



Capacitors News and Trends

3rd SPCD 9-12th October 2018

ESA/ESTEC, Noordwijk, The Netherlands

Tomáš Zedníček Ph.D.
EPCI president

Content



- Electronic Industry Trends
- Capacitor Technologies Overview
- 2017/18 Capacitor Headline News
- Summary

Electronic Industry – Growth Paradigms



Computing Sector Changing Paradigms
over the past 60 years.



Digitalisation - Enabling Technologies
Electronic Drivers

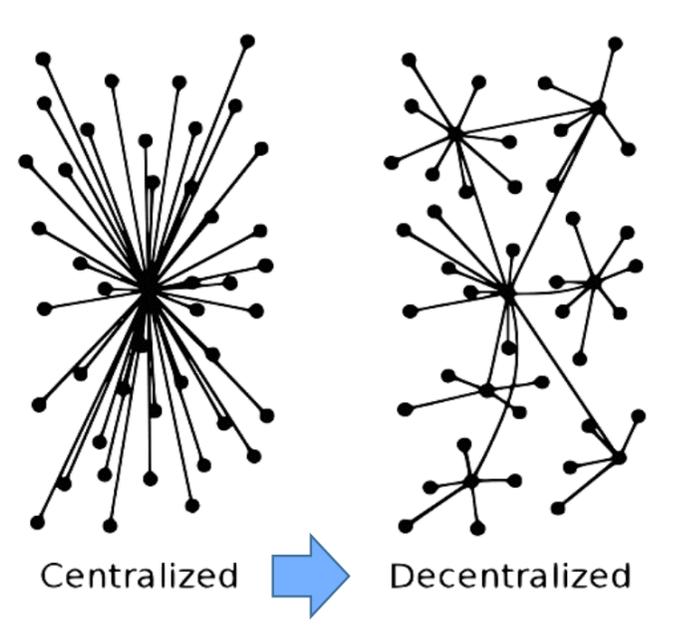
AI	2020 ~			
Services	2015 ~ 2020			
Mobile & Social	2010 ~ 2015			
Internet	2000 ~ 2010			
PC	1980 ~ 2000			
Mainframe/Mini	1960 ~ 1980			

Technology Trends – Dramatic Changes



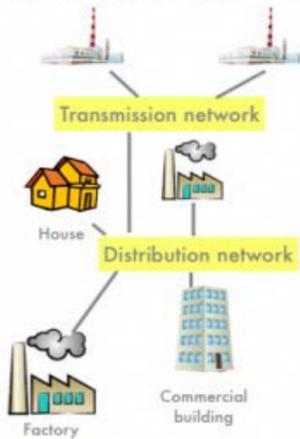
System Architecture Changes

- Structured
- Master – Slave
- Defined
- Known Risk
- Limited Innovation
- Changes Difficult

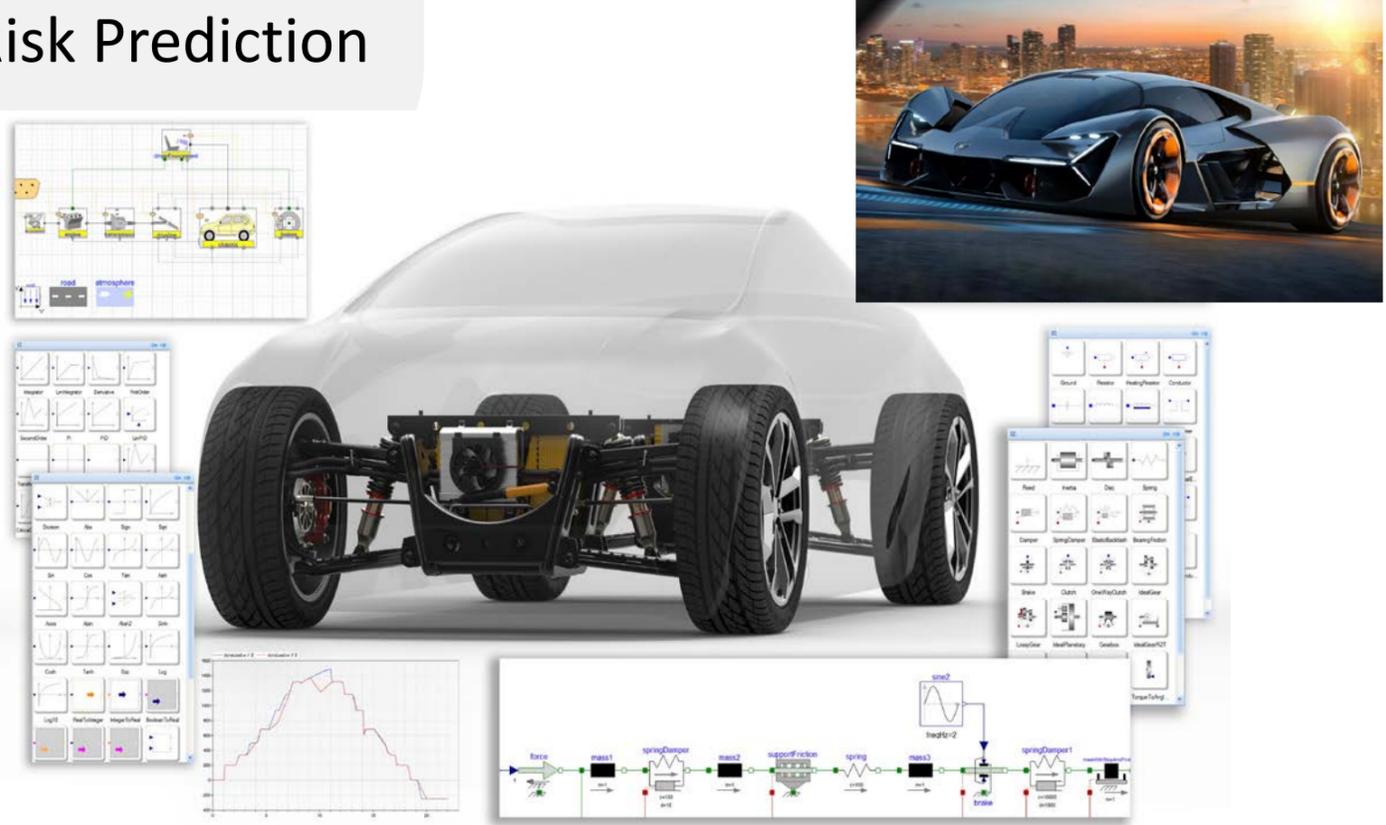
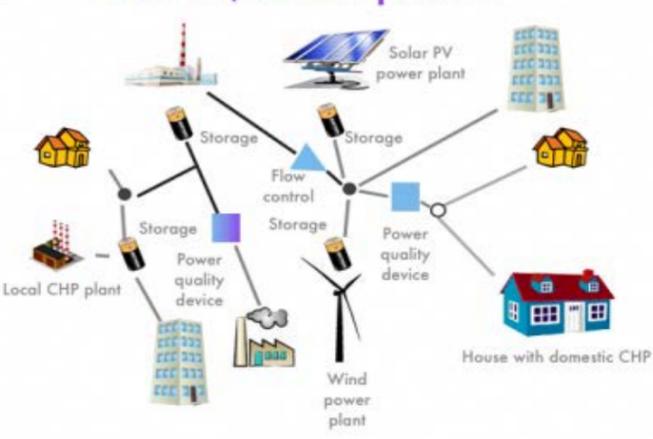


- Open Architecture
- Semi-structured
- Flexible
- Continuous Changes
- Innovation Required
- Challenging Risk Prediction

