T598 Polymer Capacitors in AD and ADAS Designs

Introduction

A tantalum polymer capacitor is constructed with a tantalum (Ta) anode, a tantalum pentoxide (Ta_2O_5) dielectric, and a solid polymer electrolyte. This construction method offers a variety of advantages, including high-temperature ratings and stability over temperature, voltage, and time. These characteristics allow tantalum polymer capacitors to meet and exceed AEC-Q200 automotive standard requirements. KEMET's tantalum polymer capacitors (KO-CAP™ series) offer low ESR to minimize power losses and unwanted noise and can withstand high temperatures and extended lifetimes of automotive applications. Specifically, the T598 tantalum polymer capacitor has ideal high capacitance, low ESR, and exceptional ripple performance, supporting increased power consumption on AD and ADAS DCUs.

Advantages of KEMET's T598 tantalum polymer capacitors

- Low series resistance, from 6 mΩ to 150 mΩ (100kHz, RT)
- Stable capacitance and ESR across temperatures from -55°C to 125°C
- Improved capacitance retention at high frequencies
- Ultra-long-life expectancy for high and ultra-extended mission profiles

State-of-the-art and Challenges with software define vehicles.

Autonomous Driving is a highly complex system that consists of many different tasks. To support the highest level of autonomy, the EE architecture evolution is moving from a large number of ECUs to functional DCUs, such as AD/ADAS, Connectivity, Smart Cockpit, etc., to ZCUs with centralized computer and zonal gateways.

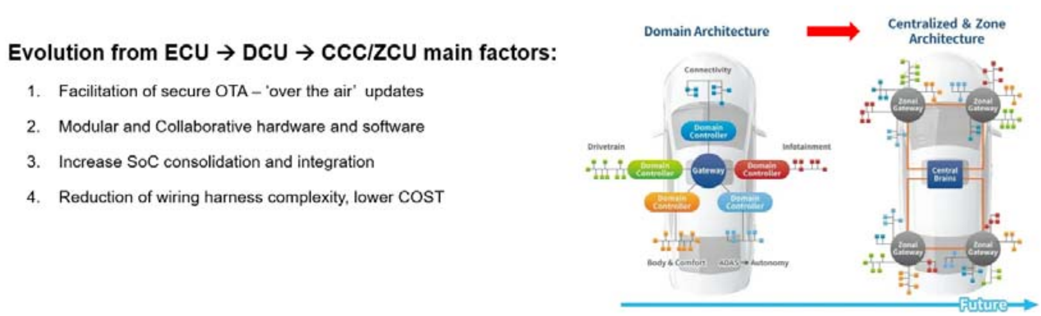


Figure 1 – EE Architecture Evolution ECU → DCU → ZCU/CCU and Key Change Factors
source: (https://www.eetasia.com/the-role-of-centralized-storage-in-the-emerging-zonal-automotive-architecture/)

In recent years, autonomous electrical vehicle development has gained significant attention from researchers and engineers [(1)]. Many changes are revolutionizing the automotive EE architecture, leading to autonomous driving and the associated challenges. An autonomous vehicle must be capable of sensing the environment and safely navigating without human input [(2)]. The US NHTSA has defined 5 different levels of autonomy [(3)].

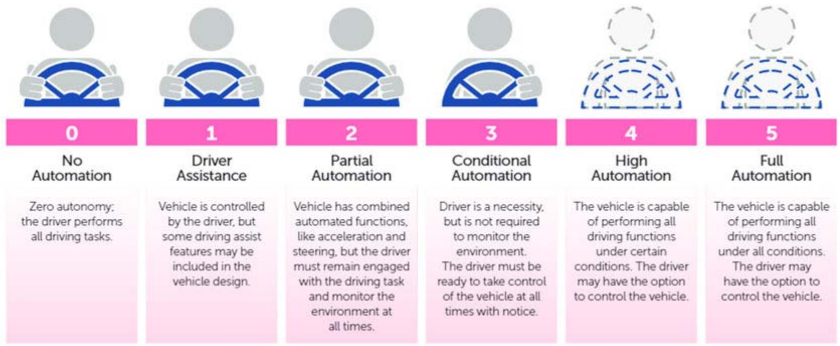


Figure 2 – Levels of Autonomous Driving by NHTSA
(US Department of Transportation's National Highway Traffic Safety Administration)

