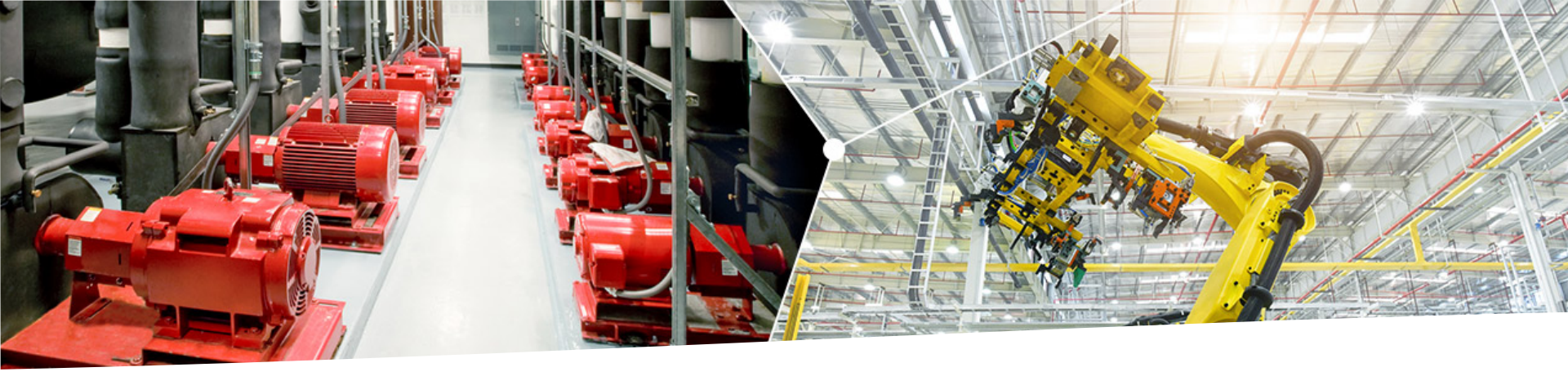

CoolSiC™ – The perfect solution for servo drives

Infineon’s comprehensive portfolio for industrial drives applications

December 2020

Agenda

1. Application requirements
2. System level benefits
3. Case study of IGBTs and CoolSiC™ MOSFETs for industrial drives
4. Auxiliary power supply
5. CoolSiC™ MOSFET evaluation boards
6. Industrial CoolSiC™ portfolio
7. Key takeaways

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Specific drives applications and motor types in the industry

Industrial Drives

- Low voltage drives
  - General purpose drives
  - Servo drives
  - C-HVAC
- Medium voltage drives

Industrial motor types

- Induction motor
- Switched reluctance motor
- Permanent magnet synchronous motor
- Servo motor
- Brushed DC motor
- Brushless DC motor

Industrial automation

- Industrial automation

Overview of three major areas in low voltage drives

General purpose drives

370 W – 1250 kW

Requirements

- Performance and reliability
- Safety features
- Good price / performance ratio

Key applications

- Pumps & fans
- Process automation
- Cranes
- Marine drives

Infineon products

- iMOTION™
- CIPOS™ IPM
- EiceDRIVER™ gate driver
- EasyPIM™
- EconoPIM™
- EconoDUAL™
- PrimePACK™
- CoolSiC™ MOSFETs

Servo drives

370 W – 315 kW

Requirements

- High positioning accuracy
- Fast response with no overshoot
- High reliability

Key applications

- Robotics
- Material handling
- Machine tools

Infineon products

- CIPOS™ IPM
- Discretes
- EiceDRIVER™ gate driver
- EconoPACK™
- EasyPACK™
- EconoDUAL™
- CoolSiC™ MOSFETs

C-HVAC

3 kW – 75 kW

Requirements

- Good price / performance ratio

Key applications

- Commercial Heating & Ventilation Air-Conditioning (C-HVAC)

Infineon products

- EconoPIM™
- EasyPIM™
- EiceDRIVER™ gate driver
- CIPOS™ IPM
- iMOTION™

Overview of medium voltage drives

Medium voltage drives

250 kW — 36 MW

Requirements

- Long life cycle
- Fast repair
- Redundancy
- High efficiency

Key applications

- Water pumps
- Material handling
- Power generation
- Oil & gas

Infineon products

- PrimePACK™
- PrimePACK™ .XT
- XHP™ 2
- XHP™ 3
- EconoDUAL™
- 62mm
- EiceDRIVER™ gate driver

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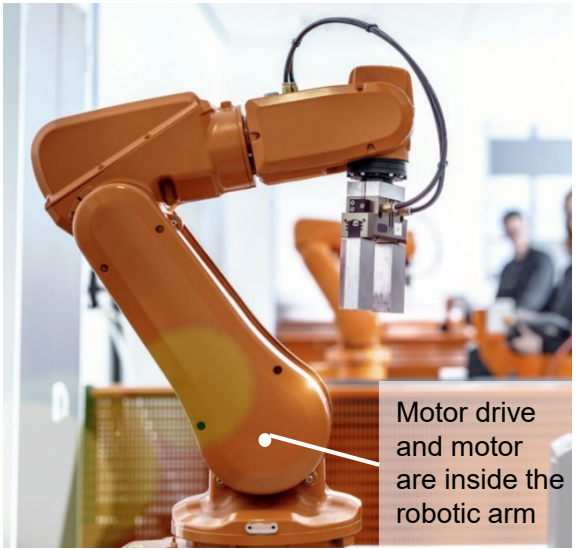
CoolSiC™ MOSFET - next generation of servo drives

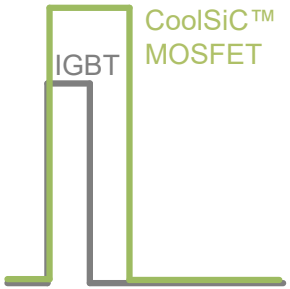


Servo motor

Automation

Industrial robots

Enhance pulse current capability



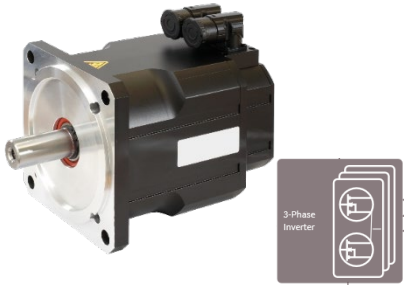
Current rating jump

Same frame extra current

Passive cooling

Fanless

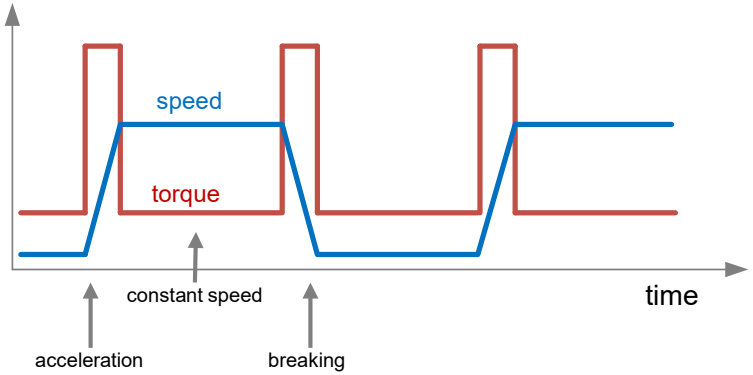
Inverter motor integration



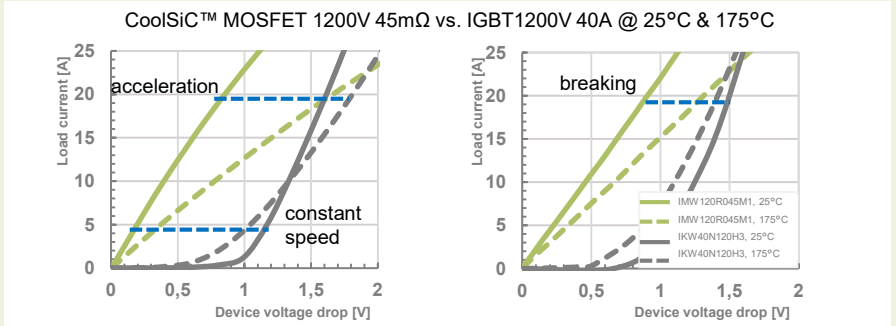
CoolSiC™ MOSFET in servo drives: conduction loss reduction in all operation modes

Typical load profile for a servo drive

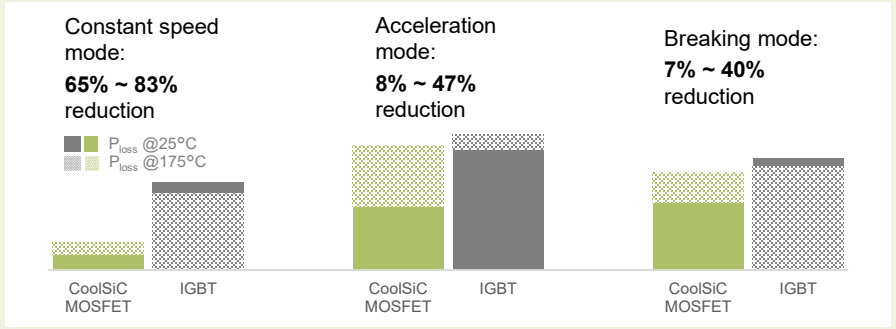
- High torque (current) in acceleration and breaking period
- Low torque (current) in constant speed period
- >90% time in low torque operation