Yesterday Centralized Power



Tomorrow Clean, local power

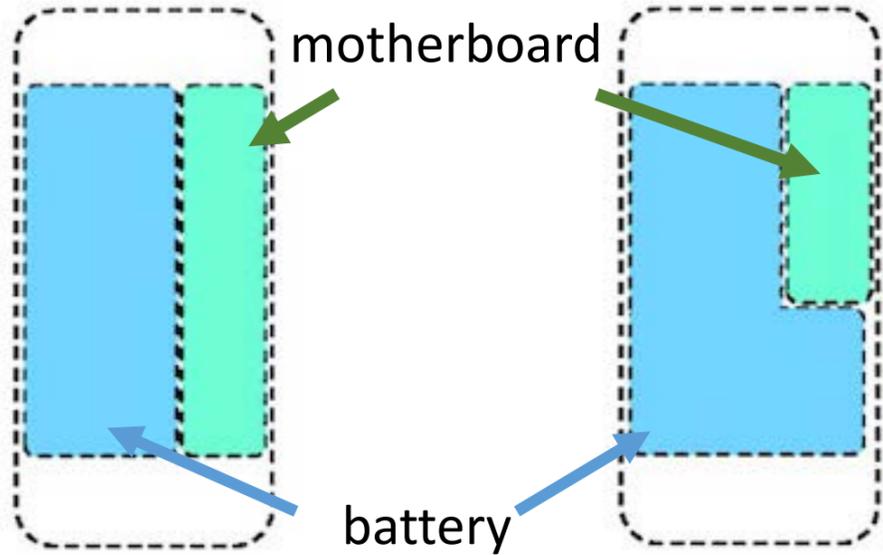


Fight for space – Capacitor Challenges



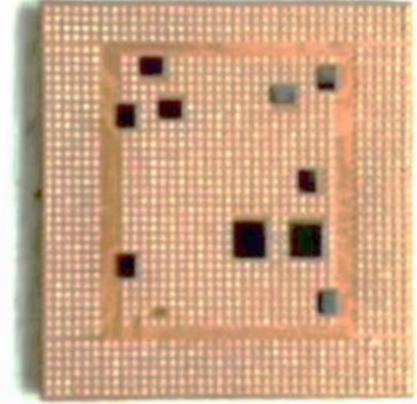
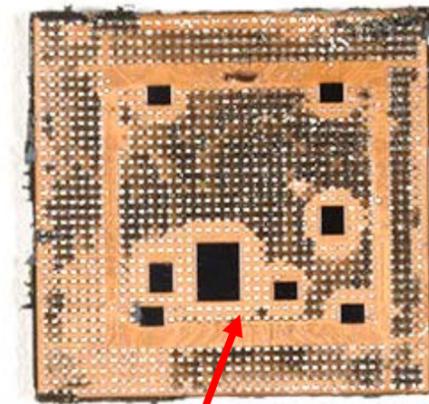
iPhone 6/7/8

iPhone X / Xs



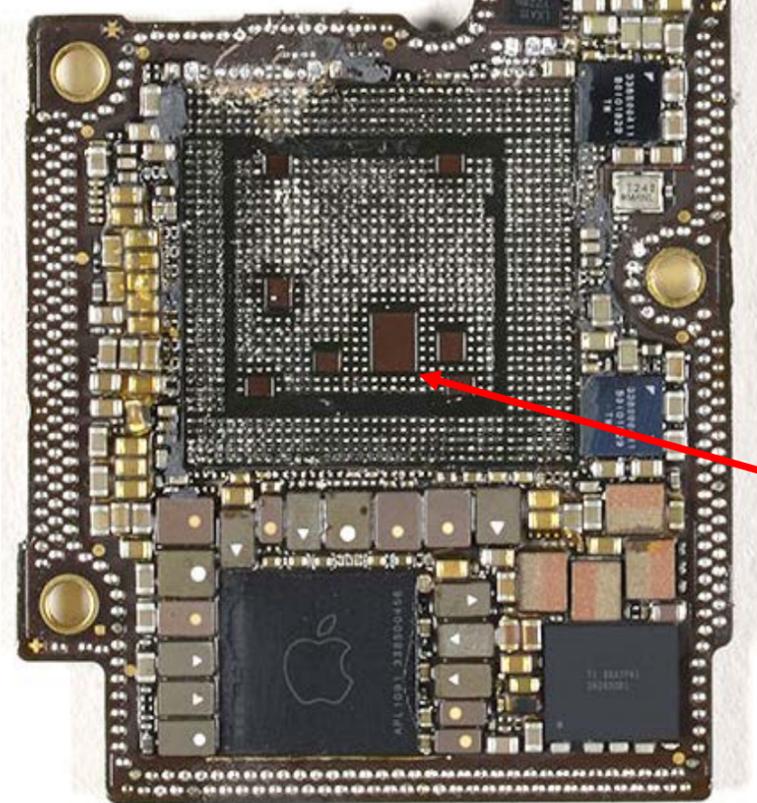
A12 (iPhoneXs)
2018

A11 (iPhoneX)
2017

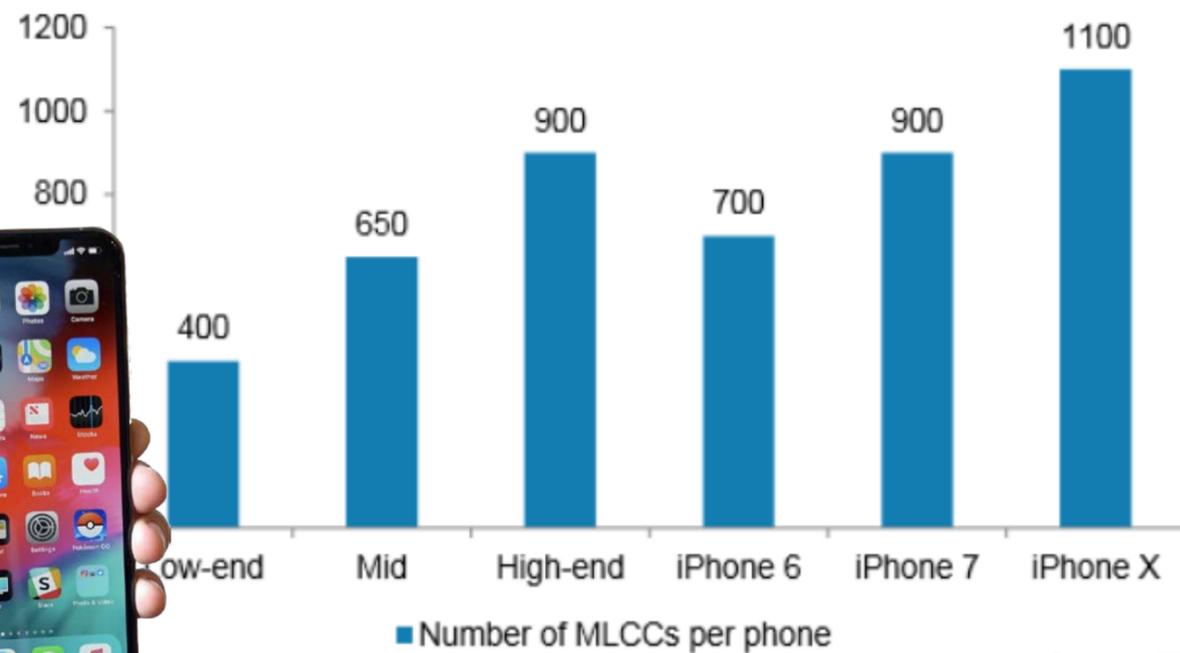


processor bottom view

“cavity” embedded passives (reverse geometry MLCC)



