Nové Technologie Pasivních Součástek pro Efektivní Přeměnu Energie

29 Listopadu 2023
PEL 2023, Rožnov pod Radhoštěm

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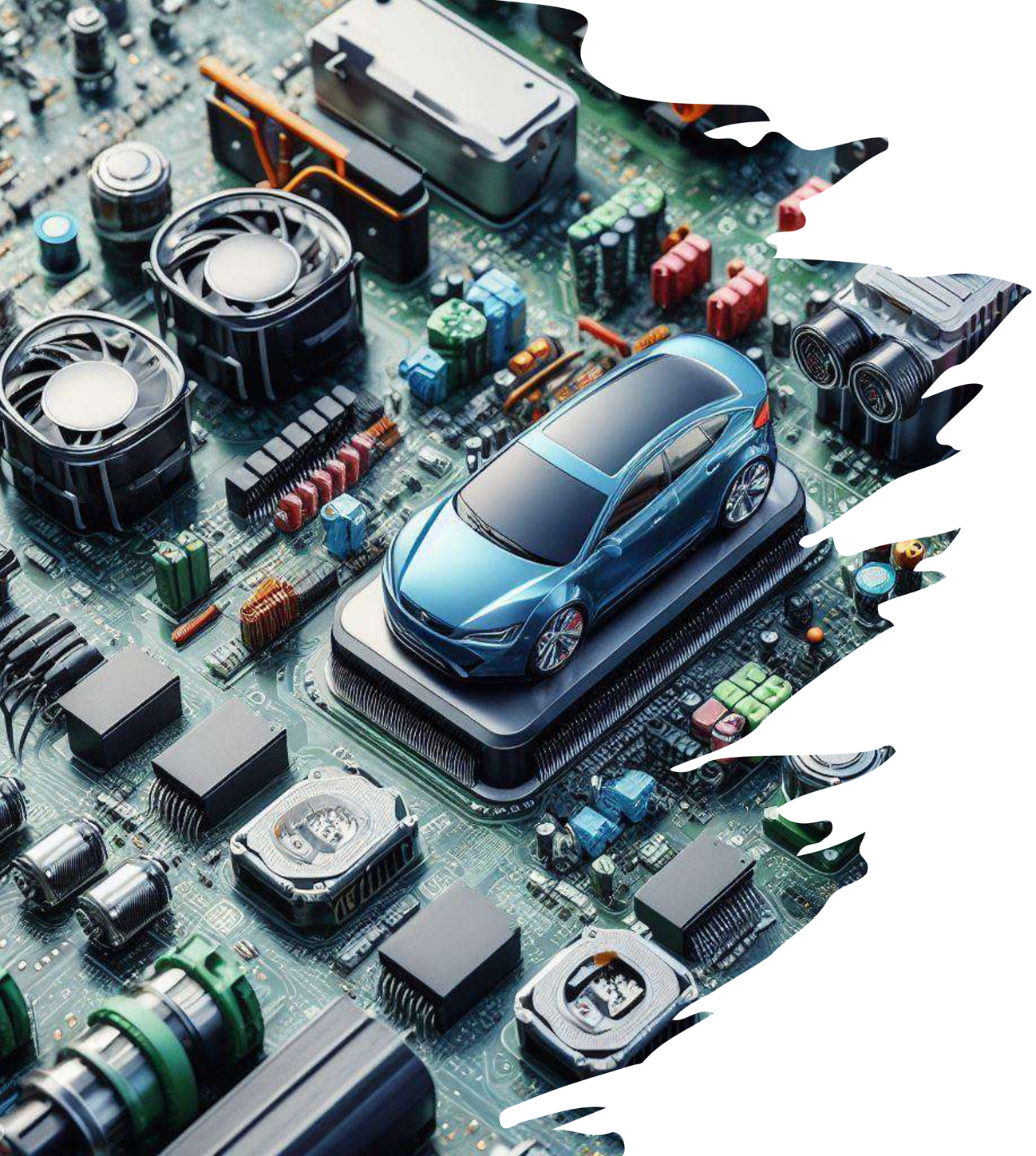
www.passive-components.eu



Content

- Introduction
- Part I. Power conversion drivers – market trends and semiconductors
- Part II. Passive components for power energy conversion
- Summary

Introduction – EPCI

EPCI European Passive Components Institute

- Free filterable newsletter on passives
- Database of passive component manufacturers
- Passive components Knowledge Base

WHO is WHO in Passives
free online database of global passive components manufacturers & suppliers

be active with passives !

- **One of few educational and information resources dedicated solely to passive components**
- Established 2015, Elektra 2016 Finalist
- EPCI among the top 15 best rated global component blogs since 2018
- **PCNS Passives Symposium** organizer since 2017

EPCI Members and Supporters:

Basic Members

www.passive-components.eu

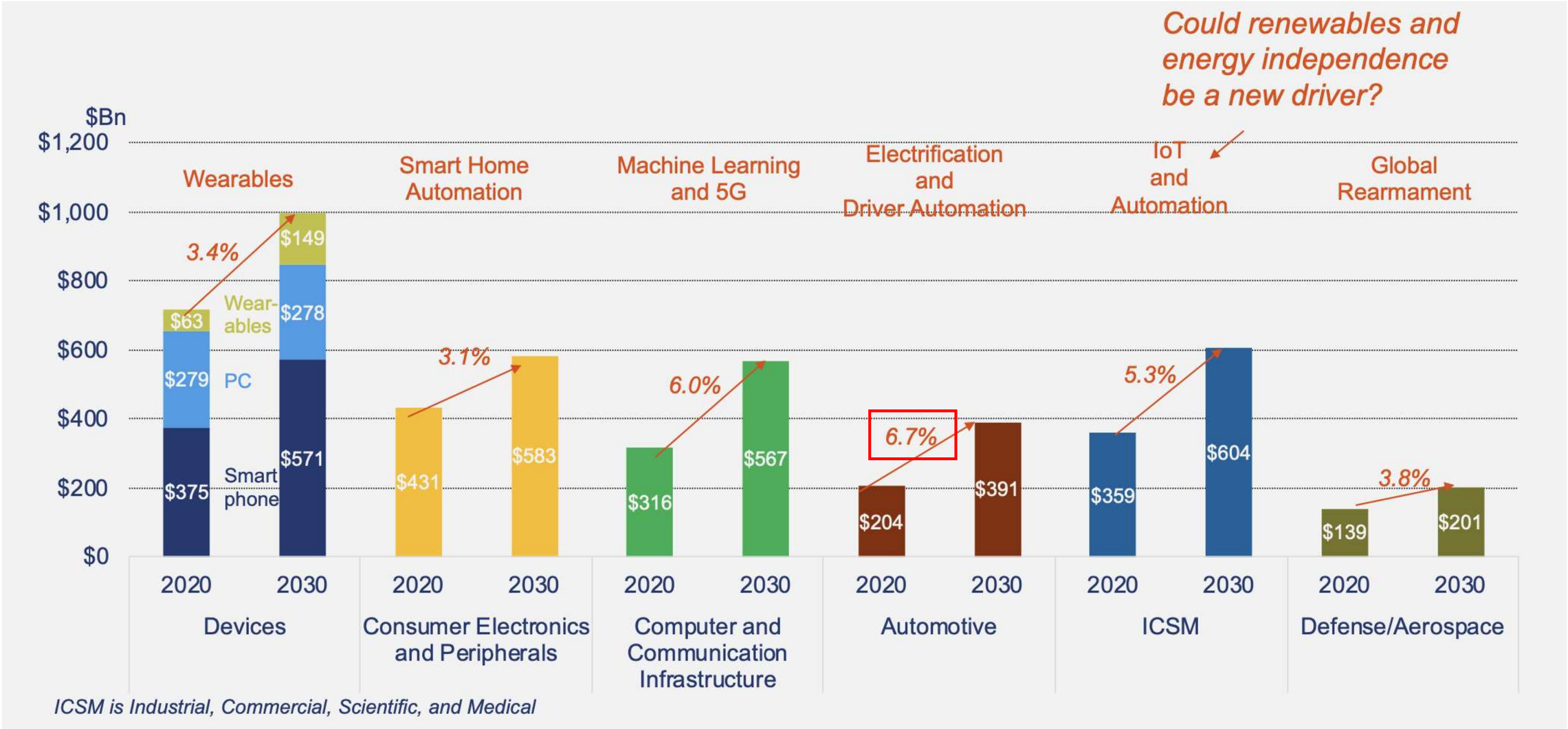
| Passive Components Educational & Information Blog

2023 passive-components.eu web profile:

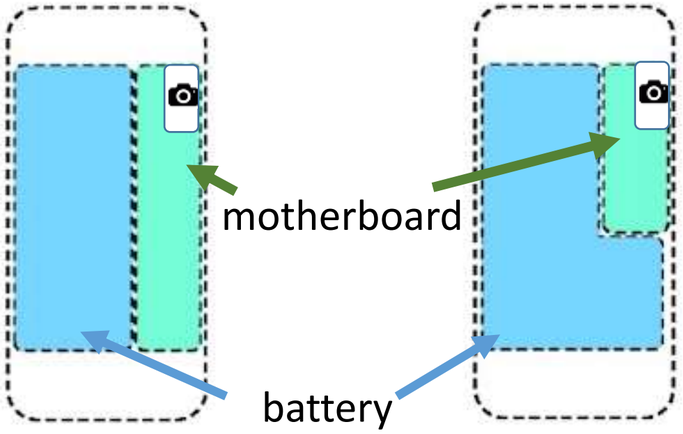
Active visitors: ~**40K/month**
Google Search views: ~ **2 million views /month**
Google Search clicks: ~ **35 thousands clicks / month**
Newsletter: > **781** subscribers related to passive components
Top countries: USA, India, Germany, UK, Canada, France, Sweden

