needed in case of low resistance of the speakerphone to get the full rich bass spectrum sound. Therefore, it is always a compromise between the output power appearing on the speaker phone, which is determined by speakerphone resistance (2) and signal level on the speakerphone.

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

Where R is the speakerphone resistance and C is capacitance of the coupling capacitor at low frequency range (120Hz).

$$P_{out} = \frac{V_{out}^2}{R} \tag{2}$$

Where V_{out} is signal voltage level in RMS value and R is resistance of the speakerphone.

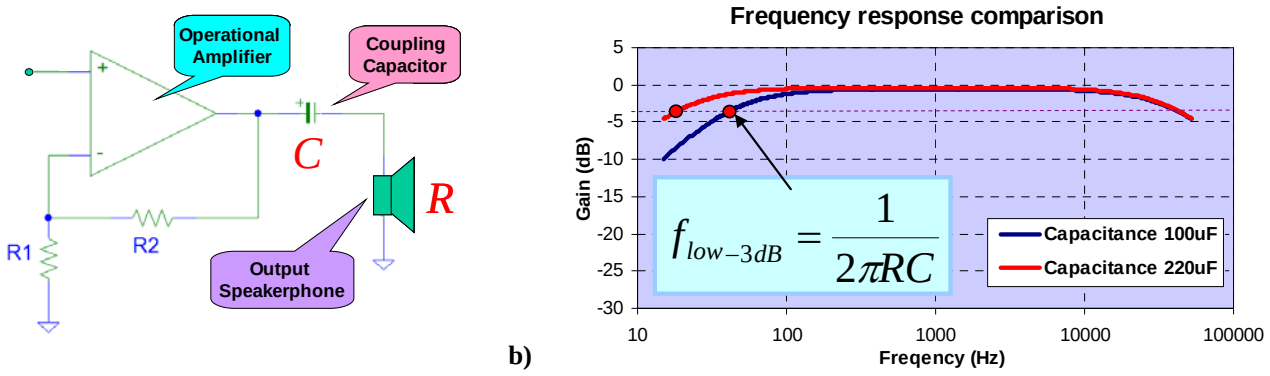

Figure 1: ***a) Simplified model of the final amplifier, b) Frequency response comparison between two different capacitance values***

Designers of mobile phone audio accessories typically use capacitors in the 22uF to 33uF capacitance range to compromise between size of the component and its performance in the circuit. However, there are further opportunities to use low profile 0805, 1206 and 1210 footprints up to 1.5mm height limit with a capacitance value up to 220uF. The coupling capacitor doesn't require high voltage derating. The capacitor can be even used without any derating since there is no risk of over-voltage spikes or surge current through the capacitor. Typical a DC voltage on the amplifier output is half of the battery voltage i.e. about 2V. Therefore a 2.5V rated voltage capacitors can be considered suitable for the application.

Capacitors Adapted for the Battery and the Power Amplifier

Tantalum capacitors are important for decoupling applications of the battery and power amplifiers where high capacitance is required to support the battery for high energy feed during the transmission (Figure 2 a). The capacitor supports the battery to give enough energy to the power amplifier during its transmitting period. The battery voltage would not be stable without the capacitors support and would drop down during the operation, which would have a negative influence on other functional modules in the mobile phone (Figure 2 b) and could cause instability in the circuit. Therefore the capacitor secures the operational stability of the system by supporting the energy demand during the battery discharge.

