

Silicon Carbide in AC Motor Drives

SEMICON Europa, November 18-21 2025, Munich Germany



Silicon Carbide in Motor Drives

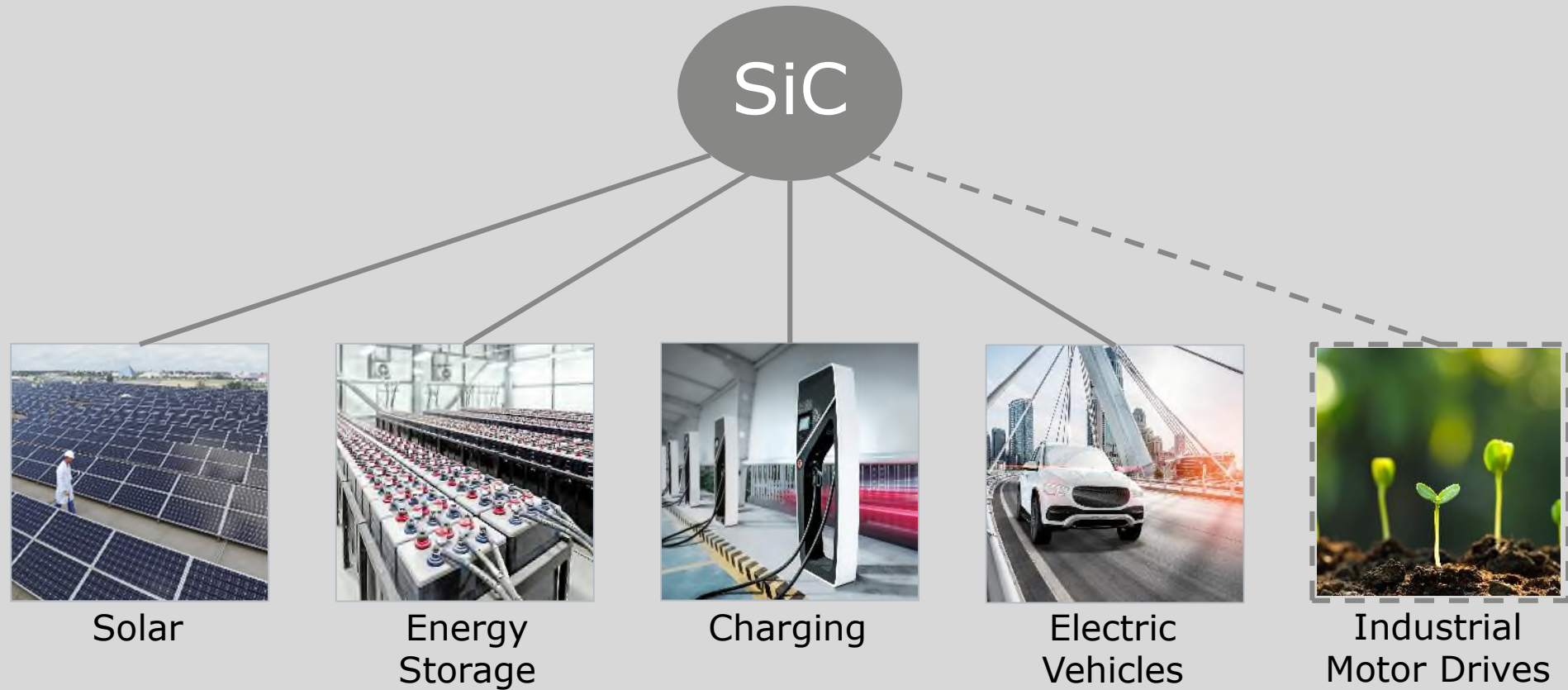
Common assumptions and myths of SiC in motor drive application:

- Too expensive and never pays back
- Only makes sense when switching fast
→ dv/dt too high for electric motors
- Can't withstand short circuit
→ Application reliability is not given

→ SiC is not usable for Motor Drives



Silicon Carbide in Motor Drives



Content



Why Silicon Carbide?

