2019 Power Technology Roadmap

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CPSSC-PSMA Workshop 2019
Presented with content/approval from
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Partnership

- 谢谢 CPSS-PSMA Workshop

Power Sources Manufacturers' Association

- Promotes the interests of the Power Electronics industry
- Sponsors conferences, workshops, research
- On-line industry standards database
- Power Technology Roadmap (PTR)
- PSMA is 35 years old in 2019
- *Congratulations to CPSS for 35 years in 2018!*

Conferences, Workshops

中国电源学会第二十三届学术年会

The 23rd China Power Supply Society Conference (CPSSC'2019)

2019年11月1日至4日

地点：深圳

2019 WiPDA

Raleigh, NC | October 29- October 31 |

7th Annual IEEE Workshop on Wide Bandgap Power Devices & Applications

The State View Hotel
2451 Alumni Drive
Raleigh, NC 27606

EnerHarv 2020

PWR SOC 20

APEC 2020

New Orleans

MARCH 15-19, 2020

3D-PEIM

INTERNATIONAL SYMPOSIUM ON 3D POWER ELECTRONICS INTEGRATION AND MANUFACTURING

Power Technology Roadmap (PTR)

- Guidance on
  - Product metrics
  - Technology
  - Applications

  …for the next 3-5 years
- 17 presentations from industry on trends, new technologies
- Industry commentary on product applications and component technology
- Started 1994, now every 2 years. 2019 = 670 pages
- Based on surveys of PSMA & CPSS members - 谢谢
  - Metrics include cost, efficiency, power conversion density
  - Drivers and barriers to change are identified

Roadmap: Application Trends

- Automotive / Electric Vehicle
- Battery Charging
- Data Center and Cloud Computing
- Energy Harvesting
- LED Lighting
- Variable Speed Motor Trends in HVAC and Appliance
- Renewable Energy / Grid Storage
- Safety and Compliance

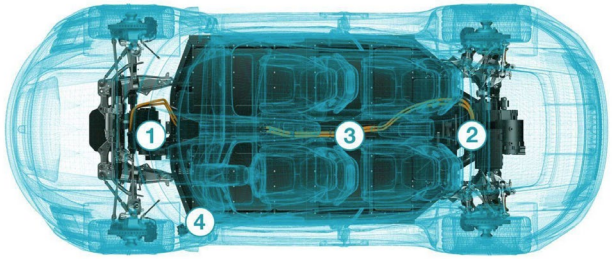

Figure 1. Porsche Taycan 800 V Powertrain (image courtesy of Porsche) (1) Front Motor (2) 800 V Battery (3) Rear Motor (4) Charge Inlet

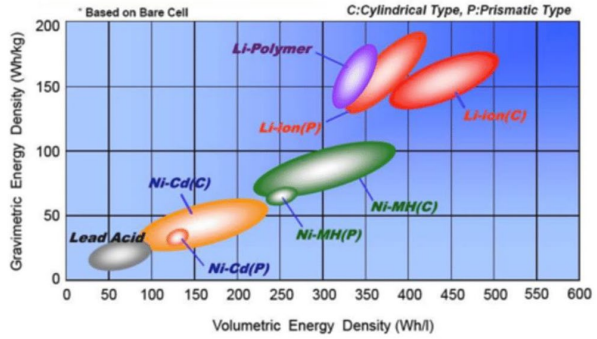

Figure 6. Comparison of Energy Density in Battery Cells [NASA-National Aeronautics and Space Administration]

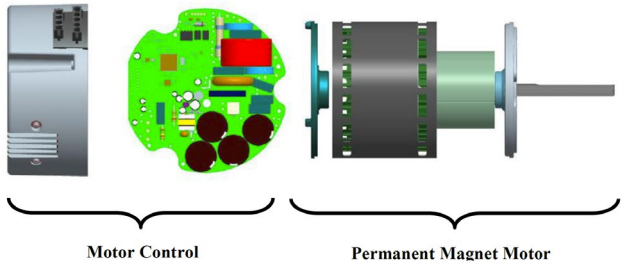

Figure 32. Typical Residential HVAC Integrated Motor Drive

Roadmap: Component Technologies

- Prismatic Aluminum Electrolytic Technology
- The Future of Magnetics
- Low Voltage MOSFETs
- Silicon Super Junction MOSFETs
- Isolated Gate Drivers
- SiC Diodes and MOSFETs Overview
- GaN Devices and Integrated Circuits
- Packaging in High Power
- First-Time-Right Discrete Power Electronic Design