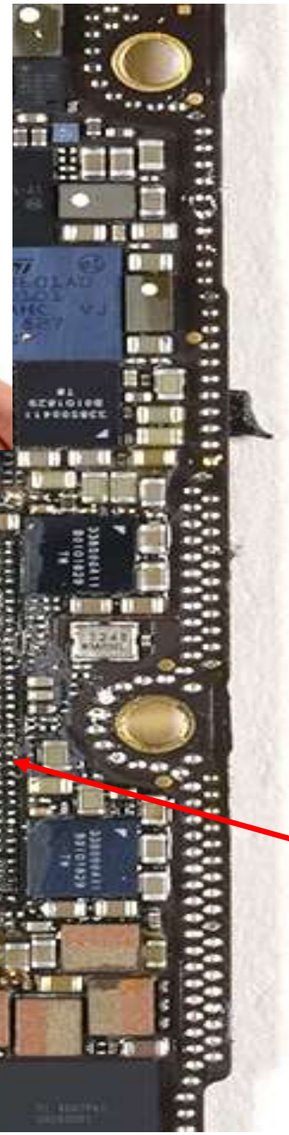
Key Growth Areas

Mega Trends in Electronics for the Rest of the Decade



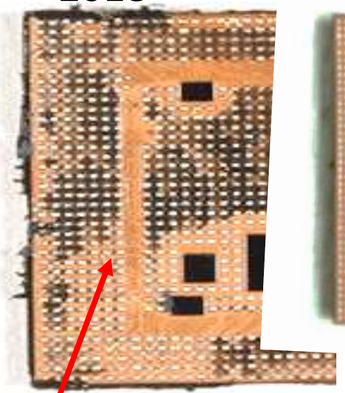
Key Growth Areas

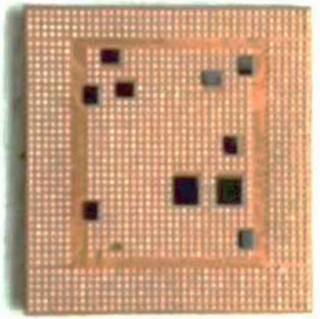




A12 (iPhoneXs) 2018

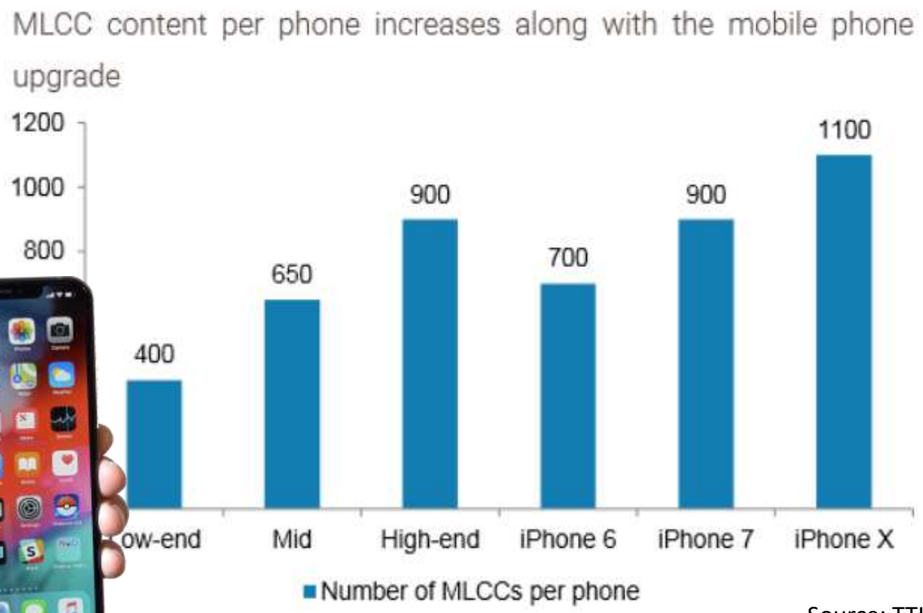
A11 (iPhoneX) 2017





processor bottom view

“cavity” embedded passives (reverse geometry MLCC)



Source: TTI

Source: TechInsight

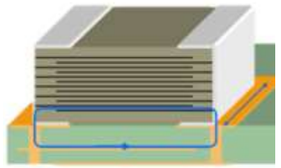
Key Growth Areas

Technology Background

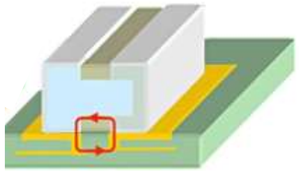
Semiconductor IC Development – Processors

DIE SCALING HAS DROPPED IC SUPPLY VOLTAGE

- ***Capacitors job decoupling more critical***
- ***Clock & data speeds making Di/Dt drawn larger***

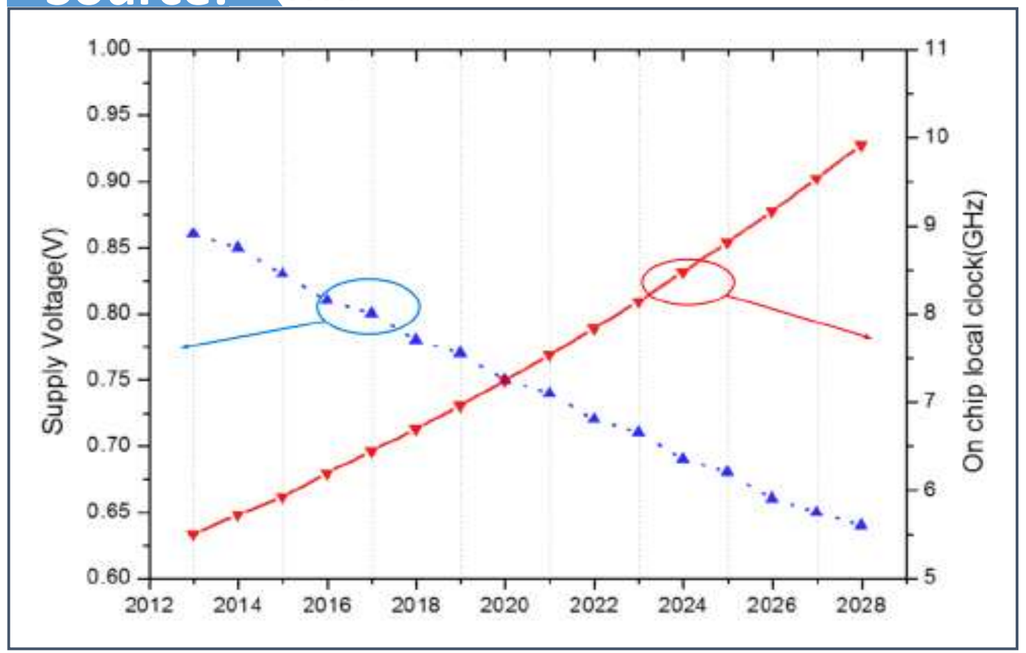


0805 MLCC
ESL ~ 600pH



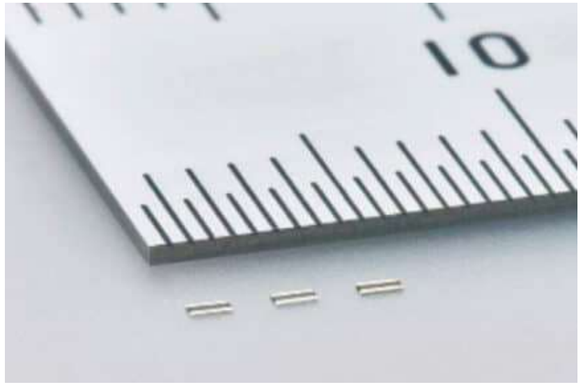
0508 MLCC
ESL ~ 45pH

Source: ITRS



Capacitor Requirements

- Low ESL
- Low ESR
- High power
- Small Size
- Low Profile



source: Tayo Yuden

Reverse geometry
MLCC 0.47uF 4V size:
0.52 x 1.0 x 0.1 mm

Best Fit Mass Volume Capacitor Technology:

Past: Tantalum + MLCC
Current: MLCC Ceramic Capacitors
Future: Integrated on Chip

Key Growth Areas

Mobile Internet / 5G

5G Key Technology Advancements

Low Latency

High Downlink Speed

- Multiarray Antennas (MIMO) & Beamforming
- Higher Frequency

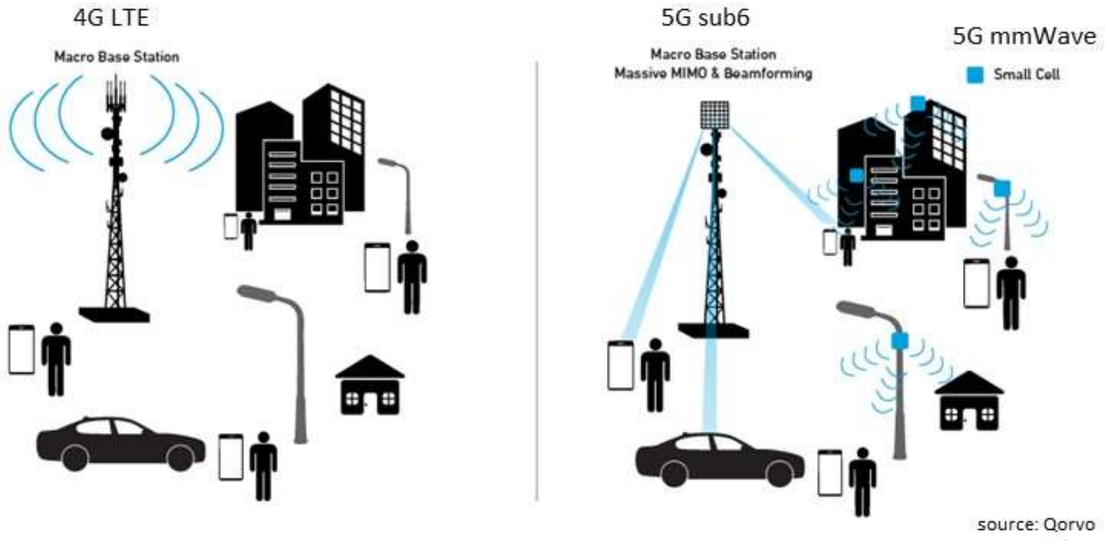
Low Interference

More Focused Energy & Energy Savings Potential

High Air Attenuation & Short Range

Increase Bandwidth & Device Coverage Density

Moisture & Barriers (walls) Attenuation

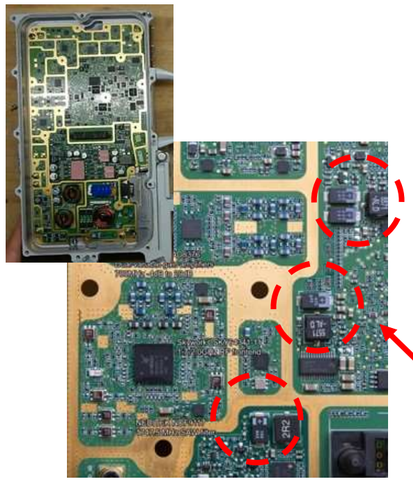


5G network will consist macro base station at 5G sub 6GHz (in combination with existing 4G) covering larger areas and 5G mmWave micro base stations and small cells to provide high speed hot spots