On the higher autonomy levels, the vehicles must sense their surroundings using multiple sensors, such as LiDAR, Cameras, GPS, etc. Based on the sensor inputs, the vehicles need to locate themselves and, in real-time, make decisions and act on driving. The abbreviation ADAS stands for advanced driver-assistance systems. The sensors aim to improve driving safety and are called **Sensing**. On the other hand, the abbreviation AD refers to autonomous driving, in which the AD system processes the data from Sensing, making decisions, and command orders to actuators (brake, steering, etc.). It is named **Cognitive** ('brain' with the ability to process sensing data, perception, and decision), as presented in Figures 3 and 4. The KEMET T598 Automotive Polymer Grade Series has been successfully on the different functional DCUs.

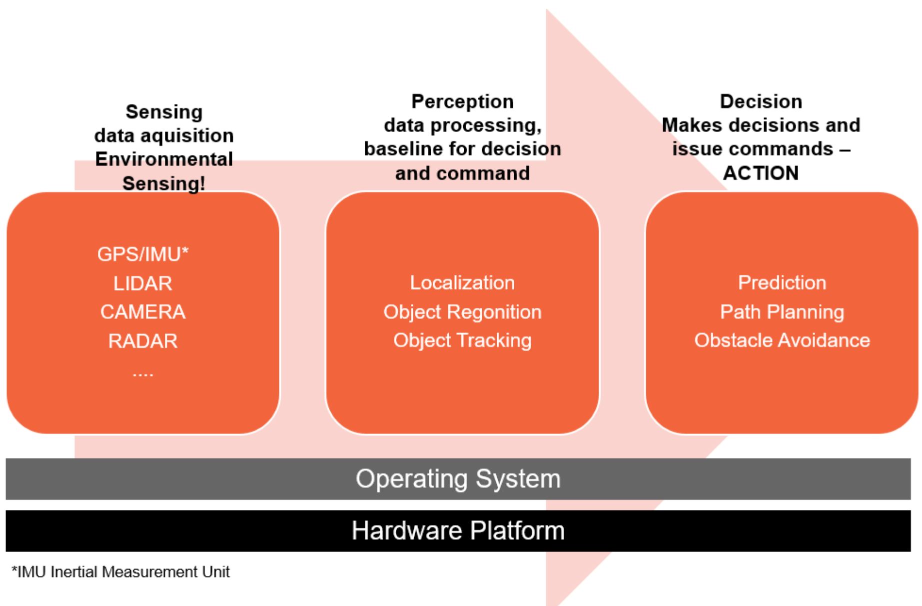


Figure 3 – Tasks in Autonomous Driving: 3 main stages: Sensing → Perception and Decision

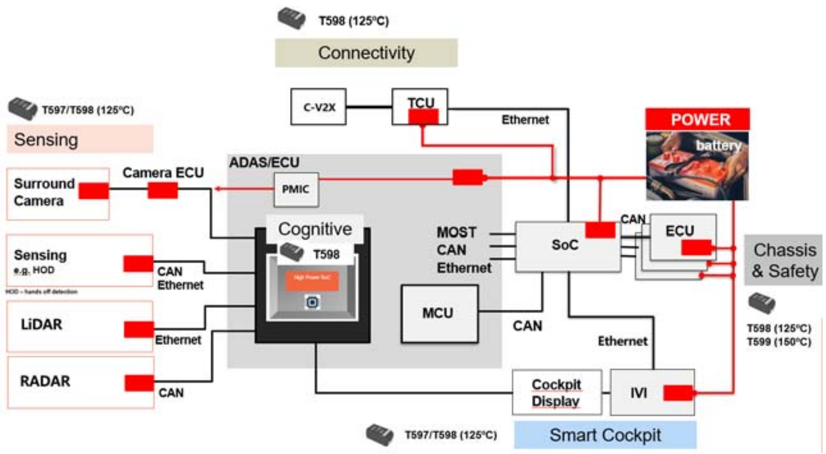


Figure 4 – Automotive Placement Strategy with Polymer Capacitors

AD computing systems can be divided into computation, communication, storage, security/privacy, and power management. [4]