Output characteristic comparison



CoolSiC™ MOSFET reduces conduction loss in all operation modes

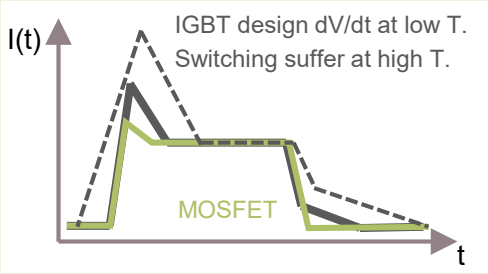


CoolSiC™ MOSFET in servo drives: switching loss reduction

Switching loss reduction by using CoolSiC™ MOSFET even at the same EMC level

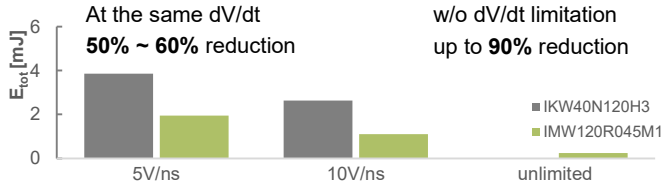
› Low Q_{rr} and No tail current

› Temperature independent switching losses

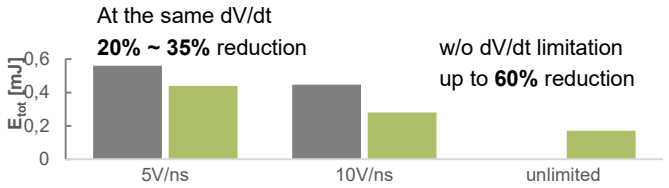


CoolSiC™ MOSFET reduces switching loss in all operation modes

Total switching loss at 150°C, acceleration and breaking (20 A)



Total switching loss at 25°C, constant speed operation (5 A)



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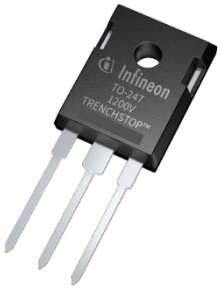
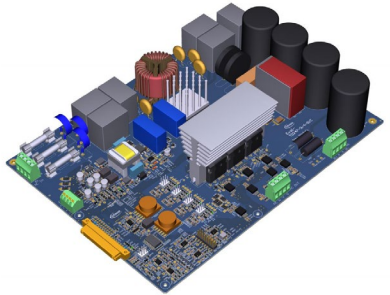
Case study of IGBTs and CoolSiC™ MOSFETs for industrial drives

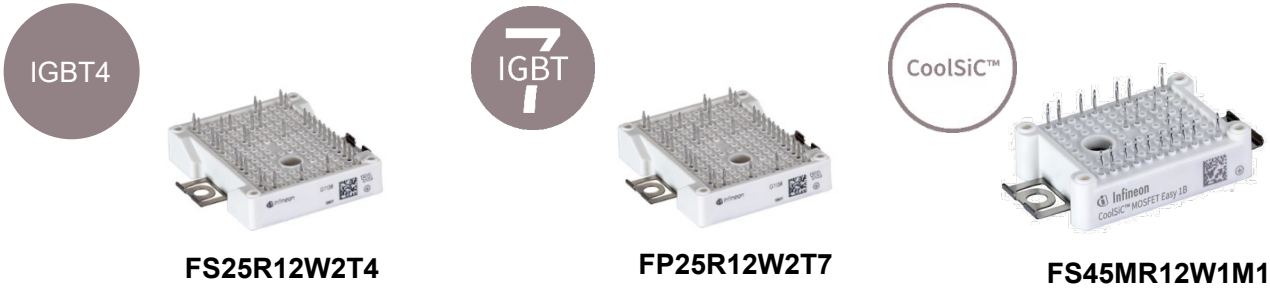
- Easy module
  - TRENCHSTOP™ IGBT4
  - TRENCHSTOP™ IGBT7
  - CoolSiC™ MOSFET
- dv/dt selection
- Switching losses
- Application simulation

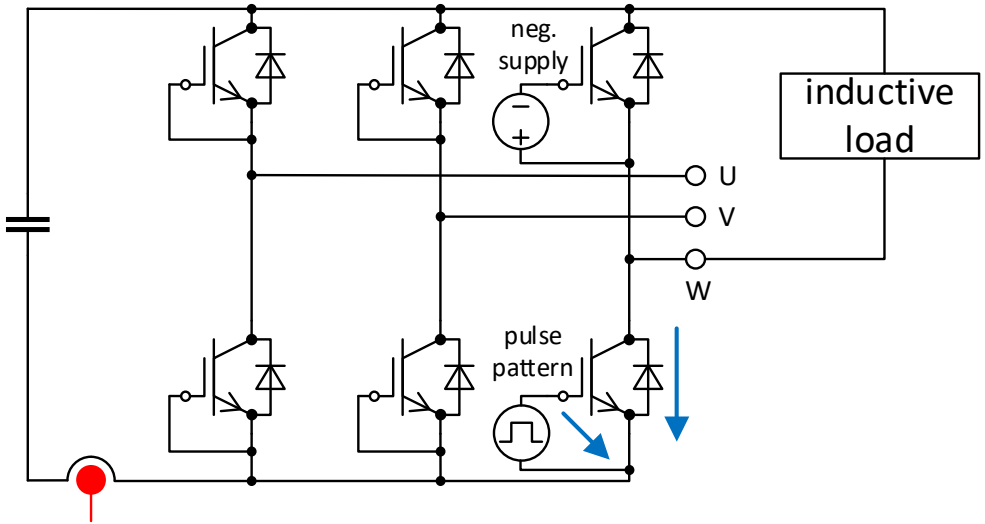
- Discrete device – TO247
  - HighSpeed 3 IGBT
  - CoolSiC™ MOSFET
- dv/dt selection
- Switching losses
- Application simulation
- Application measurement



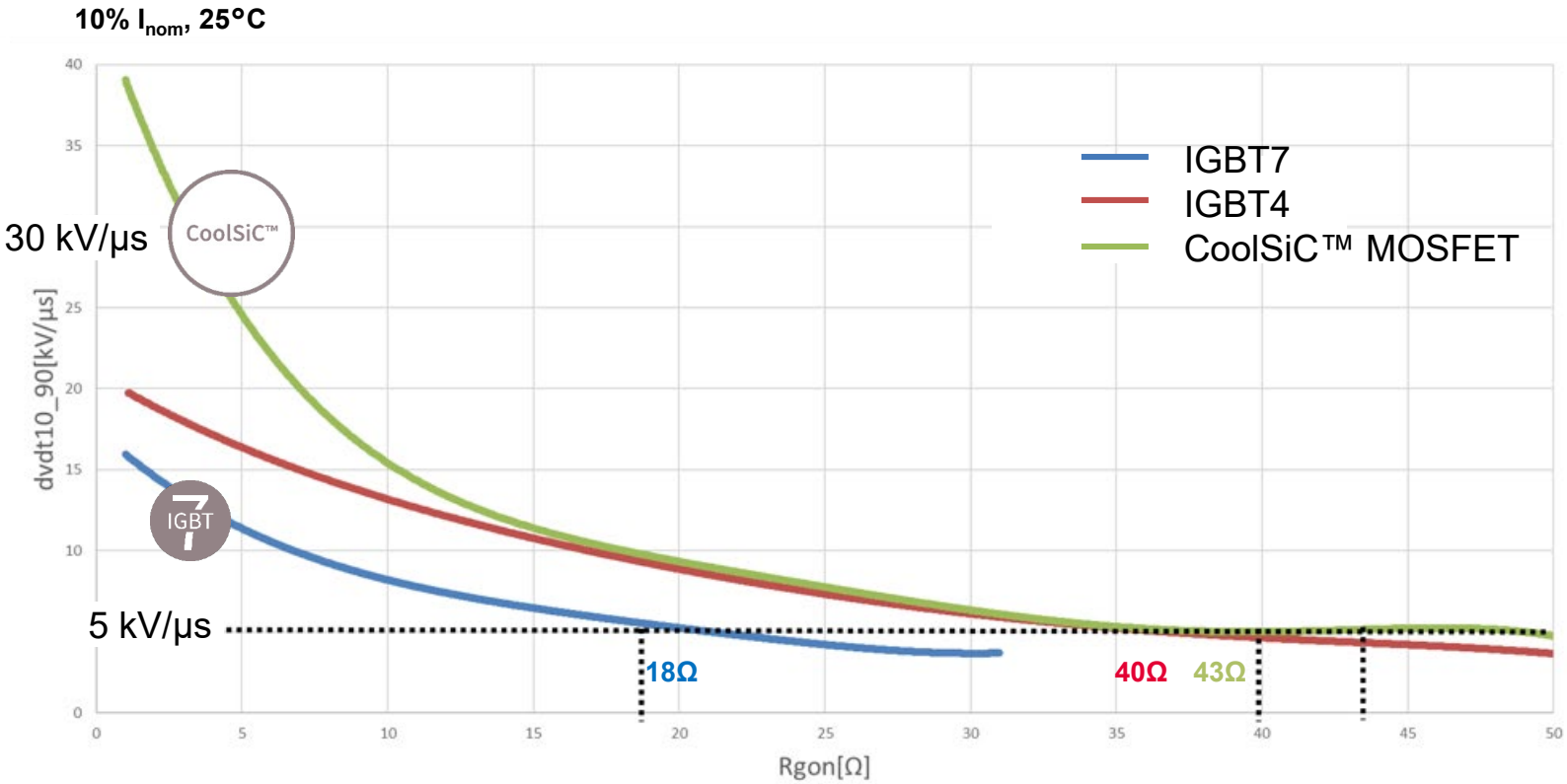


Case study: Easy package laboratory test configuration





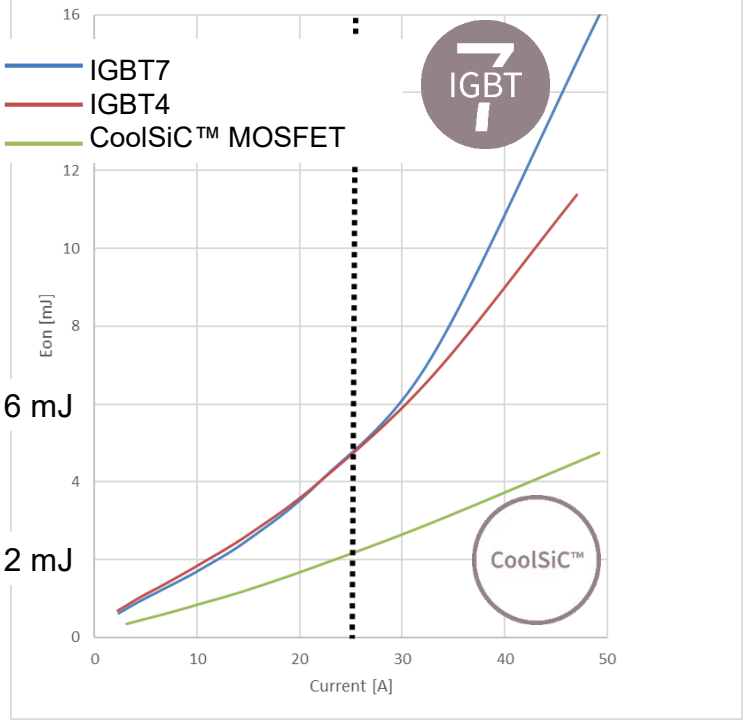
Case study: Easy package defining the gate resistance