MLCC content per phone increases along with the mobile phone upgrade



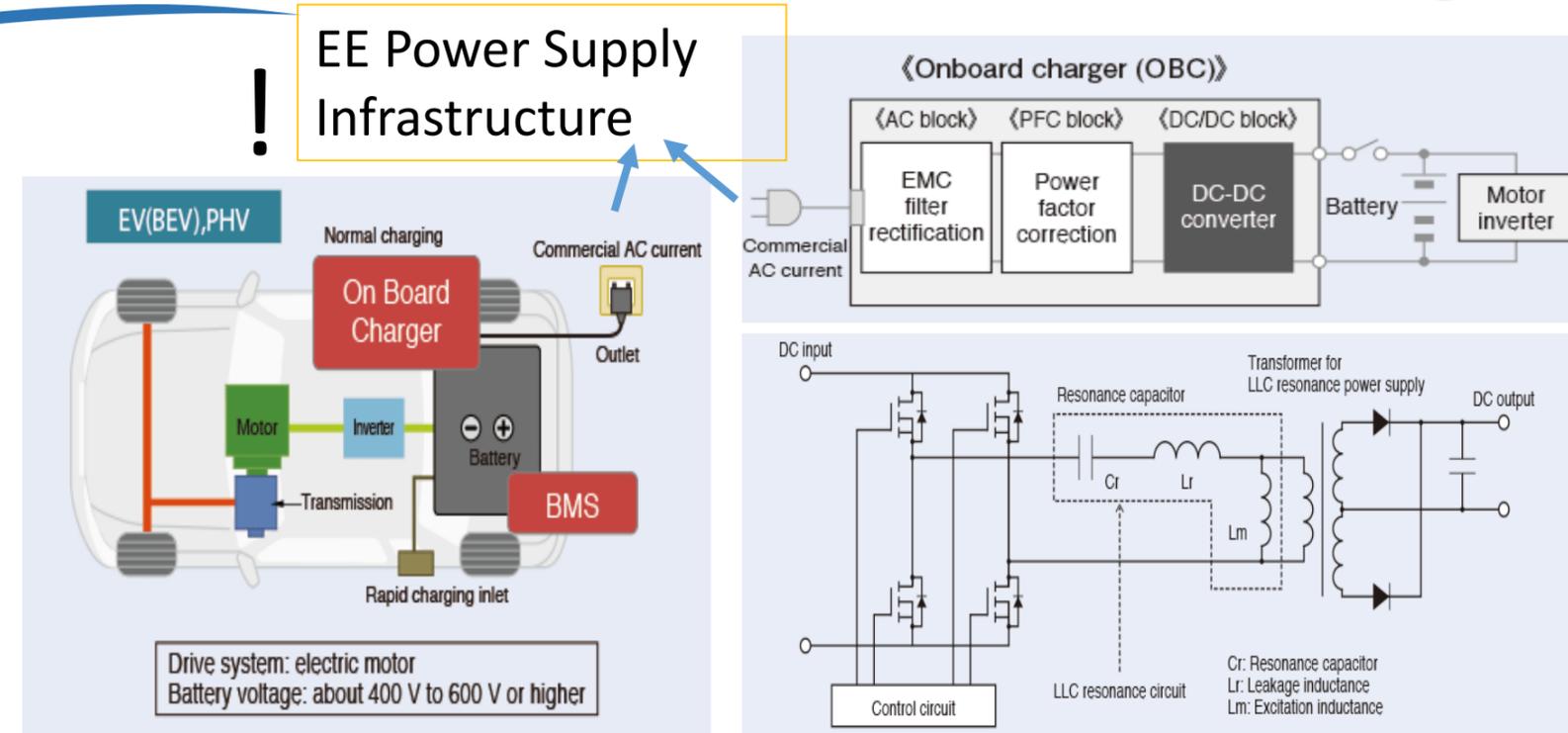
Source: TTI

Source: TechInsight

Automotive – EV/HEV

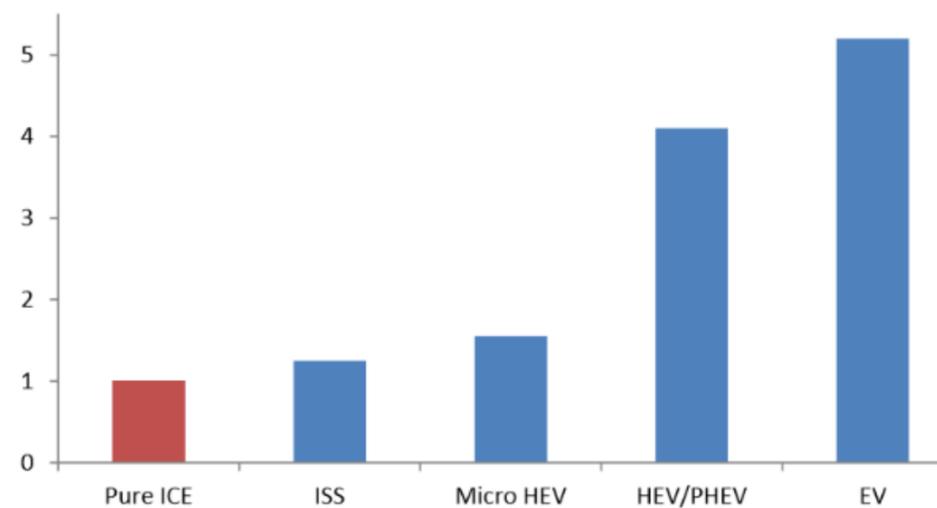


Lamborghini moved away from standard batteries and focused on supercapacitors at their Terzo Millennio concept 4 electric motors powered by supercapacitors as its energy storage devices located on body panels

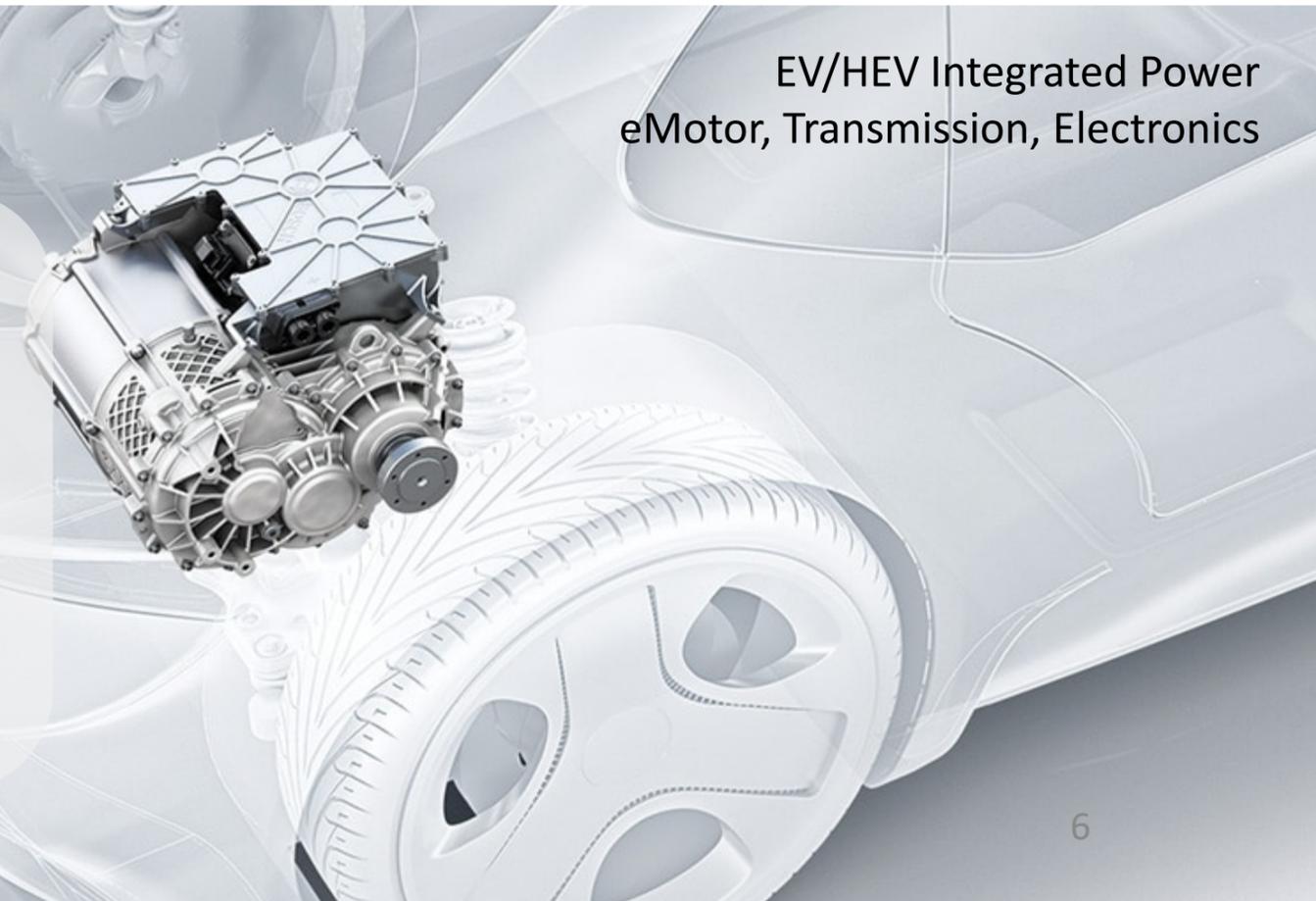


EV/HEV Integrated Power eMotor, Transmission, Electronics

MLCC content by power train (number of Pure ICE=1)