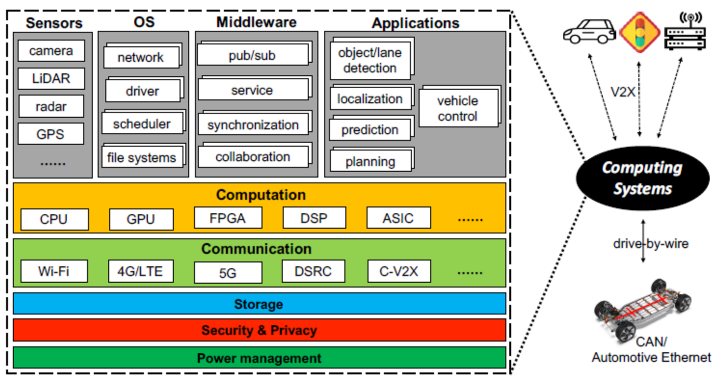


Figure 5 – Schematic EE AD Computing System [4]

The continuous effort to increase the autonomy level significantly enhances computing system capabilities for AD. According to Liangkai *et al*. [4], today's *"state-of-the-art"* computing system for AD includes 7 performance metrics, 9 key technologies, and 11 open challenges.

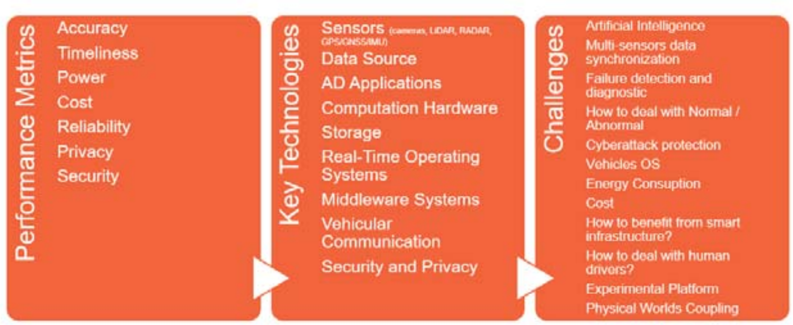


Figure 6 – AD Computing Systems State of the Art and Challenges [4]

As the level of autonomous driving increases, the number of sensors installed must increase accordingly to acquire data on the surrounding environment. As the number of sensors increases, the amount of data processed by SoC increases, and the power consumption of the main semiconductor device that performs data processing increases. This evolution increases power consumption and optimizes the cognitive 'brain' capabilities.

Inside a DCU schematic exists (a) a transceiver circuit that communicates with sensing ECUs, (b) an SoC (System on a Chip) that processes data and makes decisions, (c) various memories (DDR/Flash), (d) a microcontroller MCU that controls driving based on the information assessed by the SoC, and (e) DC/DC converter power supply circuits to operate the various functions with different voltage rails (<1V, 3.3V, 5V etc.), Figure 7 and 8