! 5G Calls for New Infrastructure Architecture !

to use its potential

Parameter	4G	5G	
	4G LTE	5G (Sub-6G)	5G (mmWave)
Frequency	2.1GHz	2-6 GHz	6-60GHz
Downlink Speed	1.2 Gbps	6.5 Gbps	18 Gbps
Latency	10-30ms	5-6ms	< 1 ms
Average Range (from a tower)	10km	1-6km	300m
Device Coverage Density	1 million devices per $500km^2$	1 million devices per $100km^2$	1 million devices per $1km^2$
Implementation	Macro Base Stations	Macro Base Stations	Micro Base Stations & Small Cells



Harsh Environment
Reliability
Low Profile

Small & Low Profile BS ~ 5G mmwave

At least **8x low profile D case** tantalum capacitors

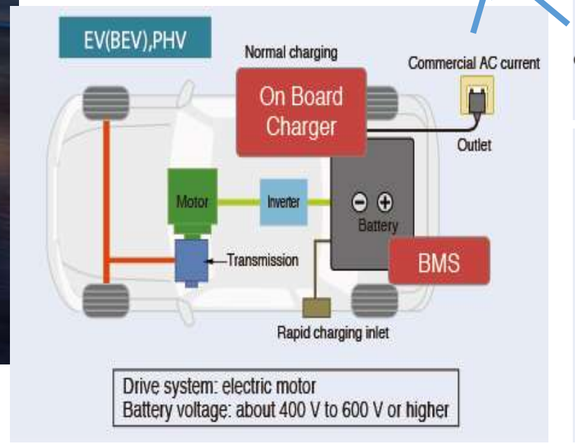
Key Growth Areas

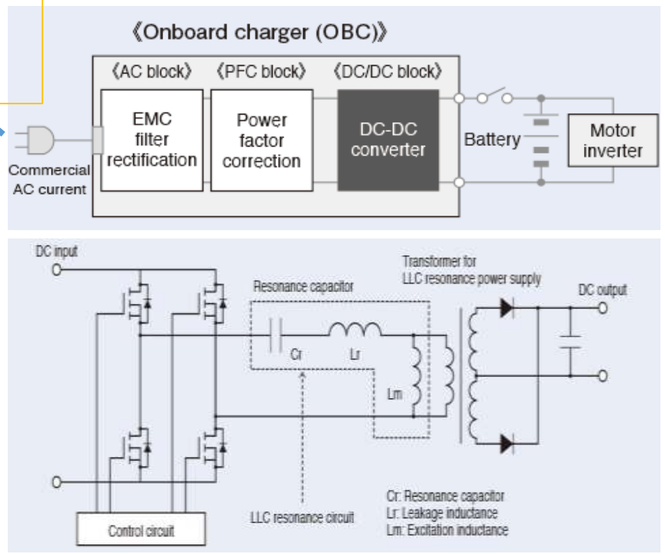
Automotive – EV/HEV

New Arrival Lamborghini Sián
first supercapacitor-based hybrid V12

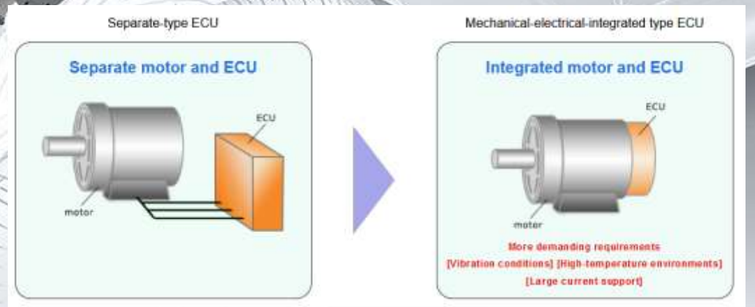
Lamborghini supercapacitors Terzo Millennio.
4 electric motors powered by supercapacitors as its energy storage devices located on body panels

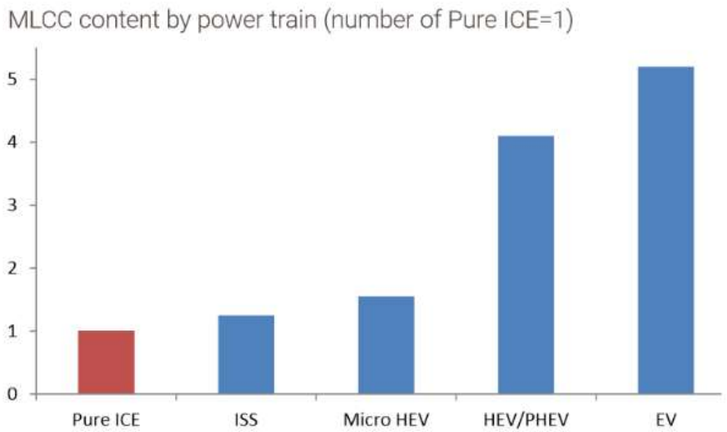
! EE Power Supply Infrastructure





EV/HEV Integrated Power
eMotor, Transmission, Electronics





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

Source: Bosch Mobility Solutions, TTI, TDK, Lamborghini, Panasonic

Key Growth Areas

Automotive – EV/HEV

High Power Switching & High Processing Power & Lowering of Processor Voltage

NOISE SUPPRESSION & EMC SHIELDING CHALLENGES

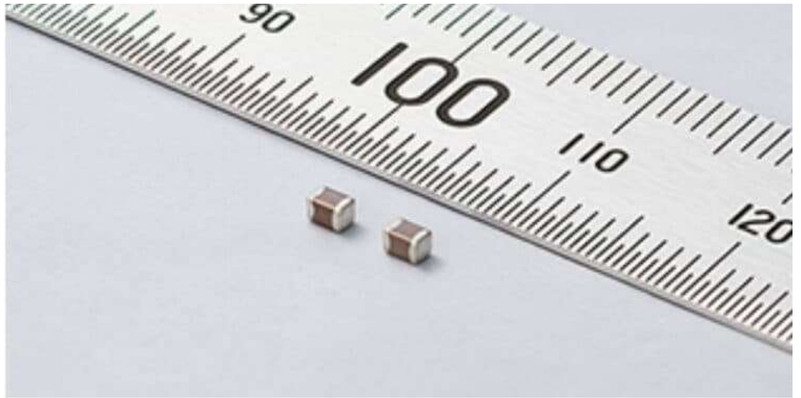
CAN-FD high speed, high accuracy miniature ceramic resonators

High Speed Data Transmition

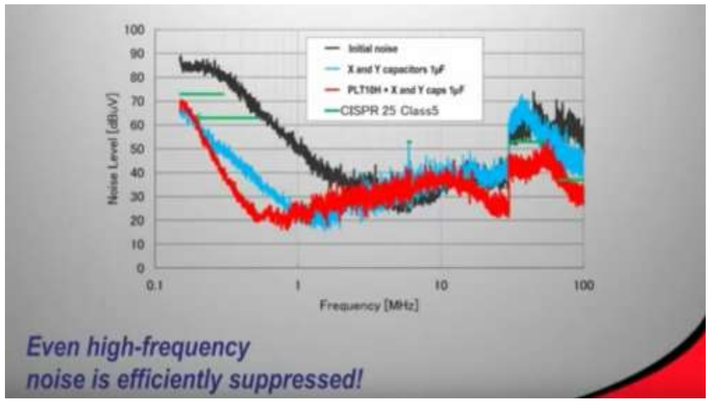
- **Integration & Miniaturization** of detection sensors (cameras, LIDAR, radar, etc…)
- **Power Over Coax** for image data transmission combines data and power transmission over a single coaxial line to reduce the amount of cable

Noise suppression by high current common (500mA) mode chokes in miniature 0201 case size

MLCC 10uF/25V in 2012 case size for 12V line smoothing applications in automobiles



Impact of safety capacitors and common mode choke to EMI suppression effectiveness



source: Murata; passive-components.eu

Key Growth Areas

Automotive

Each Vehicle is becoming
- It is own cloud
- Large cloud data center
- **High power computing center**

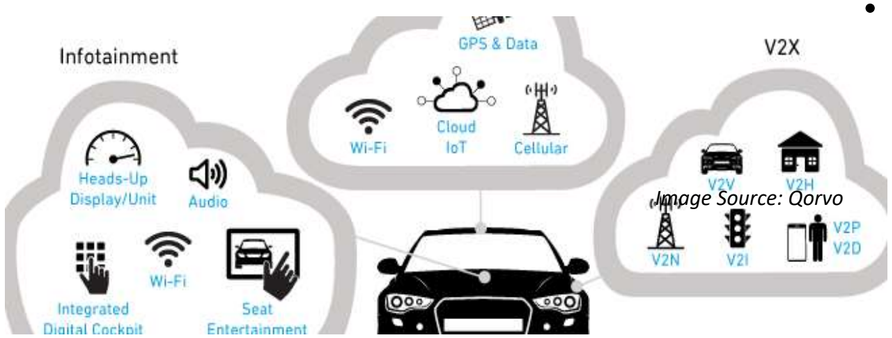


Image Source: Qorvo

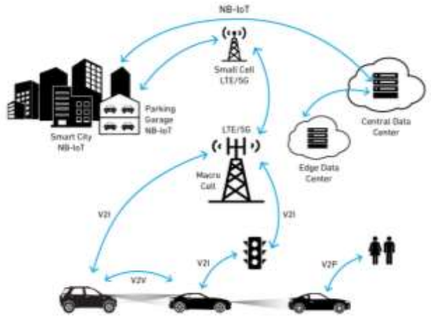
The Amount of Data in an Autonomous Vehicle
> 4,000 GB Per Day