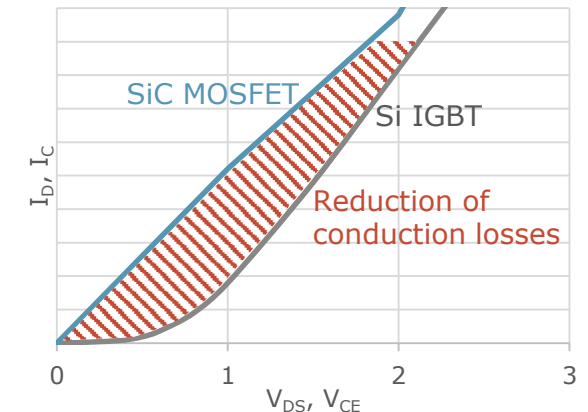
Application Examples

Conclusion

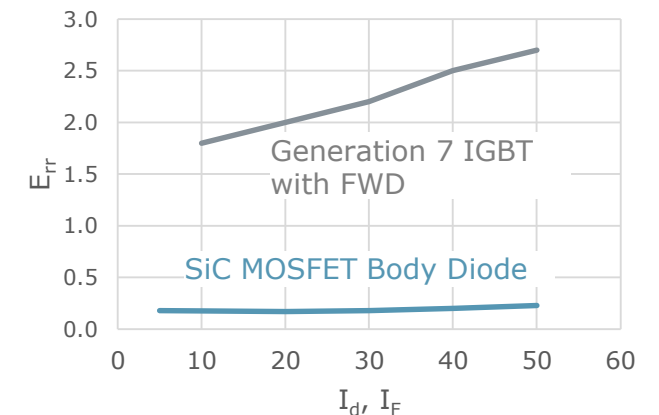
Why Silicon Carbide SiC Benefits

- **Reduced on-state conduction losses** in partial load conditions compared to Si IGBTs and FWDs thanks to the resistive output characteristics
- **Reduced switching losses** thanks to the unipolar channel and low Q_{rr} of the embedded body diode
- **Reduced ΔT_j over the fundamental period of output current** in two-level topologies when using the MOS channel in reverse conduction compared to separate IGBT and FWD solution
- **2 μ s short circuit withstand** capability when using the latest chip technologies