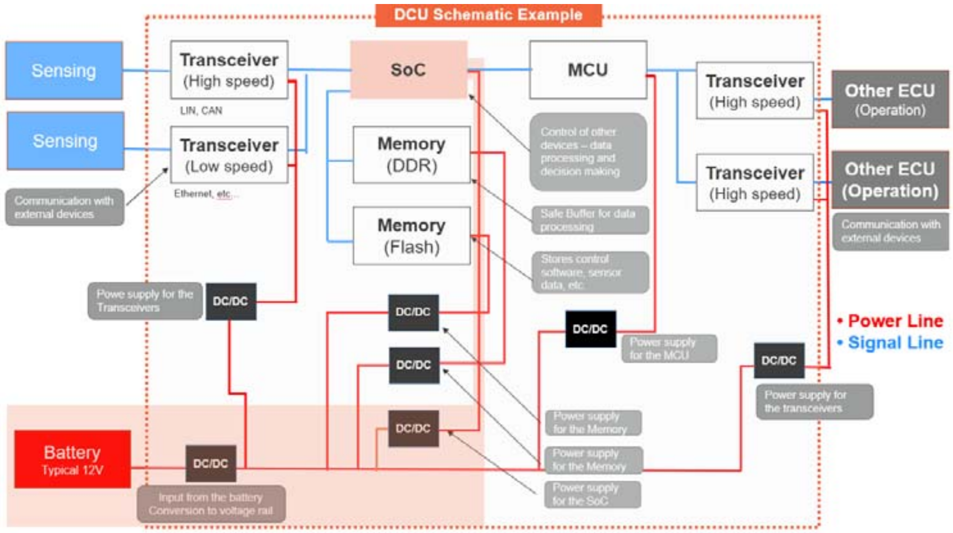


Figure 7: Schematic example - AD/ADAS DCU, highlight in light orange the DC/DC sequence from battery to SoC

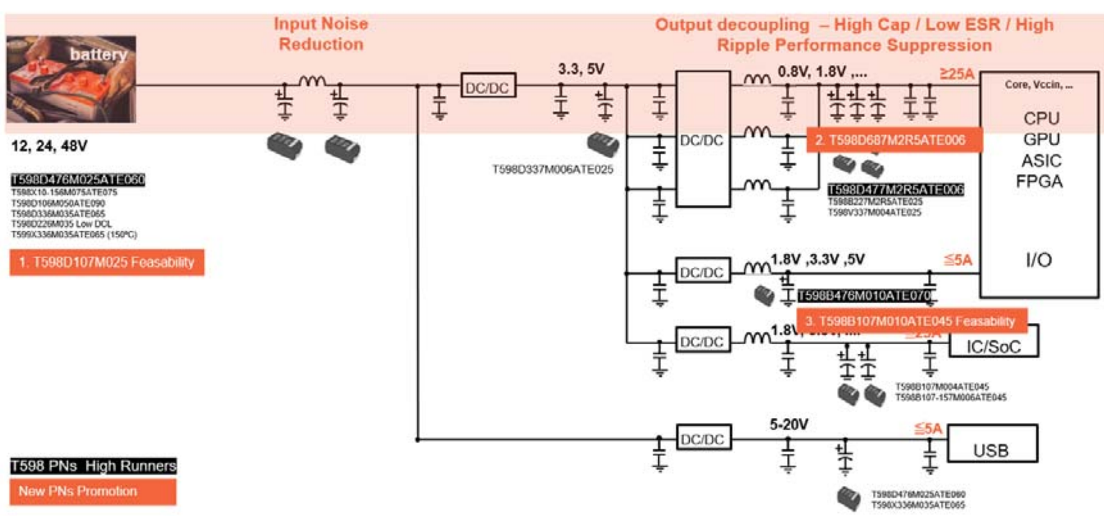


Figure 8: Schematic example - AD/ADAS DCU, highlight in light orange the DC/DC sequence from the battery to SoC processing the Sensing collecting data.

The SoC power line, typically with a voltage lower than 1V and current > 25A, on the DCUs/ZCU/CCUs requires components capable of: "high current," "low loss," "miniaturization," "high-frequency operation," and "high accuracy (voltage)." T598 capacitors with volumetric efficiency and 2.5V-rated voltage high capacitance offerings are suitable options. Typically, rated capacitance between 220 to 680uF and single-digit ESR solutions are preferred.

