SiC Power Solutions for Sustainability

- **Sustainability L3 by SiC BU**
- **Mar. CY23**

About Microchip Technology

Microchip is a leading provider of:

- High-performance standard and specialized microcontroller (MCU), Digital Signal Controller (DSC) and microprocessor (MPU) solutions
- Power, mixed-signal, analog, interface and security solutions
- Clock and timing solutions
- Wireless and wired connectivity solutions
- FPGA solutions
- Non-volatile EEPROM and Flash memory solutions
- Flash IP solutions

$6.8 Billion Revenue for FY2022

Headquartered Near Phoenix in Chandler, AZ

Approximately 21,000 Employees

120,000+ Customers

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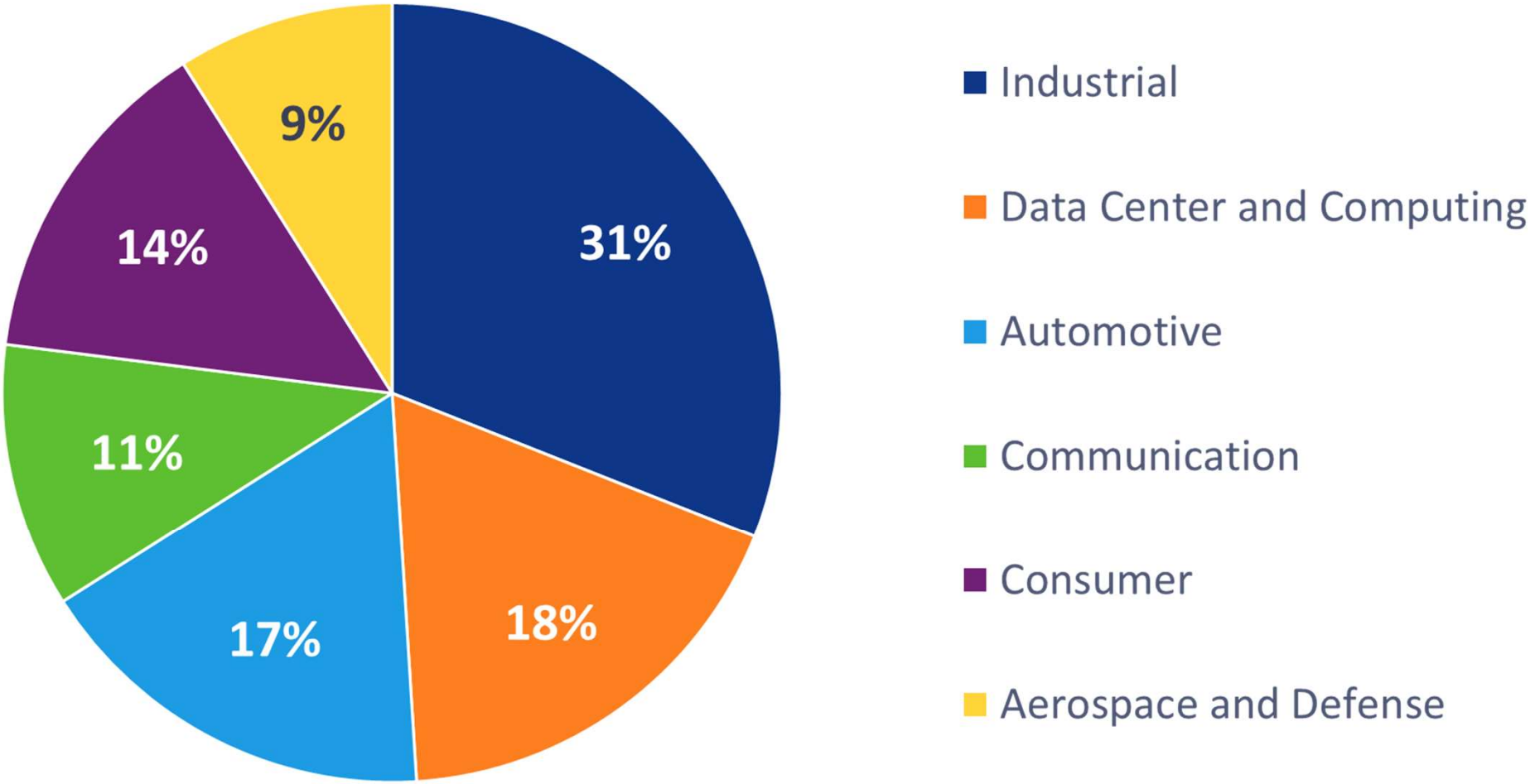
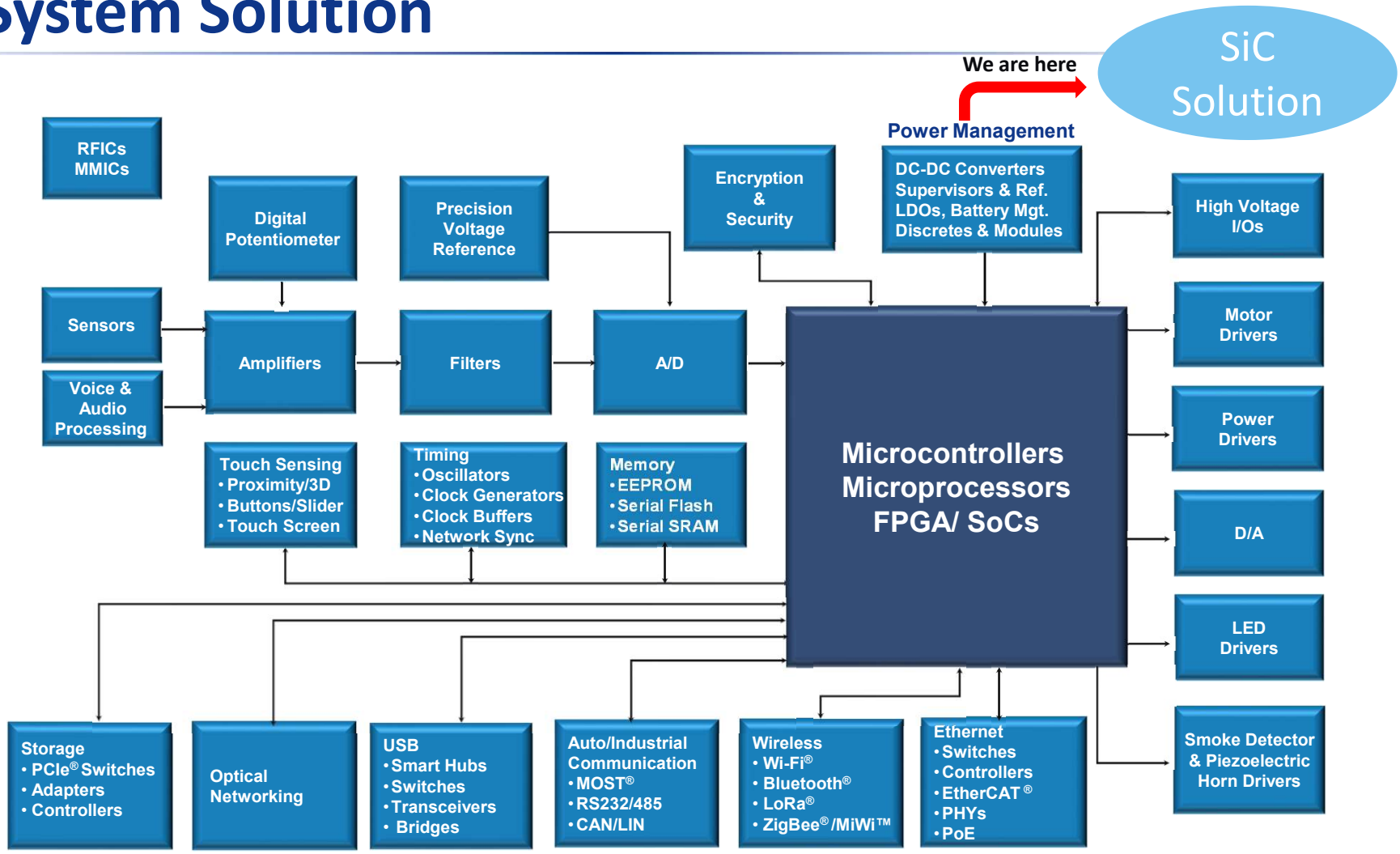
Revenue by End Market



Microchip Corporate Presentation: FY22

Total System Solution



Sustainability Overview

Energy Generation, Storage and Distribution

- Solar Power Systems
- Wind Turbines
- Alternative Energy such as Biomass
- Hydrogen Fuel Cells
- Energy Storage Systems (Battery Charging, Battery Management Systems)
- Smart Grid Applications

Efficient Energy and Water Use

- Smart Agriculture (targeted irrigation & fertilization)
- High Efficiency Power Supplies
- Solar Inverters
- Higher Efficiency Motor Control
- LED Lighting
- Smart Dimmers, Actuators and Valves
- Heating, Ventilation and Air Conditioning
- Energy Star Appliances

Resource Monitoring and Optimization

- Smart Electric/Water/Gas Meters
- In-Home Energy Displays and Awareness Systems
- Motion Sensors
- Leak Detection
- Building Management (Light, Energy use)

Waste Reduction and Reuse

- Smart Waste Management
- Water Bottle Refilling Stations
- Smart Irrigation Systems
- Asset Tracking
- Public Restroom Dispensers (Soap, Paper, Water)
- Low Standby Power

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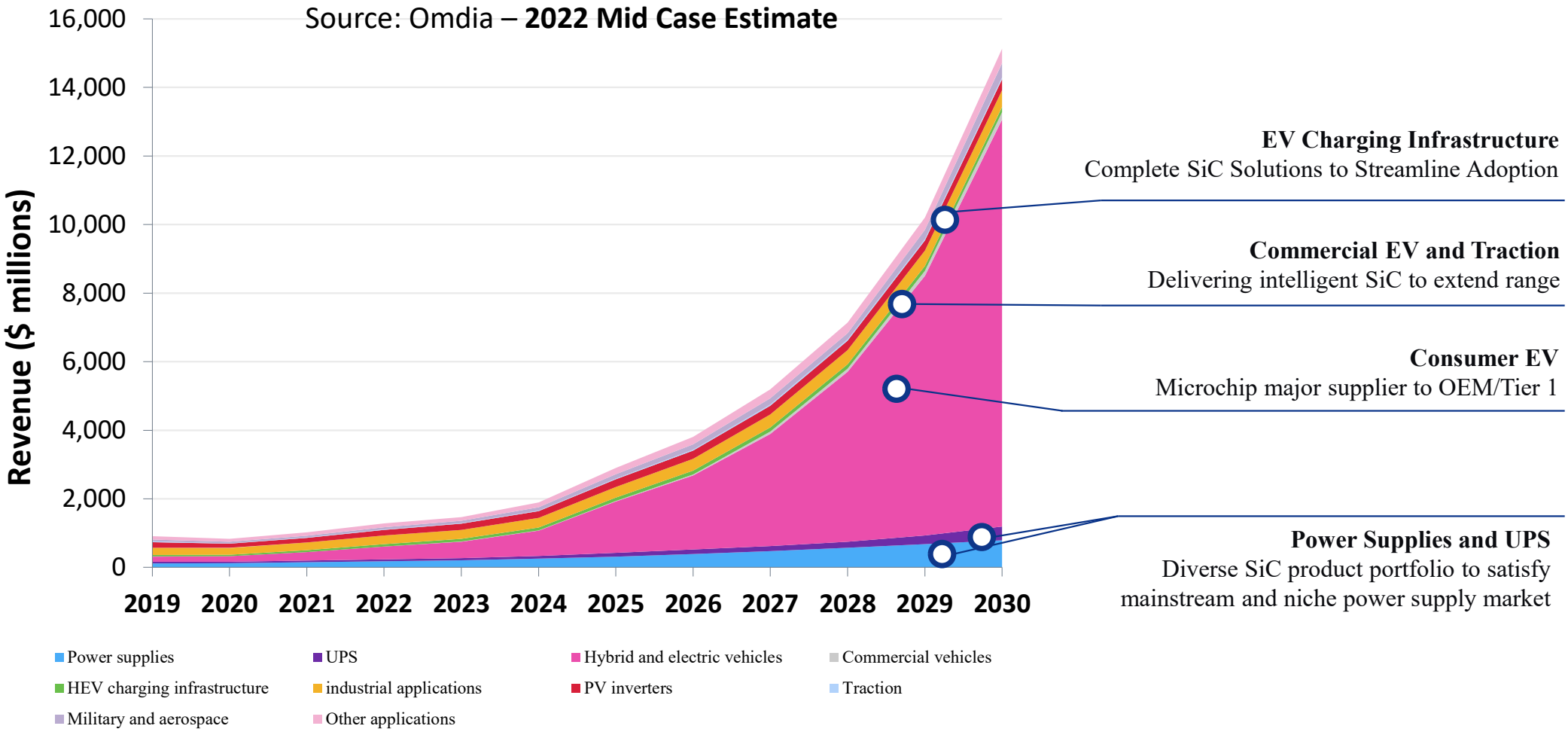
Growth Drive in the SiC Power Market