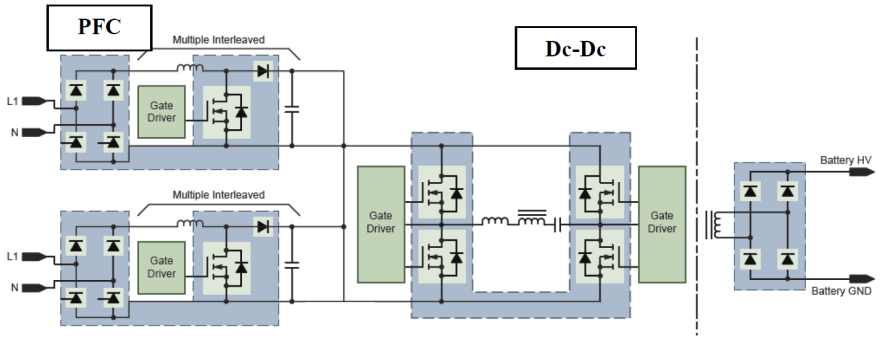

Figure 57. Circuit Scheme of an EV On-Board Charger (source: http://www.onsemi.com/pub/Collateral/BRD8044-D.PDF, 2017)

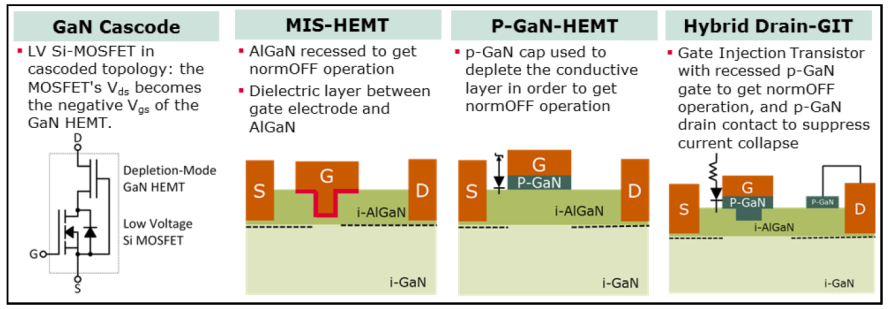

Figure 60. Schematic Representation of Four Example Power GaN Device Structures

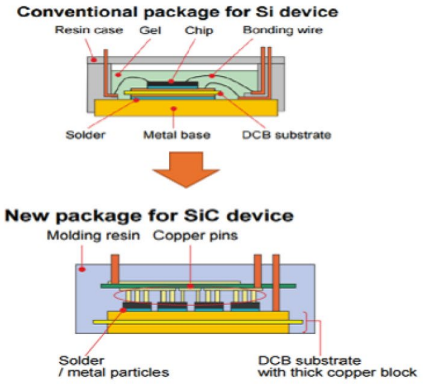

Figure 65. Conventional Power Module Cross Section versus New Power Module for SiC Technology

Power Supply & Converter Trends

- AC-DC Front-End Power Supplies
- AC-DC External Power Supplies
- Isolated DC-DC Converters
- Non-Isolated DC-DC Converters
- Power Supply on a Chip (PSiP)
- Power Supply on a Chip (PwrSoC)
- A Subsection of Non-Isolated DC-DC Converters

- *Note: % = number of designs (not production quantity)*

AC-DC Front-End Power Supplies (200-2,000W)