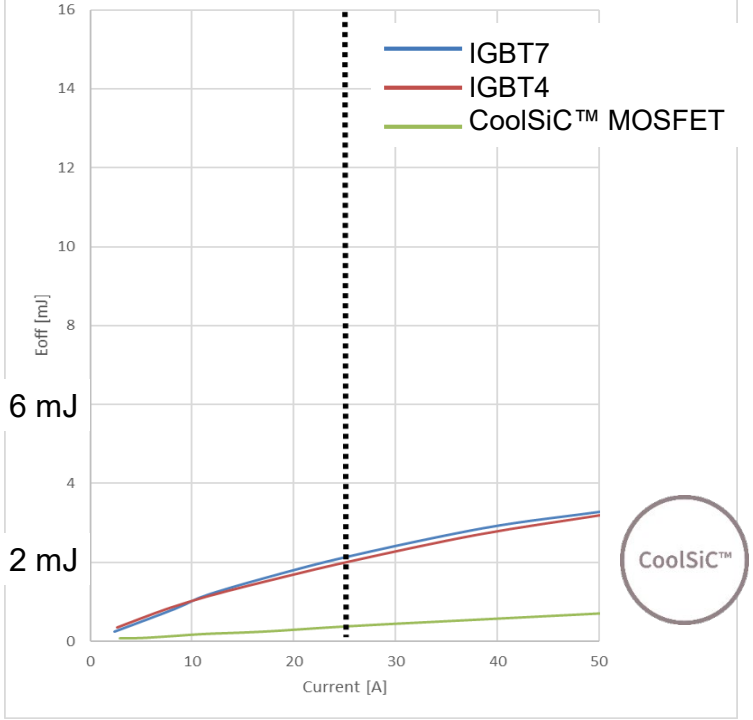
100% I_{nom}, 25°C → Worst case for turn off → Usually the off gate resistance can be smaller for 5 kV/µs

Case study: Easy package switching losses at R_G for 5 kV/µs

E_{on} @ 125°C with R_G for 5 kV/µs



E_{off} @ 125°C with R_G for 5 kV/µs

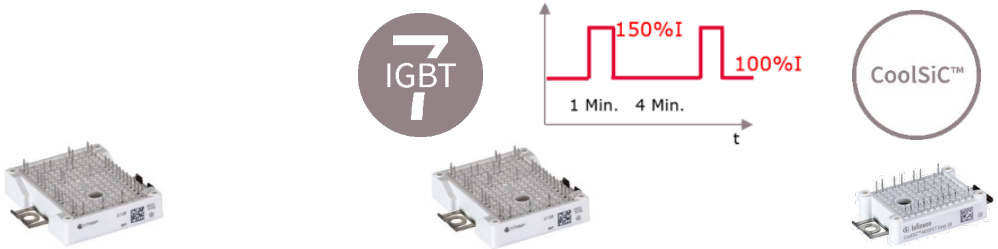


*Note that these graphs might not be 100% compatible with the following slides, due to systematic/random errors in measurement. Different dates/modules

Case study: Easy package input parameters

- V_{DC} = 600 V
- f_{out} = 50 Hz
- dv/dt_{1090} = 5 kV/µs
- f_{SW} = 3 kHz (6 kHz SiC)
- m_i = 1
- cos φ = 1
- T_A = 50°C
- τ_{thHA} = 60 s

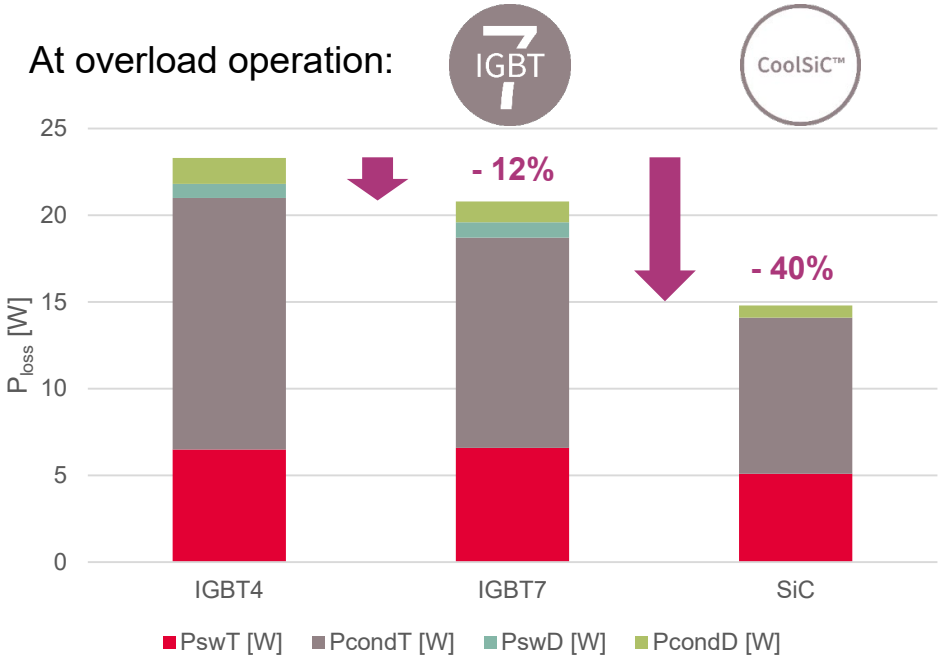
Load profiles	Overload profile
Heavy duty at 50 Hz	**12.5 A (100%) / 18.75 A (150%)**



Module parameters	25 A IGBT4 Easy2B	25 A IGBT7 Easy2B	45 mΩ (25 A) SiC Easy1B
$V_{CE,0}$@25 A, 125°C	2.15 V	1.75 V	1.5 V
$E_{on} + E_{off} + E_{rec}$ @ 25 A, 125°C $dv/dt_{10\text{-}90}$ = 5 kV/µs	290 µJ/A	306 µJ/A	98 µJ/A
$T_{vjop,max}$	150°C	175°C	150°C

Case study: Easy package power losses – 50 Hz operation

› At overload operation:



Source: siemens.com

Si or SiC – which technology is the better fit for servo drives

› SiC-MOSFET will not replace IGBT in most servo drives applications, if
  › Sufficient power semiconductor cooling is possible
  › Only moderate output frequencies are required f_{out} < 800 Hz

› Conduction losses decrease significantely from IGBT4 technology to IGBT7.
› With SiC a reduction in switching losses is also possible, which would allow us to operate at higher switching frequencies.

Case study of IGBTs and CoolSiC™ MOSFETs for industrial drives

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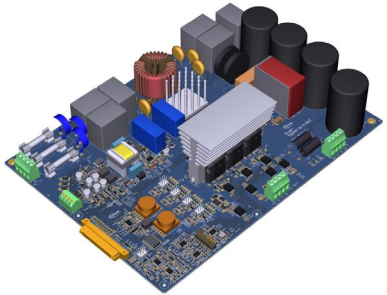
  - TRENCHSTOP™ IGBT7
  - CoolSiC™ MOSFET
- dv/dt selection
- Switching losses
- Application simulation

- Discrete device – TO247
  - HighSpeed 3 IGBT
  - CoolSiC™ MOSFET
- dv/dt selection
- Switching losses
- Application simulation
- Application measurement

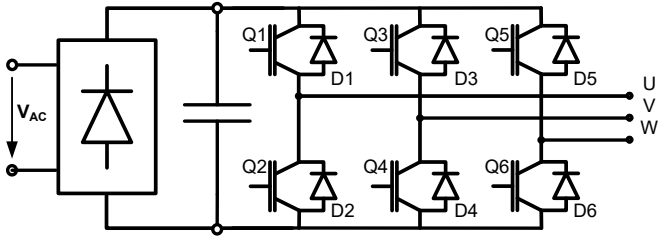


Case study: discrete device – TO247 model and parameters

- Three-phase voltage source inverter (B6) topology was used in order to understand the behavior of servo-drives
- Estimation of junction T_j performance and corresponding losses of the inverter for 1200 V CoolSiC™ MOSFET vs HighSpeed 3 IGBT solutions
- The simulation study was done based on experimental test results

Test/simulation conditions

- Simulation validation model of a three-phase voltage source inverter (B6) was used:

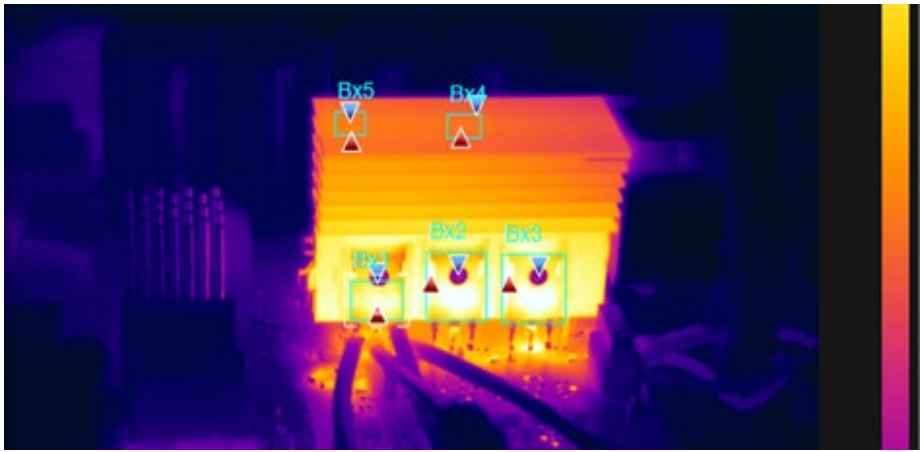


Based on calibration test results with following conditions:

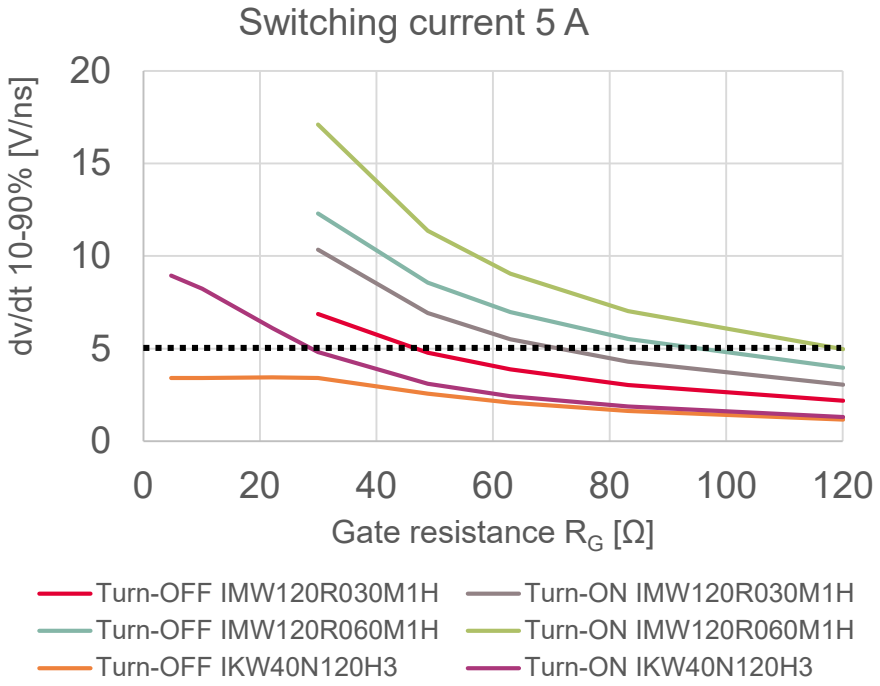
V_{dc} = 600 V, $V_{N,out}$ = 400 V, **$I_{N,out}$ = 5 A – 25 A**, $f_{N,sin\text{-}out}$ = 50 Hz,

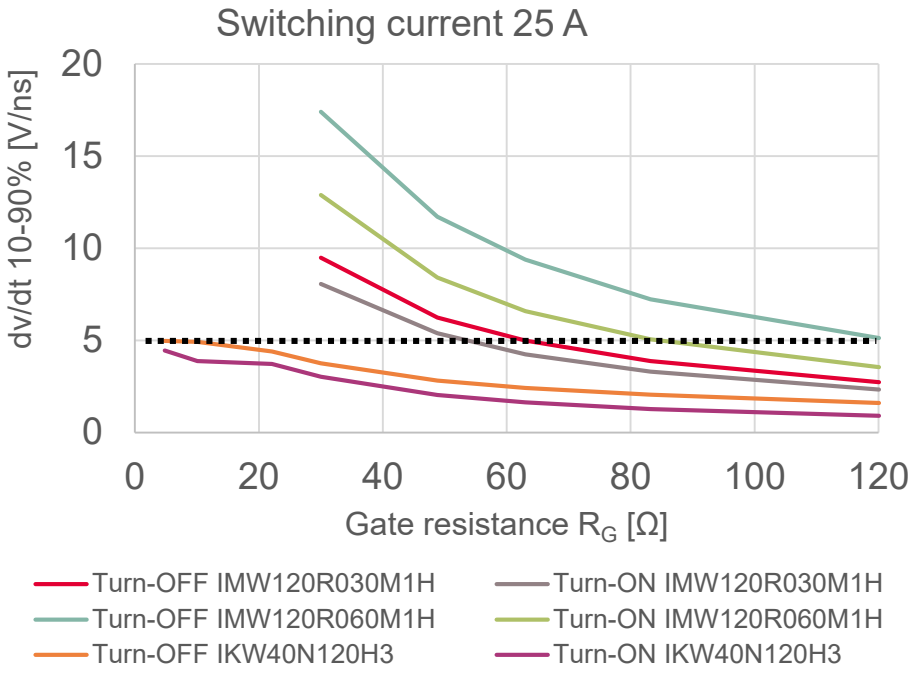
f_{sw} = 4-16 kHz, T_{amb} = 25°C, $\cos(\varphi)_N$ = 0.9, $R_{th,HA}$=0.63 K/W, **dv/dt = 5 V/ns**

Thermal measurement of a servo-drive evaluation board



Case study: discrete device – TO247
Gate resistance R_G selection to assure < 5 V/ns





IKW40N120H3
25 A Turn OFF – **39 Ω**
5 A Turn ON – **39 Ω**

IGBT3

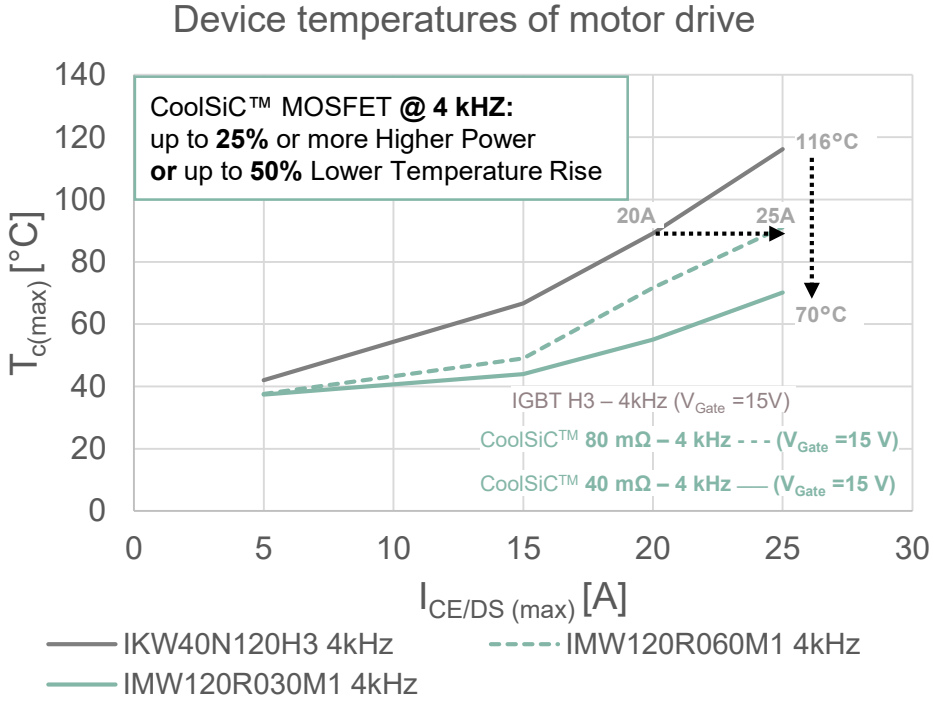
IMW120R030M1H
25 A Turn OFF – **68 Ω**
5 A Turn ON – **68 Ω**

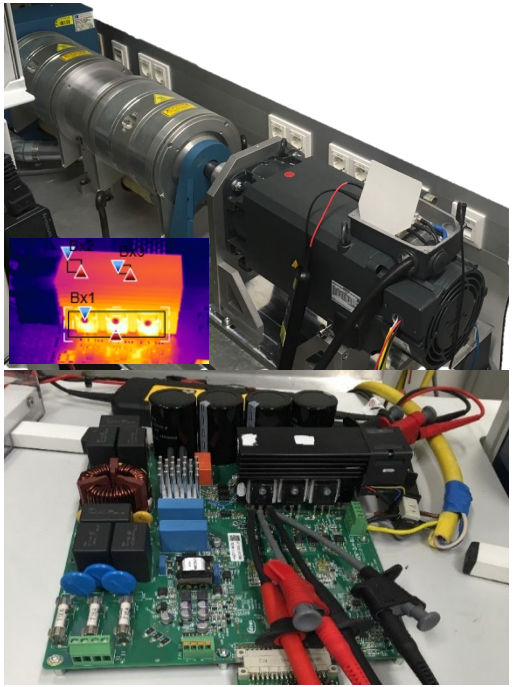
CoolSiC™

IMW120R060M1H
25 A Turn OFF – **120 Ω**
5 A Turn ON – **120 Ω**

CoolSiC™

What is the benefit of CoolSiC™ MOSFET at low switching frequency (4 kHz)?

