KEMET White Paper:
Polymer Technology for High-Power GaN-Based Smart Chargers

Power electronics assume today a key role and a significant growth in multiple industrial segments as automotive electrification, telecom equipment's, storage and industrial automation and the biggest challenge for these industries is the power losses mitigation. Improved energy efficiency driven by the pressure from the society and more strict legislation regarding CO_2 emissions and a growing demand for longer battery life are stressing the power electronics designers to dedicate special attention to the wide-bandgap (WBG) semiconductor solutions, operating at higher voltages, temperatures and frequencies when compared with existing technologies.

GaN and SiC are named wide bandgap (WBG) semiconductors because the energy the is necessary to move the electrons from the valence band to the conduction level. For the traditional silicon, the required energy is 1.1 eV and for SiC, is slightly higher (3.2 eV) with GaN calling for 3.4 eV. As a result of this difference, WBG offers a higher break down voltage with power switches offering higher current density, faster switching frequencies (extended to megahertz range).

With GaN transistors achieving higher levels of efficiency, the development of converters can either operate at higher switching frequencies reducing the transformer size or for example, offer solutions where becomes possible to reduce or even eliminate the need of heat sinks. The improved efficiency using GaN switches started appearing in chargers and adapters in 2018 and was the main driver of a considerable reduction in charger/adapter footprint and volume. *Figure 1, presents* one example where GaN transistor technology is compared with a 2008 design and a high-performance design using the best available silicon switch technology from 2019.

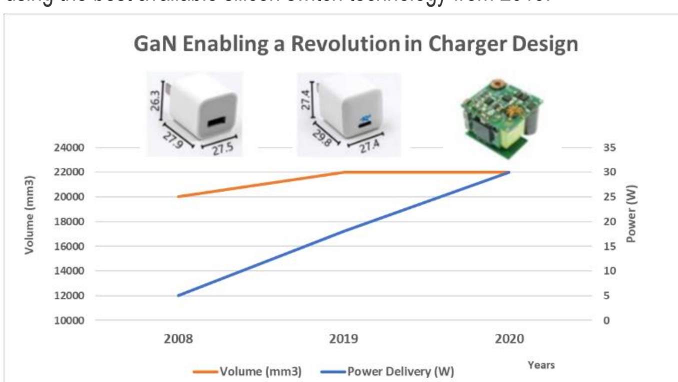

Figure 1: Improvements of power switch with GaN technology and miniaturization opportunity of power chargers (Source: eeWeb.com)

Smartphones and notebooks adapters to charge their batteries will be using a USB-PD function that makes charging convenient because the smartphone charger and notebook PC adapter are combined to one converter. Figure 2 shows a typical diagram of this converter.

Figure 2. Typical Diagram of USB-PD Adapter

Typically, chargers operate over a wide input voltage range from 85-V to 265-V AC and must be able to power different equipment with different voltage demands automatically with a high power density that can achieve up to 65W to 100W, fully compatible with USB PD2.0 and the output operates usually from with 5V/3A, 9V/3A, 15V/3A, and 20V/3.25A.

Converters operate at a considerable high switching frequency 500 / 600 kHz (max), which enable the size reduction of the transformer and capacitors, also it is expected that the EMI filter will be much simpler and smaller than low frequency converters.

The best evidence of this trend is the volumetric comparison between the 65W GaN USB-C PD Charger (US Plug) charger as opposed to conventional silicon versions.

Figure 3. Volumetric efficiency comparison (source: https://www.esrgear.com)

What can be the role of KEMET Polymer capacitors (KO-CAP®) in the volumetric efficiency development of future AC/DC adapters?

Looking into the 65W charger from Baseus, we can easily detect a clear opportunity for additional volumetric efficiency. The output filtering of the two-way buck output is assured by two solid aluminum polymer capacitors with large dimensions (8x12mm). The adoption of a **KO-CAP SMD** solution for the output filtering function, will support the mechanical downsizing of the charger (7343 footprint with 3.1mm Height) and also will offer ESR stability over time.

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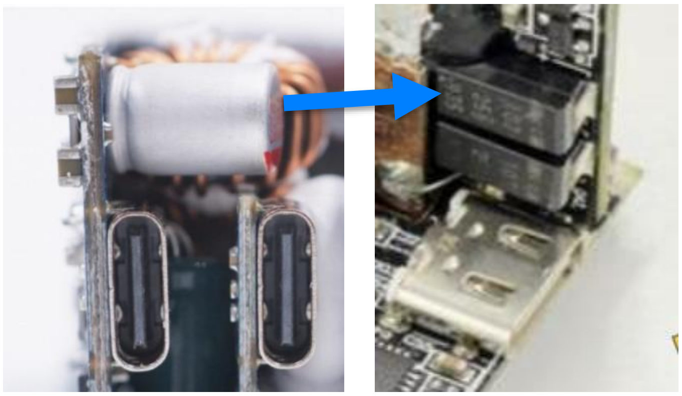

Figure 4. Volumetric efficiency comparison (Source: http://www.chargerlab.com)

KEMET KO-CAP® T52X/T530 Polymer Electrolytic Capacitors offer very low ESR and improved capacitance retention at high frequencies. KO-CAP combines the low ESR of multilayer ceramic, the high capacitance of aluminum electrolytic, and the volumetric efficiency of tantalum into a single surface mount package. Unlike liquid electrolyte-based capacitors, KO-CAP has a very long operational life and high ripple current capabilities.