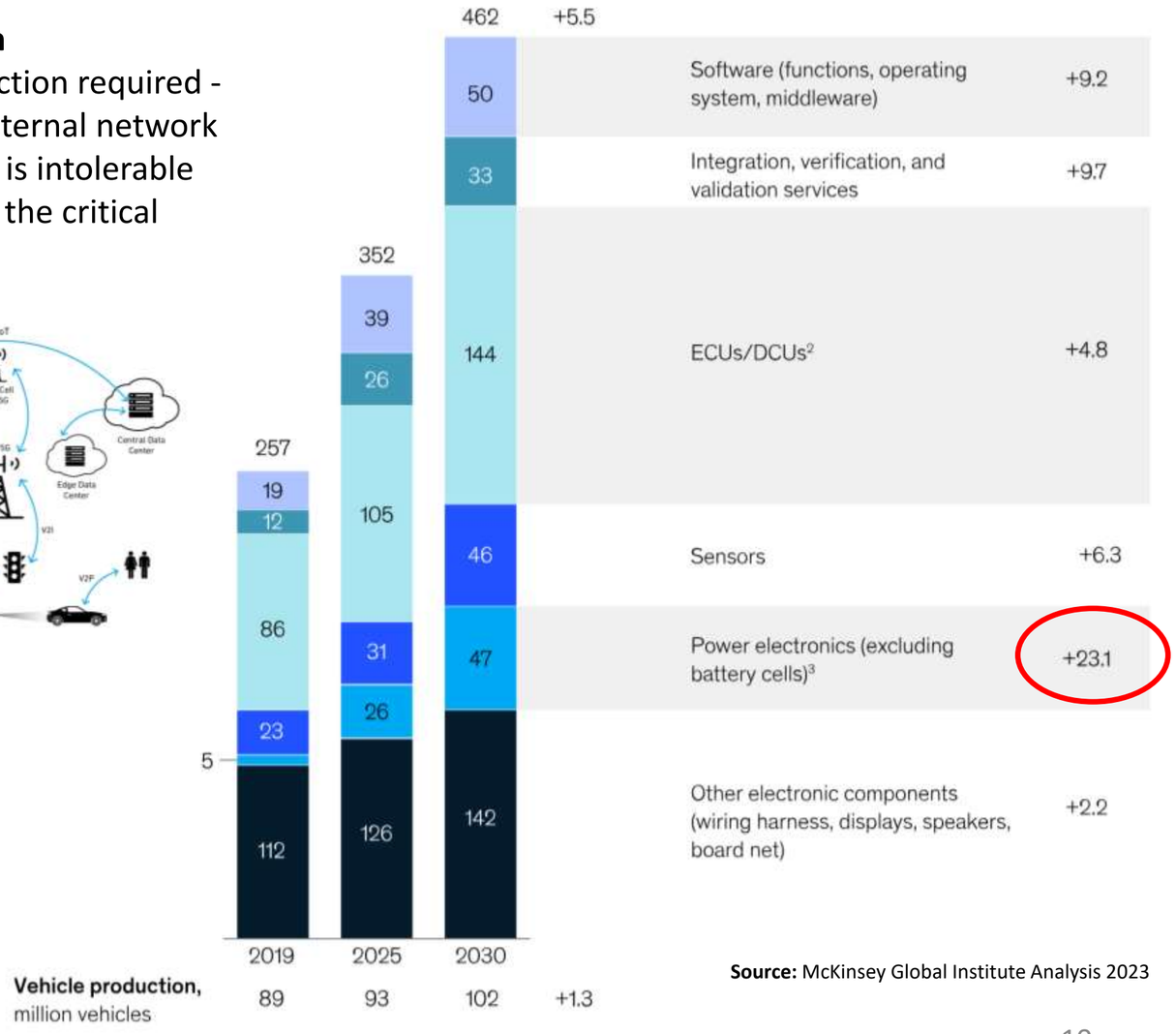
- Connected Car is becoming the prime IoT connected device with higher bit rate then smartphone

Heterogenous Vehicle Connectivity

Interactive Cabine
- Focal Point of AI and human interface

V2X Communication
- Fast real time reaction required - can not rely on external network
- Too much latency is intolerable
- V2V may become the critical communication

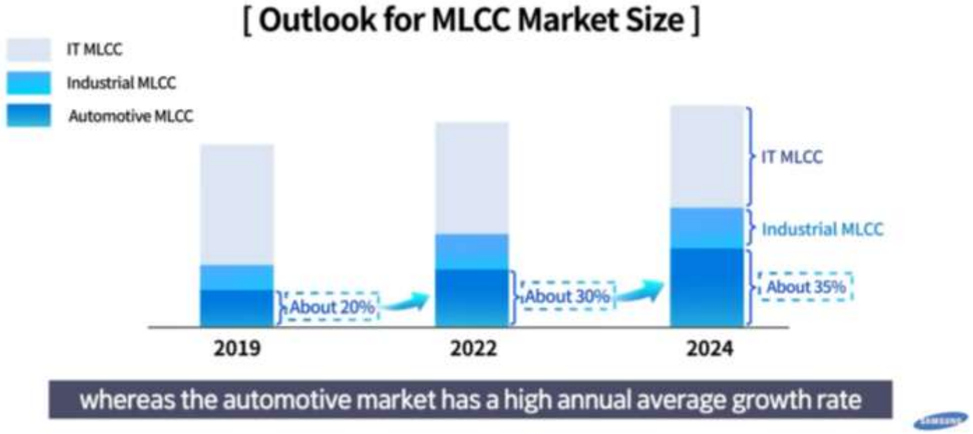


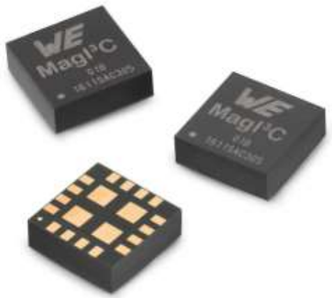


Source: McKinsey Global Institute Analysis 2023

Key Growth Areas

Consequences for Passive Components Manufacturers





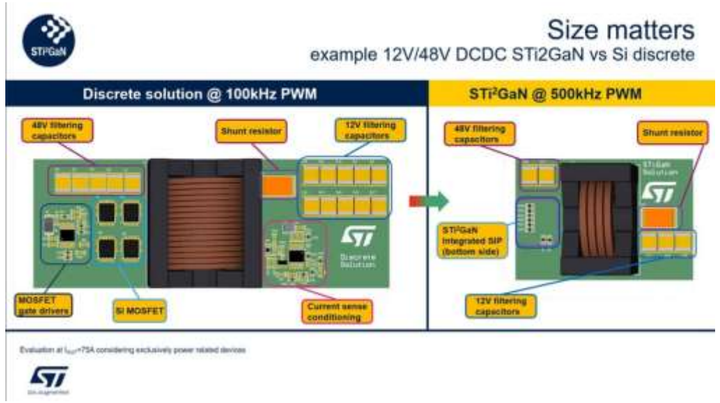
- Fast growth of digitalisation-based services cause an exponential growth of data **communication**
- Need for high-speed data processing, computing power, wireless **communication** and storage
- **Automotive** are projected as the fastest growing electronics systems segment

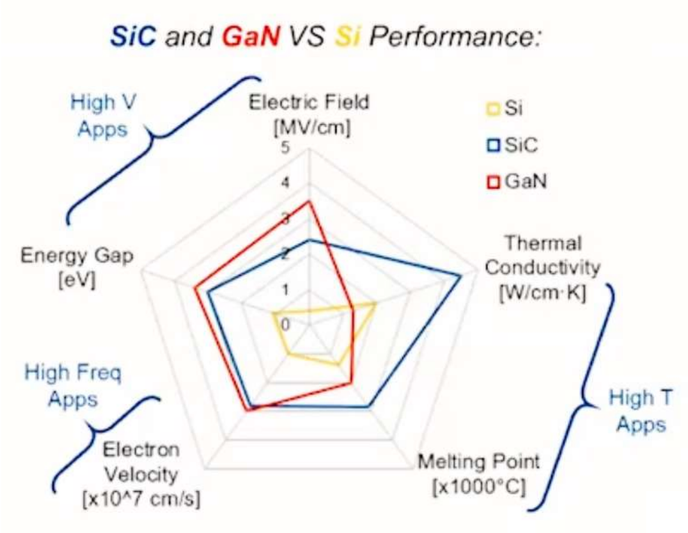
- Passives manufacturers are shifting **focus** from computers, handsets and tablets **to automotive, and telecommunications** as the growths in these new sectors are higher than the traditional consumer electronics markets

- The supply chain management trend is that passive component makers are more and more concentrating on development of **module solutions rather than development of individual components**.