- Market: “Efficiency!” → “Power Density!”
  - Platinum → Titanium…? Cost?
- HVDC input
  - 2019 = 9% → 2021 = 16%
- Bridgeless Topologies (AC/PFC)
  - 2019 = 11% → 2021 = 24%
- Wide Band Gap
  - Big Increase in SiC, GaN
  - Reduction in Si FETs, IGBTs
- Digital, digital, digital control

AC-DC External Power Supplies

- Market:
  - USB-A and custom connector → USB-C, USB-PD/PPS
  - Bigger phone batteries (and 5G) → higher power chargers
  - “One-for-all” & more 2-/3-output chargers
- Efficiency up, Power Density up
  - 2x smaller, 2x lighter
- Topology, Frequency
  - CrCM PFC (BLB?), QRF, ACF, LLC, buck…
  - 65 kHz – 600 kHz
  - Bobbin → planar transformer
- Wide Band Gap
  - Si → GaN
  - Aftermarket → In-box

Isolated DC-DC Converters

- Full brick → half → quarter → custom?
- More 'narrow' $48V_{IN}$ (2019 = 12% → 2023 = 21%)
- More HVDC (26% → 30%)
- 150 kHz → 500 kHz → 1 MHz
- Wide Band Gap (primary switch)
  - Si 2019 = 70% → 2021 = 26%
  - GaN 2019 = 4% → 2021 = 54%

Non-Isolated DC-DC Converters

- Load V down ~25 mV / year, but A & W up 10% / year
  - 1.2 V to stay ~25%, also 1.8 V for Intel (FIVR on-board regulators)
  - Others moving from ~1 V to ~0.6 V_{OUT}
- Focus was power density, EMI, noise
  → now power density, transient response & heat (efficiency)
- 12 V_{IN} → 48 V_{IN} (high-end server, automotive)
- Very slow Si → GaN conversion (cost)
- PSiP (Power Supply in Package (<=1 in^3, include L, C)
  - Most ~12 V_{IN}, 3-10 A_{OUT} can be 100 A (1.2 V)
  - Focus power density, easy-to-use
- PwrSoC (Power Supply on Chip)
  - Embedded L, C (e.g. FIVR, iVRM)
  - Early research into GaN integration

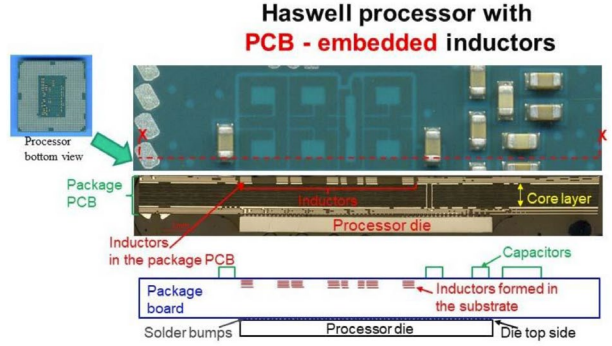

Figure 91. Granular FIVR within the Intel Haswell Processor (source: LTEC Corporation)

“The Research Lab Today Holds The Future’s New Products”

International University Research

University of Colorado Boulder

Massachusetts Institute of Technology

Aalborg University Denmark

Tyndall National Institute

The Ohio State University

Universidad Politécnica Madrid

The University of Texas at Austin

Illinois – University of Illinois at Urbana-Champaign

FREEDM systems center

University of Arkansas

Universidade Federal de Santa Catarina

ETH zürich

Special thanks

Xi'an Jiaotong University

Harbin Institute of Technology

25 universities invited to participate, 13 responded

Responding University Data

University or Institution	Number of Tenured or Tenure Track Faculty	Number of Instructors or Non-Tenure Track Faculty	Number of Master's Degree Students	Number of Ph.D. Students	Approximate Annual Research Funding (US$)
Federal University Of Santa Catarina	1	3	12	4	500,000
Harbin Institute Of Technology	14	10	90	40	25,000,000
MIT	3	1	10	20	No Response
NC State/ FREEDM Center	No Response	No Response	No Response	No Response	No Response
Ohio State University	7	1	20	38	5,000,000
Polytechnic University of Madrid	5	2	12	6	1,000,000
Swiss Federal Institute Of Technology	No Response	No Response	No Response	No Response	No Response
Tyndall Research Institute	No Response	No Response	No Response	No Response	No Response
University of Aalborg	30	20	50	75	3,000,000
University of Arkansas - Fayetteville	14	5	20	60	10,000,000
University Of Colorado - Boulder	3	4	50	20	1,500,000
University of Illinois, Urbana-Champaign	3	—	20	20	700,000
University of Texas at Austin	2	5	3	20	1,000,000
Xi'an Jiaotong University	16	2	110	40	1,500,000