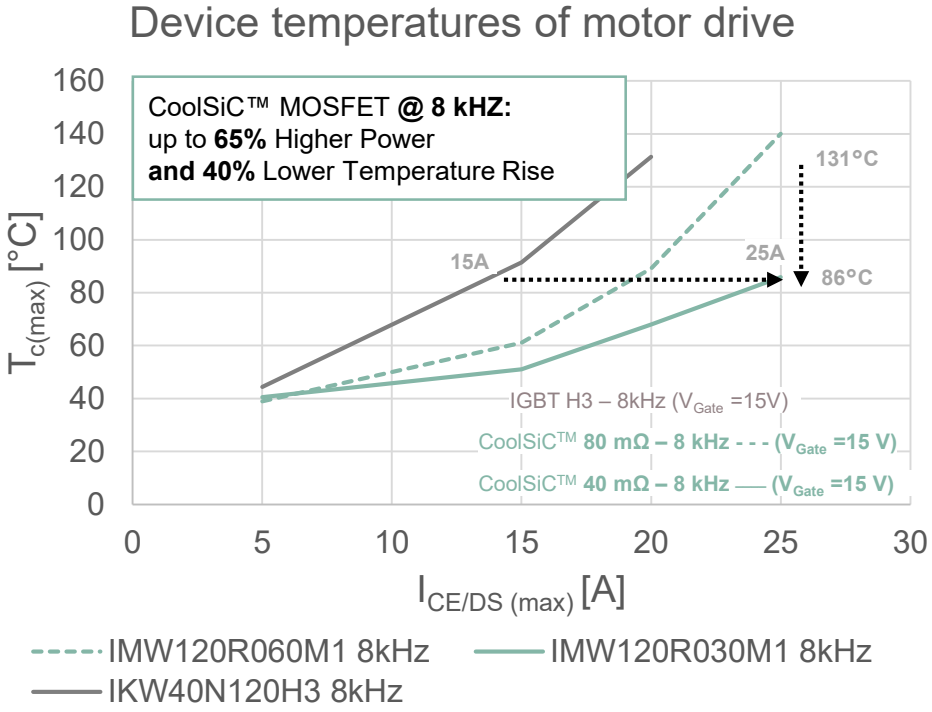


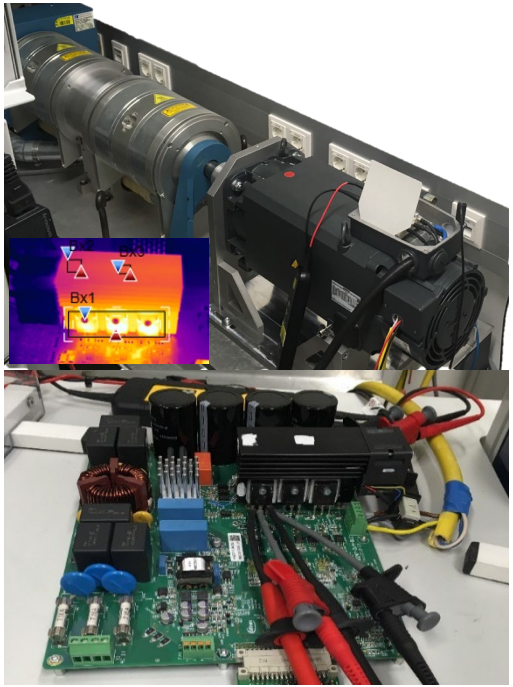


Temperature Results **at 5 V/ns**

The motor drive conditions
M=1, V_{dc}=600 V, f_{sin}=50 Hz, R_G @ dv/dt=5 V/ns, f_{sw}=4-16kHz with cable length (C.L.) of 5 m, T_{amb} = 25°C

What is the benefit of CoolSiC MOSFET™ at higher switching frequency (8 kHz)?

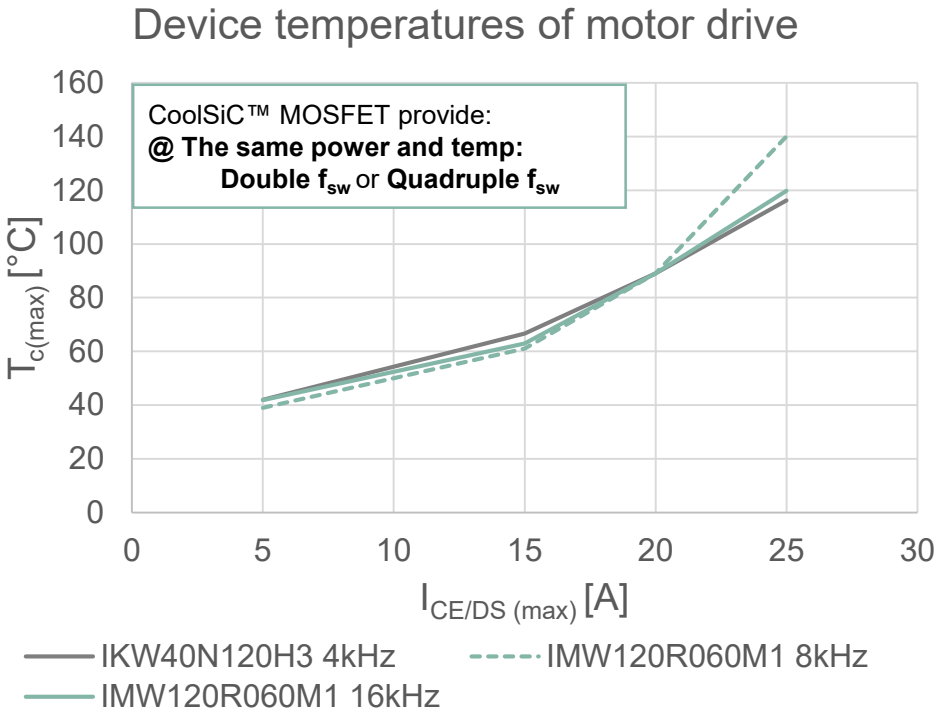


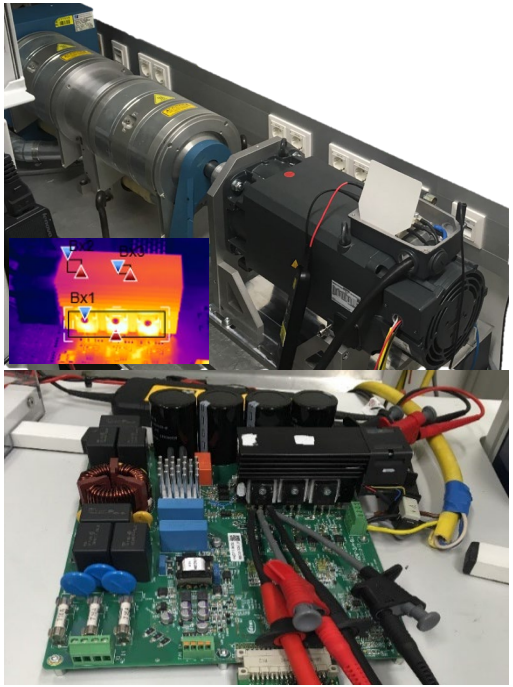


Temperature Results **at 5 V/ns**

The motor drive conditions
M=1, V_{dc}=600 V, f_{sin}=50 Hz, R_G @ dv/dt=5 V/ns, f_{sw}=4-16kHz with cable length (C.L.) of 5 m, T_{amb} = 25°C

What is the max f_{sw} of CoolSiC MOSFET™ at the same power and 4 kHz?





Temperature Results **at 5 V/ns**

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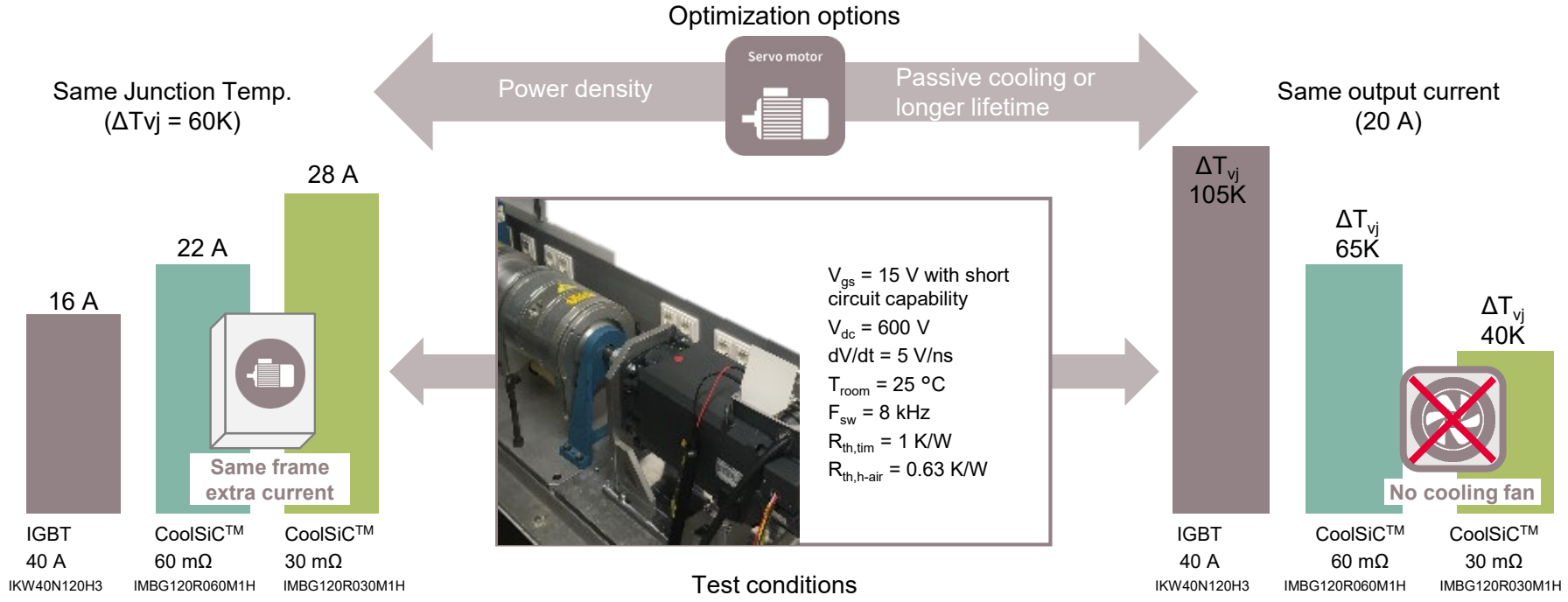
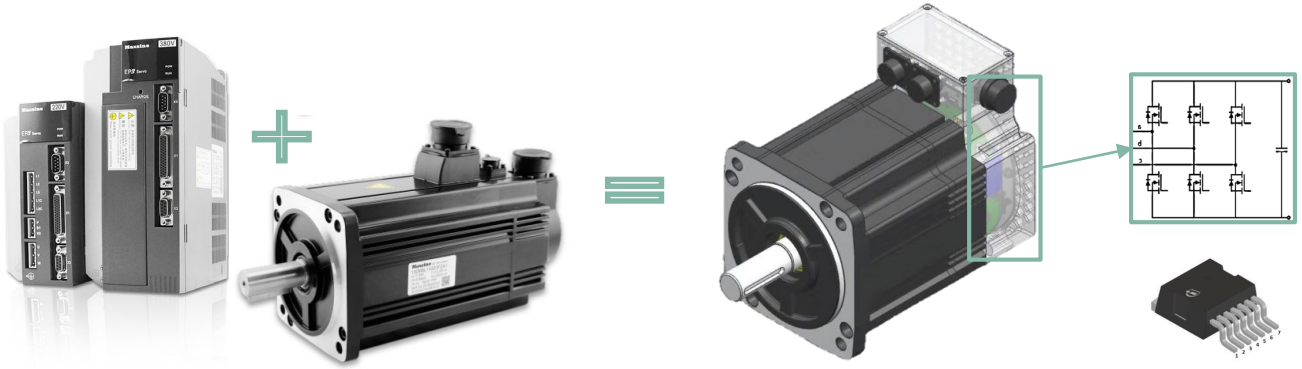
M=1, V_{dc}=600 V, f_{sin}=50 Hz, R_G @ dv/dt=5 V/ns, f_{sw}=4-16kHz with cable length (C.L.) of 5 m, T_{amb} = 25°C