It is common for DC/DC converter to use T598 polymer capacitors for noise reduction at the input and smoothing/decoupling at the output, typically the **T598D476M025ATE060** (EIA 7343-31 47uF25V, 60mOhm) has been adopted at the input and the **T598D477M2R5ATE006** (EIA 7343-31 470uF2,5V, 6mOhm) has been successfully design at output smoothing/decoupling. To further advance future needs, KEMET now has prototype samples available for the next generation of input noise reduction, with the **T598D107M025ATE050** (EIA 7343-31 100uF25V, 50mOhm) and capacitance extension **T598D687M2R5ATE006** (EIA 7343-31 680uF2,5V, 6mOhm) for optimum output smoothing.

The demand increase in power consumption to support higher processing data and action will continue to use the T598 Series' main advantages: high capacitance combined with low capacitance roll-off in frequency and temperature stability, low ESR and high ripple performance, and extended life span performance.

Output Smoothing/Decoupling Capacitor

The T598 Series with the specific case size EIA 7343-31 with 470uF rated capacitance and 2.5V rated voltage and single digit ESR (6mOhm at 100kHz/Room temperature) has been successfully adopted in ADAS /AD DCUs.

(a) Design, Material Settings, and Process – Capacitor Reliability

The design, material settings, and manufacturing process lead to robust performance and high reliability. The over-formation during the Ta_2O_5 dielectric build-up allows a significantly high breakdown voltage (~14V), figure 9.

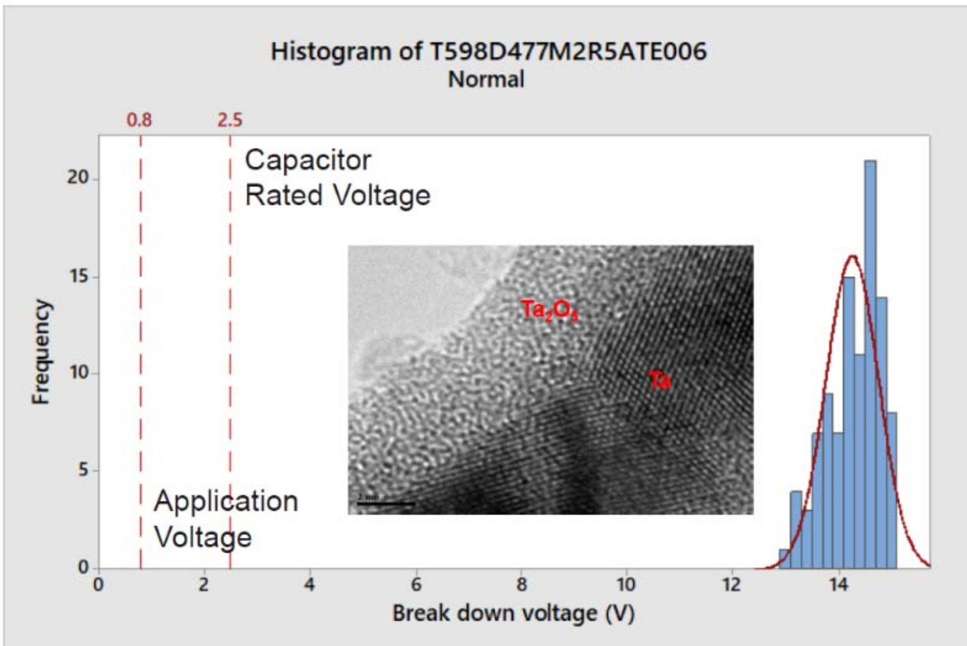


Figure 9. T598D477M2R5ATE006 470uF 2.5V 6mOhm Break Down Voltage (V) Histogram

(b) Surge Current Performance

Combined with the robust reliability design, the capacitors are 100% inline subject to surge current screening at rated voltage, 4 cycles, and room temperature with a circuit resistance of < 0.5 ohms. To evaluate the extended performance, extra surge current tests were performed at room temperature, 2.5V, with <0.1Ohm low resistance showing a maximum peak of 16.6A, Figure 10. All the electrical parameters were inside the initial specification after testing.