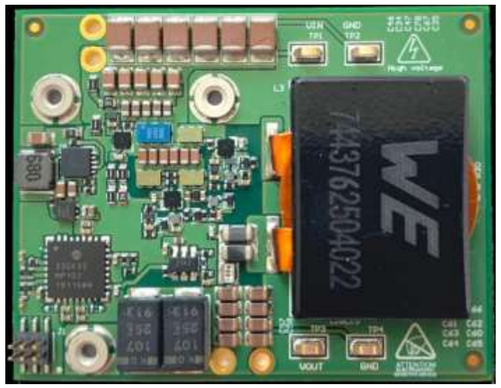
AUTOMOTIVE AEC-Q200 IS BECOMING INDUSTRY „UNIVERSAL“ QUALIFICATION STANDARD

Semiconductor IC Development – Wide Gap GaN/SiC Transistor „Revolution“





Need for Low Loss, High Power Components



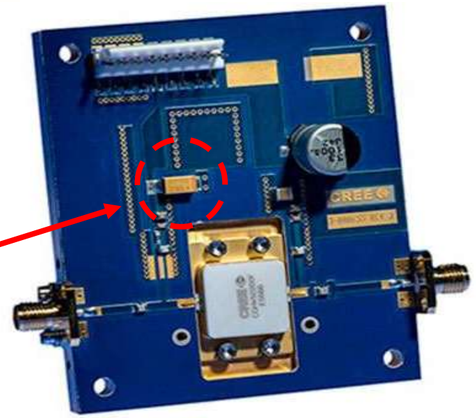
48 V three-stage synchronous buck converter with GaN technology

Output Capacitor Changes:

- Lower ESR, High Ripple Current
- Low ESL, Higher Frequency
- Lower Capacitance Needed
- Small & Thin Profile
- **Move away from tantalum & electrolytics to MLCC Class II or Class I** output capacitors

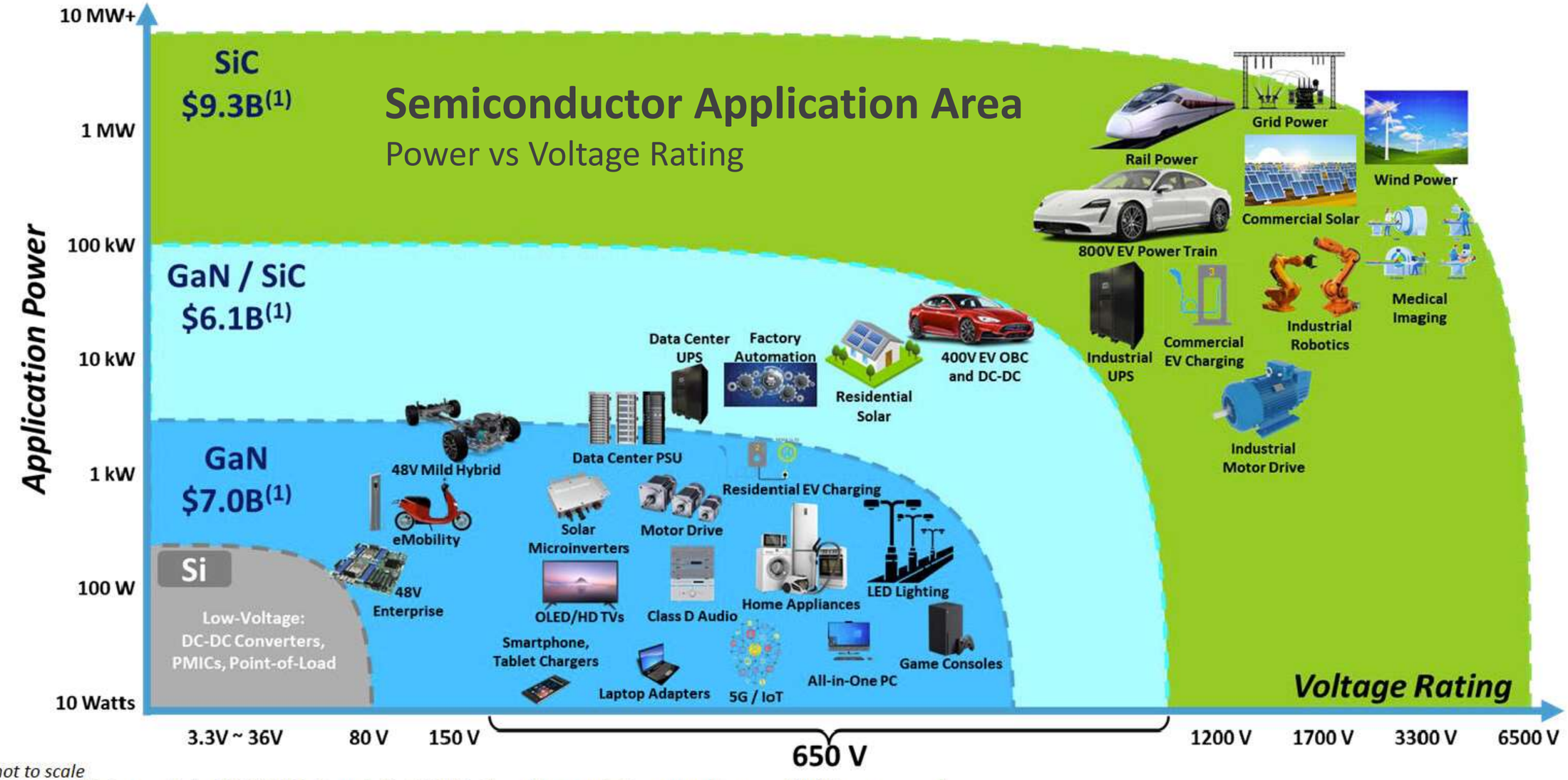
New Requirements:

- **Stable Gate Drive Voltage Capacitors** (tantalum)
- Output low loss, high power inductors



Key Growth Areas

Semiconductor IC Development Background



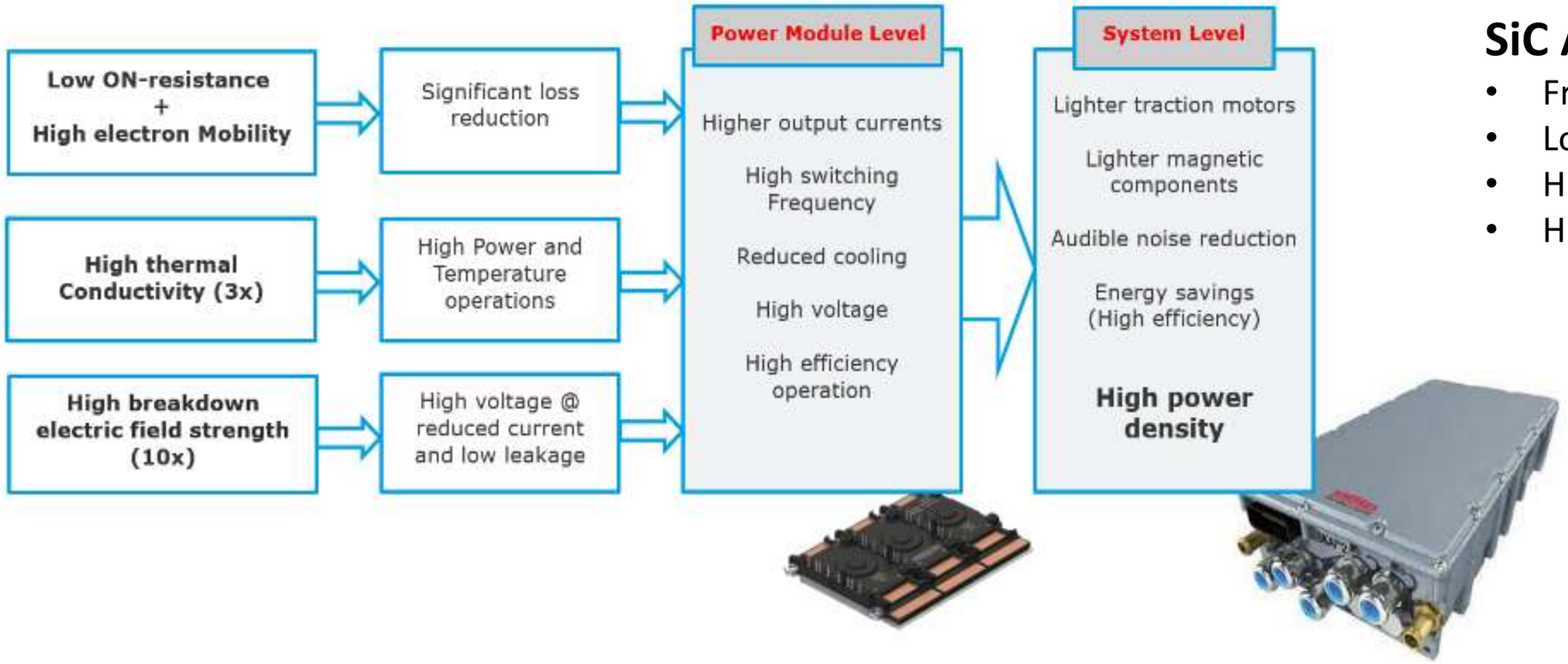
Axes not to scale

1) 2026E potential, Source: Yole, DNV, IRENA, Fraunhofer ISE, IHS, Cisco, Hyperscale, Peer annual reports, Wall Street research.

Key Growth Areas

SiC enabling Power Module and System optimization

- Latest Gen (Planar and Trench-gate) SiC-MOSFET are offering outstanding performances vs. Si-IGBTs
- Drop in pricing is making SiC devices a mainstream technology for **Automotive** and **Industrial**