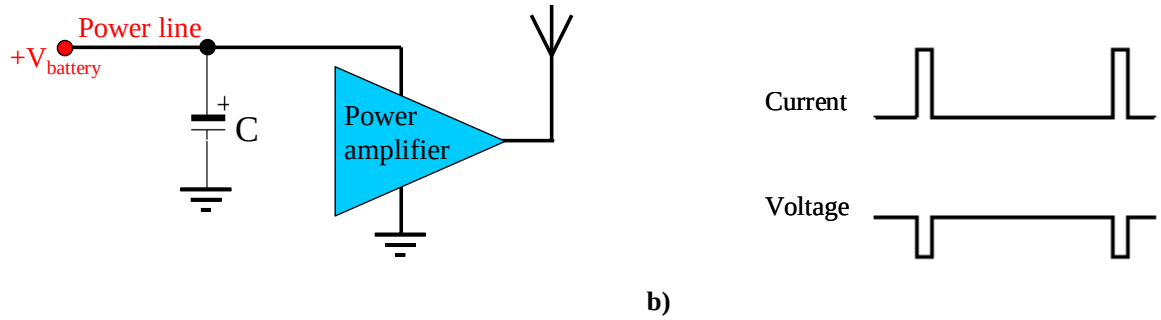

Figure 2: a) Basic circuit diagram of the battery and power amplifier connection, b) Battery current pulses and voltage drops during the transmission if a decoupling capacitor is not used

When the power amplifier starts transmitting, it consumes more energy/current than during other operations. The energy gained from the battery decoupling capacitor helps battery to provide adequate power to the load and keeps the battery voltage stable. Power line voltage is compensated and stabilized by the energy released from the decoupling capacitor. The capacitor has to have an appropriate capacitance value to be able to act as a battery substitute during its voltage drop. The application typically requires capacitance over 33uF. However, higher capacitance than that, typically 100uF is preferred and often employed in this voltage 'hold up' function.

Mini Hard Drives Integrated into Mobile Phones

Increasingly mobile phones have implemented high capacity memories intended for storing sound tracks, movies, video sequences, pictures and other infotainment facilities. Large capacitance memories are usually built-in into micro and mini hard drive systems having over 4 GB memory size distinguished by small physical dimensions as shown in Figure 3a and 3b.

a) **b)** **c)**

Figure 3: a) Hard drive image, b) Hard drive internal structure image, c) Parallel capacitor combination energy storage and backup

The construction (Figure 3c) of a micro/mini hard drive requires high bulk capacitance devices working as an energy storage and backup system. Additional energy is required for the safe parking of a hard drive's reading/writing head during unexpected loss of energy/support power (accidental switching off of a mobile phone, battery disconnection, etc.). Discharge energy coming from the bulk capacitors will secure the safe parking of the head. Therefore specifically high capacitance devices of small size fitting in such low profile equipment are demanded. The "securing" system usually operates at 7V DC. There is not a risk of surge current since the resistance of the head is in range of 100Ohms and even more hence the capacitors suitable for the application can adopt a 10V rated voltage component. However, to secure adequate energy for the operation needs a total bulk capacitance in range of 150 - 440uF. There are challenging criteria regarding dimensions for capacitors as the maximum height should not exceed 1mm due to slim design of the hard drive. Designers of mini hard drives have already found that tantalum technology best fits this application. They have experimented with MLCC performance but without sufficient success as such capacitors have a number of negative features preventing their usage in energy back up applications. There is also a drop off of capacitance due to applied DC voltage which further worsens the MLCC performance in this application.

Decoupling of LED Backlight Driver

Tantalum capacitors can provide great decoupling and smoothing of the output of a current source LED backlight driver working at 1MHz switching frequency. A smooth current source secures a smooth change of LED brightness. It operates on high frequency, which needs to be filtered and smoothed at the output of the converter. The output voltage typically varies up to 16V. Voltages can rise even up to 25V in cases of some ICs. Therefore a high rated voltage capacitor is required for the application. Tantalum capacitors provide stable capacitance values with changing applied DC voltage. MLCC capacitors cannot provide the same degree of stability under such operating conditions as its capacitance is hugely impacted by changes of DC voltage level. The application typically requires a small package of 0805 size with capacitance in 2.2uF range and 25-35V rated voltage.

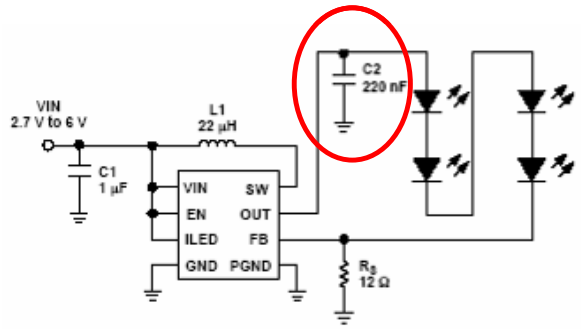

Figure 4: Typical application of tantalum decoupling capacitor in the current source LED backlight driver