Microchip SiC Fab Overview

Colorado Springs, CO

- 580k sq. ft. Building
- 310k sq. ft. Clean Room
- 50 Acre Site
- 6-inch Wafer Manufacturing
  - 8-inch ready equipment
- Certifications
  - C-TPAT
  - ISO/TS-16949 & ISO14001
  - ITAR, MIL-PRF-19500 & AS9100

Microchip Plans to Invest $880 Million to Expand its Silicon Carbide (SiC) and Silicon (Si) Capacity in Colorado

Ramping up production at its Colorado Springs fabrication campus will enable Microchip to respond to growing semiconductor demand across a wide swath of industries

CHANDLER, Ariz., February 17, 2023 — Microchip Technology Inc. **(Nasdaq: MCHP)** a leading provider of smart, connected and secure embedded control solutions, today announces plans to invest $880M to expand its silicon carbide (SiC) and silicon (Si) production capacity at its Colorado Springs, Colo. manufacturing facility over the next several years.

One significant phase of the expansion is to develop and upgrade its 50-acre, 580,000-square-foot Colorado Springs campus for increased SiC manufacturing for use in automotive/E-Mobility, grid infrastructure, green energy, and

https://www.microchip.com/en-us/about/news-releases/corporate/microchip-plans-to-invest-880-million-to-expand-its-silicon

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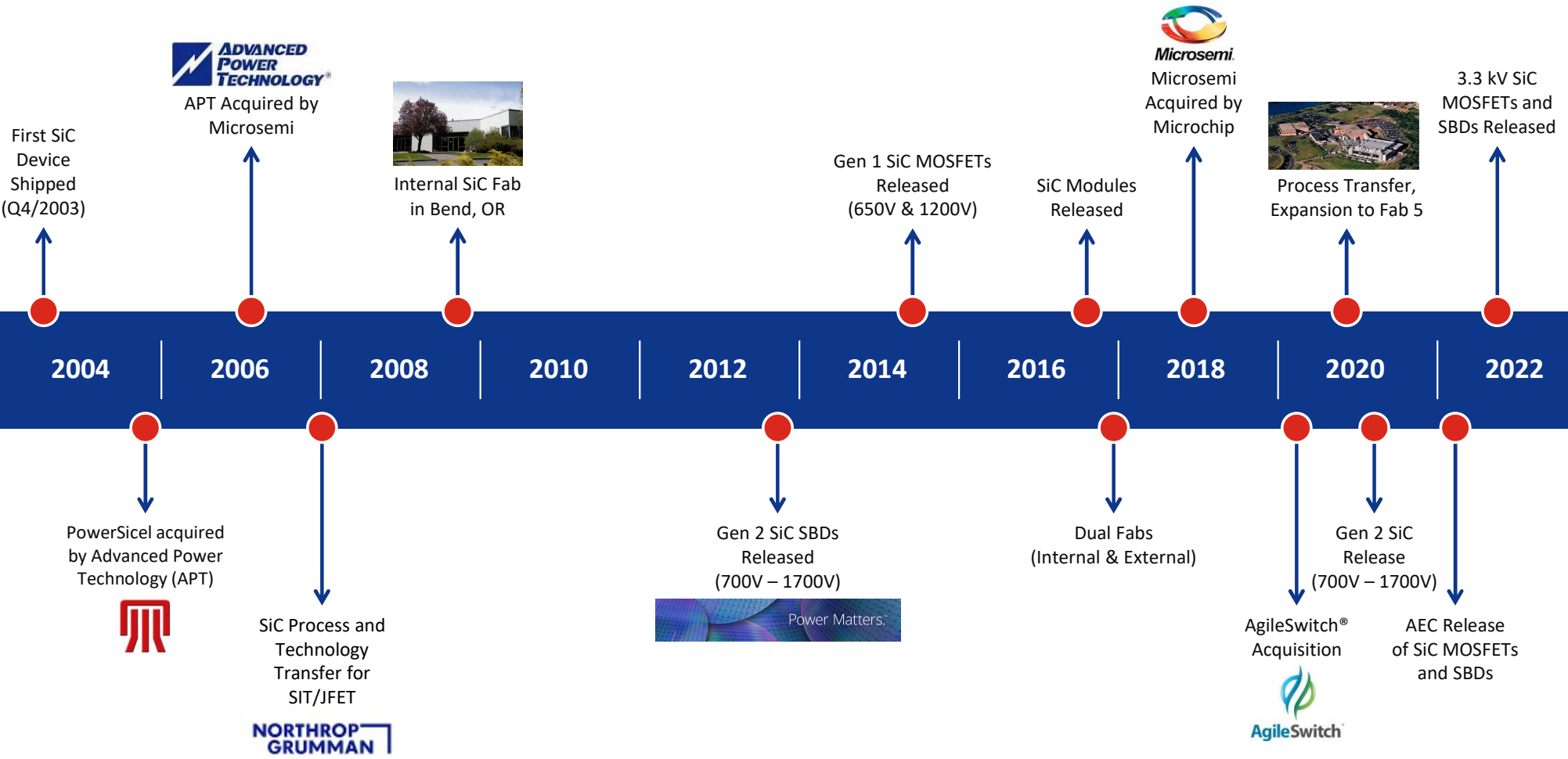
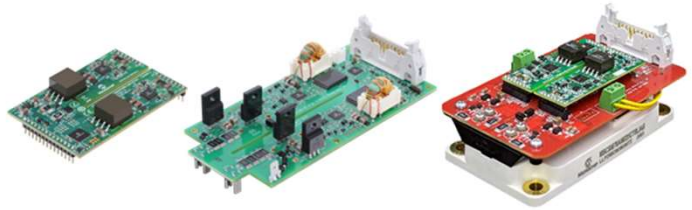
Microchip SiC Timeline



SiC Portfolio: 700V – 3.3 kV

Product Family	Packaging	Key Differentiation
Die		Unrivaled Ruggedness and Performance
Discretes		Widest Breadth
Modules		Lowest Inductance Standard and Custom-Tailored
Gate Drivers		Fastest to Market Highest Efficiency

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Adopt MCHP SiC With Ease, Speed and Confidence

Lowest System Cost

Unrivaled ruggedness and performance - No Redundancy

Fastest to Market

Gate drivers and total system solutions - Rapid Development

Lowest Risk

Multi-source epi wafers and dual fabs - Supply Certainty

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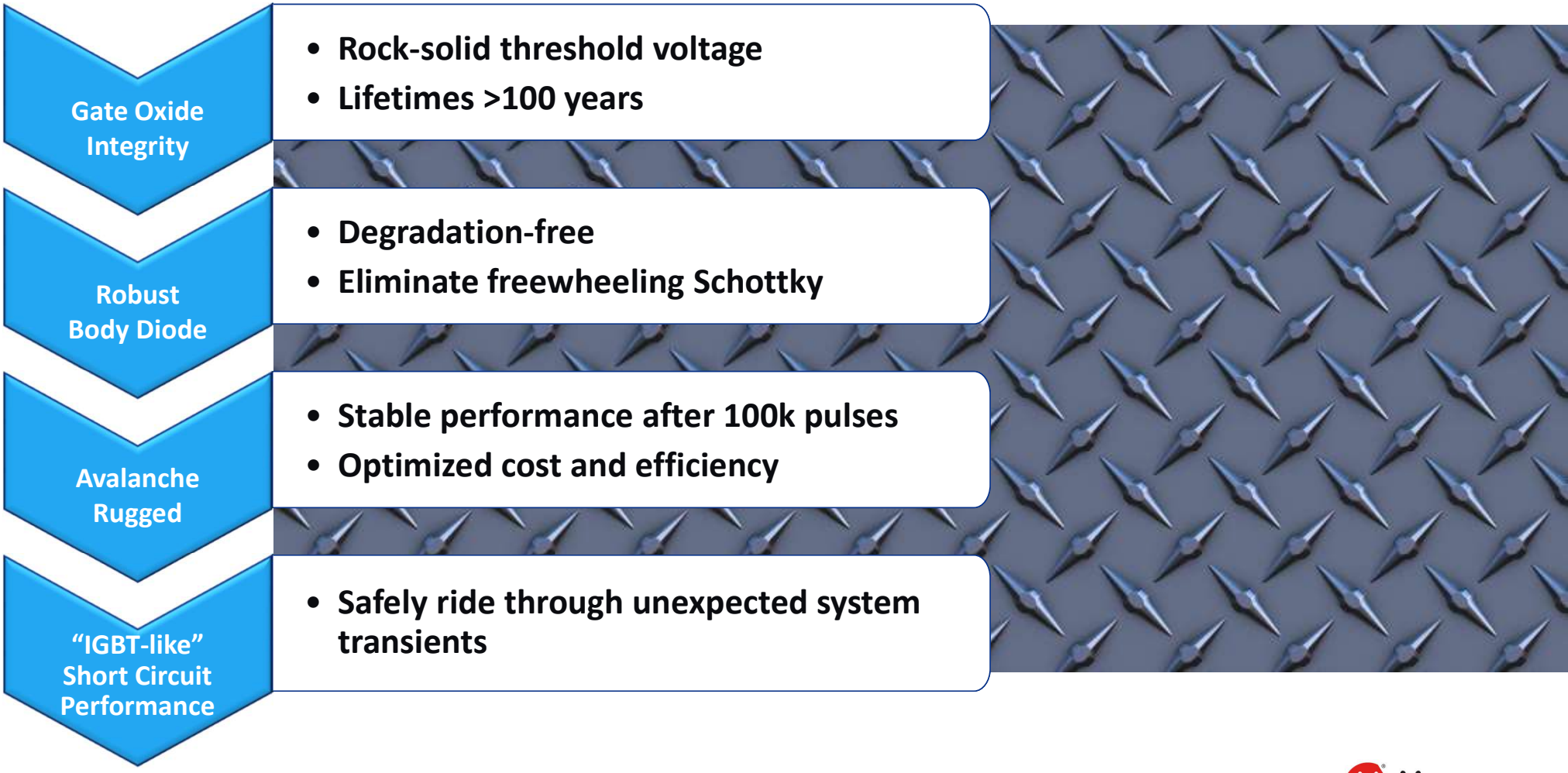
Unrivaled Ruggedness and Reliability