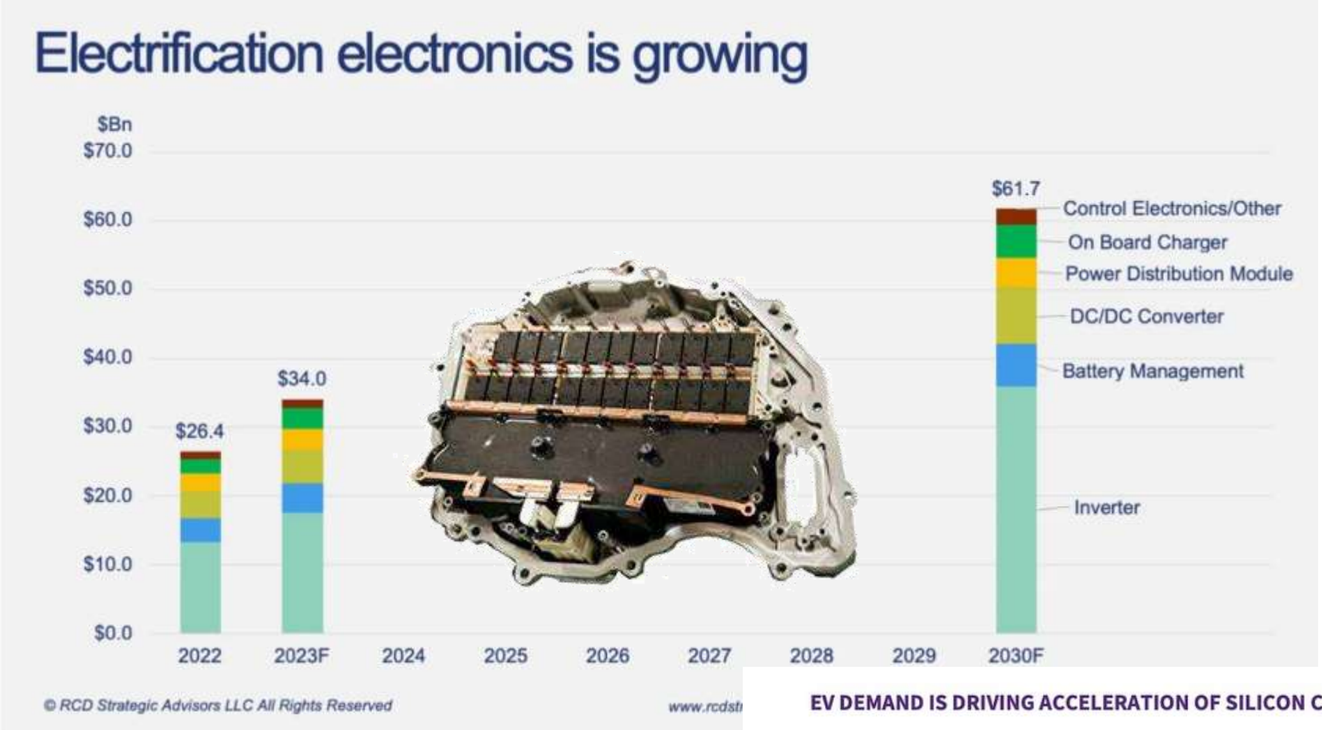
SiC Advancements

- From SiC-IGBT to SiC-MOSFET
- Loss Reduction
- High Power and Temperature
- High Voltage & Low Leakage

Key Growth Areas

Automotive – BEV Inverters

[Investigating SiC's Role in the Growing Electric Vehicle Market](#) (passive-components.eu)

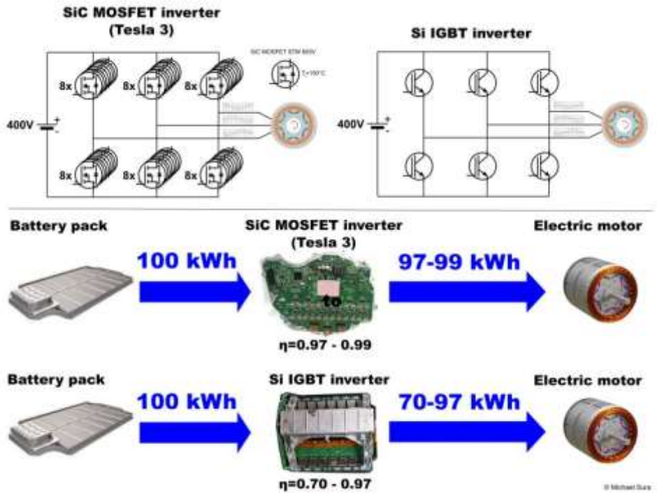


source: www.rcdstrategicadvisors.com © RCD Strategic Advisors LLC All Rights Reserved; **used by EPCI under permission**

Rohm signs $1bn silicon carbide supply deal with Vitesco

June 19, 2023: Motor inverter maker Vitesco has signed a SiC component supply deal with Rohm "worth over one billion US dollars until 2030", **adopting Vitesco inverters built around Rohm SiC components**

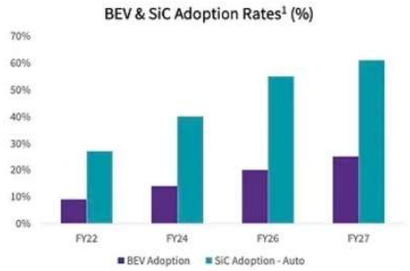
Is SiC the Ultimate Future Solution ?



Tesla achieved a significant milestone in 2018 when it incorporated STMicro's SiC power MOSFETs in the Tesla Model 3 inverter

- SiC is 3-5x more expensive than Si IGBTs
- Tesla next-generation drive train unit could use up to 75% less SiC

EV DEMAND IS DRIVING ACCELERATION OF SILICON CARBIDE ADOPTION



Key Drivers

- Estimated **92.5M vehicle sales in FY27**
- Battery Electric Vehicle (BEV) ramp
- Electric vehicle **charging infrastructure momentum**
- **New applications enabled** by Silicon Carbide

Wolfspeed estimates that 60% of all BEVs will use SiC by 2027

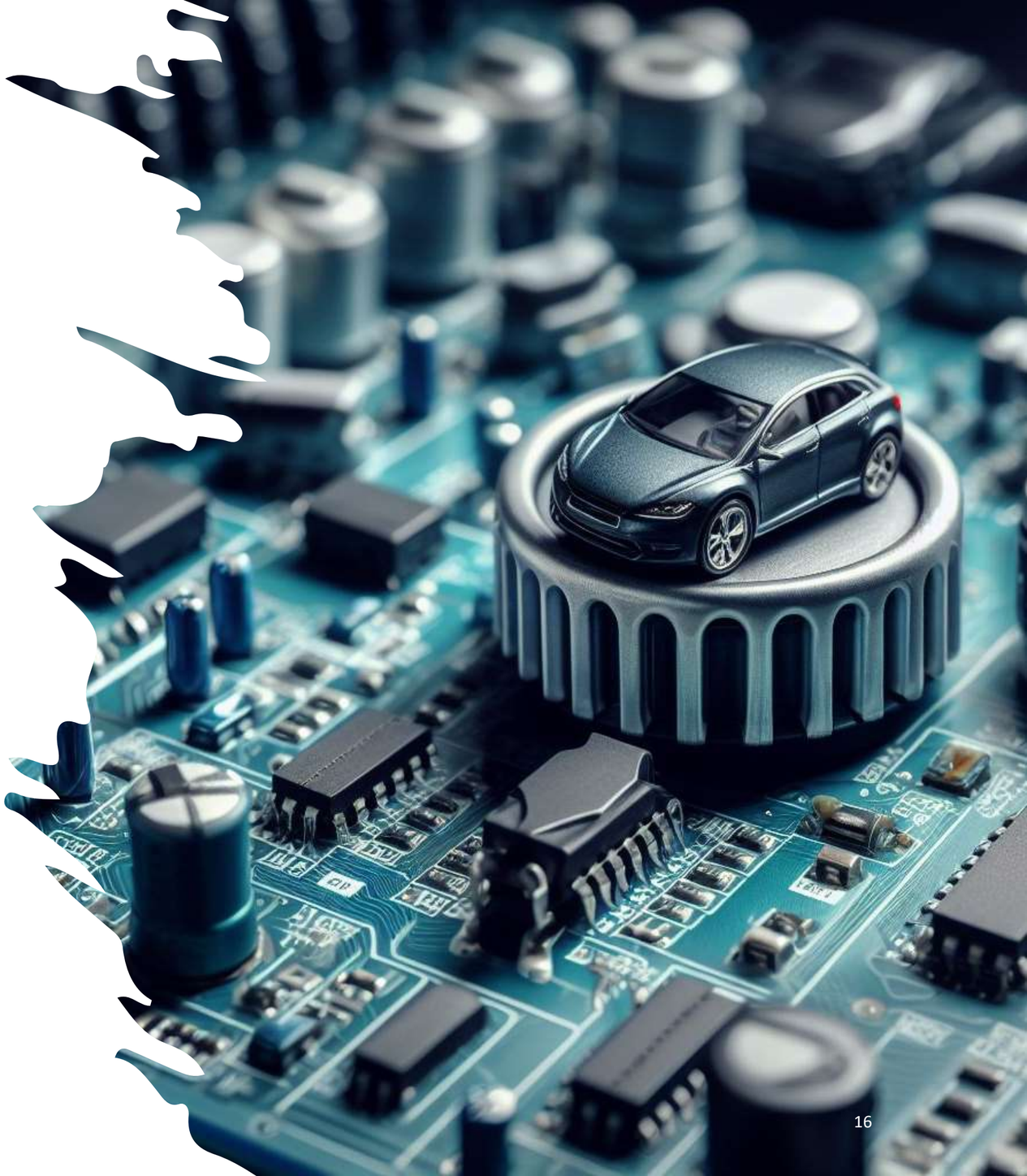
Next generation high-voltage Power Devices are subject to different headwinds and tailwinds than the broader silicon semiconductor industry

Source: Wolfspeed Investor Day 2022

SiC MOSFET enables EV cost savings

Battery cost savings	Heat sink considerations
• SiC inverter is 3.4% more efficient vs. IGBT inverter at average EV operating condition (15% load) • Compared to IGBT based EV with 85kWh battery, SiC version requires only 82.1kWh for same range • Typical battery cost: $150 per kWh • **Battery cost savings with SiC based inverter (this example) : $435**	Heat sink must be sized according to power dissipation at maximum operating condition Inverter dissipation at peak load (250Arms): IGBT: 3973W, SiC MOSFET: 2434W (Power Dissipation) SiC based inverter will only need to dissipate **61% of the heat** compared to IGBT version ➔ **SiC MOSFET allows smaller, lower cost heatsink**

PASSIVES for POWER ENERGY CONVERSION



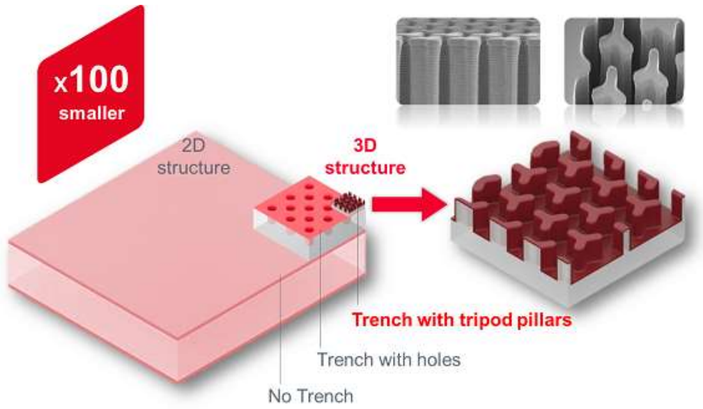
PC 2 NS 3
11-14th September
Sønderborg, Denmark