Forward Output Characteristics

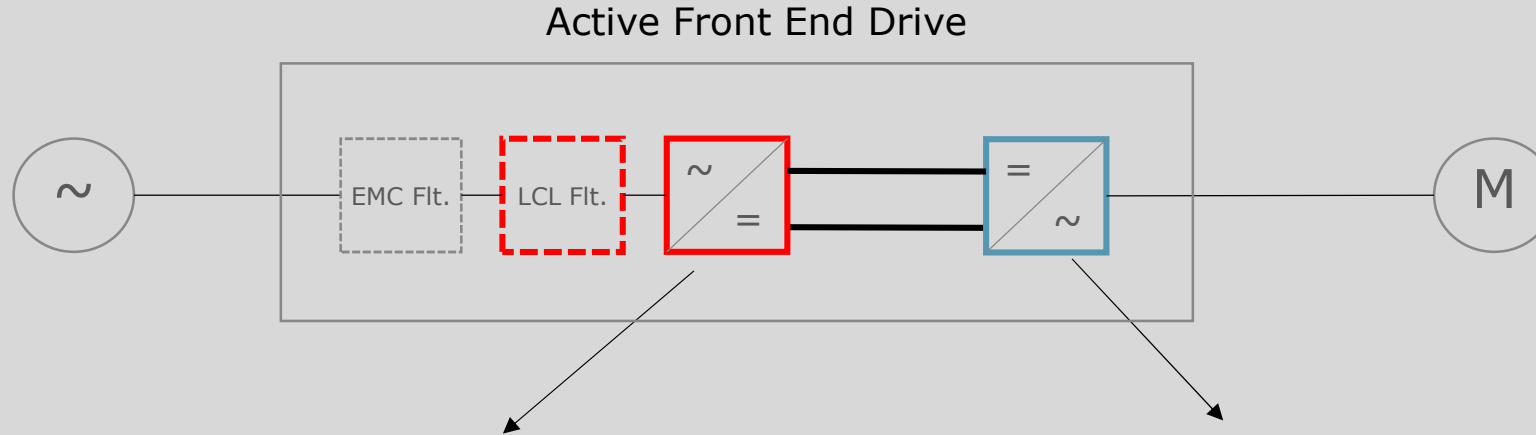


Reverse Recovery Losses



Why Silicon Carbide

Applications of SiC MOSFETs in a Motor Drive



Low Harmonics / Active Front End Input

- Fully controlled line side converter (IGBT sixpack)
- 5...6 kHz carrier frequency
- Large LCL filters (iron and copper) either drive embedded or as separate filter/converter units
- Requirements to harmonics depend on application and the locally relevant standards

Standard 3 Phase Inverter

- Switching speed limited to $\sim 5...(10) \text{ kV}/\mu\text{s}$ to reduce insulation stress of motor windings and over voltages at the motor end of cables
- Switching frequency typically 4...6 kHz
- Goal: small size, low losses

Content



Why Silicon Carbide?

Application Examples

– **Active Front End**

– Standard Inverter

– Servo Axis

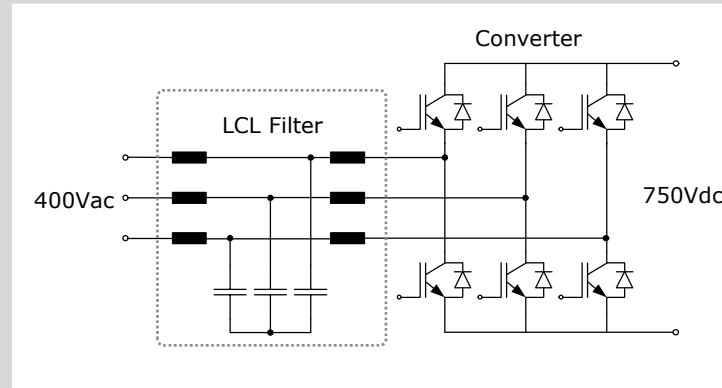
Conclusion

Application Example

Active Front End for Low Harmonics/Power Regeneration

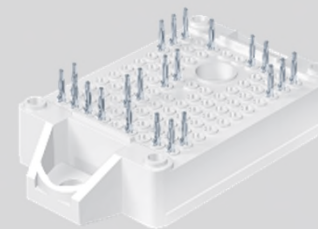
Operating Conditions:

- V_{DC} : 750V
- V_{grid} : 400V
- I_{Phase} : 30A
- $\cos \varphi$: 0.98
- f_{grid} : 50Hz



Comparison:

- Replacing Generation 7 IGBT with latest generation of SiC MOSFET
- 50A rated sixpacks
- Quadruple the carrier frequency for SiC to have similar junction temperature: **5kHz → 20kHz**
- Simulation Tool: [Semikron Danfoss SemiSel](#)



Application Example

Active Front End for Low Harmonics/Power Regeneration

	Watt Losses	Filter Volume	Filter Weight
Si IGBT	Converter: 247W Filter: 463W Total: 710W 	8225cm ³ 	19.4kg 
SiC MOSFET	Converter: 175W Filter: 291W Total: 466W  34% More Efficient	2448cm ³  70% Smaller	10.2kg  47% Lighter

Application Example

Active Front End for Low Harmonics/Power Regeneration

- More compact frequency converter and less panel space needed
- Reduction of audible noise in magnetics
- Reduced Total Cost of Ownership (TCO)
 - Energy savings and reduced CO2 emissions
 - Reduced freight and storage costs
 - Easier handling and lower mounting effort
- Further optimization is possible with 3-level SiC topologies



Key: Consider the total system!

Content



Why Silicon Carbide?