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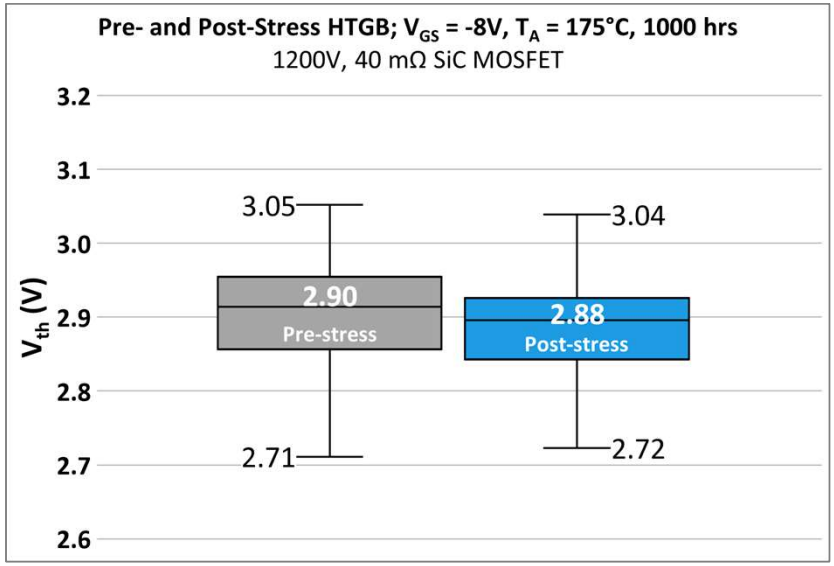
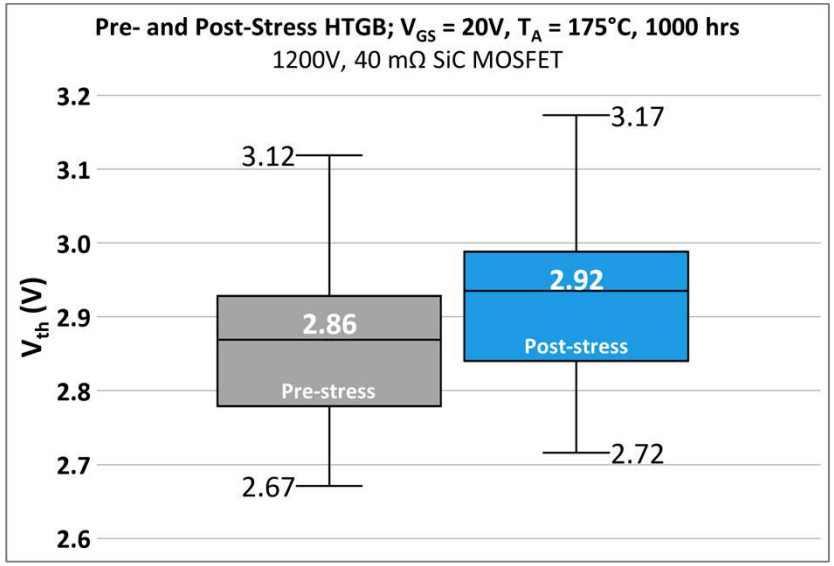
Ruggedness | *Gate Oxide Stability*

Stress: V_{GS} = -8V, 1000 hrs at T_A = 175°C | Change: -0.02V



Stress: V_{GS} = 20V, 1000 hrs at T_A = 175°C | Change: +0.06V



V_{th} measurements before and after 1000 hours of High-Temperature Gate Bias (HTGB) stress show negligible shift

Application Benefits

- Operate routinely & reliably
- Meet (exceed) desired service lifetime

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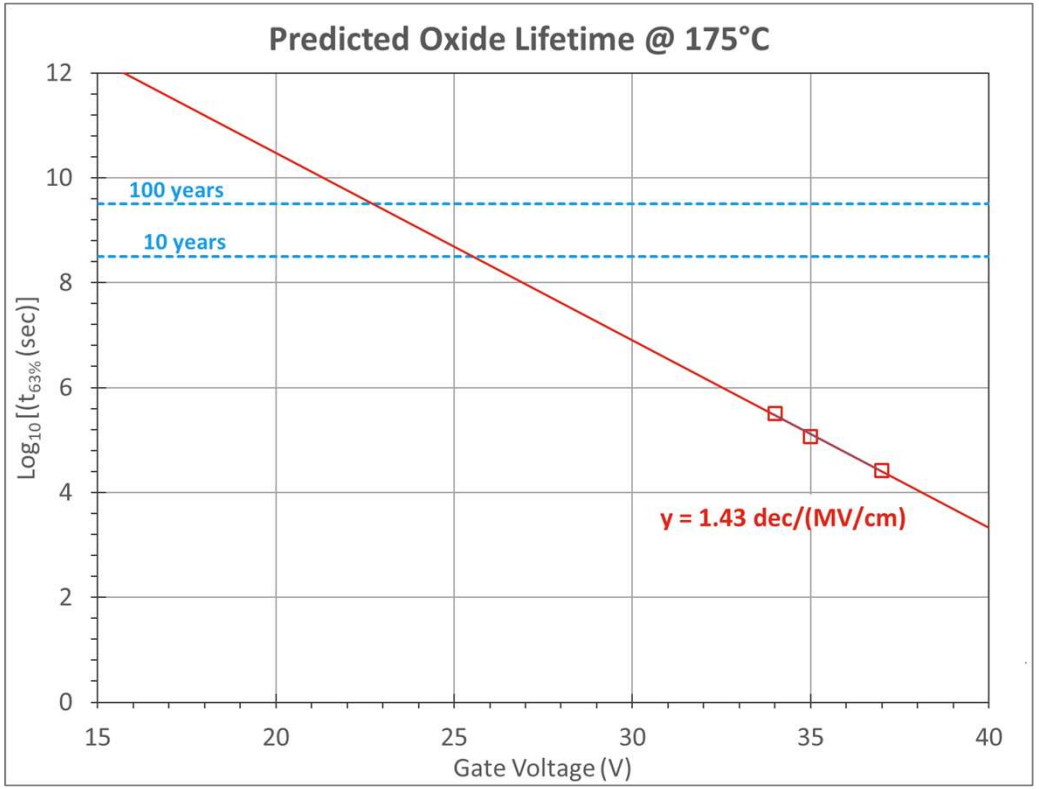
Ruggedness | *Gate Oxide Lifetime*

i. Oxide failure (breakdown) accelerated with temperature and electric field across the oxide

ii. Failure modes extracted from Weibull plots

iii. Arrhenius equation used to predict oxide lifetime

Data from production-grade 1200V, 40 mΩ SiC MOSFETs



Oxide predicted to last more than 100 years at recommended V_{GS} and T_J = 175°C

Application Benefits

- Operate routinely & reliably
- Meet (exceed) desired service lifetime
- Survive electrical transients

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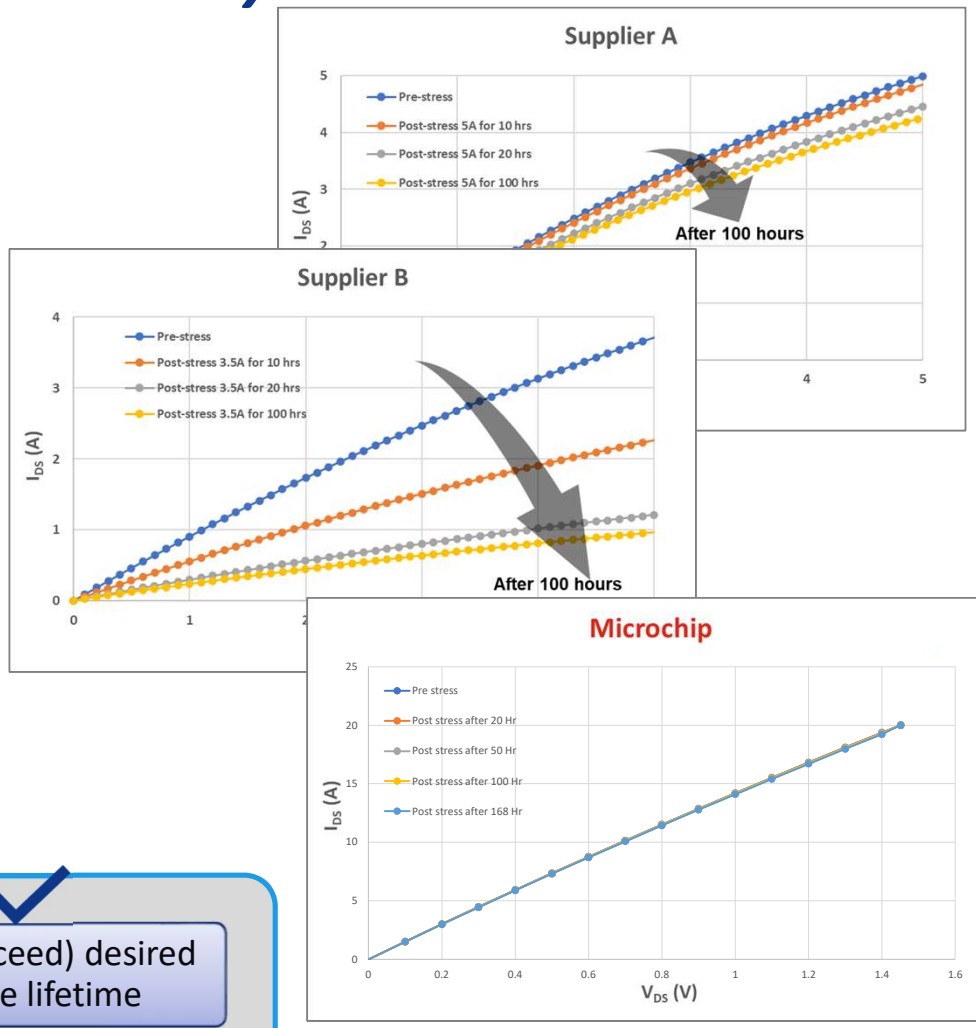
Ruggedness | *Body Diode Stability*

i. SiC MOSFET body diodes stressed with a constant forward current

ii. Body diode I-V curves and $R_{DS(on)}$ measurements made before and after stress

Data from commercially available 1200V, 80 mΩ SiC MOSFETs*
*Courtesy: A. Agarwal and M. Kang, Ohio State University

M. Kang *et al*, *2019 IEEE 7th Workshop on Wide Bandgap Power Devices and Applications (WiPDA)*, 2019, pp. 416-419, doi: 10.1109/WiPDA46397.2019.8998940.



No degradation observed in Microchip body diodes

Also, lower component cost by using body diode and eliminating freewheeling Schottky diode

Application Benefits

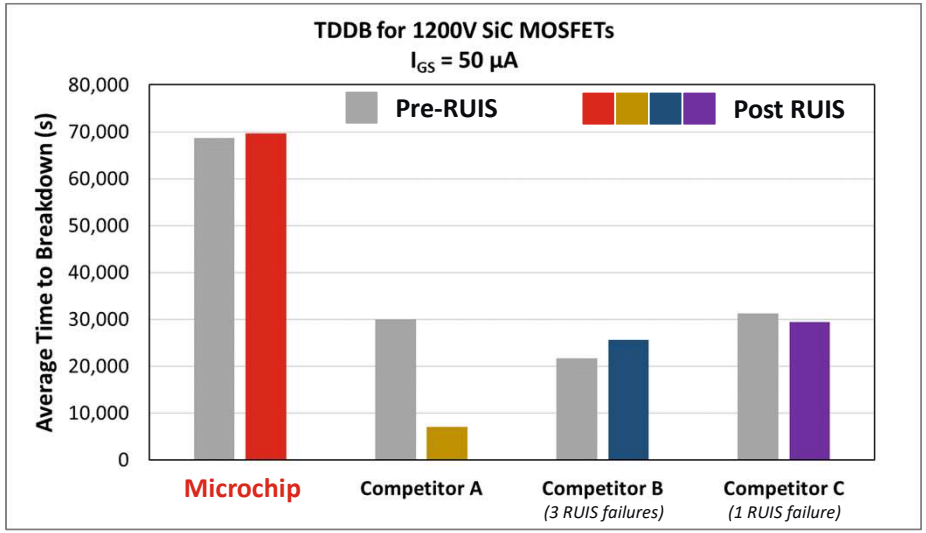
- Operate routinely & reliably
- Meet (exceed) desired service lifetime