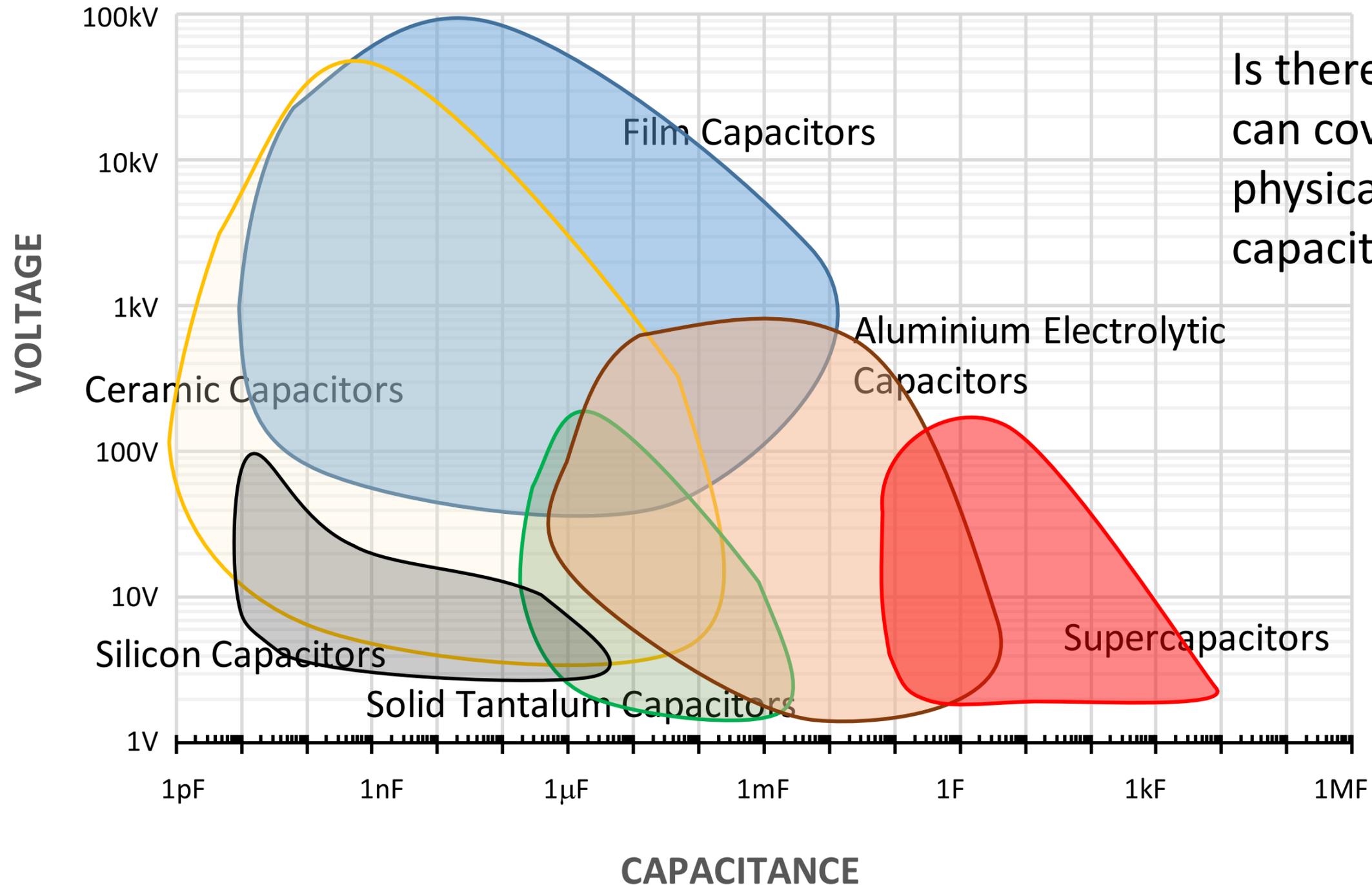
- More Components
- Smaller & Higher Temperature
- Higher Voltage & Power
- Component Selection Changes
- New Applications
- New Technologies



Capacitor Technologies



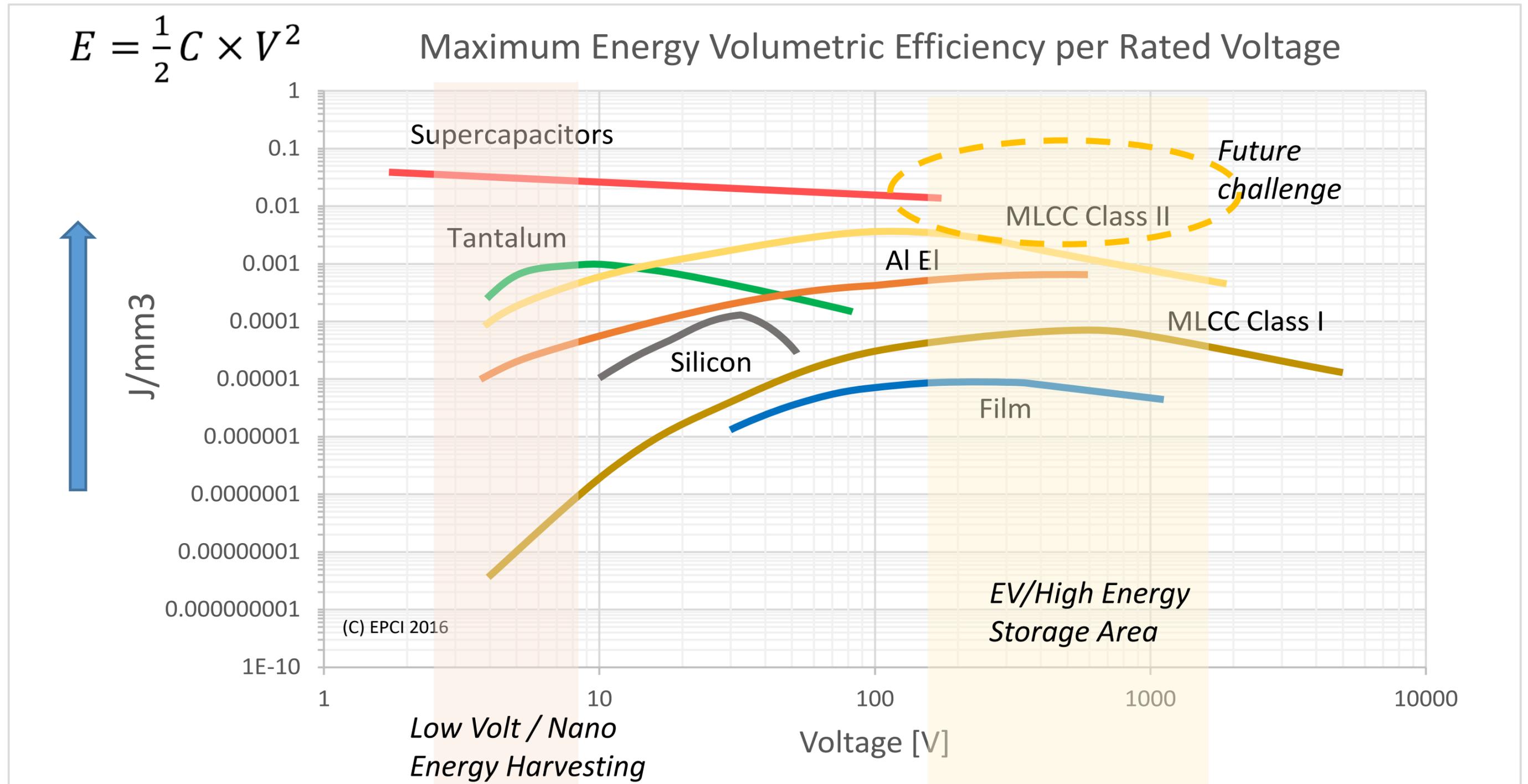
Capacitance value offering is **17 ranges** wide !