Application Examples

– Active Front End

– **Standard Inverter**

– Servo Axis

Conclusion

Application Example

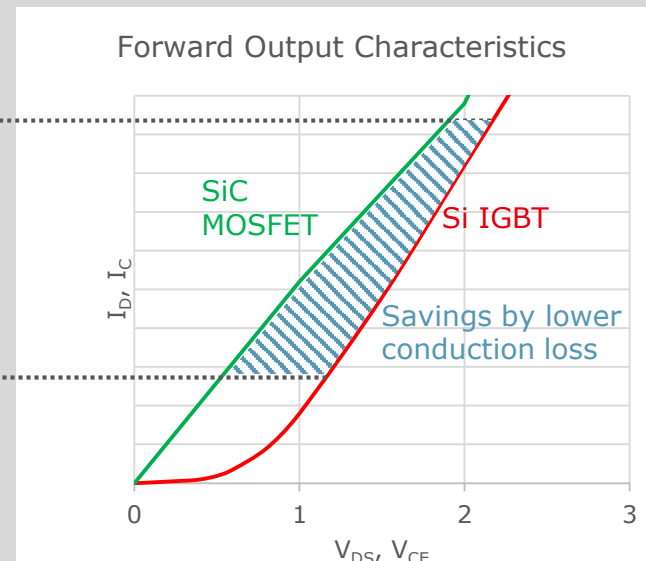
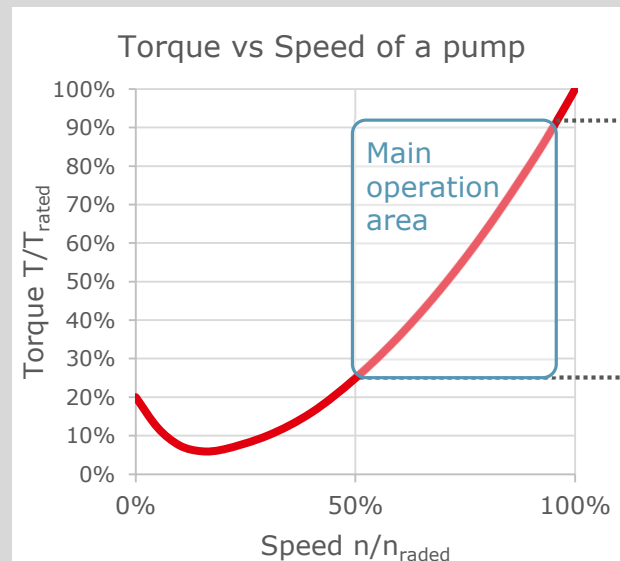
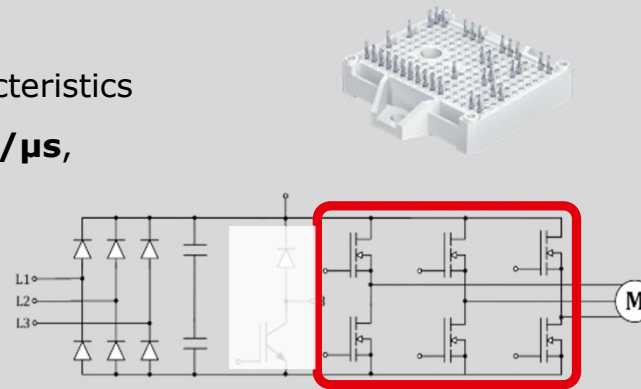
Centrifugal Pump Inverter

Operating Conditions:

- 15kW centrifugal pump, quadratic torque characteristics
- $V_{DC}=560V$, $I_{motor}=25.5A$, $f_{sw}=5kHz$, **$dv/dt=5kV/\mu s$** ,
OL=110%/1min

Comparison:

- Identical switching speed, 5kHz and 5kV/ μs
- Identical cooling



Application Example

Centrifugal Pump Inverter – Watt Loss at Module

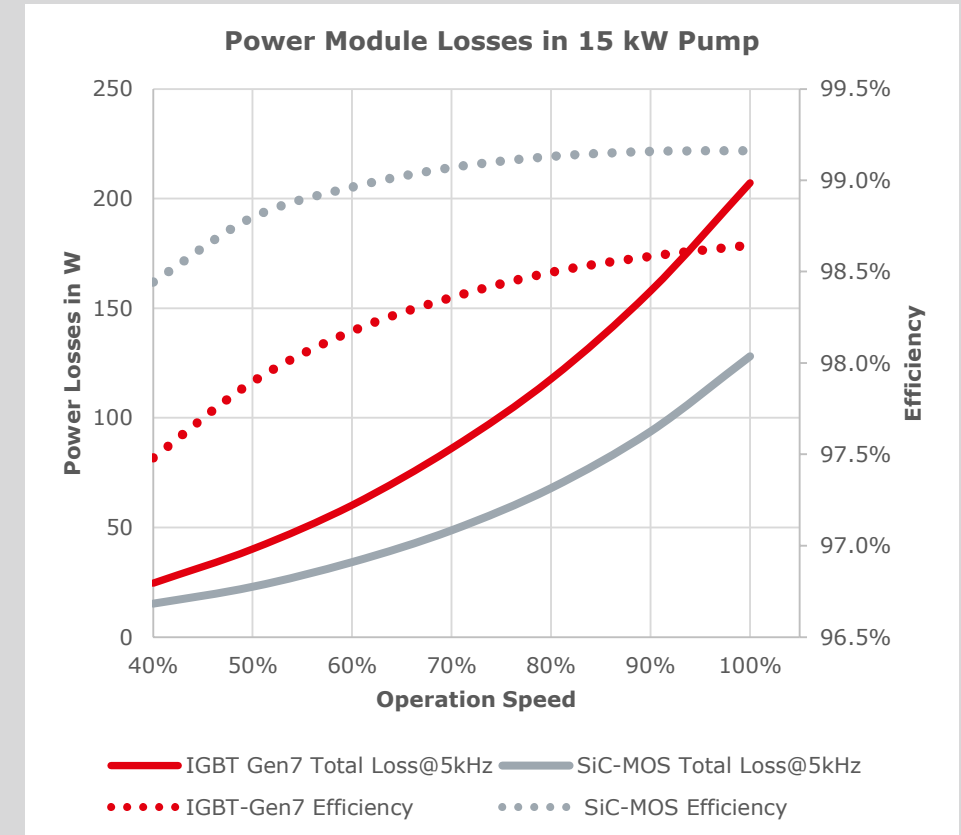
Comparison:

- Identical switching speed, 5kHz and 5kV/ μ s, for motor friendliness
- Identical cooling
- Simulation Tool: [Semikron Danfoss SemiSel](#)

Result:

Typical operation range of a pump 40...80% load

- More than 40% lower losses from 40% to 80% speed
- Up to 0.6...1% boost in efficiency between 40% and 80% of speed



Application Example

Centrifugal Pump Inverter – Return on Investment (ROI)

Assumptions:

- Price difference of a 400Vac/15kW drive to end user 60€
- Energy Cost: 0.20€/kWh*
- Operation profile →

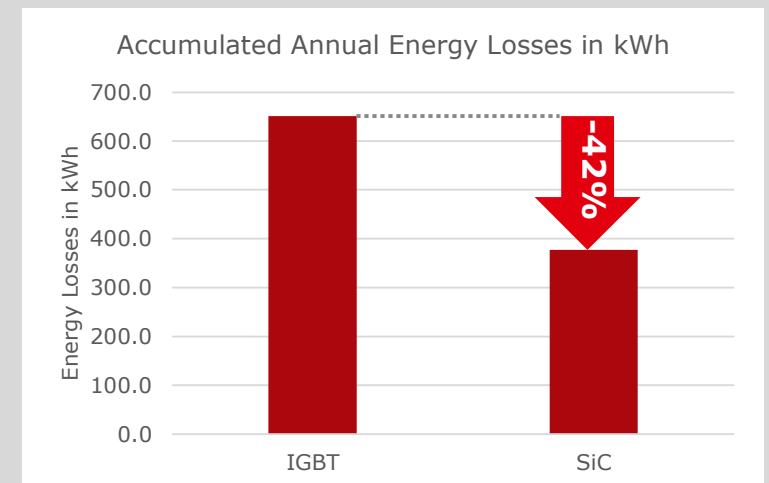
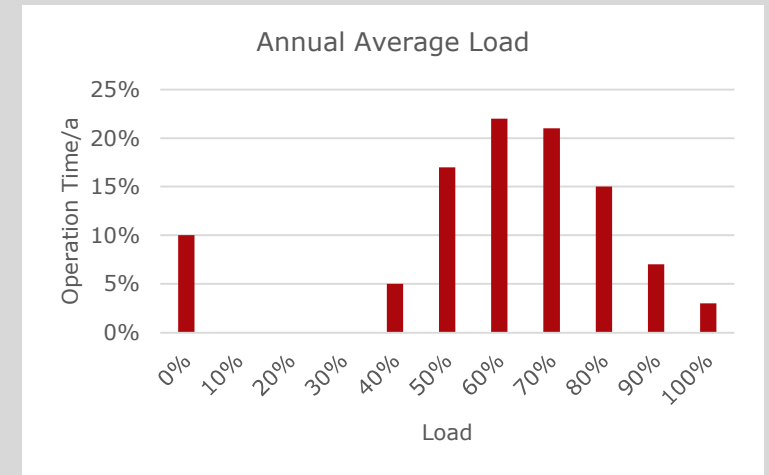
Result:

- 42% lower accumulated annual energy losses
- 274kWh savings equaling 127 kg CO₂**
- 56€/year savings with current German energy prices for industrial use
- Payback for drive user in 13 months
- Higher energy cost = more savings + faster payback of SiC

Key: Consider TCO!

* Source: VDW-Bayern Studie (Prognos) – Internationaler Energiepreisvergleich Oktober 2023

** Emission factors IEA



Content



Why Silicon Carbide?

Application Examples

- Active Front End
- Standard Inverter

– Servo Axis

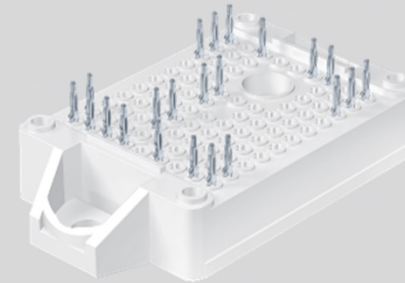
Conclusion

Application Example

Pick and Place Servo, 4kW (e.g. gantry application, robot)

Selected Power Modules:

- IGBT Module: SK50GD12T7ETE1_HPTP, 50A
- SiC Module: SK50MD120RM04TE1_HPTP, 18mΩ
- Both selected to withstand a certain number of power cycles
- Same dv/dt, 8kHz, $V_{DC}=560V$
- Simulation Tool: [Semikron Danfoss SemiSel](#)



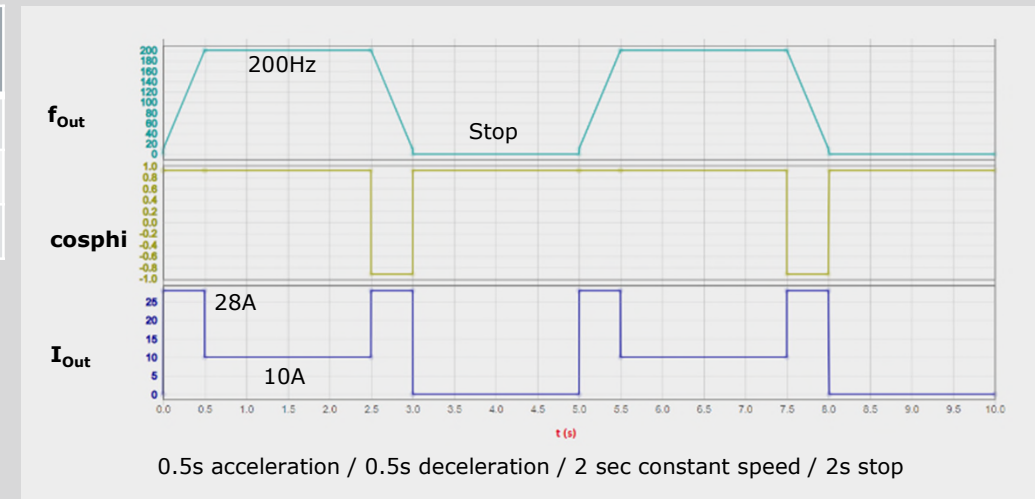
RESULT for a single axis

	Avg. Loss	Efficiency	Annual Energy cost savings*	Annual CO ₂ Reduction**
IGBT Gen7	86.7W	96.9%		
SiC	44.7W	98.4%		
Savings	48.4%	1.6%	35€	78kg

