TECHNICAL PAPER

Tantalum Capacitors in 5G Smartphone Applications

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Abstract

The global smartphone market has grown enormously over the past decade. In 2019, about 1.32 billion smartphones were shipped globally, of which 367 million units were shipped in China alone, accounting for 27.8% of the global total. With the ongoing investment into the construction of 5G networks, especially in China, 5G-enabled smartphones are set to become ubiquitous in the near future.

TANTALUM CAPACITORS IN 5G SMARTPHONE APPLICATIONS

AN OVERVIEW OF THE SMARTPHONE INDUSTRY

The global smartphone market has grown enormously over the past decade. In 2019, about 1.32 billion smartphones were shipped globally, of which 367 million units were shipped in China alone, accounting for 27.8% of the global total. With the ongoing investment into the construction of 5G networks, especially in China, 5G-enabled smartphones are set to become ubiquitous in the near future.

5G phones are projected to grow by 10% starting in 2020 compared to the previous year. Under favorable economic and regulatory conditions, there will be ample opportunities for both leading and emerging manufacturers to capture more market share. Additionally, there are several design houses for smartphones that design products for major brands and smaller players. As of 2019, 73% of all smartphones produced by major OEMs were designed by external ODMs or design houses.

Small players are essential drivers in the development of smartphones. Among the collection of components integrated into smartphones, capacitors are some of the most essential. Electrolytic capacitors, such as tantalum types, are favored for use in small-footprint applications, including smartphones. This whitepaper discusses the construction, mode of operation, benefits, and applications of tantalum capacitors in the smartphone industry.

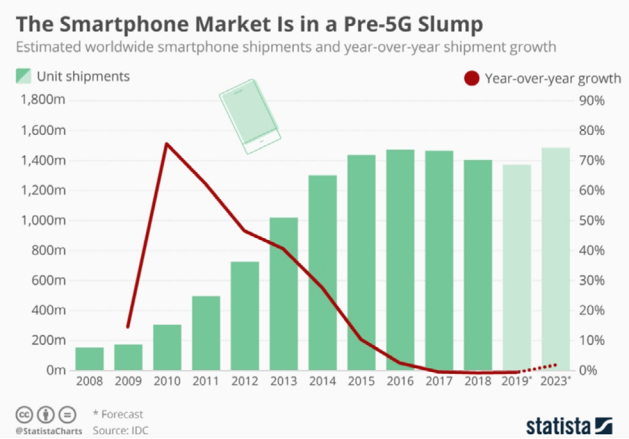

Figure 1: Global smartphone shipment volumes vs. YoY growth. Image courtesy of Statista, provided by KYOCERA AVX.

WHAT ARE TANTALUM CAPACITORS?

Tantalum capacitors are a class of electrolytic capacitors comprising a tantalum anode covered in tantalum pentoxide serving as the dielectric and a cathode made of solid manganese dioxide or conductor polymer material. Tantalum is a hard, blue-gray, and lustrous transition metal that is highly corrosion-resistant. It allows for a thin dielectric layer with very high permittivity and higher capacitance per volume compared to alternative materials.

Tantalum capacitors overcome several challenges with other electrolytic capacitors, such as the leakage current issue caused by the parasitic current when a DC voltage is applied to the terminals.

The structure of a solid tantalum electrolytic capacitor consists of 3 main elements: a primary electrode (anode), dielectric, and the primary electrode system (cathode).

WHAT ARE TANTALUM CAPACITORS?

The cathode usually has secondary carbon and silver material layers to improve its electrical characteristics and facilitate its connection to the lead frame. The traditional solid tantalum capacitors use manganese dioxide as their cathode. These capacitors are robust, have a wide operating temperature range, have good resilience against humidity, and have stable electrical characteristics. Unlike most electronic components' bath-tub curve lifetime characteristics, tantalum capacitors do not have a wear-down end-of-life mechanism — the more you use it, the better its reliability. This is due to the tantalum capacitor self-healing properties when they are in constant use.