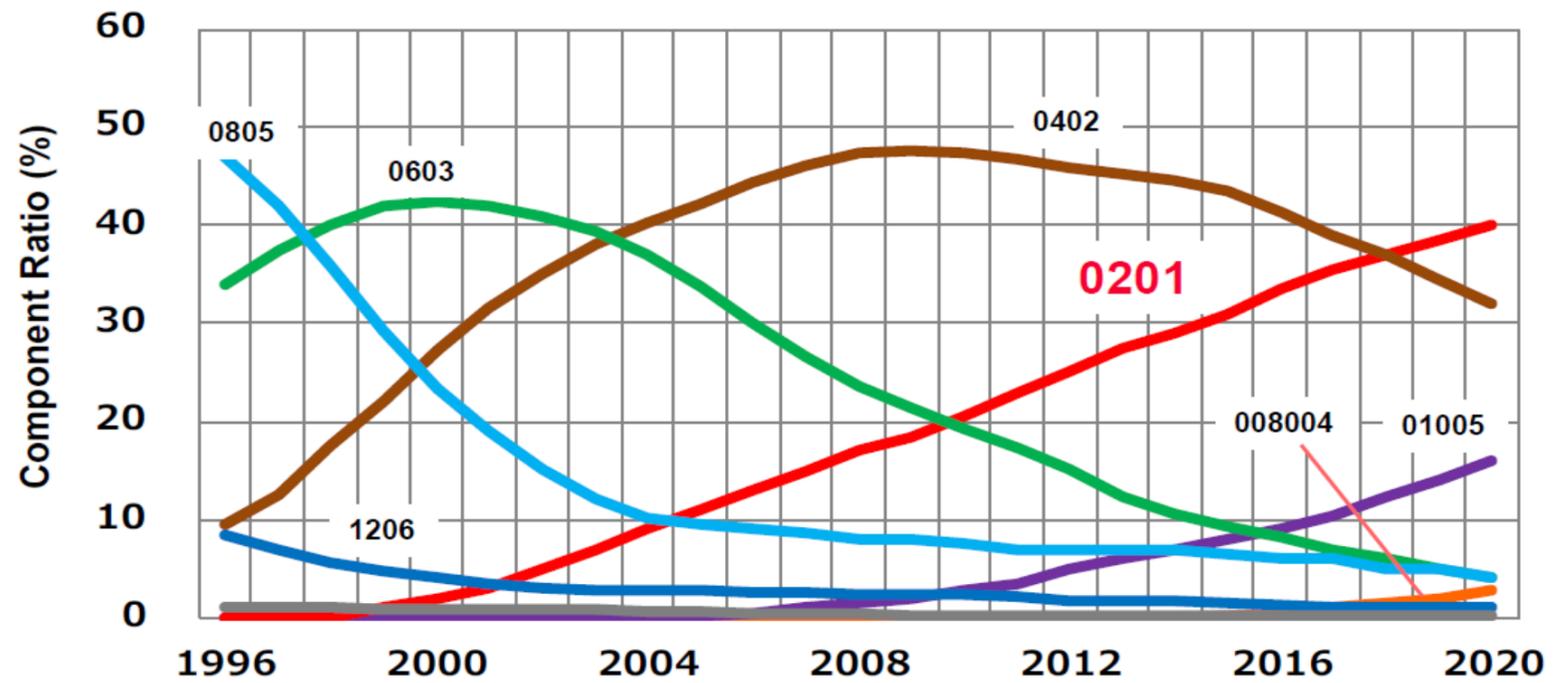
Is there any other technology that can cover such wide range of a physical parameter such as capacitors in its capacitance value ?

Fixed Capacitor CV Overview

Capacitor Technologies Benchmarking – Energy Volumetric Efficiency



Capacitor Technologies 17/18 Trends – Ceramic Capacitors



- 0201 has become the major MLCC case size in 2018
- 1000uF MLCC capacitor 2.5V
- World smallest 008004 MLCC capacitor
- 1000V 0603 COG and X7R MLCC
- 10uF 100V 3525 MLCC capacitor

New Ceramic Materials Research

- Rolls-Royce linked with Superdielectrics Ltd. to explore an entirely new group of polymeric superdielectrics, but also a development of new dielectric types for direct ~1kV voltage
- General Atomics develops new (ceramic) capacitor for power electronics >1000V and temperatures as high as 500C. GA-EMS has demonstrated pulsed power capacitors of more than 415 kJ in a single capacitor.
- EESstor has developed modified barium titanate (CMBT) dielectric powder with a relative permittivity over 30,000 and low residual polarization enabling capacitors designs with 19.04 J/cc.