- Almost 50% lower power losses
- Smaller drives, less panel space, benefits in logistics, ...
- Less panel cooling required

* 250d/16h, 0,20€/kWh, Source: VDW-Bayern Studie (Prognos) – Internationaler Energiepreisvergleich Oktober 2023

** Emission factors from IEA



Content



Why Silicon Carbide?

Application Examples

Conclusion

Silicon Carbide in Motor Drives

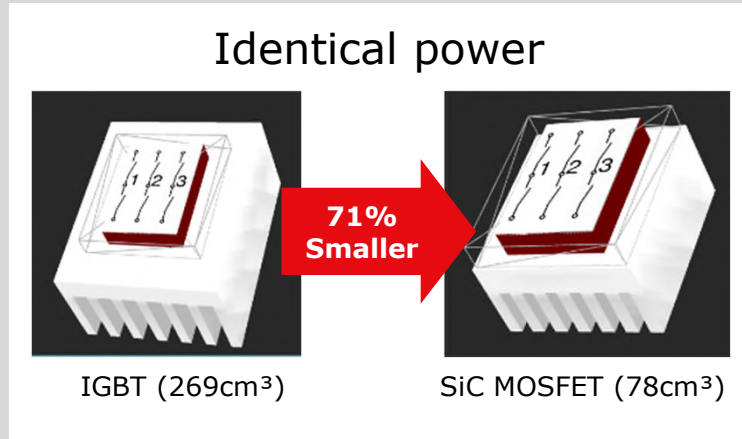
Common assumptions and myths:

- Too expensive and never pays back
- Only makes sense when switching fast
 - dv/dt too high for electric motors
- Can't withstand short circuit
 - Application reliability is not given

→ **SiC is not usable for Motor Drives**

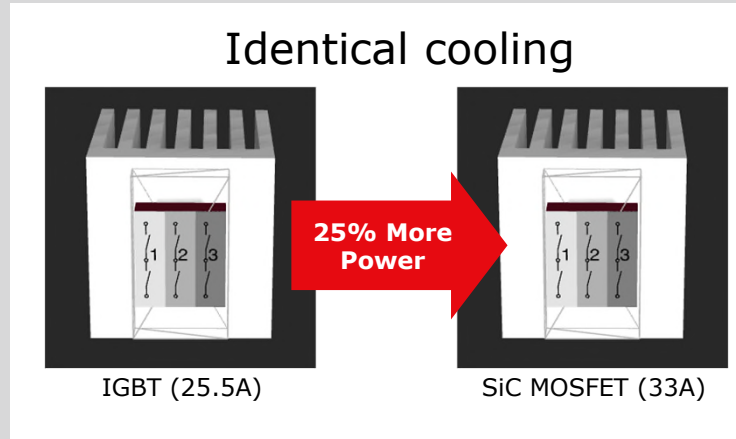


Power Density and Quality



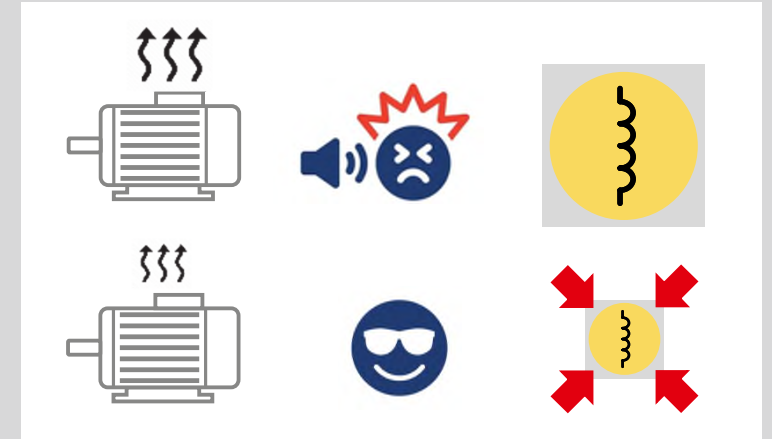
Smaller/More Efficient Drives

- More compact frequency converters and less panel space needed
- Reduced total cost of ownership (TCO)
- Ideal for embedded or IP5x+ drives
- Benefits through complete supply chain by smaller packages, lower weight, storage etc.