Newer product lines of tantalum capacitors were introduced with conductive polymer material instead of manganese dioxide as the cathode to address the growing demand for higher power hungry and energy-efficient electronics. These polymer tantalum capacitors have significantly lower ESR and require less voltage derating on their circuit application than the traditional manganese dioxide tantalum capacitors. This results in high-efficiency circuitry with lower power and heat losses. Figure 3 shows the structure of the KYOCERA AVX SMD Solid Tantalum Capacitors:

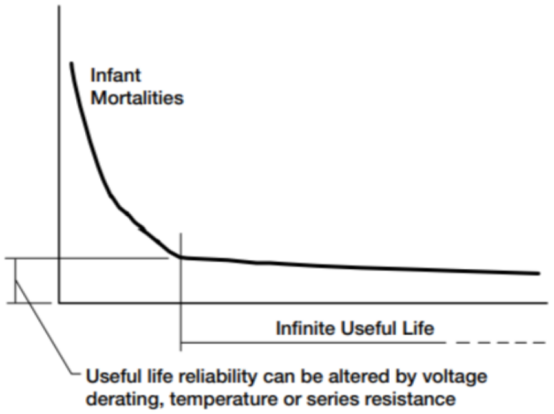

Figure 2: A table showing the reliability of tantalum capacitors. Image courtesy of KYOCERA AVX.

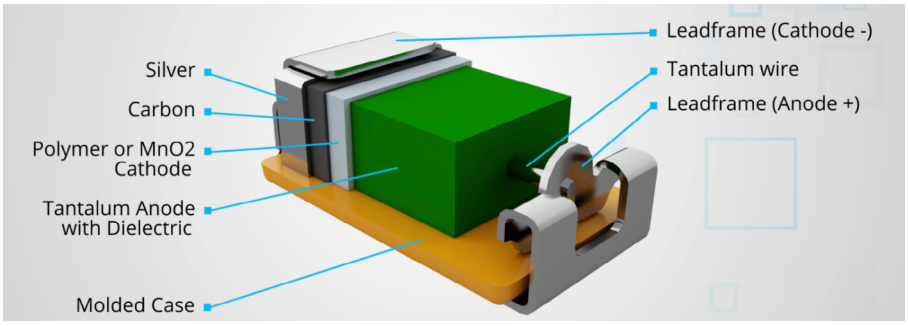

Figure 3: KYOCERA AVX SMD tantalum capacitor construction. Image courtesy of KYOCERA AVX.

TANTALUM CAPACITORS IN 5G SMARTPHONE APPLICATIONS

TANTALUM VS. CERAMIC CAPACITORS

Although using tantalum products tends to incur a relatively higher cost than ceramics, they provide several benefits that make them viable in the long run. Unlike multilayer ceramic capacitors (MLCCs), tantalum types exhibit a minimal change in their capacitance in the event of temperature or DC voltage fluctuations.

Figure 4 shows the stable performance of tantalum capacitors compared to SMD ceramic X7R/X5R dielectric capacitors. Designers most often are concerned with ceramic capacitors' DC bias. A 10 uF 6.3 V ceramic capacitor with a 6.3 V DC bias can result in a capacitance drop of more than 50% to 5 uF. Many ceramic manufacturers do not publish the DC Bias characteristics in their specifications.

Compared to ceramics, tantalum is an incredibly durable substance; it is mostly immune to the logarithmic decrease in capacitance over time (aging) that affects ceramic capacitors, greatly increasing the component's lifespan. The volumetric efficiency and piezoelectric effect response are also much better in tantalum capacitors than MLCCs.

Figure 5 shows the performance of different SMD tantalum and ceramic capacitors at 125°C, with the capacitance measured at regular time intervals. Both manganese dioxide and polymer tantalum capacitors have no noticeable changes in capacitance readings over time. For SMD ceramic capacitors, most product specifications for capacitance are measured at 25°C. Some popular high CV ceramic dielectrics, like X5R, are not designed to handle 125°C applications — its maximum temperature is 85°C.

The main drawback of using tantalum capacitors is their unfavorable failure mode, leading to thermal runaway issues. If the tantalum anode contacts the magnesium dioxide cathode during a voltage surge, a chemical reaction occurs, producing self-sustaining heat as well as smoke and flame. Fortunately, current-limiting devices or thermal fuses integrated into PCBs ensure failsafe usage.