1210: 3.2mm x 2.5mm x 2.5mm x **10 pcs** = **200mm³**

0201: 0.6mm x 0.3mm x 0.3mm x **3700 pcs** = **200mm³**

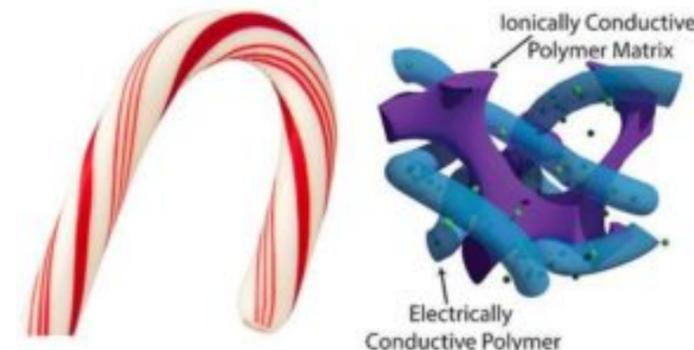
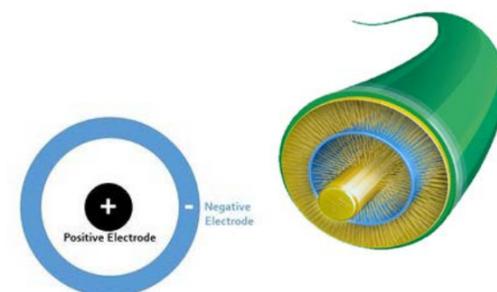
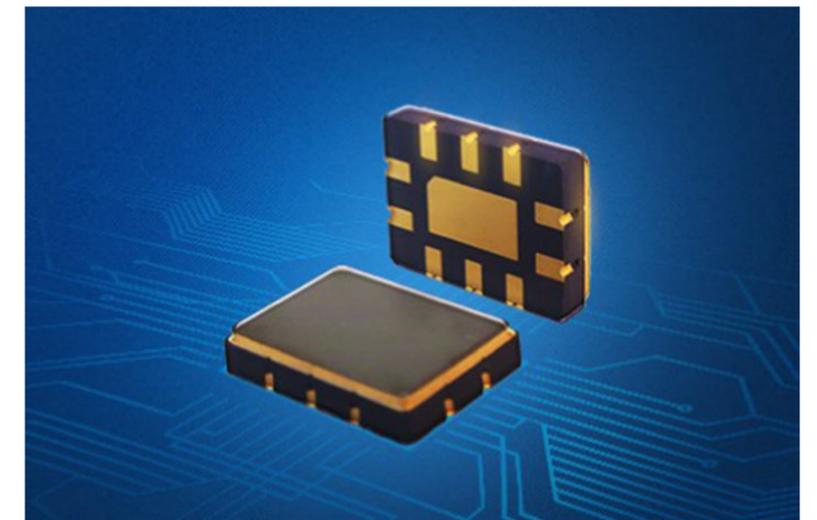
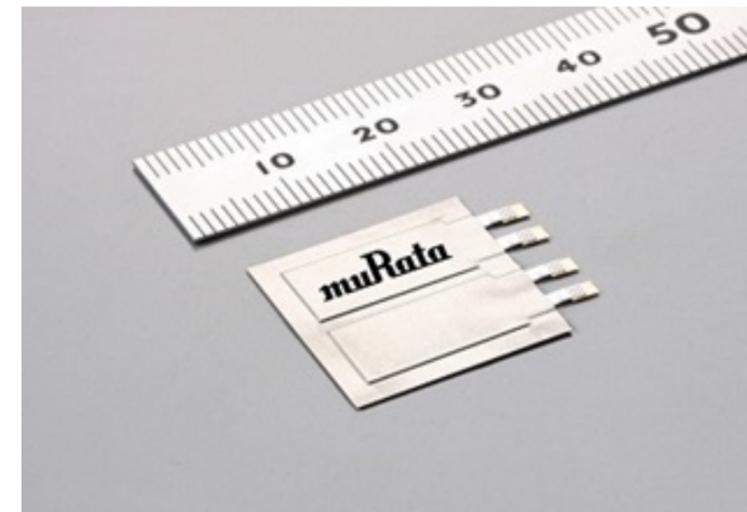
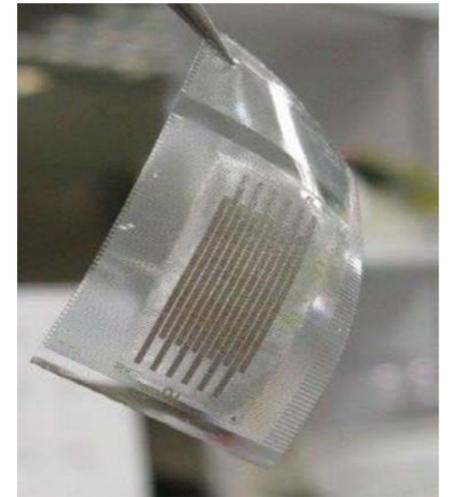
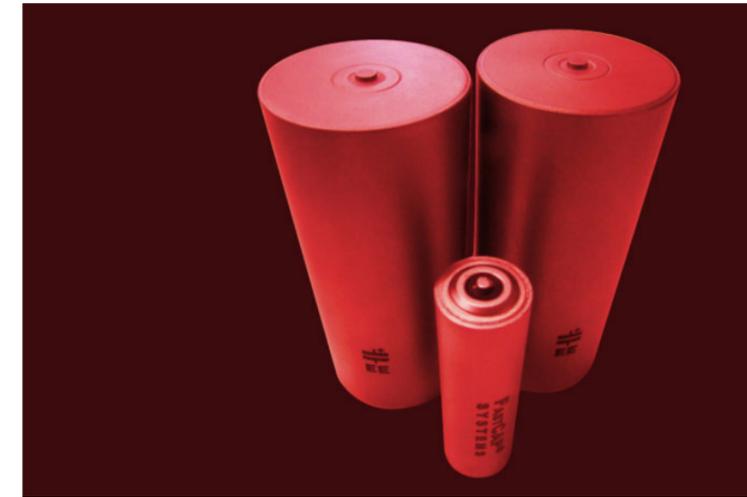
Source: Murata

Capacitor Technologies 17/18 Trends - Supercapacitors



Supercapacitor technologies demonstrated its capability:

- to operate up to 150°C (FastCap, Yunasco),
- down to -80°C temperatures (University of California)
- reflow-able chip package construction. (FastCap)
- world's lowest profile of 0.4mm (Murata)
- Candy cane flexible structure to power mobile or wearables
- CBC Cable Based Capacitor concept introduced (Capacitech)



Capacitor Headline News 17/18 Selection



Aerospace and Defence

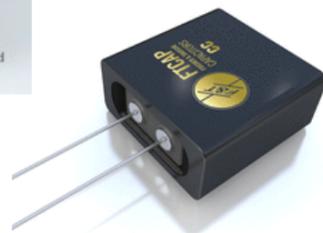
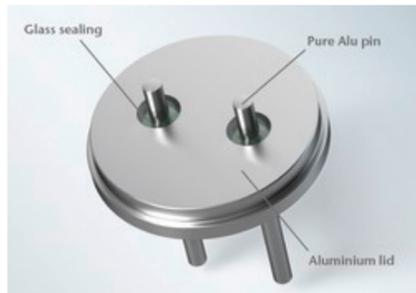


- **BME MLCC** qualified to space level (AVX)
- extension of **PME MLCC** technology is going on (AVX)
- 0402 10-25V PME NP0 and X7R qualified to QPL (Exxelia)



- **Tantalum wet capacitors** are getting multisourced at MIL level (Exxelia)
- **Tantalum polymer capacitors** qualification – EPPL (Kemet), multianodes under evaluation (Kemet, AVX)

- **Aluminium capacitors** with hermetical sealed package are trying to enter the defence and aerospace business claiming advantages (and lower cost) over tantalum capacitors (Cornell Dubilier)
- New glass to aluminium sealing is considered as a new potential to support this idea. (Schott)
- Fischer & Tausche cubic design offers better cooling due to the larger surface area. It supplies up to 6 joules of energy at dimensions of 16x35x35mm



VERTICALLY ALIGNED
CARBON NANOTUBES

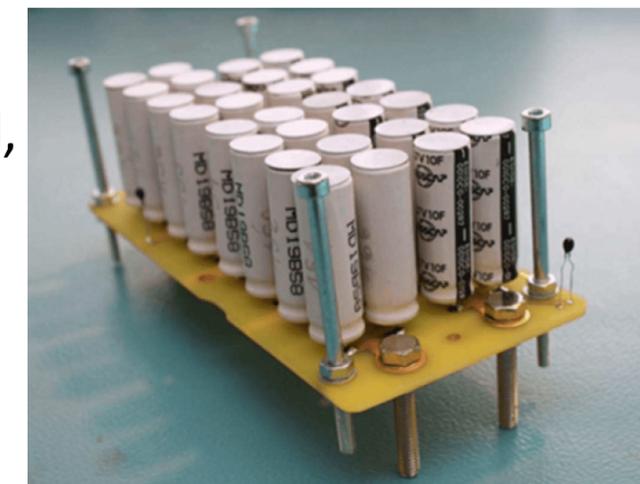
PIONEERING
NANO-MANUFACTURING
PROCESS

MIXTURE OF CARBON AND
GRAPHENE WITH A UNIQUE
COATING

CAPABLE OF CHARGING AND
DISCHARGING IN SECONDS FOR
UP TO ONE MILLION CYCLES

5X
MORE POWERFUL THAN
EXISTING ULTRA CAPACITORS

- **Supercapacitors** under evaluation at space (both ESA and NASA)(Maxwell, Skeleton Technologies ...). The solution is 60 times lighter and 30 times more efficient than the batteries it will replace.
- Ongoing qualification of Maxwell/Nesscap Supercapacitors by ESA
- Combining of lithium batteries with fast charging carbon ultra-capacitors claims lower weight and 5x more power. (Nawa Technologies)



Capacitor Headline News 17/18 Selection



Automotive

- **MLCC capacitors** AEC-Q200 range extension from 2kV up to 4kV (Syfer) designed for EV applications in X7R or X8R designs
- **Film capacitors** are under pressure to be replaced in vehicle on-board **by MLCC** due to size, life and temperature limitation. The film focuses on quick chargers infrastructure. Focus on higher voltage (450V Murata) and temperature (Kemet PP film -40 to +110C) automotive grade products but still limited to 125C at high side, whereas the MLCC just released 175/200C X8R and C0G automotive qualified range (Murata, Kemet) or specific humidity resistant series (Murata).
- **Tantalum polymer capacitors** (Kemet, AVX) are now available in automotive grade level capable to withstand 85/85 1000hrs life test and AECQ-200 requirements
- 150C Celsius Automotive Qualified Polymer Electrolytic Capacitors (Kemet).
- **Aluminium electrolytic capacitors** with polymer electrolyte did not get a good reputation due to its DCL instability, the industry responded with new range of automotive ready “hybrid” electrolyte solution combining polymer and liquid electrolyte solution. The hybrid aluminium capacitors are now recommended as a superior lifetime and stable parameters option by manufacturers for wide range of automotive and industrial applications. Lower ESR, high ripple, higher vibration resistance parts are available. (Panasonic)
- New series of **automotive grade aluminium electrolytic capacitors** guarantee resistance to 30G vibrations. (Panasonic)
- Engine Start Module **supercapacitors** (Skeleton), providing the highest power and energy density on the market, and is available in 24V and 12V versions with 69 – 109kW peak ratings.
- supercaps are currently used with stop-start and kinetic energy recovery systems (KERS) where fuel savings of up to around 25 percent compared to ICE-only models can be achieved.