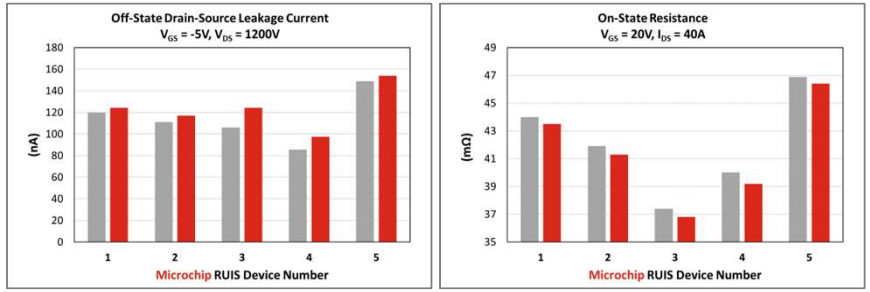
Ruggedness | *Avalanche / Repetitive UIS*

i. Measures the MOSFET's ability to repetitively sustain an avalanche current being switched off from an unclamped inductive load (RUIS)

ii. Cells are not enhanced (MOSFET is OFF); peak current increases rapidly until $V_{DS} = V_{BR}$; avalanche current likely to crowd around die edge

Data from commercially available 1200V, 40 mΩ MOSFETs





Microchip devices exhibit excellent avalanche ruggedness and parametric stability following 100k pulses of RUIS

Application Benefits

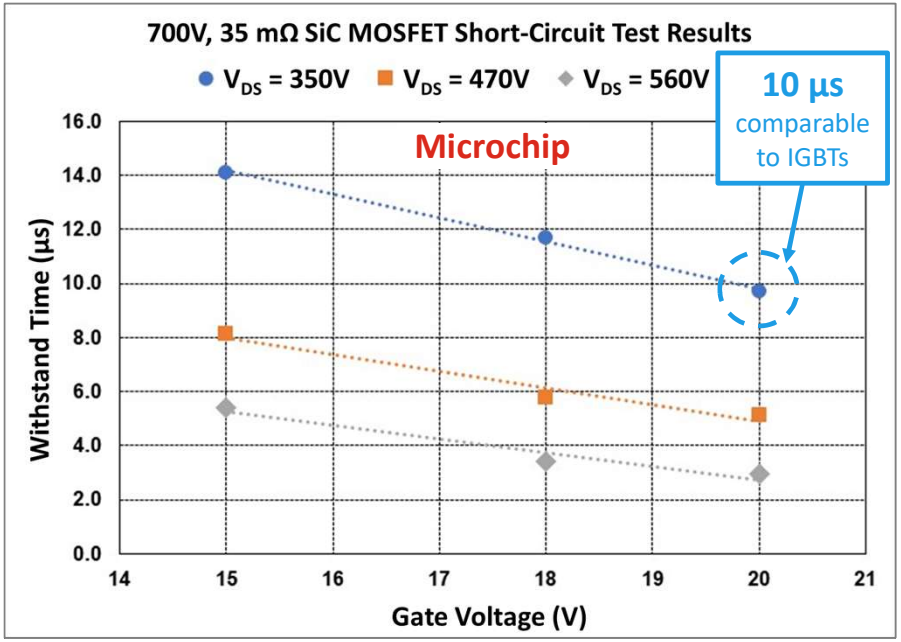
Safely ride through harmful electrical transients

Ruggedness | *Short Circuit Capability*

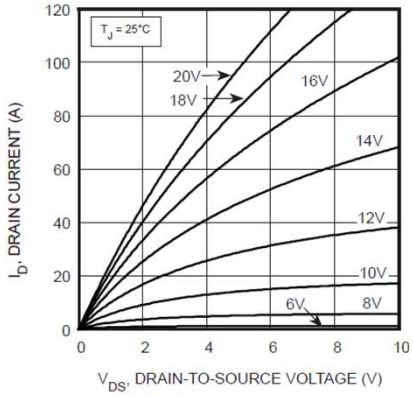
i. Short circuit emulates the application condition of shorting the MOSFET's drain-source across the DC link

ii. Cells are enhanced (MOSFET is ON); peak current intended to distribute uniformly across die

Data from production-grade 700V, 35 mΩ SiC MOSFETs



Designed to survive short circuit events, even at higher DC voltages (with adequate gate driver)



Application Benefits

Safely ride through harmful electrical transients

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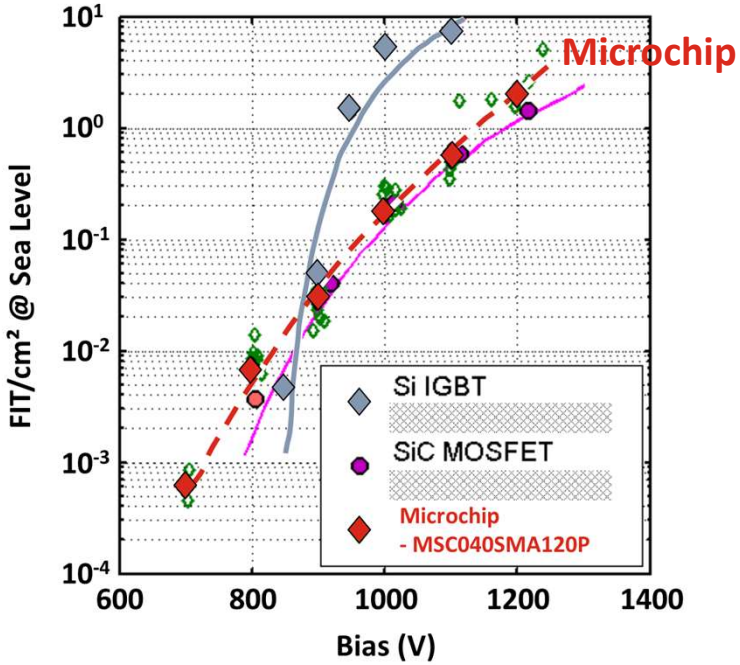
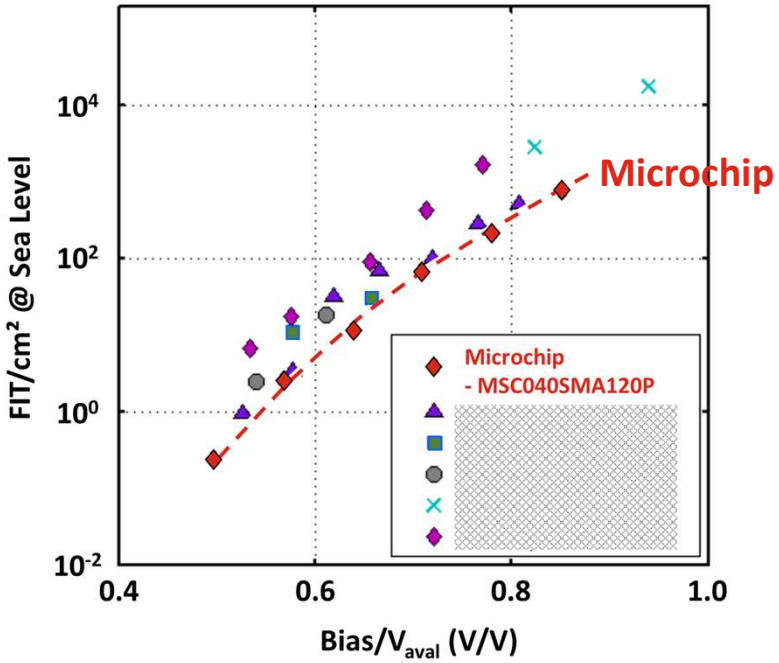
Ruggedness | *Terrestrial Neutron Susceptibility*

- **Neutrons can damage or degrade system performance at sea level or in higher elevations**
- **<u>Application benefit</u>: Using SiC provides higher immunity to terrestrial radiation and lowers FIT rate across low to high elevations**

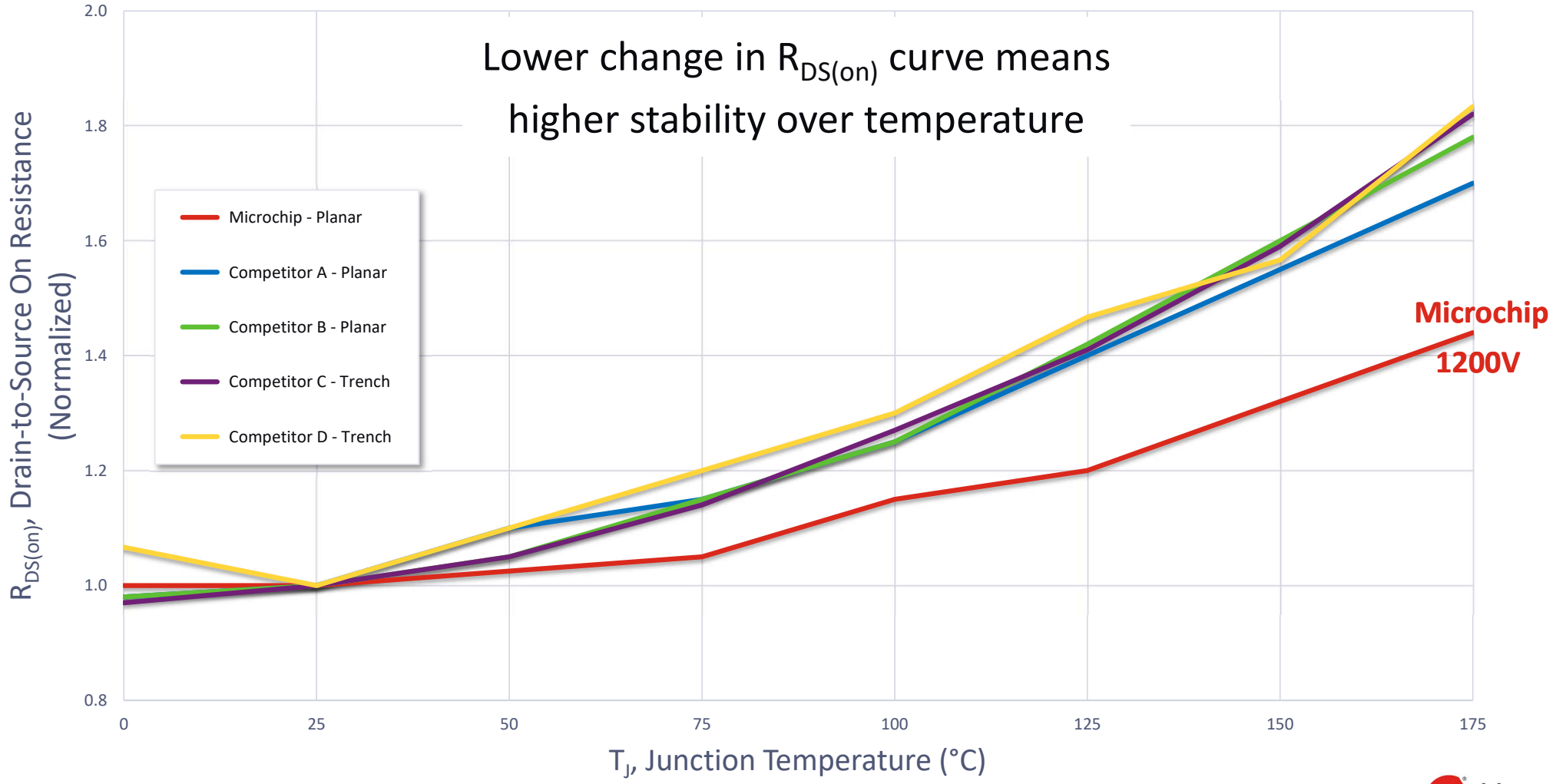


SiC MOSFETs have 10X lower FIT rate than comparable Si IGBTs @ rated voltage



Microchip SiC MOSFETs perform well against SiC competition regarding neutron irradiation