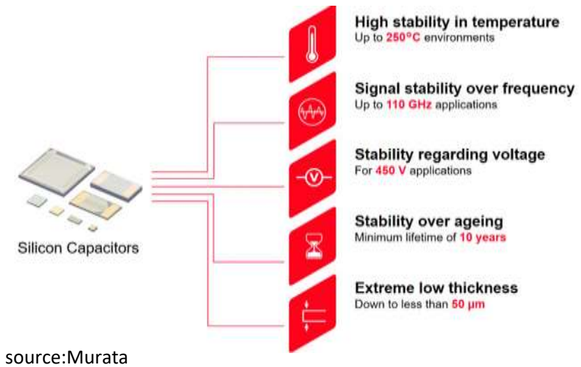
- 4 Passive Components Technologies Highlighted During 4th PCNS Symposium September 2023, Sonderborg, Denmark

Silicon Passives for Power Applications

Integrated Capacitors

SiO_2 Dielectric Base (mass production stage)





source:Murata

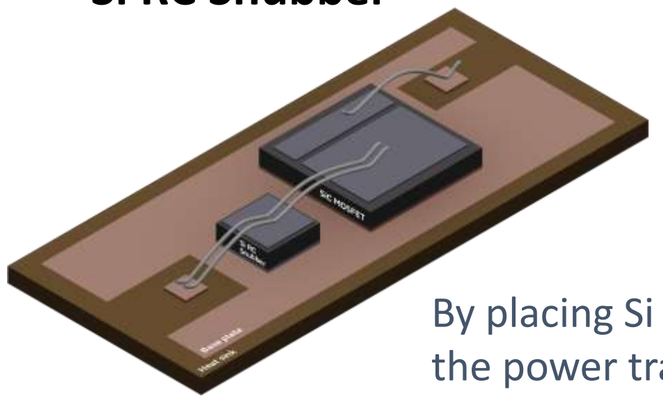
~ 1.4uF/mm^2

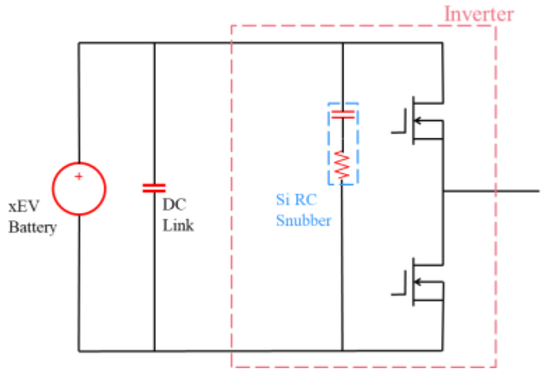
New Semiconductor Process For High Voltage Capacitors (MACOM)

- capable of achieving kilovolt (“KV”) operating levels in excess of 1,000 volts
- 200V, 500V and 1,000V, with capacitance values from 2 to 4,700 picofarads

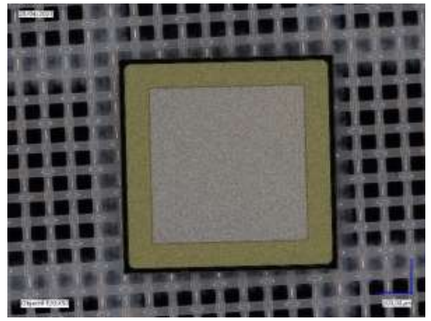
source: Macom

Si RC Snubber



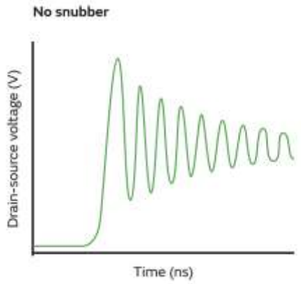


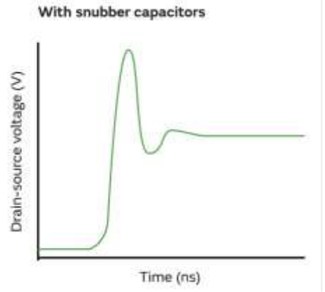
By placing Si RC Snubber as close as possible to the power transistors, you can **limit the ringing effect** and **fully harness the advantages of SiC!**



High Current RC Snubber
≃3.5x3.5mm, 1.2nF, 5Ω, ≃40A

high-current Snubber RC, available Q1 2024

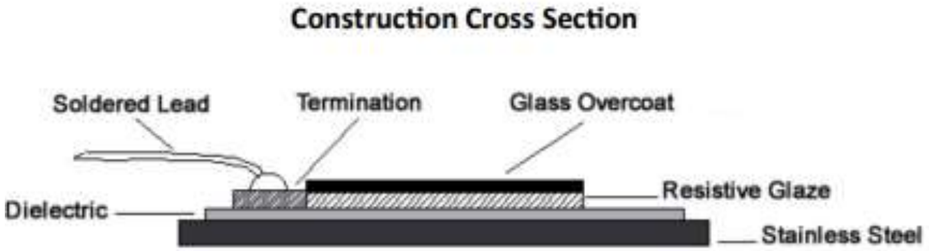


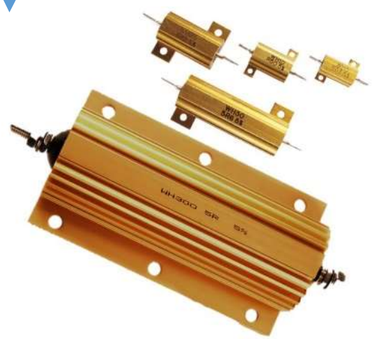


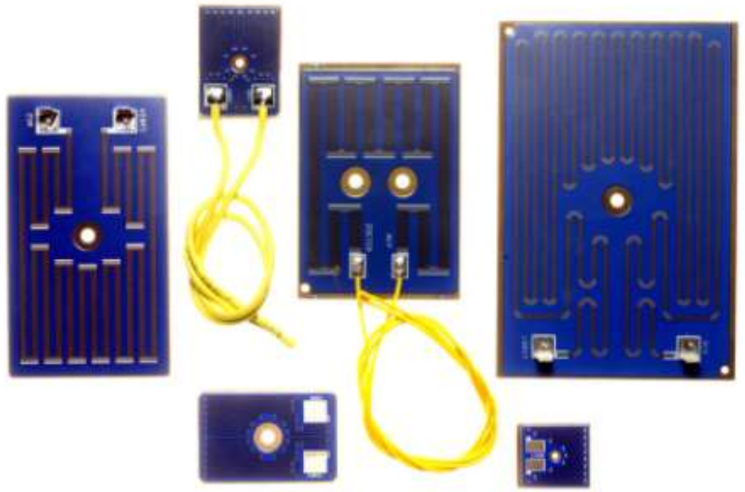
Thick Film on Steel – Increasingly Power Dense & Demanding Applications

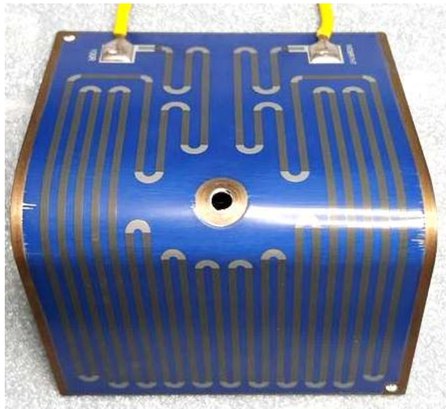
- Thick film on steel has a much greater power density than its direct competitors, a great lighter weight, power dense option.
- Typical breakdown voltage of 2.5kvDC, available higher – up to ~5kvDC in some applications.

Technology	Weight (g)*	Power (W)	Power Density (W/g)
Wirewound	475	200	0.42
On Steel	17.1	200	11.70







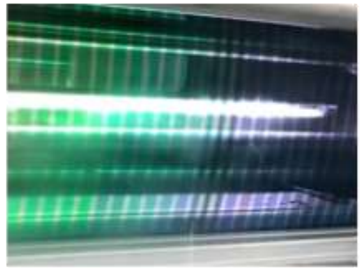


Bended 2.5kW Dynamic Breaking Resistor

NanoLam Power Capacitors HIGH TEMPERATURE POLYMER DIELECTRIC

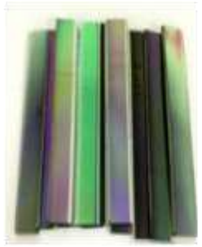
- THIN MULTILAYER STRUCTURE, Low ESR, 50V – 500V Applications (Such as DC Link)
- Excellent Dielectric Strength And Self-healing Properties
- Stable CAP And DF In Temperature Range Of -196°C To 200°C
- High Ripple Current and Energy Density Compared To Electrolytics and Film Capacitors