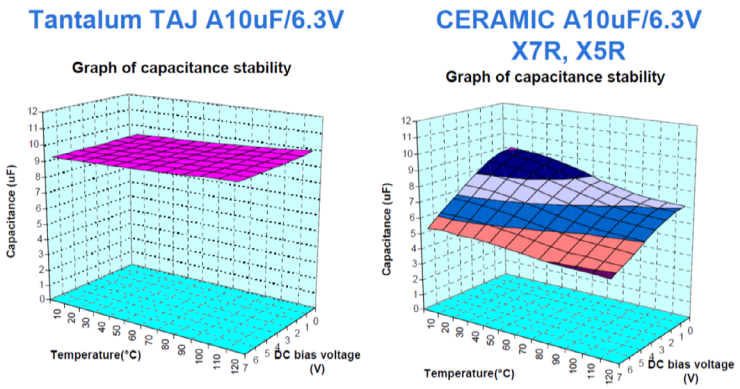

Figure 4: KYOCERA AVX SMD tantalum capacitor vs. ceramic capacitors – Capacitance vs. Temperature vs. DC Bias Electrical Characteristics: A size, 10 uF, 6.3 product. Image courtesy of KYOCERA AVX.

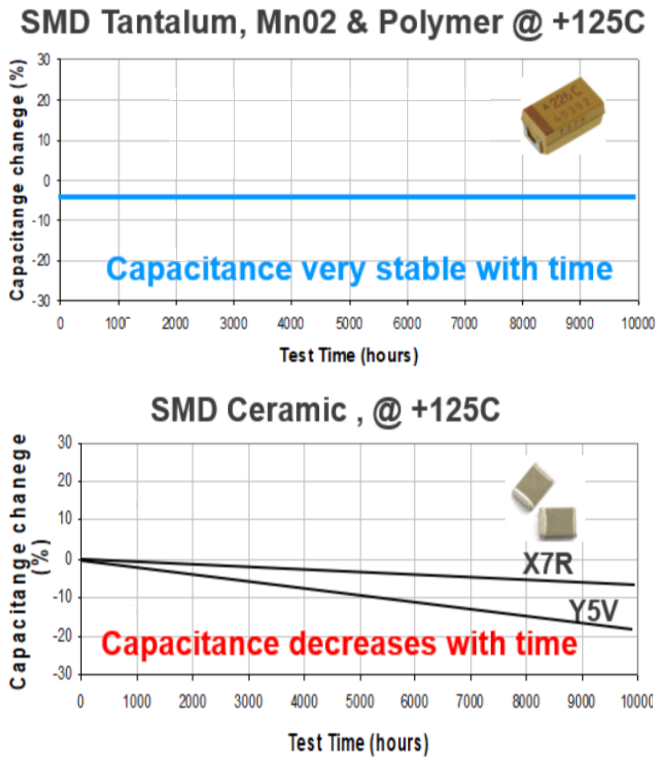

Figure 5: KYOCERA AVX Tantalum (Mn02/Polymer) Capacitors vs. Ceramic (X7R/Y5V) Capacitors – Capacitance readings @+125°C over time. Image courtesy of KYOCERA AVX.

TANTALUM VS. CERAMIC CAPACITORS

To reduce the impact of different types of circuit applications that could affect the failure rate or reliability of KYOCERA AVX tantalum capacitors, KYOCERA AVX has developed an Application Derating Table for tantalum capacitors, which is dependent on the application circuit condition for the selection of the tantalum capacitors. Application circuitries with low circuit impedance have a high tendency of current and voltage surges, and more conservative derating when selecting the capacitors is recommended.

Ceramic capacitors are widely used components in most power decoupling and signal filtering circuitries, as they are the most cost-effective component. However, these capacitors are prone to suffering a phenomenon known as the microphonic effect, referring to them as a "singing or ringing" capacitor. This effect may show up as audible audio noise on an earpiece or visible video noise on an LCD screen. This is due to the piezo-electric effect on the barium titanate ceramic material when DC bias is applied to it. It is more pronounced on the high CV ceramic material and is not present on tantalum capacitors. For this reason, tantalum capacitors are popular on audio circuitries of major audio equipment manufacturers in the world.

Rapid advances in manufacturing technologies have led to a better understanding of the pros and cons of tantalum capacitors and their application guidelines. Thus, circuit designers often use them in a wide range of portable electronics such as smartphones.