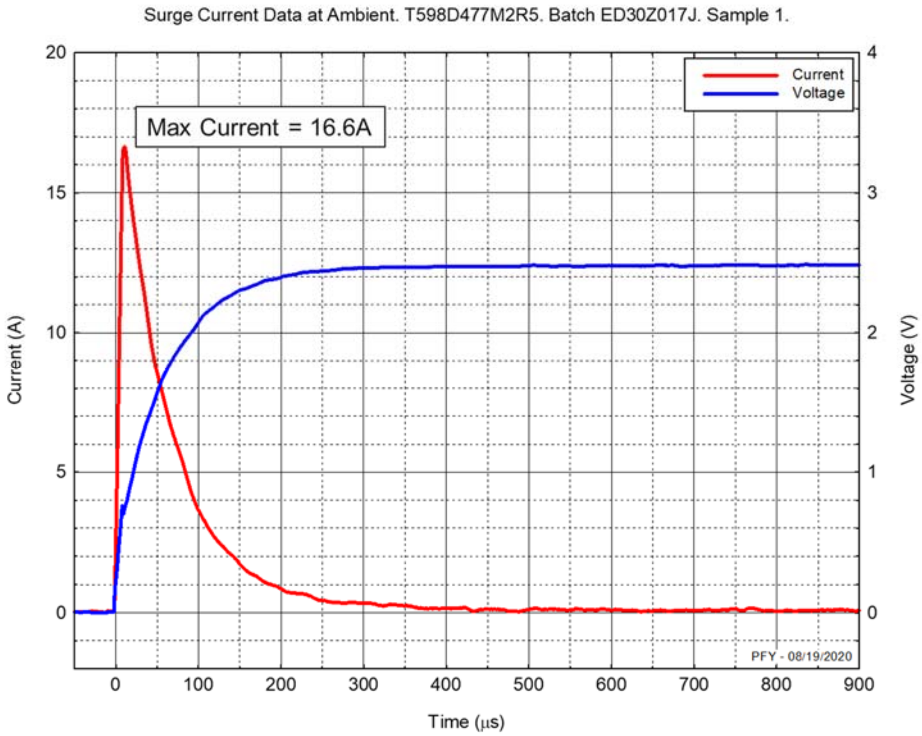


Figure 10. T598D477M2R5ATE006 Low Resistance Surge Current Results

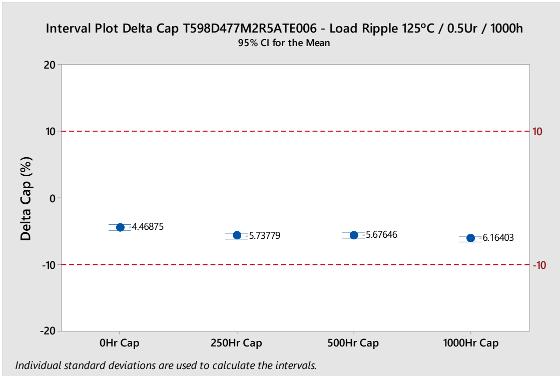
(c) Ripple Current Performance

Another important topic is the T598D477M2R5ATE006 ripple current specification, defined in the table below. This advanced ripple capability is a key factor for optimum operation.

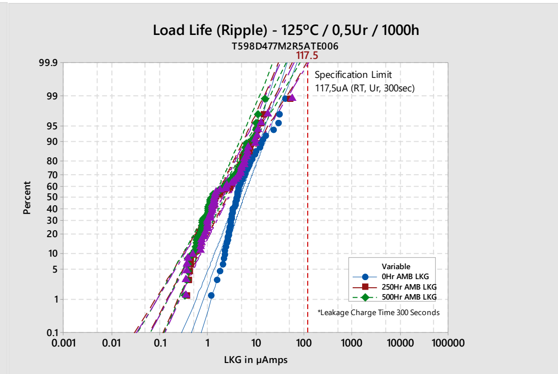
Ripple Current mA (RMS, 100kHz, 45ºC)	Ripple Current mA (RMS, 100kHz, 105ºC)	Ripple Current mA (RMS, 100kHz, 125ºC)
8860mA	6062mA	2165mA

The ripple noise included in the output voltage of DC/DC needs to be suppressed. An output ripple voltage of a step-down switching power supply is generated by the ripple component of the current flowing through the inductor and the capacitance, ESR, and ESL of the output capacitor. To suppress the output ripple voltage, increasing the capacitance and decreasing the output capacitor's ESR is effective.