	KOCAP Polymer Capacitors	Al Polymer Can case
Side View	3.1 mm	Φ8.0mm 12.0mm
Top View	4.3mm 7.3 mm	8.0mm 8.0mm
Height	3.1mm	12.0mm
Capacitance	100µF	220µF
Advantage	Small size Large capacitance	Price Large capacitance

Figure 4. Comparison between KO-CAP and AL-Polymer Can technology

The KO-CAP T521D107M025ATE040, is a 40mΩ capacitor and 25V Rated. The usage of this part for an output voltage of 20V, is possible due to the derating polymer derating guidelines. This 25V capacitor requires only 10% derating up to 105ºC (see Figure 5. Polymer derating guidelines).

Nevertheless, even if users assume a higher safety factor and define a 20% derating, the 20V output is still comfortably inside the window of voltage derating.

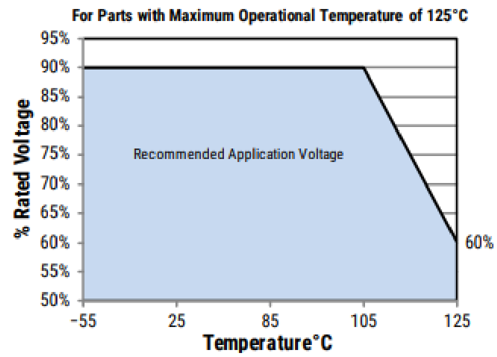

Figure 5. Polymer derating guidelines

Additionally, KEMET 25V T521 Capacitor, is 125ºC capable, being tested/qualified for 2.000hours at 125ºC and 0.67xRated voltage. This capability offers additional reliability and performance over lifetime.

Typically, polymer capacitors offer a very effective frequency response in a wide range of frequencies. In the Figure nº6, the lowest ESR performance is located between 100kHz and 1MHz.

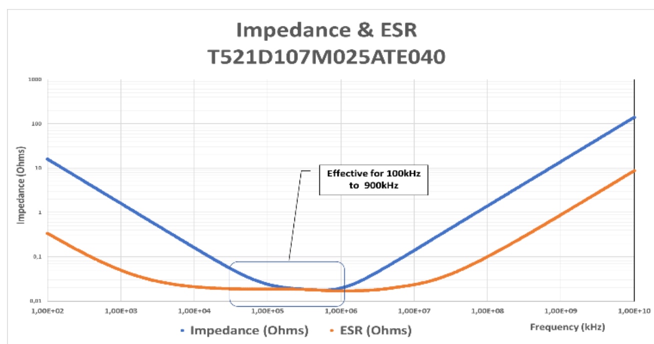

Figure 6. Impedance and ESR plot of polymer 100µF 25V

Multianode polymer technology offer multiple solutions with the lowest ESR (single digit or < 10mΩ) combined with the largest capacitance available. Additional information can be found in the KEMET web page (https://www.kemet.com/en/us.html) and in the product datasheet & K-SIM spice tool.

Conclusion

There is a clear advantage of KO-CAP® T521 Series when compared with other existing technologies. T521 100uF 25V capacitor, designed and qualified for 125ºC, is the most capable solution for applications where the working temperature is increasing (getting closer to 100ºC) and offering the lowest ESR characteristic, mitigating the transient occurrence ad possibility of high current spikes, eliminating the need, for instance, of additional MLCC capacitors in the output of the converter.

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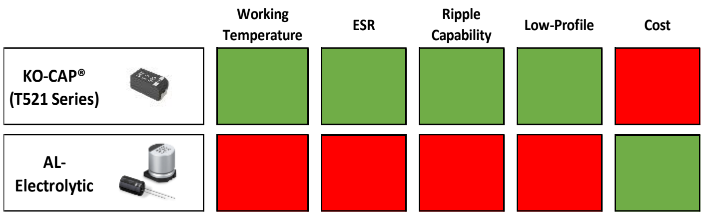

Fig 7. Technology comparison

The opportunity for height optimization and volumetric improvement of electronic components, opens the possibility for flat charger designs. KEMET continues to develop efforts in order to improve manufacturing efficiency levels and making KO technology more cost competitive when compared with existing solutions.

Fig 8. Ultra-Thin Wall charger

https://content.kemet.com/datasheets/KEM_T2076_T52X-530.pdf
https://ksim3.kemet.com/capacitor-simulation

COMPONENTEDGE

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