Most Common Research Areas

- Renewable energy related power electronics
  - Converters for solar, wind and energy storage
  - AC and DC microgrids: systems, converters, controls
- Electrification of transportation
  - Converters for electric vehicle drive systems
  - Battery chargers and battery management systems
  - Power electronics for aerospace & marine applications
- Application of wide bandgap devices (SiC, GaN)
  - Medium voltage converters incl. motor drives and solid-state transformers
- Advanced packaging and integration
  - High power modules
  - Power Supply on Chip (PwrSoC)
  - Power Supply in Package (PSiP)
  - Integration of power devices with drivers and control

- ***Drivers: "Follow the money"***
- ***Most government-funded, focus:***
  - ***Climate change***
  - ***Economic, industrial competitiveness***
  - ***Emphasis on electric transportation and renewable energy***

Least Common

- Wide band gap *devices*
- MHz+ converters
- Switched capacitor converters
- Robotics
- Server/data center power
- Digital power (0)

Unique Topics

- Ohio State
  - Converters, motor drives operating at the high end of medium voltage (69 kV)
- ETH Zurich
  - Automating the design process (optimize vs. efficiency, power conversion density, initial cost, and life cycle cost)
- University of Texas – Austin
  - Gallium oxide (GaO) power semis for very HV switching devices

Industrial Sponsorship Of Research is Small

- Power supply companies are ahead of academia
- Difference in research goals
  - Academia: publications
  - Industry: ready-to-manufacture product / revenue
- Conflict over IP (including patents)
  - Universities: “we thought it up, we own it”
  - Industry: “we paid for it, we own it”

The differences can be resolved but each side has to give something

Thank you, 谢谢


Capacitor
Education
Energy Harvesting
Energy Management
Lead-Free
Magnetics
Packaging & Manufacturing
Power Technology Roadmap
Reliability
Safety & Compliance
Semiconductor
Transportation PowerElectronics


Empowering the Electronics Industry
2019 PSMA POWER TECHNOLOGY ROADMAP
Organizing Committee Chairs
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ON Semiconductor
Conor Quinn
Artesyn Embedded Technologies
Segment Leaders
Ajay Hari
ON Semiconductor
Application Trends 2015, 2017, 2019
Upal Sengupta
Continental Corporation
Application Trends 2019
Vittorio Crisafulli
ON Semiconductor
Component Technologies 2017, 2019
Tim McDonald
Infineon Technologies
Component Technologies 2017, 2019
Mark Scott
Miami University
Isolated Dc-Dc Converters 2019
Ian Mazsa
Vicor Inc.
Isolated Dc-Dc Converters 2013, 2015, 2017, 2019
Xin Zhang
IBM
Non-Isolated Dc-Dc Converters 2019
Jeff Nilles
Independent Consultant
Non-Isolated Dc-Dc Converters 2015, 2017, 2019
Arnold Alderman
Anagenesis Inc.
Non-Isolated Dc-Dc Converters
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John Wiggenhorn
ON Semiconductor
Ac-Dc External Power Supplies
2013, 2015, 2017, 2019
Stephen Oliver
Navitas Semiconductor
Ac-Dc External Power Supplies 2017, 2019
Isolated Dc-Dc Converters 2013, 2015
Ed Massey
Methode Corporation
Ac-Dc Front-End Power Supplies 2019
Robert V. White
Embedded Power Labs
University Research 2019
Brian Zahnstecher
PowerRox
Ac-Dc Front-End Power Supplies
2015, 2017, 2019