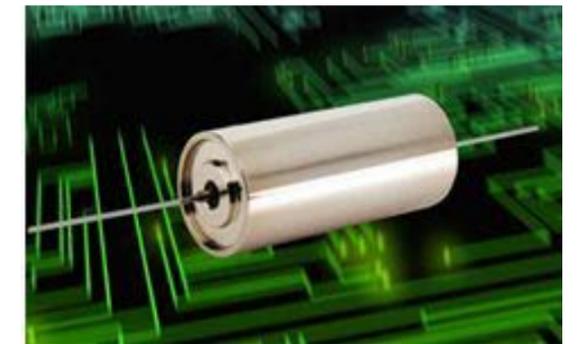
Capacitor Headline News 17/18 Selection



Industrial

Key Focus: generation, transportation, storage and harvesting of energy from nano-scale on chip solution up to high power energy applications.

- smaller DC-link **film** capacitors (TDK)
- extensions of max voltage range of Aerovox film capacitors up to 100kV (Aerovox)
- Nichicon and SBE Announce Initial Partnership to Develop Hybrid DC Link **Aluminium** Capacitor Bank for GaN and SiC systems
- Cornell Dubilier Ruggedized Axial-Leaded Aluminum Electrolytic Capacitor Performs to +175 °C without Derating
- 200/230C high temperature **tantalum wet** capacitors for oil drilling wells. (AVX, Vishay)
- industry's first **supercapacitors** to offer useful life of 2000 hours at +85 °C and meet the highest class of moisture resistance: the biased 85 / 85 1000-hour test. (Vishay)
- Laser-Welded Ultracapacitor Packs (Skeleton) providing much higher reliability and durability compared to bolted ultracapacitor pack layouts



Capacitor Headline News 17/18 Selection

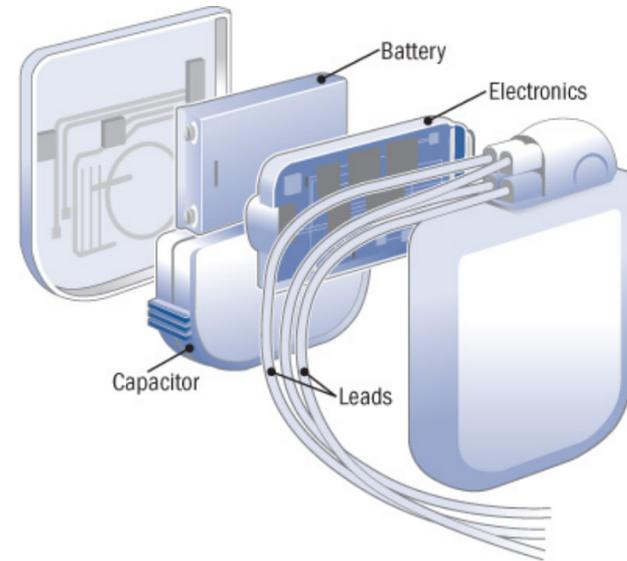


Medical

- (non-)Life support
- (not-)Implantable
- Wearable



- external AED devices **film capacitors** 800 VDC to 6,000 VDC, delivering in excess of 500 joules (Aerovox)



- implantable, life support defibrillators (FDA approved) **tantalum wet capacitors** with highest energy density (Ewans)
- Non-life supporting implantable **tantalum capacitors** ensure the lowest leakage and highest reliability of critical capacitors by Q-process with dynamic statistical screening.(AVX)

Energy harvesting and powering of wearable electronics by **supercapacitors**

- 3 Volt Ultra Thin Prismatic Supercapacitors (CapXX) for vibrate alarm as wearable Communicator (Spire)
- stretchable, flexible construction for “smart” clothes with wash resistance. (Skoltech)
- paper-based supercaps foldable thousands of times without affecting conductivity.
- Battery-free implantable medical device powered by human body supercapacitor – „biological supercapacitor“, which operates using charged particles, or ions, from fluids in the human body. Combining energy harvesters with supercapacitors can provide endless power for lifelong implantable devices that may never need to be replaced.

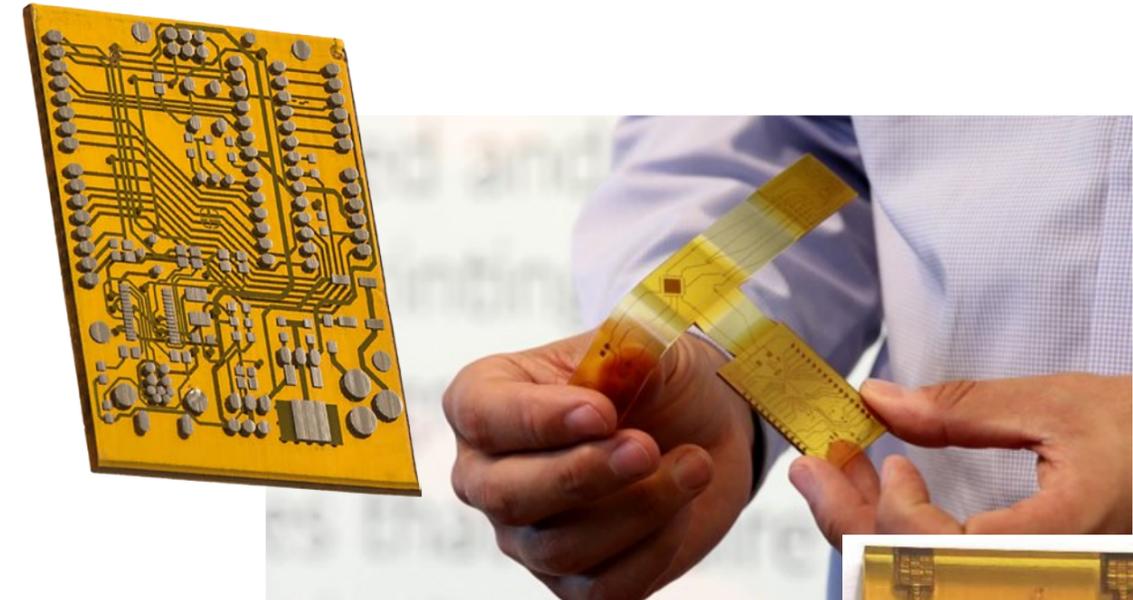
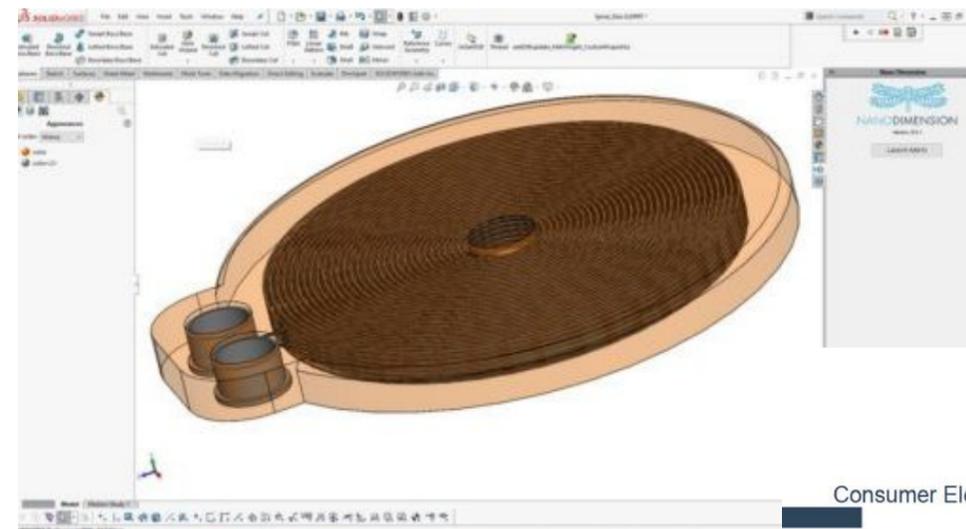


New Processes – 3D PCB Print (with embedded function)



When are we going to print PCBs on 3D printer ourselves?