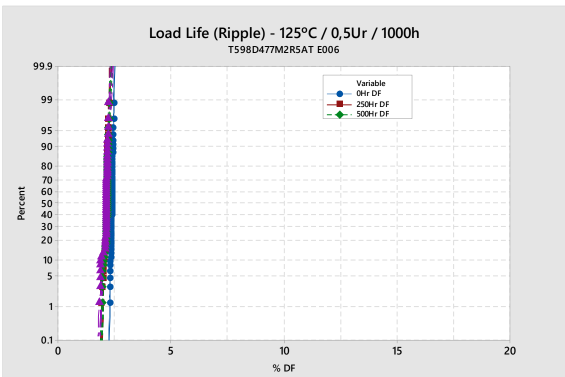
Additionally, Load Ripple life testing at 125ºC, 1.25V up to 1,000h reveals high stability in Capacitance Loss, with the Delta Cap variation lower than 2%; the leakage current, dissipation factor, and the ESR also reveal electrical stability, figure 11.



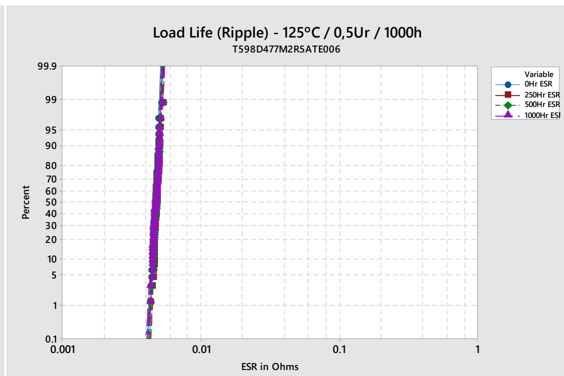
(a) Delta Cap (%)



(b) DC Leakage Current (2.5V, 300sec, RT)



(c) Dissipation Factor (120Hz, RT)

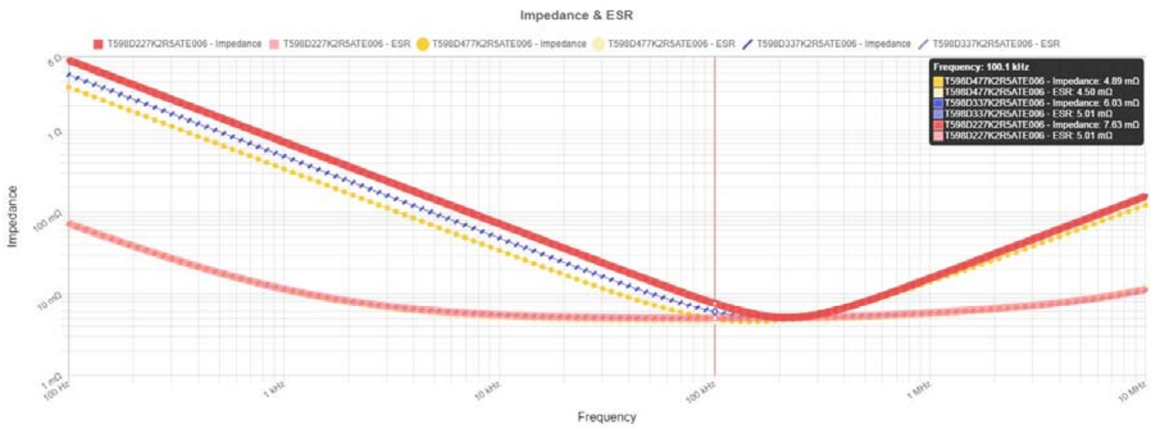


(d) ESR (100kHz, RT)

Figure 11. T598D477M2R5ATE006 Load Life Ripple Testing – 125ºC 1.25V up to 1,000h

(d) ESR versus Frequency

The ESR performance over the frequency range shows a large and broad distribution below 10mOhm for 1 single capacitor, figure 12. The combination of several capacitors in parallel reduces the ESR and supports the SoC power consumption trend on node sizes lower than 16nm.