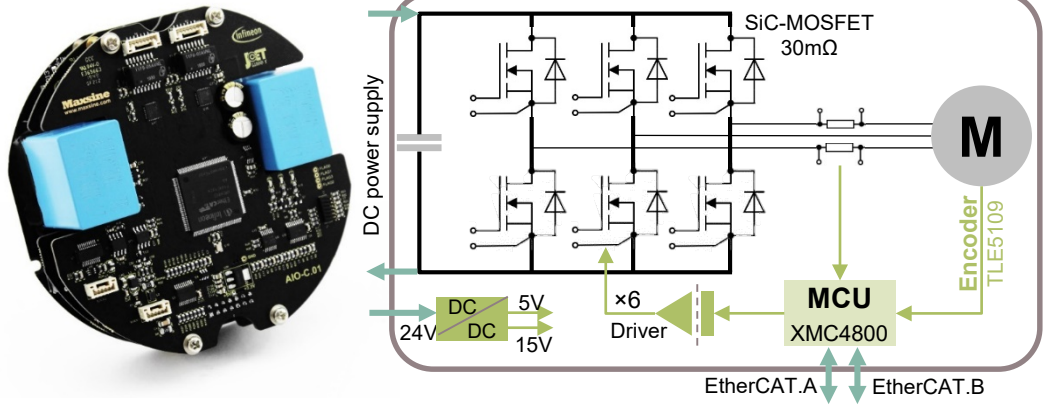
$R_{DS(on)}$ selection example for various target requirements in a servo drive solution



CoolSiC™ MOSFET enables fanless drives, higher currents for a given frame size, and more...

Application example with CoolSiC™ MOSFET for integrated servo motors





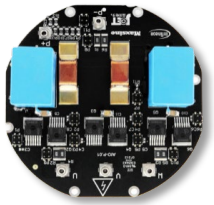
Infineon products:

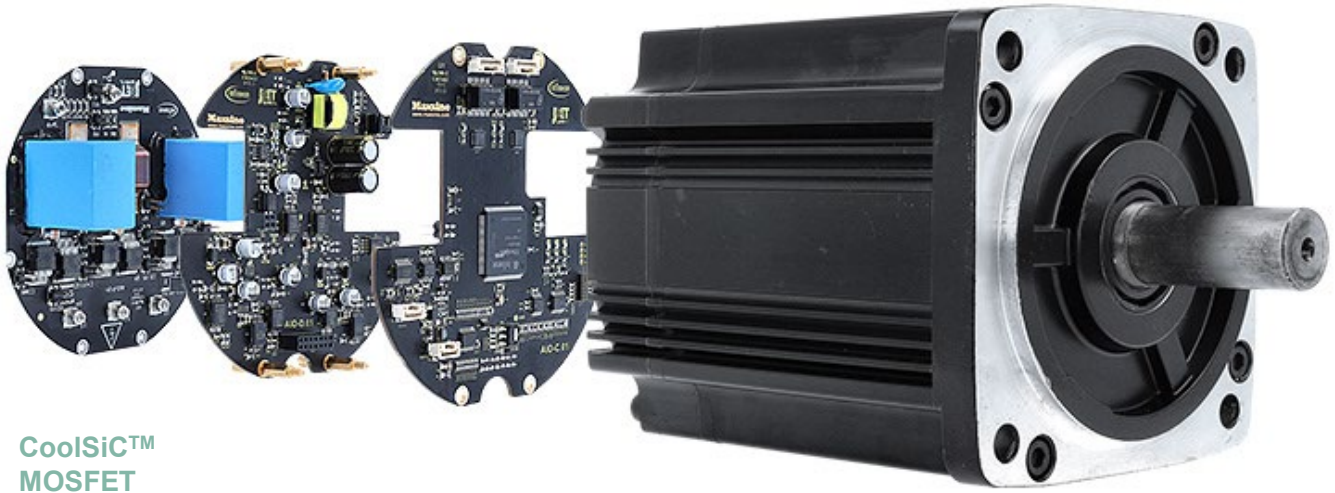
- CoolSiC™ MOSFET 1200 V 30 mΩ
  - 6 x IMBG120R030M1H
- EiceDrivers
  - 6 x 1EDI20I12MH
- Microcontroller
  - 1 x XMC™ 4800

Source: H. Weng, et al., “An integrated servo motor drive with self-cooling design by using SiC-MOSFET” *Proc. PCIM Asia*, 2020, in press

Inverter motor integration powered by Infineon products

A4 paper





CoolSiC™
MOSFET
IMBG120R030M1H

This reference design orderable in Q4 2020:

- *REF-DR3KIMBGSICMA*

Also Evaluation boards orderable in Q4 2020:

- *REF_SIC_D2pak_MC,* with Miller Clamp function
- *REF_SIC_D2pak_BP,* with bipolar power supply and separated sink/source output

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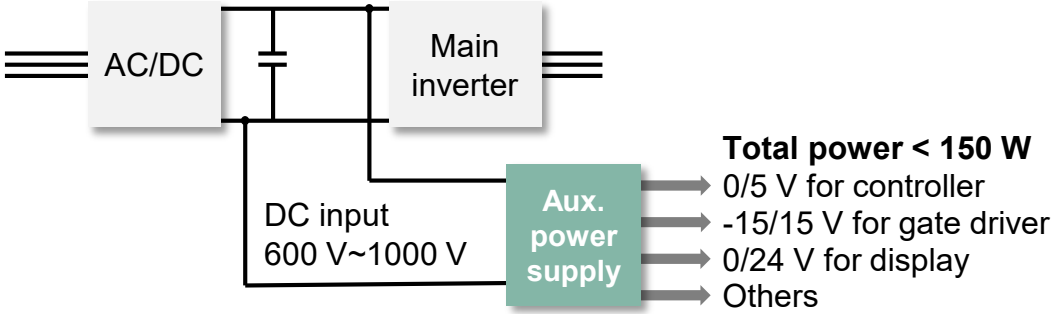
Auxiliary power supply with 1.7 kV CoolSiC™ MOSFET

Possible applications

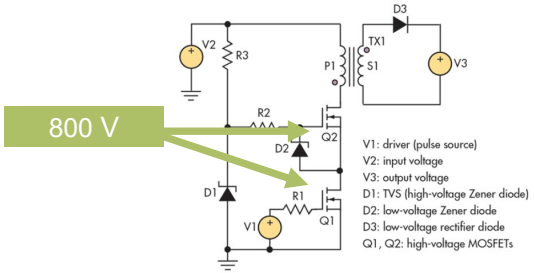


Evaluation board available

Buy online

Why 1.7 kV CoolSiC™ MOSFET?