Main Difference between Tantalum and MLCC Capacitors

Different capacitors' technologies have been developed to satisfy needs of the market in specific application areas. Capacitors have built-in specific kinds of features suitable to various places. Miniaturization of ceramic capacitors is approaching closer to range of tantalum capacitors. Their unequal features have to be also taken into an account in particular cases to select right technology for desired applications. Tantalum capacitors can achieve higher capacitance and rated voltage (CV) in small package compare to MLCC technology. Miniaturization is the first and the most demanded feature to mobile phone design. Tantalum capacitors don't degrade original signal since they don't make additional noise and haven't piezonoise as can be seen on MLCC capacitors (Figure 5).

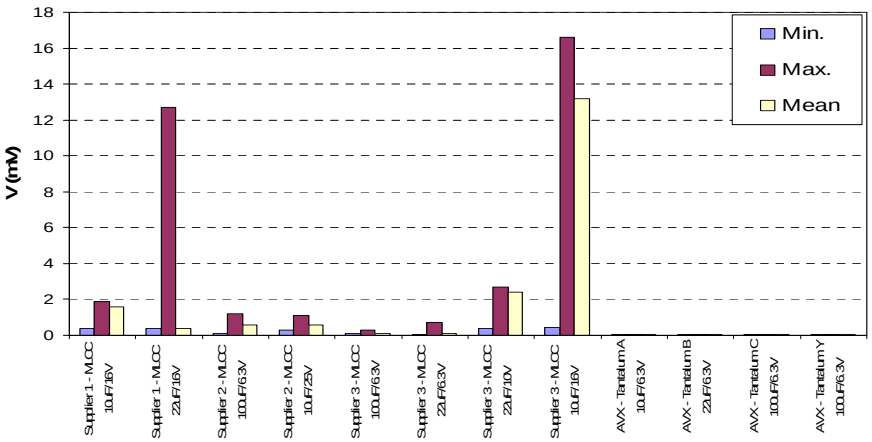

Figure 5: Piezonoise sensitivity of MLCC verses tantalum capacitors

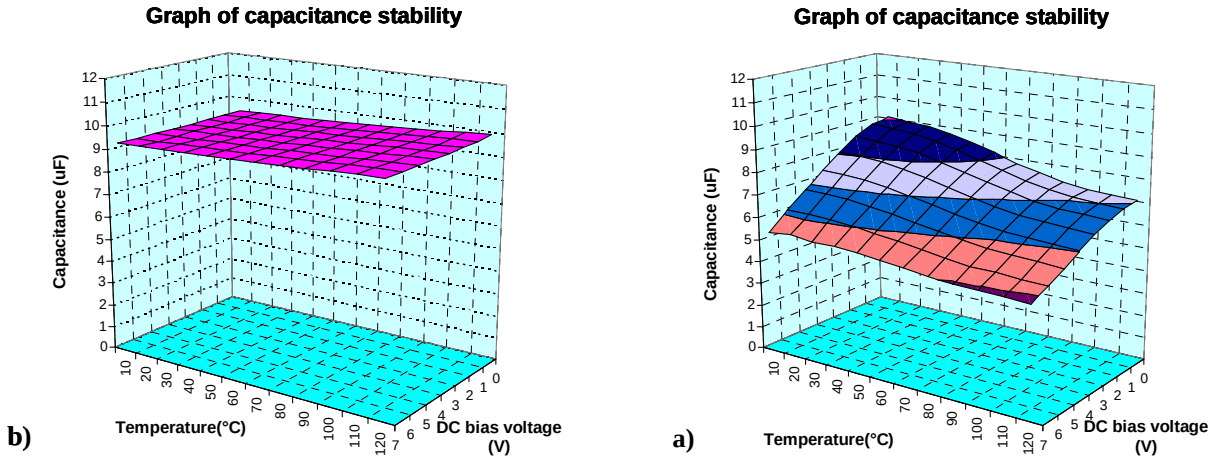

Figure 6: a) The example of capacitance stability of tantalum capacitors, b) The example of capacitance stability of MLCC capacitors

Tantalum capacitors also have better capacitance stability over a wide operational temperature range as well as applied DC voltage compared to MLCC (Figure 6). Tantalum capacitors are ideal for low and middle frequency filtering due to high CV features. Tantalum technology also provides product capable of low profile and small case size and high stable capacitance. The casing of tantalum capacitors is more robust against mechanical stress. The resin casing of such capacitors greatly protects the internal structure of the capacitor (Figure 7) along with its compliant termination system.. Multilayer ceramic capacitors are more sensitive to cracking and can crack during bending of the PCB or by accidental dropping of a mobile phone.