Legend	Tolerance	Part Number	Cap.	Voc*	Dielectric	Qty.	Bias (V)	Amb. (°C)
	10%	T598D477K2R5ATE006	470 uF	2.5	TaPoly	1	0	25
	10%	T598D337K2R5ATE006	330 uF	2.5	TaPoly	1	0	25
	10%	**T598D227K2R5ATE006**	**220 uF**	**2.5**	**TaPoly**	1	0	25

Figure 12. T598 K-SIM Graphic – Impedance and ESR 220-470uF 2.5V 6mOhm capacitors.

(e) Accelerated Storage Testing – Cap Loss and ESR Aging Modelling

During the last decade, the automotive segment extended the 'legacy' lifespan mission profile from 8,000-40,000h to ~130,000h (15 years). The T598 polymer capacitors have been extensively subject to accelerated storage tests to support the **ESR Aging** and **Cap Loss** modeling. The temperature is a key factor, and the Arrhenius formula has been followed; the experimental activation energy is E_a=1.0eV, figure 13

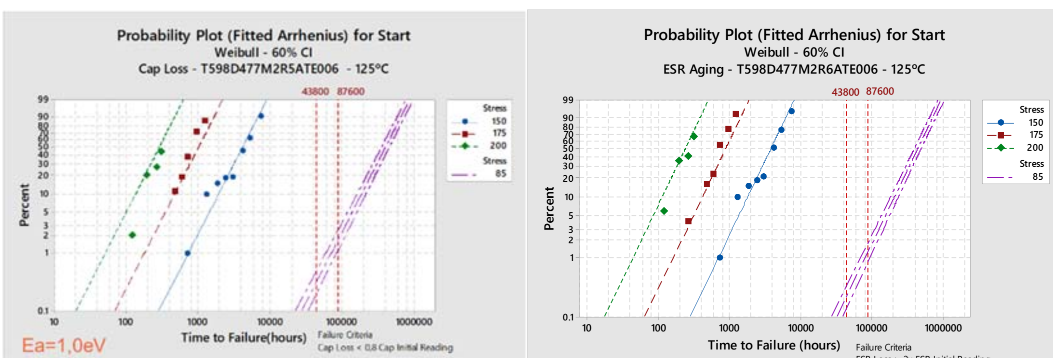


Figure 13. T598 Cap Loss and ESR Aging Modelling

Conclusion

The T598 Polymer Automotive Grade offers solutions to designers where space board saving, high volumetric efficiency/miniaturization, and reliability are required. Please contact a sales representative to support you in your challenge designing DCU/ZCU/CCU applications.

References

(1) 'Overview analysis of recent development of Self-Driving Electrical Vehicles,' Qasim Ajao and Landre Saqeeq Georgia Southern University

(2) ‘CAAD: Computer Architecture for Autonomous Driving,' Shaoshan Liu, Jie Tang, Zhe Zhang and Jean-Luc Gaudiot, IEEE
(3) Policy of Automated Vehicles, NHTSA
(4) ‘Computing Systems for Autonomous Driving: State-of-the-art and Challenges,' Liangkai Liu *et al*.

T598 Series

Datasheet

Online spec sheet → T598D476M025ATE060
https://search.kemet.com/component-edge/#/distributor?search=T598D476M025ate060&id=364&pn=T598D476M025ATE060

Online spec sheet → T598D477M2R5ATE006
https://search.kemet.com/component-edge/#/distributor?search=T598D477M2R5ATE006&id=364&pn=T598D477M2R5ATE006