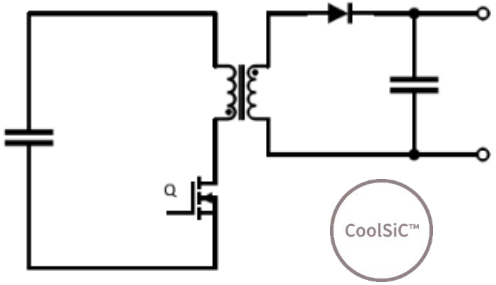
State-of-the-art solutions
(Multiple 800 V of single 1500 V Si MOSFETs)



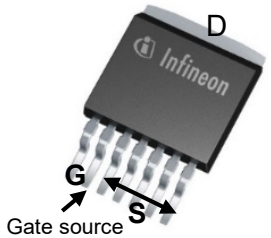
or 1500 V Si MOSFET
➔ High $R_{DS(on)}$

1.7 kV CoolSiC™ MOSFET solution

Simple fly-back topology with low ohmic transistor



D²PAK 7L for 1700 V CoolSiC™ MOSFET



Perfect fitting gate voltage 0/12~15 V

Enhanced creepage and clearance distance ensure the device meets the high voltage standards with minimum design efforts

- Comparing with multiple 800 V or single 1500 V Si MOSFET solutions:
  - Greatly reduces part counts → BoM reduction
  - Higher voltage margin and lower device count → increased reliability

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5. CoolSiC™ MOSFET evaluation boards
6. Industrial CoolSiC™ portfolio
7. Key takeaways

CoolSiC™ MOSFET evaluation boards

Board name	Description
EVAL-M5-IMZ120R-SIC	Motor drives inverter board with CoolSiC™ MOSFET in TO247 package
EVAL-M5-E1B1245N-SIC	CoolSiC™ MOSFET motor drives evaluation board for 7.5 kW in EasyPACK™ 1B package
EVAL-PS-E1BF12-SIC	Evaluation board for CoolSiC™ Easy1B half-bridge modules
EVAL_PS_SIC_DP_MAIN	CoolSiC™ MOSFET 1200 V in TO-247 3-/4-pin evaluation platform
REF_PS_SIC_DP1	Miller clamp function board for CoolSiC™ MOSFET 1200 V in TO-247 3-/4-pin evaluation platform
REF_PS_SIC_DP2	Bipolar supply function board for CoolSiC™ MOSFET 1200 V in TO-247 3-/4-pin evaluation platform
EVAL-1EDC20H12AH-SIC	Gate driver evaluation board with EiceDRIVER™ and CoolSiC™ MOSFET

find more online

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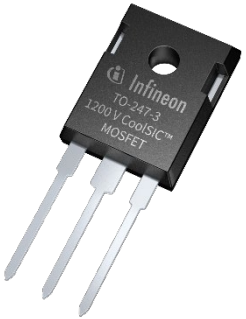
CoolSiC™ MOSFET 1200 V / 1700 V discrete

TO-247

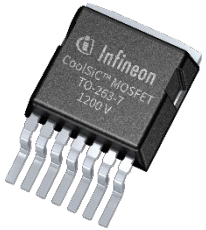
R_{dson} [mΩ]	1200 V TO-247-3
30	IMW120R030M1H
45	IMW120R045M1
60	IMW120R060M1H
90	IMW120R090M1H
140	IMW120R140M1H
220	IMW120R220M1H
350	IMW120R350M1H



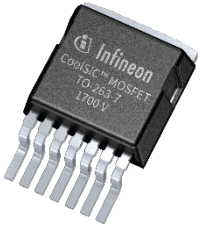
1200 V TO-247-4
IMZ120R030M1H
IMZ120R045M1
IMZ120R060M1H
IMZ120R090M1H
IMZ120R140M1H
IMZ120R220M1H
IMZ120R350M1H

SMD

R_{dson} [mΩ]	1200 V D^2PAK-7
30	IMBG120R030M1H*
45	IMBG120R045M1H*
60	IMBG120R060M1H*
90	IMBG120R090M1H*
140	IMBG120R140M1H*
220	IMBG120R220M1H*
350	IMBG120R350M1H*



R_{dson} [mΩ]	1700 V D^2PAK-7 high creepage
450	IMBF170R450M1
650	IMBF170R650M1
1000	IMBF170R1K0M1



Orderable, registerable and available / *Samples available

Solar

EV-Charging

Storage

UPS

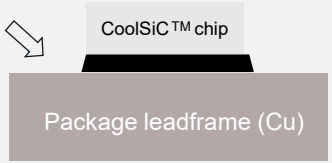
Industrial SMPS

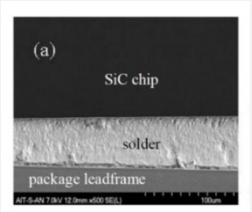
Drives

Significant improvement of thermal capabilities by .XT interconnection

Standard interconnection

Standard soldering

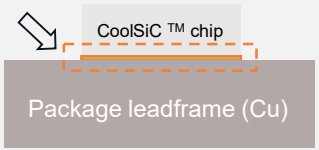


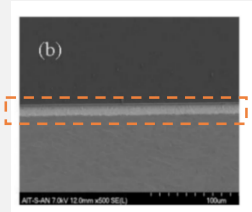


Standard soldering

.XT interconnection in TO-263-7

Diffusion soldering

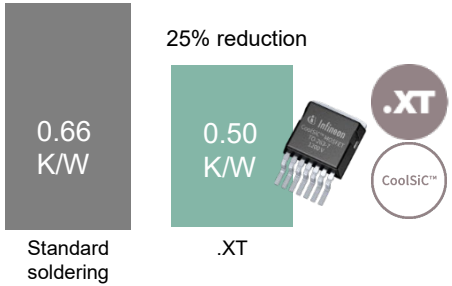




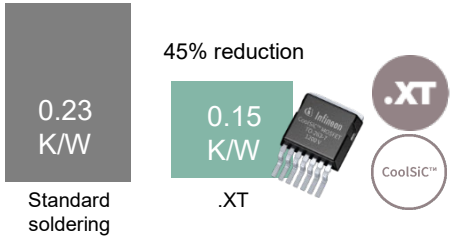
Elimination of solder joint through diffusion soldering

Thermal performance in small form factor

Max R_{th}

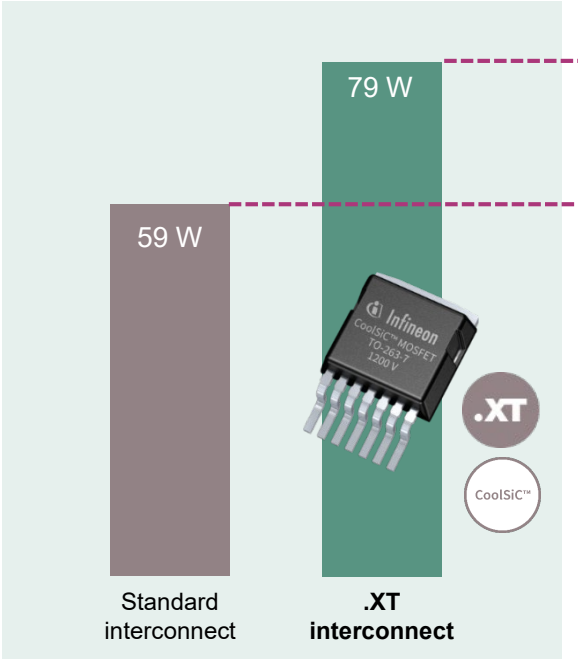


Max Z_{th} @ 1 ms



.XT enhances optimization potential even further for SiC based designs

Loss dissipation capability



>30% extra loss can be dissipated by .XT interconnection

Examples of application optimizations

Up to 14% **extra current**

Up to 14% extra power in given system size

or

Doubling f_{sw}

(2L 3-ph full bridge)

Half size of passives

or

10 ~15°C **lower temperature**

Up to 80% lifetime extension

Conditions:

T_{case} = 100°C;

Allowed temperature T_{vj} = 130°C

CoolSiC™ MOSFET: 30 mΩ, IMBG120R030M1H

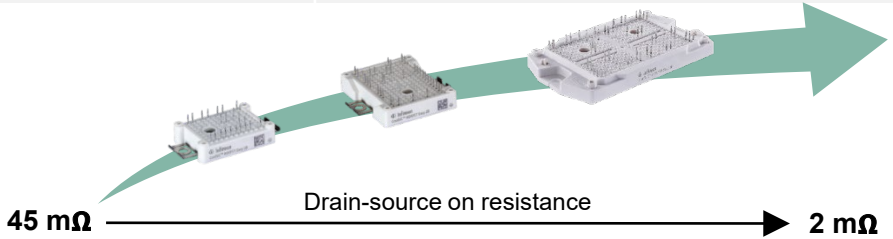
CoolSiC™ MOSFET 1200 V in EasyPACK™

R_{Dson} [mΩ]	1200 V half-bridge	1200 V SixPACK
45	FF45MR12W1M1_B11	FS45MR12W1M1_B11 MADK Board
23	FF23MR12W1M1(P)_B11 EVAL Board	
11	FF11MR12W1M1(P)_B11 EVAL Board FF11MR12W1M1_B70	
8	FF8MR12W2M1(P)_B11	
6	FF6MR12W2M1(P)_B11 FF6MR12W2M1_B70	

Orderable, registerable and available now

In development

B11 = PressFIT Pin
B70 = AlN ceramic
P = Thermal Interface Material (TIM)
E = common Emitter



CoolSiC™ MOSFET 1200 V in 62mm - released portfolio

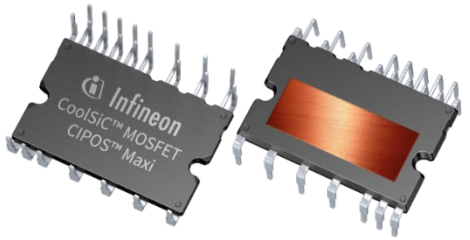
On-resist. R_{DSon} [mΩ]	$I_{D\ nom}$ [A]	1200V	Samples	SOP plan
2	**500**	FF2MR12KM1	On stock	Series
3	**375**	FF3MR12KM1	On stock	Series
6	**250**	FF6MR12KM1	On stock	Series
2	**500**	FF2MR12KM1P	On stock	Series
3	**375**	FF3MR12KM1P	On stock	Series
6	**250**	FF6MR12KM1P	On stock	Series

Modules are available both as standard and TIM version, indication “P”

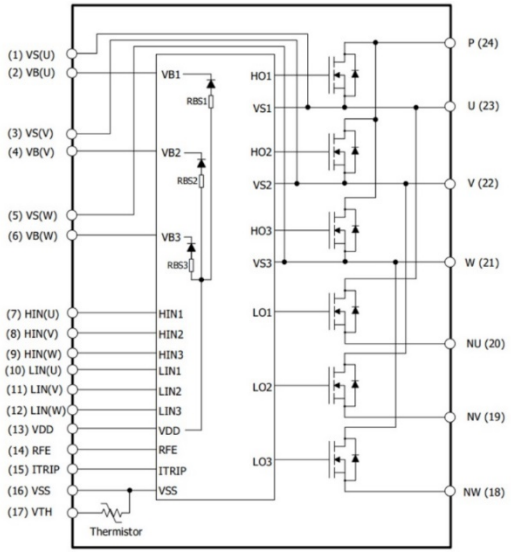
More niche application to come!