More Power

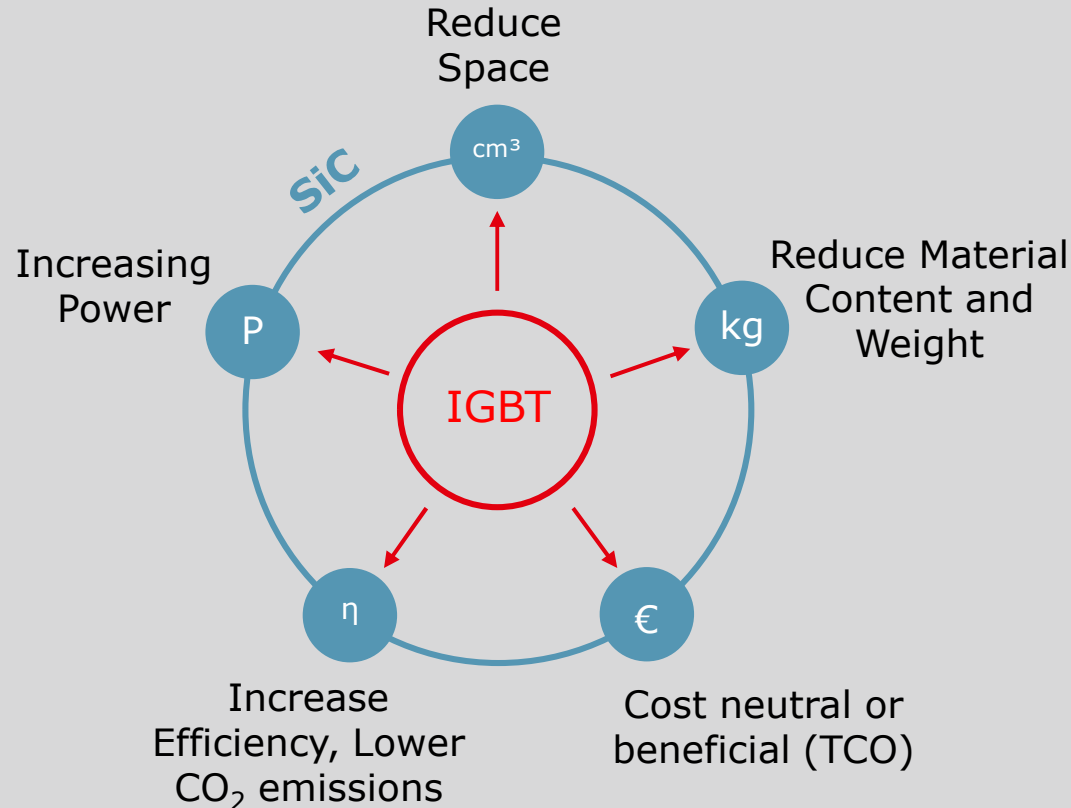
- More power from same thermal design



Higher Carrier Frequency

- Increased motor efficiency
- Lower audible noise
- Smaller magnetics
- Efficient solution for high-speed applications (compressors, spindles, etc.)

Conclusion: New Degrees of Freedom in Design



- SiC can provide cost neutrality or even advantage when looking at system and Total Cost of Ownership (TCO)
- SiC provides impressive benefits even at low switching speed and dv/dt
- Proven packages simplify implementation into production, service, etc.

SiC is THE choice for the next generation of motor drives!



**SEMIKRON
DANFOSS**

Contact us

Joonas Puukko
Senior Field Application Engineer

Email: joonas.puukko@semikron-danfoss.com