<https://passive-components.eu/when-are-we-going-to-print-pcbs-on-3d-printer-ourselves/>



Selected Parameters of DragonFly 2020 Pro 3D PCB printer

- Max PCB dimension: 20x20 cm
- Max number of layers: up to 3mm, ~20+ layers
- Max thickness of one board: 3mm
- Typical layer thickness: Same as traditional PCB
- Min dimension between conductive path: 125 μ m
- Layer Resolution: 3 μ m dielectric (FR4 close performance), 0.3 μ m conductive silver ink
- Printing cost: approx. 20-40 USD per layer of 10x10cm PCB, e.g. 200-400 USD of 10-layer 10x10cm



embedded discrete components

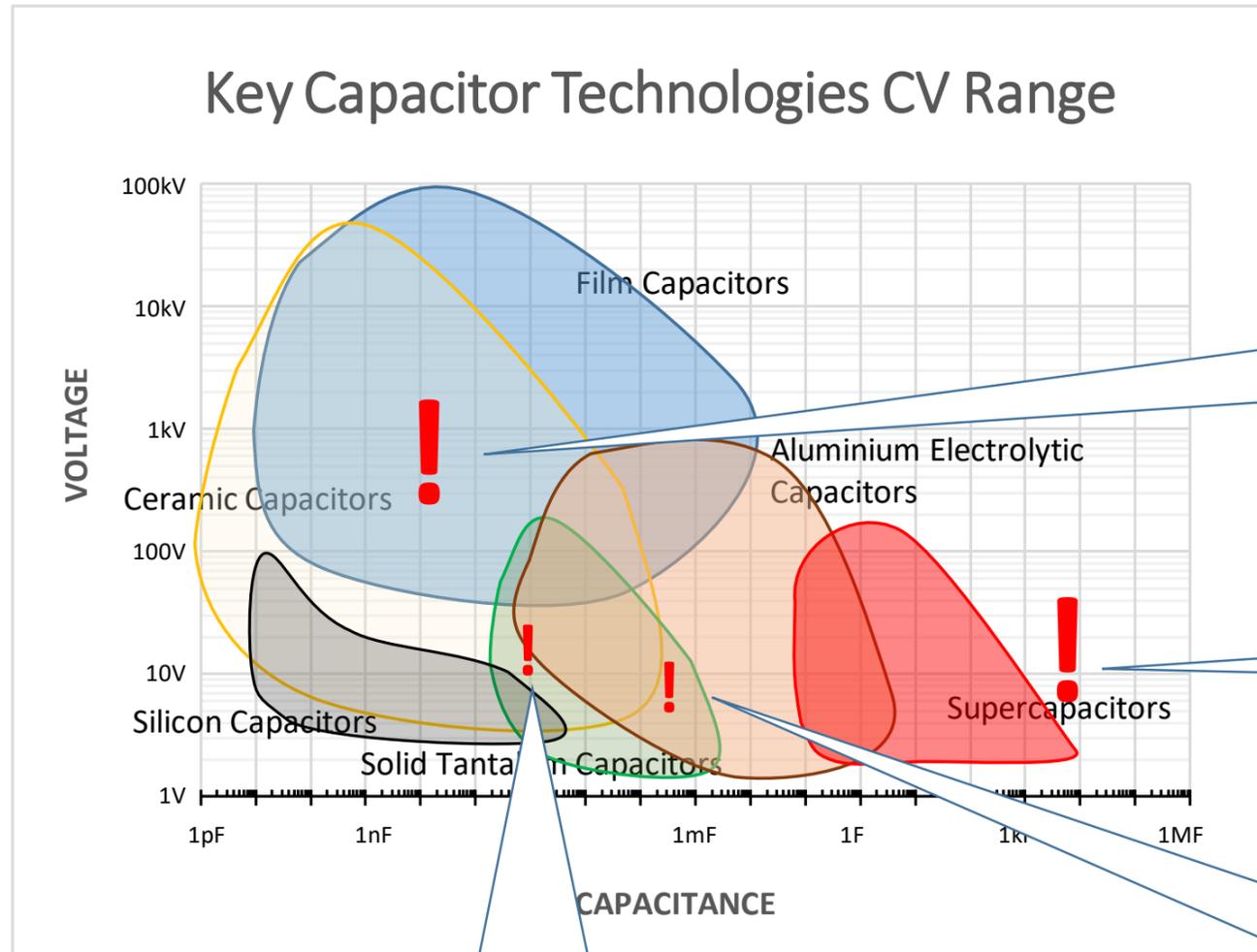


SUMMARY & CONCLUSION

Fixed Capacitor CV Overview



TECHNOLOGICAL "BATTLES"



Medium/High Voltage MLCC vs. Film
EV/HEV Applications

Supercapacitors vs Batteries
Energy Storage / Power Back Up

Film, Tantalum vs Hybrid Aluminium
Automotive, Energy Storage Systems

Solid Tantalum vs MLCC
High Vol efficiency, Portable Systems



SOME DRAMATIC MARKET CHANGES ARE APPROACHING CHALLENGING THE PASSIVE COMPONENTS DEVELOPMENT & SELECTION GUIDE

conventional „mature“ capacitor technologies are facing new challenges

MLCC and Supercapacitors Technologies are subjected to strong R&D and fast development towards new applications

Energy storage, harvesting & handling pose currently the biggest challenge for all passive components from nanoscale to high power electronics

“World first” features and parameters enhancements released in 2017/18



Power Generation, Transmission and Storage

- DC Link Film Capacitors
- Smaller DC link film capacitor
- Film foil for temperatures up to 150C



Automotive

- 175/200C MLCC automotive
- 2-4kV X7R/X8R MLCC AECQ-200
- Tantalum polymer AEC-Q200 automotive
- 30G vibration ready aluminium capacitors for automotive
- 85C 2000hrs and 85/85 1000hrs ready supercapacitors

Space

- BME MLCC qualified to space
- Tantalum polymer qualification at aerospace
- Glass to aluminium seal suggests Al El and supercapacitors reliability enhancement
- Supercapacitor under space qualification



Industrial

- COG MLCC up to 200C
- 1000V 0603 COG and X7R MLCC
- 10uF 100V 3525 MLCC capacitor
- Reflowable supercapacitor
- Up to 150C or down to -80C capable supercapacitor



Smartphones, Handhelds, Wearables, Medical

- 1000uF MLCC capacitor 2.5V
- World smallest 008004 MLCC capacitor
- 3V (Lilon coin battery) ready thin supercapacitor
- Stretchable and flexible supercapacitors

Tomas Zednicek Ph.D.
EPCI president

EPCI European Passive Components Institute



email: tom@passive-components.eu

sponsored by:



Thank You



Acknowledgement

The presented work was partially supported by ESA Contract: 40001210761/17/NL/CRS with European Passive Components Institute s.r.o. "Passive Component Support EEE331"

www.passive-components.eu