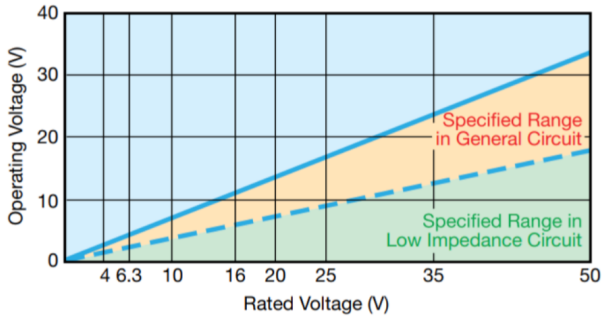

Figure 6: Application Derating Table of KYOCERA AVX tantalum capacitors (Operating Voltage vs. Capacitor's Rated Voltage)

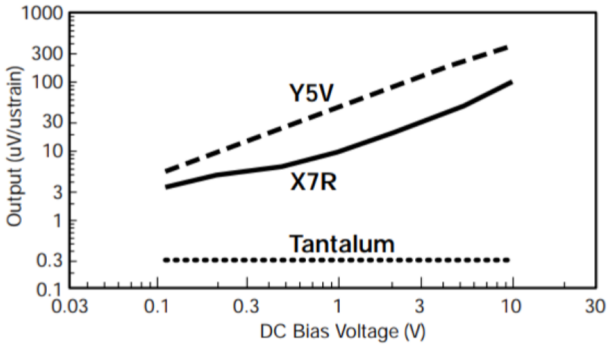

Figure 7: Microphonic effects on ceramic (XR & Y5V) and tantalum capacitors

TANTALUM CAPACITORS IN 5G SMARTPHONE APPLICATIONS

TANTALUM CAPACITOR USAGE IN 5G SMARTPHONE APPLICATIONS

Due to their compact footprints, high capacitances, and high reliability, tantalum capacitors are ideal for use in space-constrained consumer applications, such as smartphones, where they are offered in surface-mount styles and tape and reel packaging. In 2018, the market for multilayer ceramic capacitors (MLCCs) took a hit, which resulted in a shortage of components, production delays, and delayed time-to-market for new products affecting both large and small players.

The MLCC market was projected to grow from $5 billion to $7 billion USD between 2018 and 2023. The worldwide shortage, fuelled by increasing demand and limited supply, persists to a lesser extent today. In 2021 and beyond, some of the greatest demands for MLCCs and tantalum capacitors will be due to rapid 5G deployment within the telecoms industry. Notably, the utilization of sub-6GHz and mmWave frequency bands and new functionalities, including beamforming, will be contributing factors.

The ongoing shortage of MLCCs across the globe is causing manufacturers to utilize alternative products such as tantalum capacitors. Most 4G and 5G smartphones currently use MLCCs. However, tantalum capacitors can replace ceramic products with similar or enhanced performance in most smartphone applications. The extremely high surface area of tantalum in KYOCERA AVX's tantalum capacitors provides very high capacitance values in small volumes. Secondary electrodes made of manganese or polymers ensure high reliability, robust performance, and ultra-low ESR in 5G smartphone applications.

INTEGRATING TANTALUM TECHNOLOGIES

As smartphones evolve and the 5G standard becomes more commonplace, more power-hungry features will be integrated into the latest smartphones for robust audio and visual performance. Thus, there will be numerous applications of tantalum capacitors in the smartphone industry over the decade. KYOCERA AVX, a KYOCERA Group company, is the trusted provider of tantalum capacitors with four manufacturing plants across the globe, ensuring more flexibility and capacity for the rapidly growing electronics industry.

KYOCERA AVX is a leading provider of MnO_2 solid tantalum technologies, including the smallest case size MnO_2, highest temperature capabilities up to 230°C, and the lowest DC leakage current (DCL) product offerings.

KYOCERA AVX is the largest supplier of high-reliability solid tantalum capacitors for medical, military, and aerospace applications with a broad portfolio of medical, COTS-Plus, MIL, and space-grade products. KYOCERA AVX has an open and progressive policy on ethical supply and is the first to comply with OECD guidelines and legislation on conflict materials. KYOCERA AVX's Conformal technology offers cutting-edge solutions for audio and infrastructure applications.

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