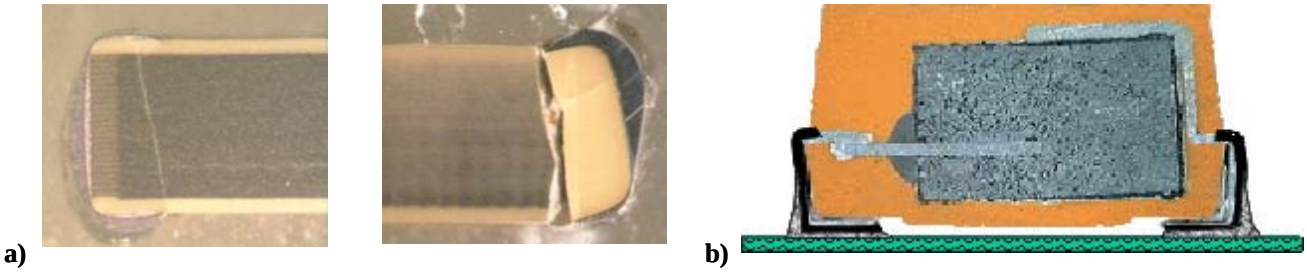

Figure 7: a) Cracking of MLCC under mechanical stress conditions, b) Protected tantalum capacitor structure by encapsulation resin and a compliant termination system.

Cracking of a MLCC structure can also lead to a short circuit as one layer could be conductively connected to the opposite polarity layer. The short circuit or low Insulation Resistance failure is clearly damaging to the system reliability and precautions need to be taken as regards the components location on the PCB or adoption of carefully controlled PCB handling.

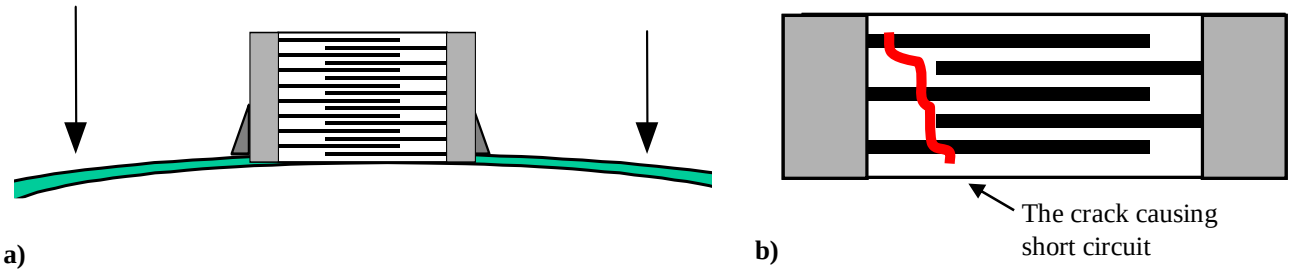

Figure 8: a) The board bending – MLCC stress sensitivity, b) The short circuit creation of MLCC layers

Summary

Tantalum capacitors are ideal components for the new generation of mobile phone designs with multi function features. The capacitors are mainly used for energy storage where high capacitance/rated voltage in small package sizes are mandated. Tantalum capacitors also are the technology of choice in audio and video coupling applications. Today the most popular capacitors are in range of capacitance from 10uF to 150uF for low voltage adoption up to 10V rated voltage. The preferred footprints are from 0603 to 1210 with height limit of below 1.5mm. Tantalum capacitors provide a stable long life operational performance due to its ability to provide a high capacitance over a wide range of conditions within a range of devices that meet both the board space and height restrictions of today's modern mobile multi-functional phones.

References

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