Ruggedness | $R_{DS(on)}$ vs. Junction Temperature



SiC Power Sustainability Segments

Solar Inverter

Power Supply

Energy Storage

Motor Control

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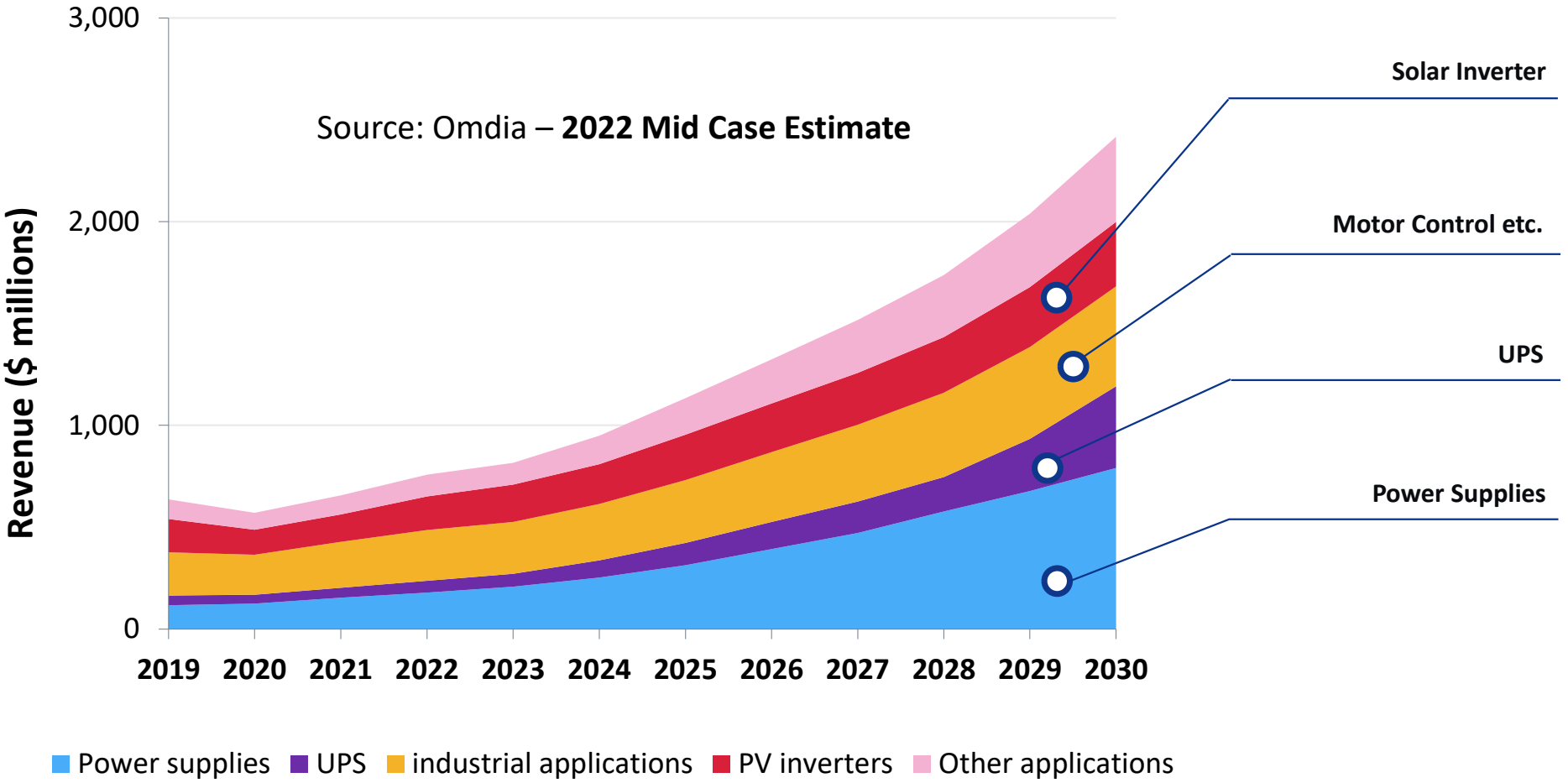
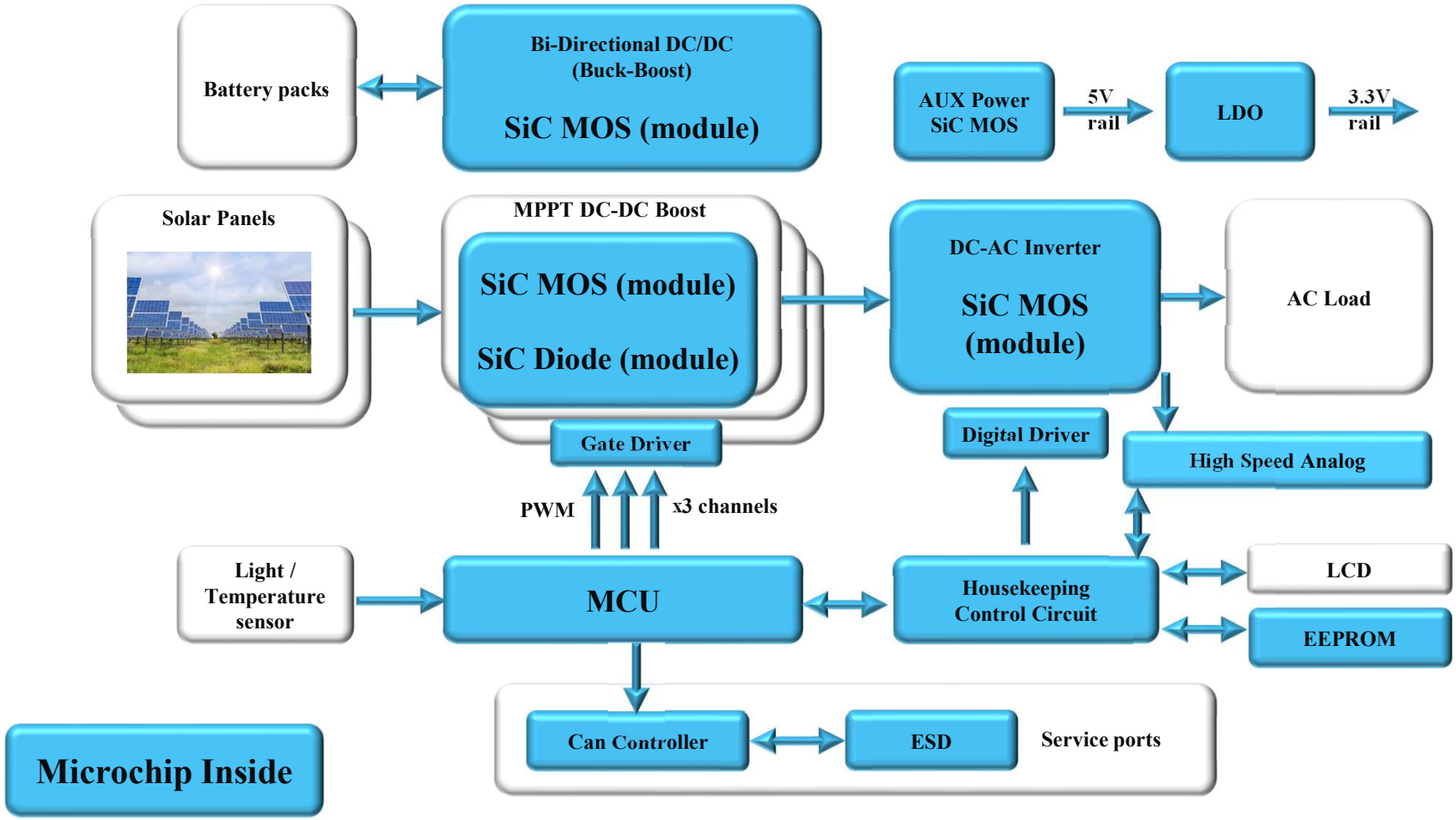
Sustainability SiC Market Data and Trends



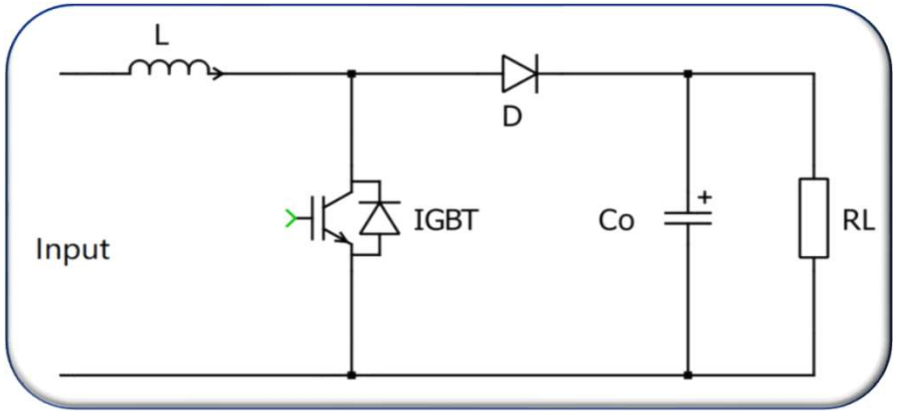
Renewable Energy

Solar Inverters, and/or Energy Storage Systems….

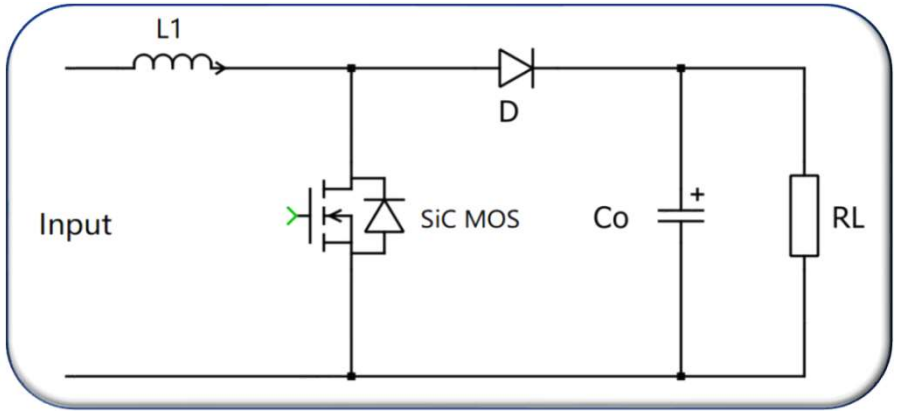
Solar Inverter and/or Energy Storage



SiC Solution - Solar Boost (or Aircon PFC, UPS)



Traditional IGBT Solution



Microchip SiC MOS Solution

HV Boost/PFC Type	Efficiency	Inductor Cost	System Cost	Size	Weight
SiC MOS @ > 40kHz	High	Low	Low	Small	Light
IGBT @ < 20kHz	Low	High	Medium	Big	Heavy

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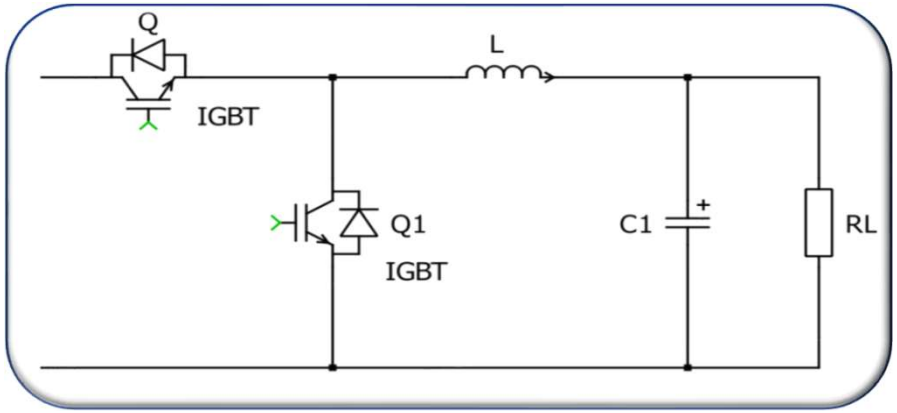
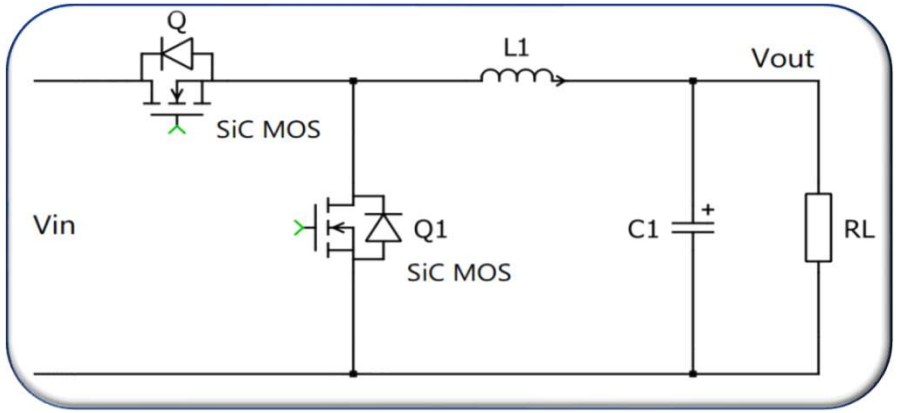
SiC Solution - (Solar) Energy Storage Buck-Boost