Mother Capacitor Material Produced on a Rotating Drum

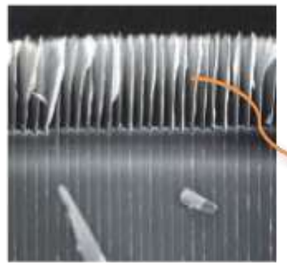


Mother Capacitor Material Segmented into Cards

Cards Segmented into Capacitor Elements



Removal of Polymer to Expose the Electrodes

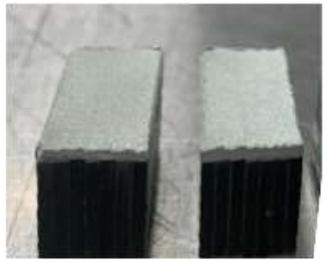


Arc Spraying To Connect Electrodes in Parallel

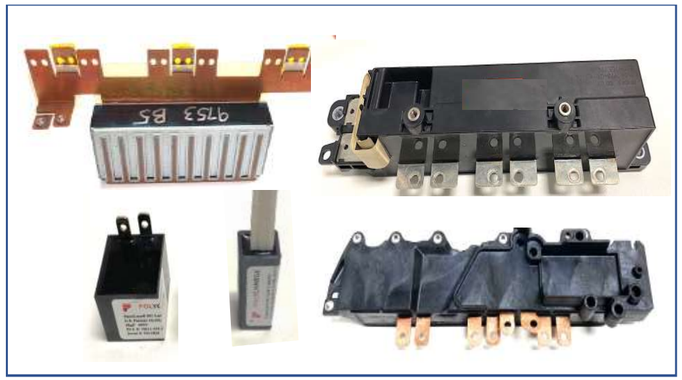
Process Flow

Fully Tested Capacitor Elements

Capacitor Block Formed by Stacked Elements



Packaged Capacitors



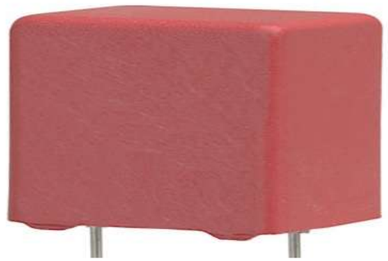
NanoLam™

NanoLam™ 4.4mF/50V
-200°C to +125°C
Energy Density: 0.1J/cc

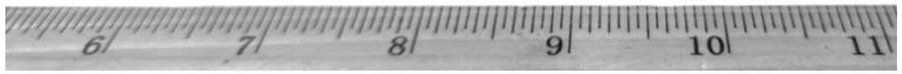
W:28mm H:33mm L:61mm

Conventional Film

Metallized PET 680∝F/50V
-55°C to 105°C
Energy Density: 0.006J/cc

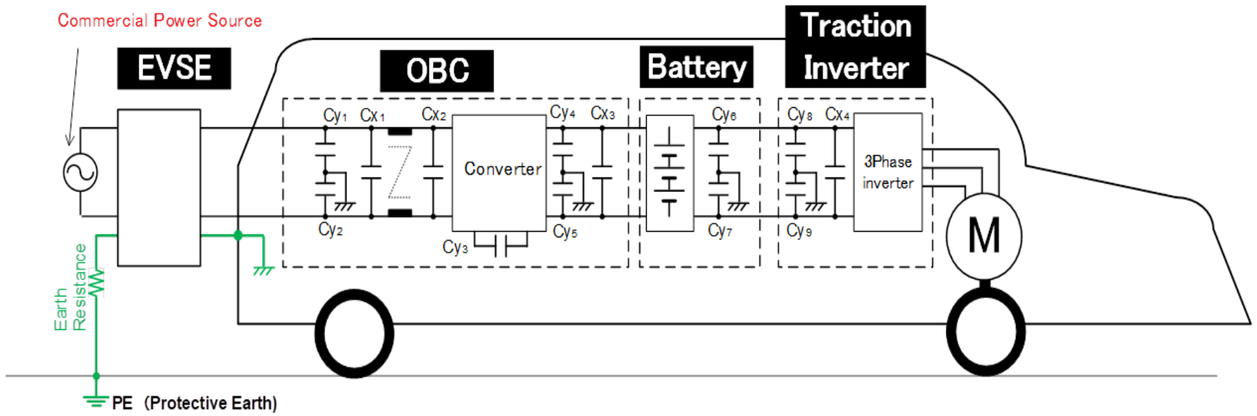


W:45mm H:55mm L:57mm



Y-Safety Capacitor – Molded Ceramic Capacitors

Y Safety Capacitor in EV applications

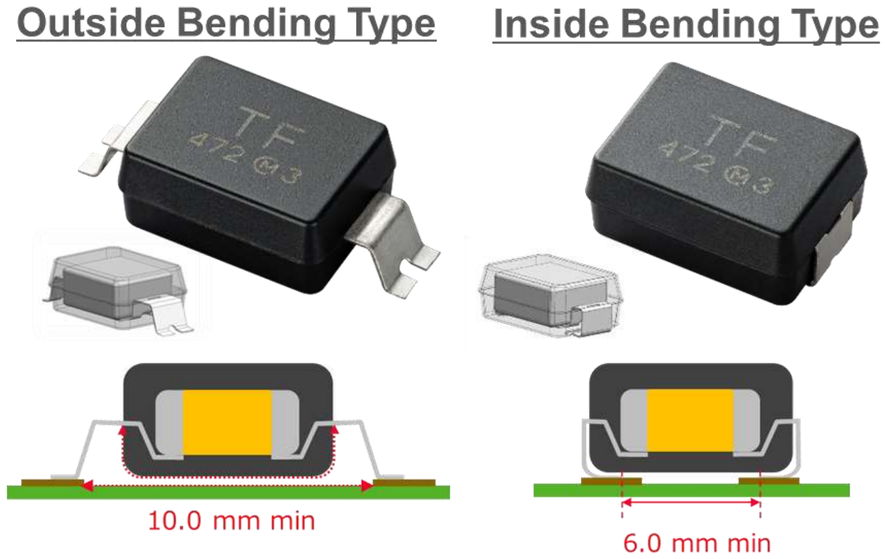


X-class capacitors are used across the line where failure would lead to burning

Y-class capacitors are used in “line-to-ground” applications where failure could lead to an electrical shock.

- **Longer creepage distance (10mm min. / 6.0mm min)** to follow safety standard (IEC60384-14 compliant, and refer to IEC60664-1)
- **Metal termination** has higher strength for board bending and vibration
- **Class X1/Y2** (305Vrms & 1500Vdc)

Murata EVA series - Mold type Safety Certified Y2 capacitors



●Suppresses Solder Cracks Caused by Heat Stress

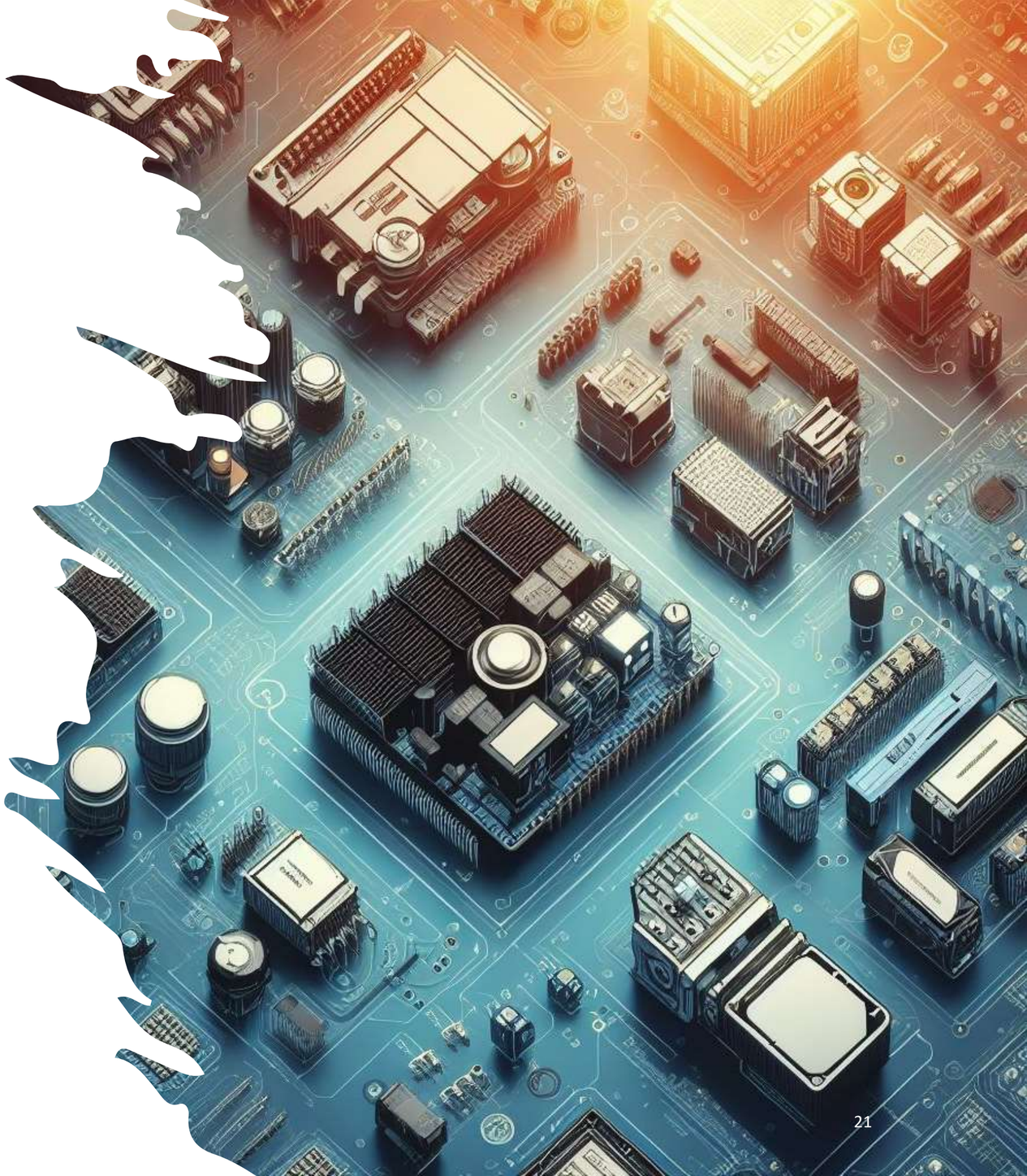
	Chip capacitor (2220)	EVA series ()
Solder Crack after 1000cycle Temp. Cycling		

*Reference data
Test condition: -55 – 125degC with FR4 (Glass Epoxy Board)

SUMMARY & CONCLUSION

Need for efficient power components is driven by:

1) IC Semiconductor Demands
2) New Applications – Industrial Power Conversion & Automotive EV
3) Emerging Active/Passive Technologies & Packages
4) Sustainable Development



Thank You

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