Traditional IGBT Solution



Microchip SiC MOS Solution

HV Buck-Boost Type	Efficiency	Inductor Cost	System Cost	Size	Weight
SiC MOS @ > 40kHz	High	Low	Medium	Small	Light
IGBT @ < 20kHz	Low	High	Medium	Big	Heavy

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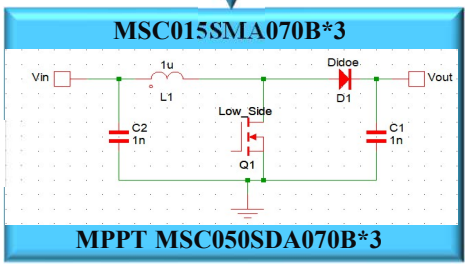
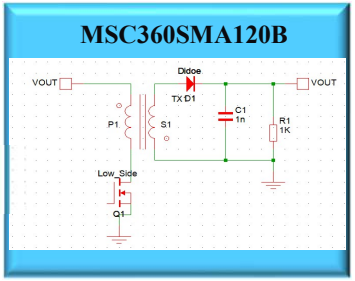
Successful Story - 11kW Solar Inverter with ESS - China





dsPIC33CK256MP506

EEPROM
24LC256

PWM1

PWM2

PWM3

MSC015SMA070B*3

MPPT MSC050SDA070B*3

480V

Inverter
Full Bridge

480VAC for Home Device
45-55Hz

MSC360SMA120B

48V

BUCK-BOOST

200V

CLLC

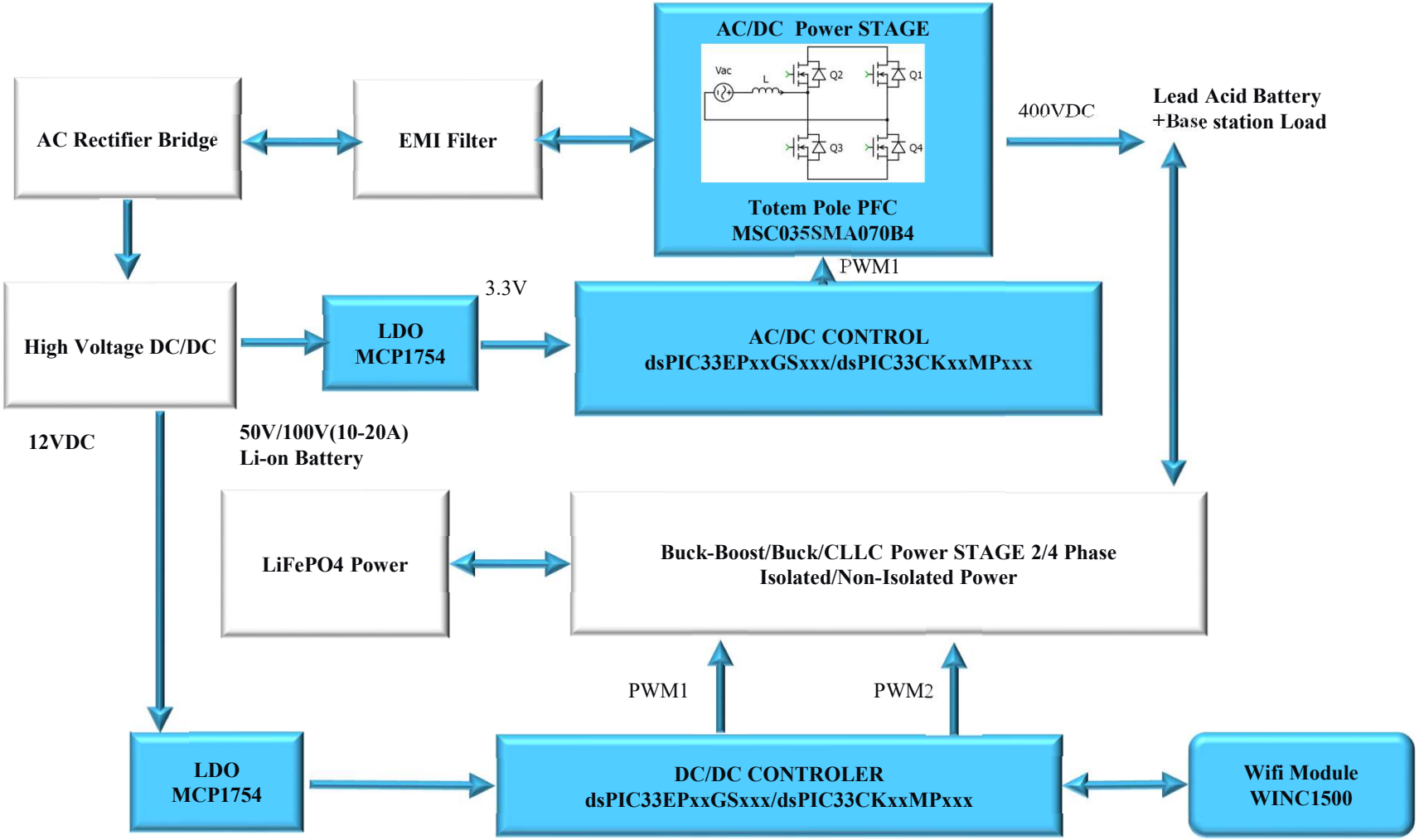
dsPIC33CK256MP506

5V

BUCK
MIC23201

3.3V

Successful Story – 6.6kW Energy Storage - China



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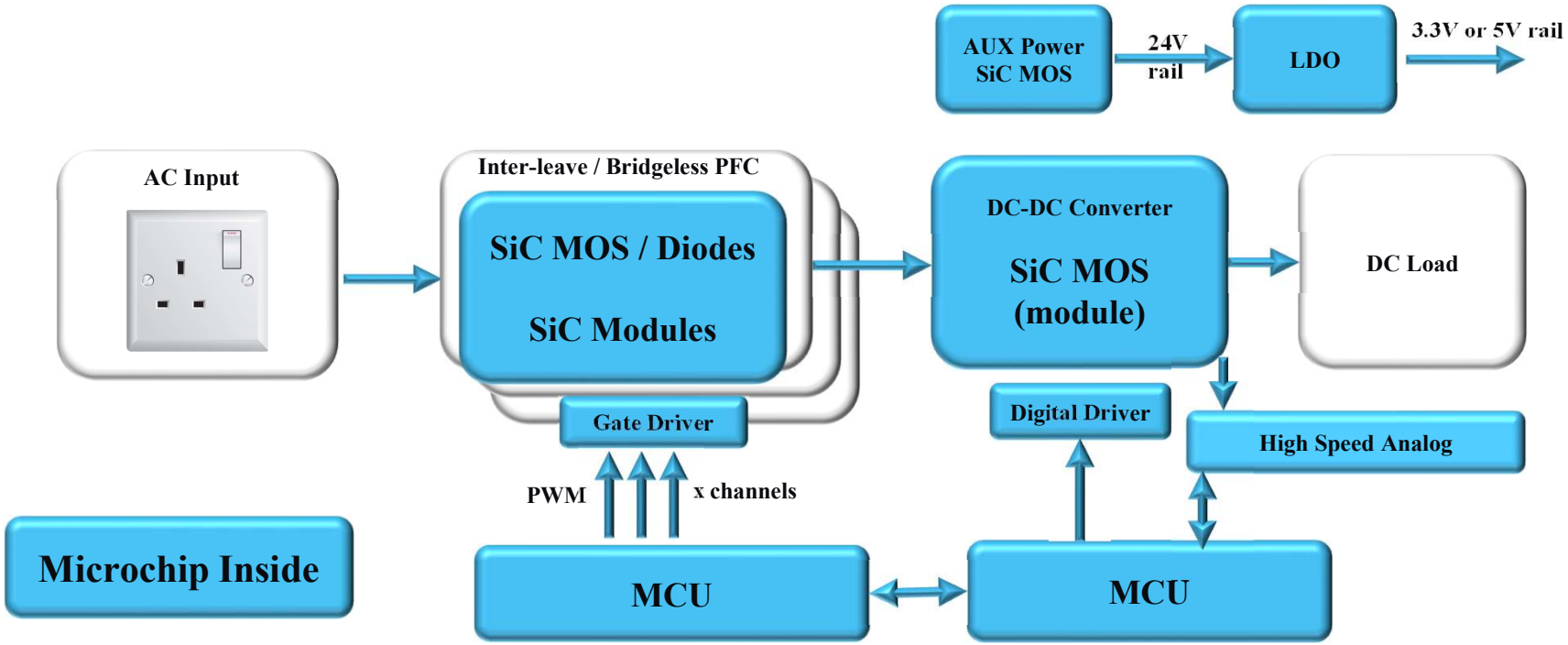
SiC MOS Spec. Comparison – 1200V 40mohm

SiC vs. IGBT Spec.	MSC040SMA120B4	Best IGBT Gen. 6 75N120	Best SiC Gen. 3 0040120
V_{DS} (V)	1200	1200	1200
Eon @ 25 ℃ (uJ)	280	2200	243
Eoff @ 25 ℃ (uJ)	85	2950	104
Von typ. @ 25 ℃ (V) *	1.4	1.85	1.4
Von typ. @ 175 ℃ (V) *	2.17	2.25	2.38
Qrr typ. (nC)	550	4700	691
Qg typ. (nC)	137	530	99
Package	TO247-4	TO247-4	TO247-4
* Note - 35A DC current			

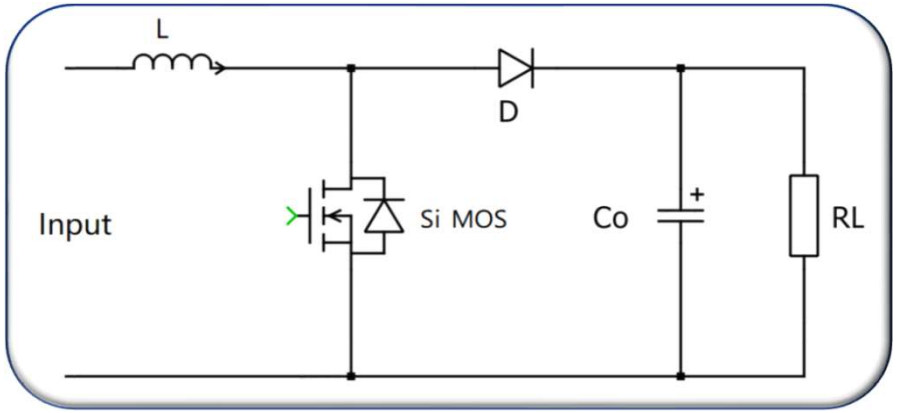
High Efficiency Power Supply

Medical and/or Industrial Power Supply, Server AC-DC,….

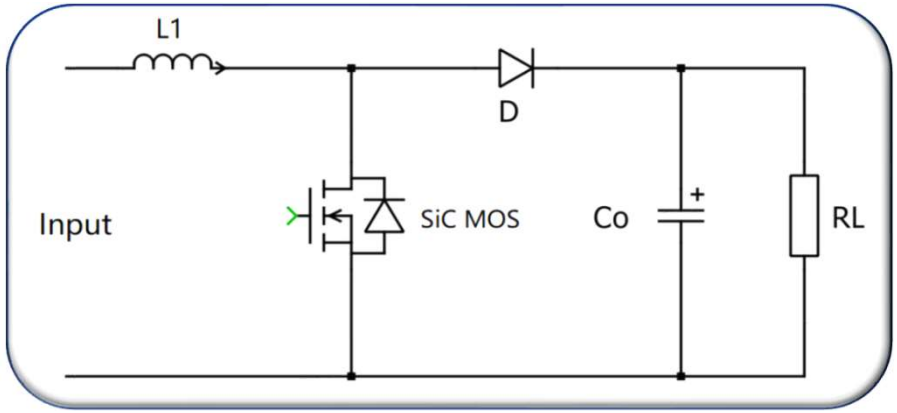
High Efficiency Power Supply



SiC Solution - Boost PFC



Traditional Silicon MOS/Diode Solution



Microchip SiC MOS Solution

Boost PFC Type	Efficiency	Inductor Cost	System Cost	Size	Weight
SiC MOS	High	Low	Medium	Small	Light
Silicon MOS	Low	Medium	Low	Medium	Medium

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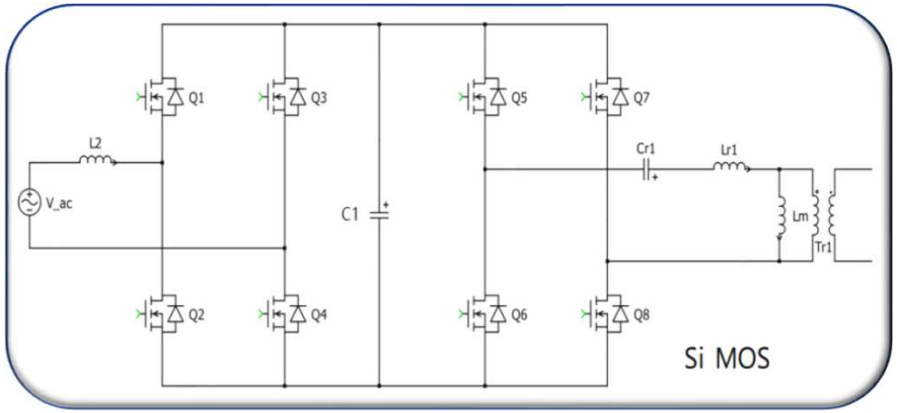
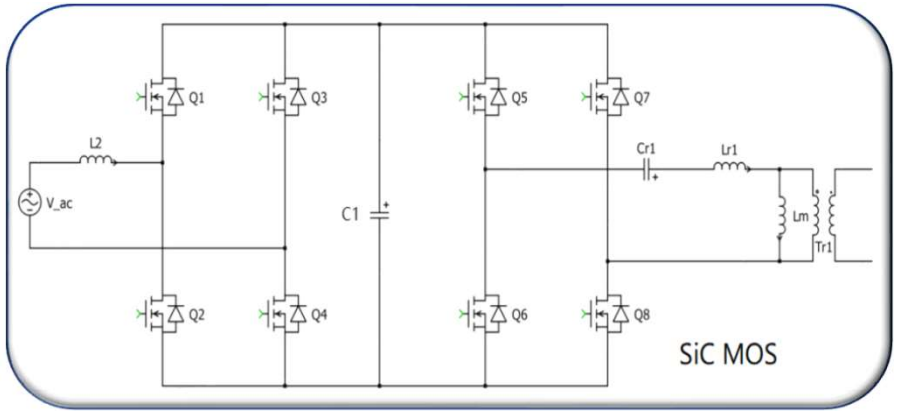
SiC Solution - Bi-Directional PFC and LLC



Traditional Silicon MOS Solution



Microchip SiC MOS Solution

Bi-D. PFC / LLC Type	Efficiency	Thermal	System Cost	Power Density	
SiC MOS	High	Low	Medium	High	
Silicon MOS	Low	Medium	Low	Medium	

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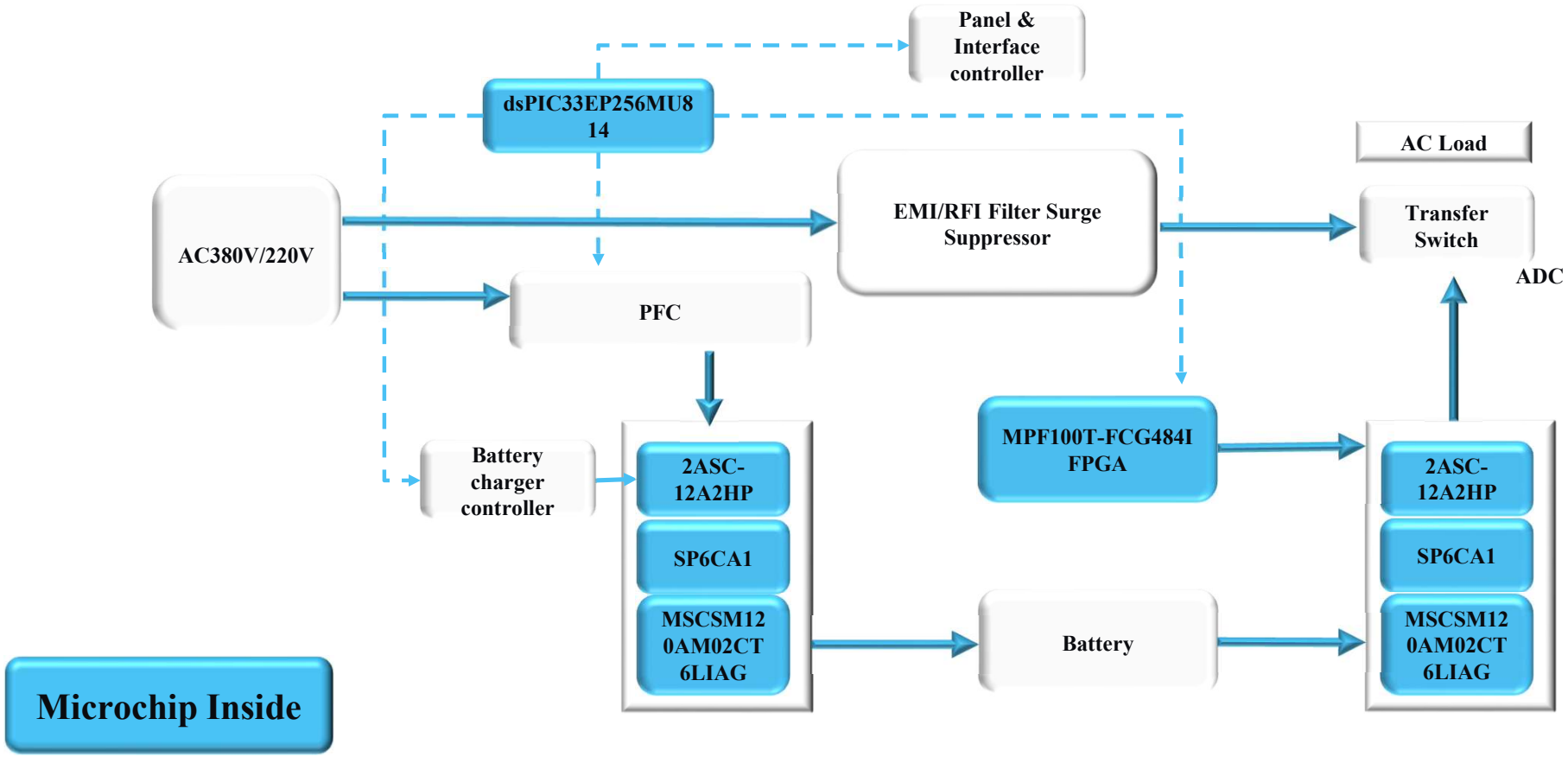
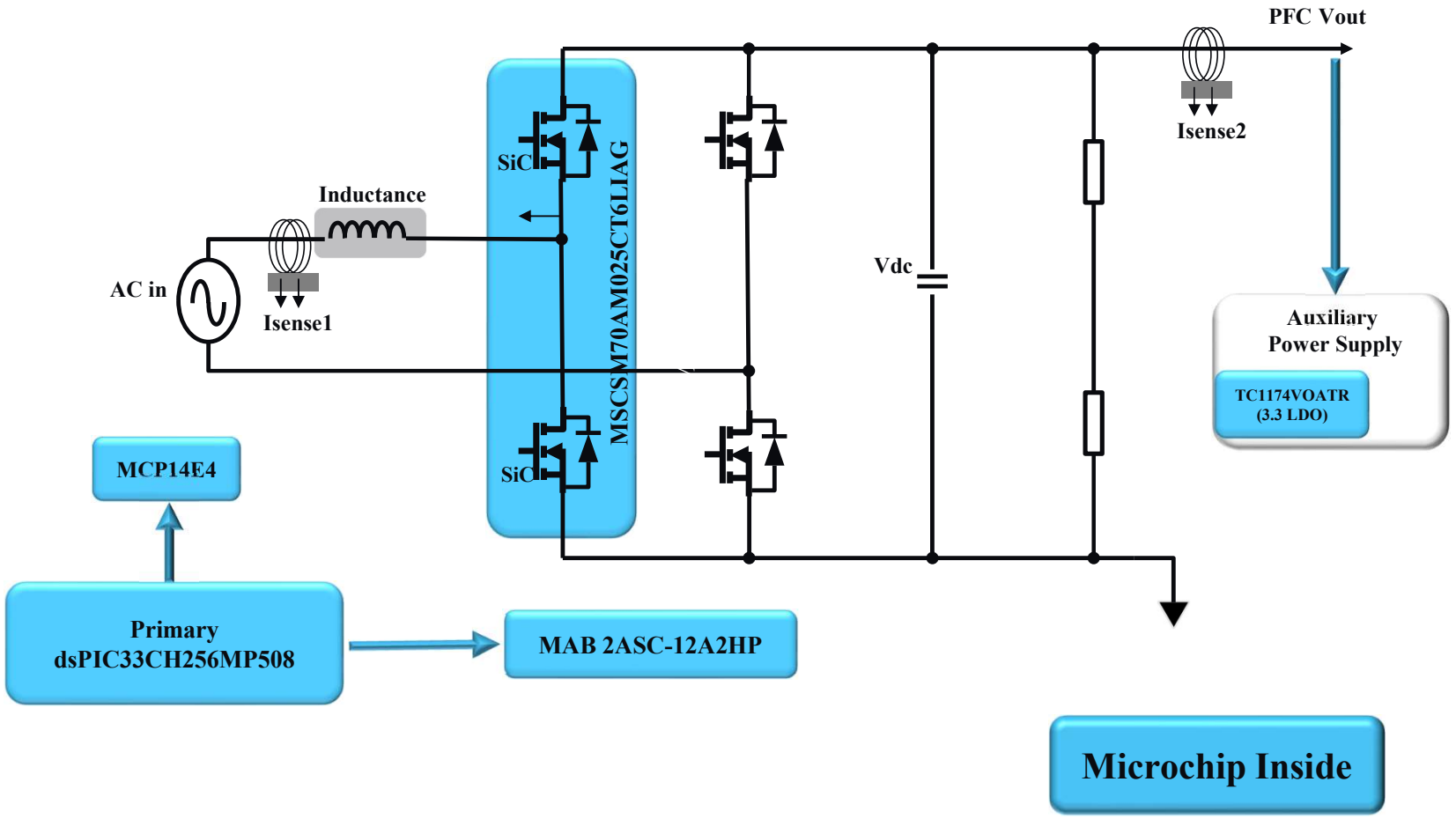
Successful Story - High Power UPS - Korea



Successful Story - Totem Pole PFC 3.4KW - Japan



SiC MOS Spec. Comparison – 700V 60mohm

SiC vs. SJ MOS Spec.	MSC060SMA070B4	Best SJ MOS Gen. 7 65R060CFD7	Best SiC Gen. 3 0060065K
V_{DS} (V)	**700**	650	650
$R_{DS(on)}$ max. @ 25 ℃	75mohm @ 20Vgs	60mohm @ 10Vgs	79mohm @ 15Vgs
$R_{DS(on)}$ max. @ 150 ℃	**86mohm @ 20Vgs**	**132mohm @ 10Vgs**	100mohm @ 15Vgs
Qg typ. (nC)	56nC (-5~20Vgs)	68nC (0~10Vgs)	46nC (-4~15Vgs)
Eas (mJ)	Typ. **1150mJ**	Max. 171mJ	**N/A**
trr typ. (nS)	25nS (1500A/uS)	**156nS (100A/uS)**	16nS (2400A/uS)
Qrr typ. (nC)	170nC	**860nC**	110nC
Package	TO247-4	TO247-3	TO247-4
SCWT (uS)	**3uS**	**N/A**	**N/A**

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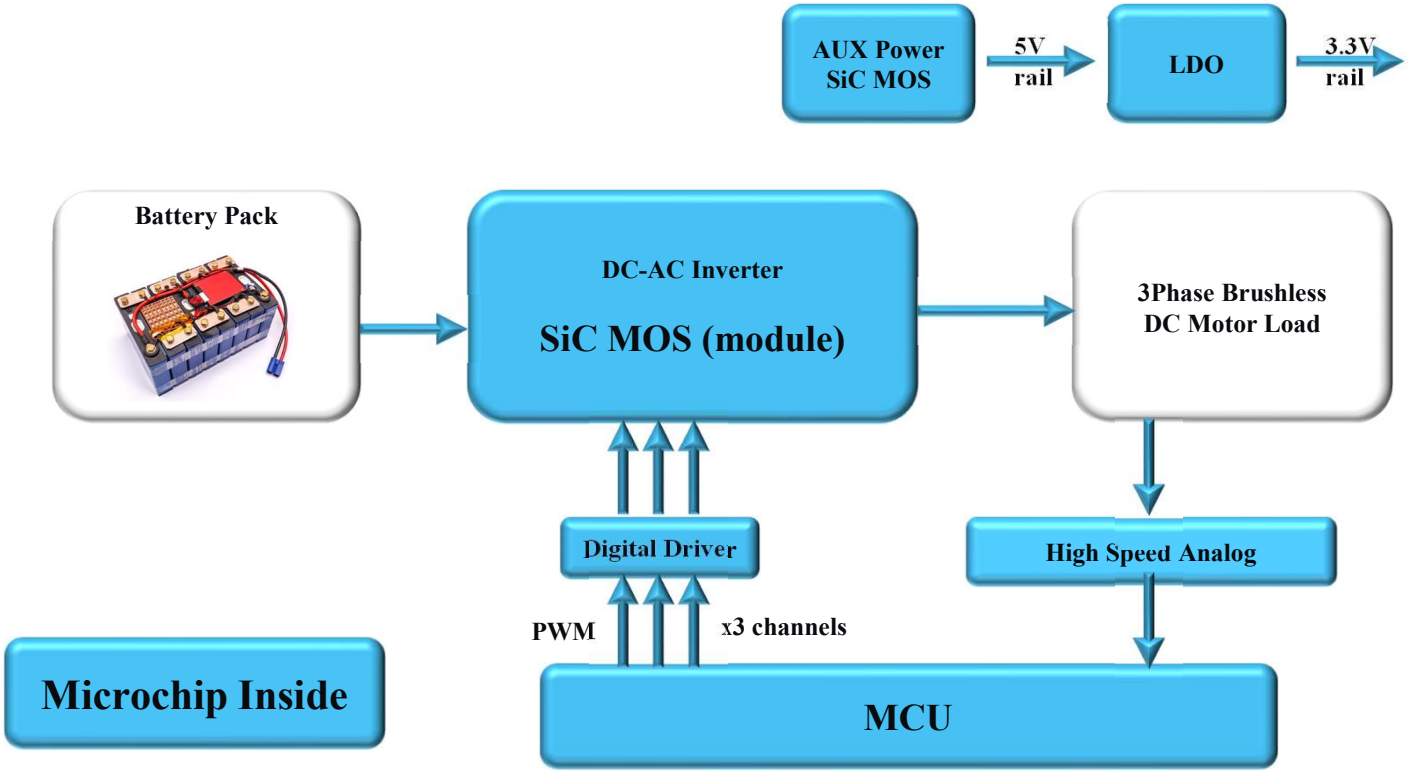
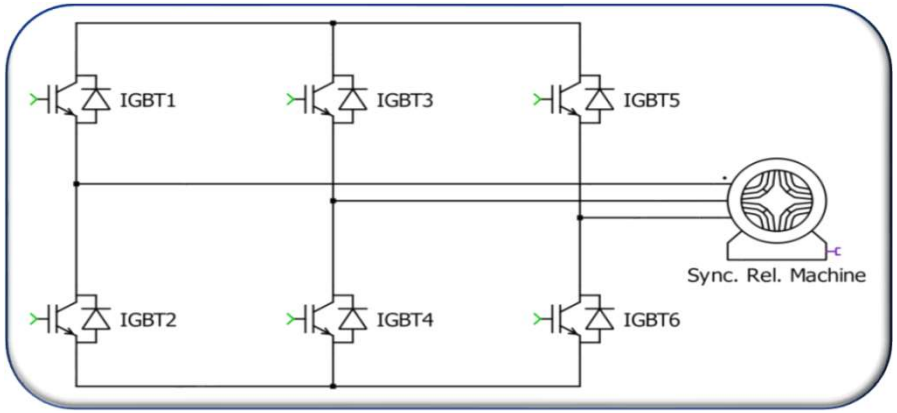
High Efficiency Motor Control

Pump, Compressor Drive, ….

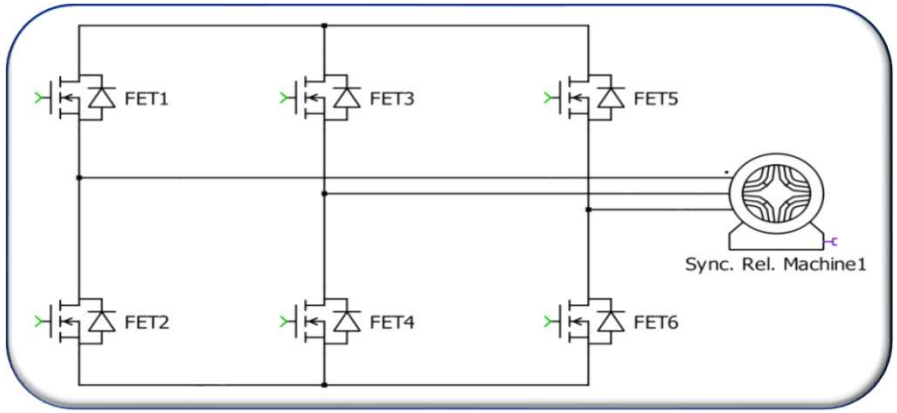
High Efficiency Motor Control



SiC Solution - Motor Control (Pump, Compressor Drive)



Traditional IGBT Solution



Microchip SiC MOS Solution

Motor Control Type	Efficiency	Battery Cost	System Cost	Size	Weight
SiC MOS	High	Low	Low	Small	Light
IGBT	Low	High	Medium	Big	Heavy

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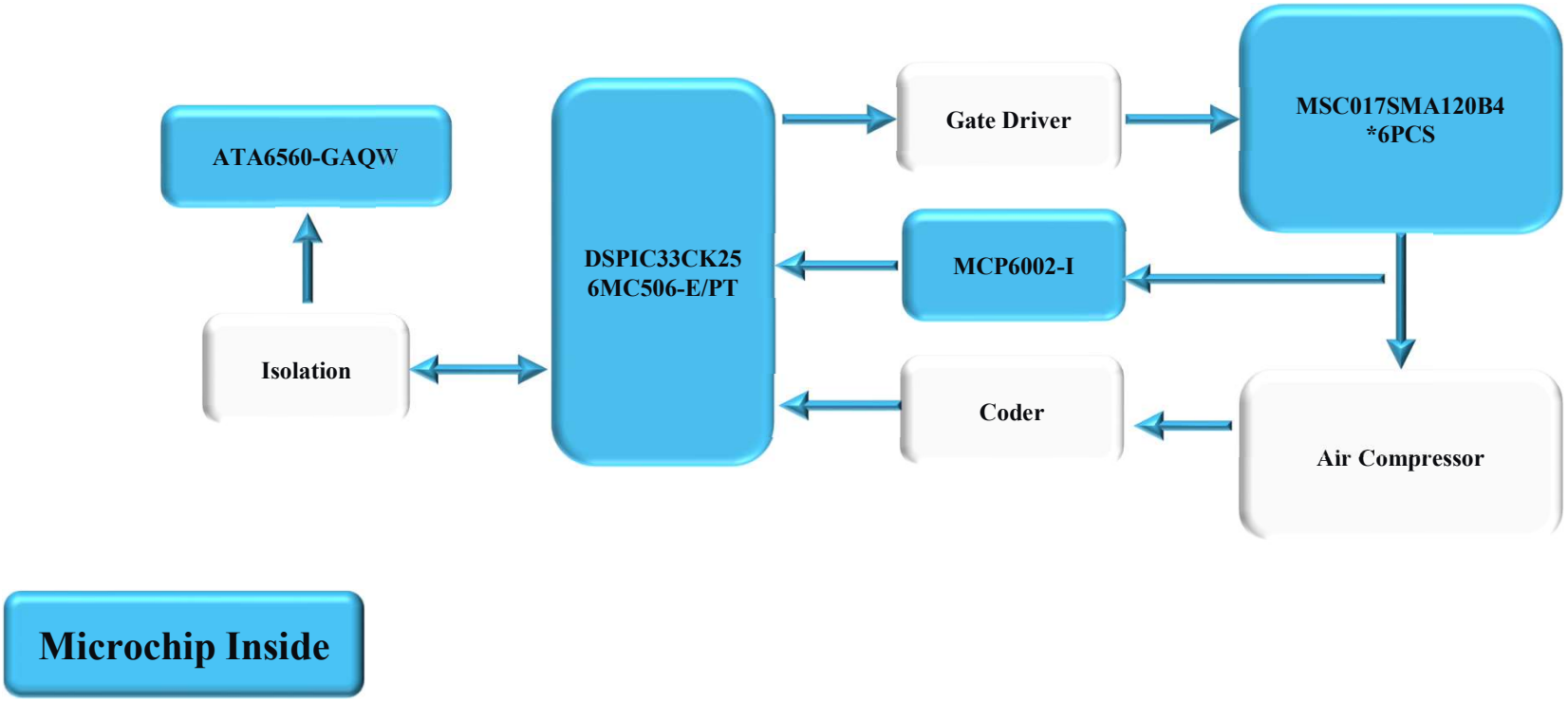
Successful Story - 26kW Pump Drive - China



Summary

- **Unrivaled ruggedness and performance**
  - Best-in-class avalanche ruggedness, short circuit capability and neutron susceptibility
  - Oxide lifetime in excess of 100 years and a stable body diode
- **Qualified and secured long-term substrate and epi supply**
  - Multiple vendors that exceed high-side demand
  - Not reliant on competitor substrate/epi material
- **Dual fab strategy**
  - Protecting the supply chain from a natural disaster or major line yield issue
- **Short lead times**
  - 20 - 30 weeks typically
- **Stability of Microchip**
  - 125+ consecutive quarters of profitability
  - 30+ years of power semiconductor expertise
  - 20+ years of SiC expertise
  - No "EOL" practice

MICROCHIP

SiC Power Solutions