CIPOS™ Maxi 1200 V, 20 A three-phase intelligent power module

CIPOS™ Maxi 1200 V - IM828-XCC



- Based on 1200V CoolSiC™ MOSFETs
- Motor power rating up to 4.8 kW at 10 kHz
- Rugged 1200 V SOI gate driver technology with stability against transient
- Over current shutdown
- Under-voltage lockout at all channels
- All of 6 switches turn off during protection
- Cross-conduction prevention
- Built-in NTC thermistor for temperature monitor
- Programmable fault clear timing and enable input



Challenges of driving CoolSiC™ MOSFETs

- **SiC MOSFETs** are **fast switching** AND high voltage devices, whose **common mode transient (CMT)** can reach **50 V/ns** or above
- Higher switching speed requires **higher gate drive current**, **well-matched delays** & **accurate timing**
- **SiC MOSFETs** may need a **negative gate voltage** or a **Miller clamp**
- **SiC MOSFETs** may need **fast short circuit protection** as its short circuit capability is less than traditional IGBT

Recommended EiceDRIVER™ for 1200 V CoolSiC™ MOSFETs

Products	Part Number	Typ. Peak drive current	V_{CC2}–V_{EE2}	Typ.UVLO thresholds	Typ. Prop. delay	Miller-Clamp	Other key features	Package
1EDI compact isolated High-Side driver family (active & preferred)	1EDI20I12MF	4.1 A	20 V	11.9 V / 11 V	≤ 300 ns	Yes	Functional isolation	DSO-8 150 mil 
	1EDC20H12AH	3.5 A	35 V	12 V / 11.1 V	≤ 125 ns	No	8 mm Creepage clearance; UL 1577 certified with V_{ISO} = 3 kV(rms) for 1 s Miller-Clamp option	DSO-8 300 mil 
	1EDC60H12AH	9.4 A	35 V	12 V / 11.1 V	≤ 125 ns	No		
	1EDC20I12MH	4.1 A	20 V	11.9 V / 11 V	≤ 300 ns	Yes		
1ED-F2 isolated High-Side driver with integrated protection (active & preferred)	1ED020I12-F2	2.0 A	28 V	12 V / 11 V	≤ 170 ns	Yes	Short circuit clamping; DESAT protection; Active shutdown	DSO-16 
2ED-F2 isolated dual High-Side driver with integrated protection (active & preferred)	2ED020I12-F2	2.0 A	28 V	12 V / 11 V	≤ 170 ns	Yes		DSO-36 
1EDS Slew Rate Control (SRC) isolated High-Side driver (active & preferred)	1EDS20I12SV	2.0 A	28 V	11.9 V / 11 V	≤ 485 ns	Yes	Real-time adjustable gate current control; OCP; Soft turn-off shut down; Two-level turn-off; UL 1577 certified with V_{ISO} = 5 kV(rms) for 1 s	DSO-36 

Recommended EiceDRIVER™ for 1200 V CoolSiC™ MOSFETs

Products	Part number	Typ. Peak drive current	V_{CC2}–V_{EE2}	Typ.UVLO thresholds	Typ. Prop. delay	Miller-Clamp	Other key features	Package
1ED31xx isolated High-Side driver family	1ED3121MU12H	5.5 A	35 V	12.5 V / 10.5 V	≤ 100 ns	No	8 mm Creepage clearance; short circuit clamping; active shutdown; UL 1577 certified Miller-Clamp option	DSO-8 300 mil 
	1ED3122MU12H	10 A	35 V	10 V / 8 V	≤ 100 ns	Yes		
	1ED3124MU12H	14 A	35 V	12.5 V / 10.5 V	≤ 100 ns	No		
1ED34xx isolated High-Side driver with integrated protection	1ED3431MU12M	3 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes	Short circuit clamping; fast & accurate DESAT protection; active shutdown, soft turn-off; UL 1577 certified	DSO-16 
	1ED3461MU12M	6 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes*		
	1ED3491MU12M	9 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes*		
1ED38xx isolated High-Side driver with I²C configurability & integrated protection	1ED3830MU12M	3 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes	Short circuit clamping; fast & accurate DESAT protection; active shutdown; soft turn-off; UL 1577 certified	DSO-16 
	1ED3860MU12M	6 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes		
	1ED3890MU12M	9 A	35 V	12.6 V / 10.4 V	≤ 255 ns	Yes		

*Clamp driver for external MOSFET

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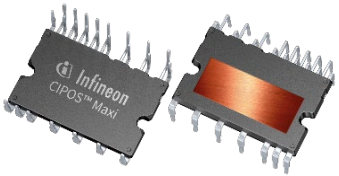
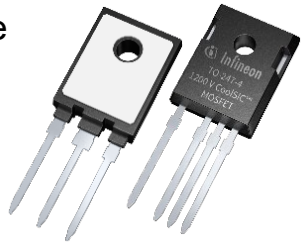
CoolSiC™ MOSFET
Solutions for integrated servo motor for robotics

› **CooSiC™ IPM – CIPOS™ Maxi**
- IM828
- Compact design
- Integrated driver and protection circuit



› **CoolSiC™ module – EasyPACK™**
- FS45MR12W1M1_B11
- B6 topology with NTC
- Simple mounting

› **CooSiC™ discrete – TO-247-3/4**
- IMW120R045M1
- Different $R_{DS(on)}$ values are available



› **CooSiC™ discrete – TO-263-7**
- IMBG120R030M1H
- Cooling concept via IMS
  ➔ Good thermal performance
- Different $R_{DS(on)}$ values are available

› **Infineon EiceDRIVER™** enables highest performance of SiC MOSFETs

This makes CoolSiC™ the perfect solution for servo drives

Si or SiC – which technology is the better fit for servo drives

- SiC-MOSFET will not replace IGBT in most servo drives applications, if
  - Sufficient power semiconductor cooling is possible
  - Only moderate output frequencies are required f_{out} < 800 Hz
- SiC-MOSFET will be used to enable compact design and to enable savings on system level, e.g. less cabling, fanless operation

- Lower switching losses compared to IGBTs at same dv/dt level and enhanced switching control (dv/dt) is possible via gate resistor
  - Efficiency increase is feasible and reduction of cooling effort
  - Simplification of inverter integration into the motor
- Simple and efficient auxiliary power supply design with 1.7 kV CoolSiC™ MOSFETs
- Four different package types are available with CoolSiC™ – a unique Infineon offering: IPM, modules, through hole (TO-247) and SMD (TO-263)

Useful information material and tools

Product page links

- CIPOS™ IPM
- iMOTION™
- CoolSiC MOSFETs
- TRENCHSTOP™ IGBT7
- Easy power modules
- EconoPIM™ 2 & 3
- EconoDUAL™ IGBT modules
- EconoPACK™ 4
- PrimePACK™ IGBT modules
- 32-bit XMC™ microcontroller
- ISOFACE™ digital input ICs
- OPTIGA™ security solutions
- Magnetic sensors
- Current sensor
- EiceDRIVER™ gate driver
- External memory
- Wireless connectivity
- PSoC62, PSoC64

Application pages

- Overview
- Induction motor
- Permanent magnet synchronized motor
- Servo motor
- Motor control for industrial automation
- Robotics

MADK

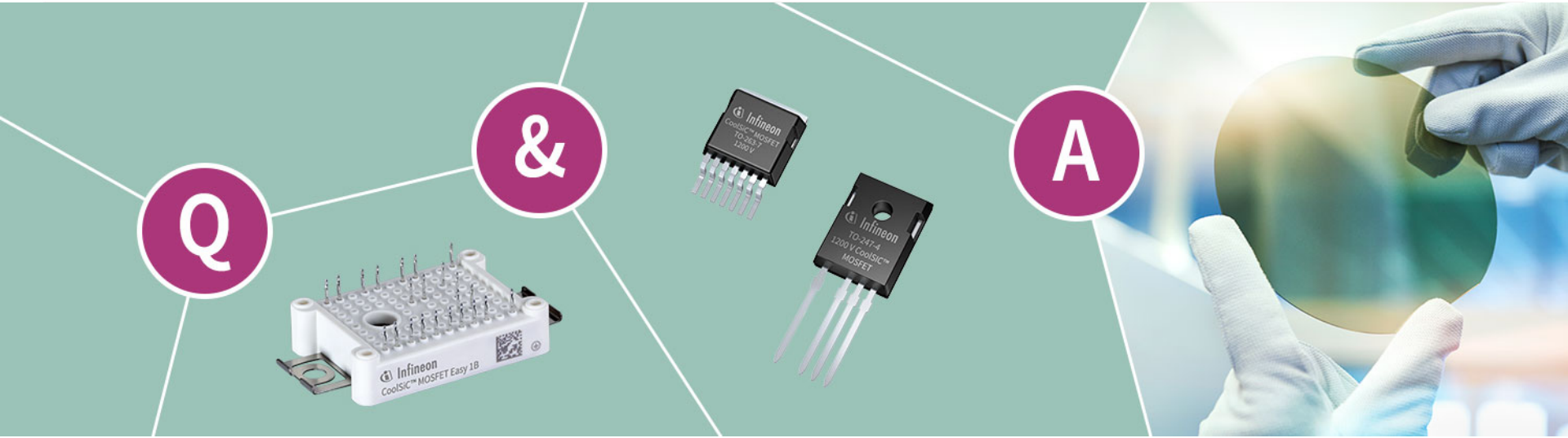
- iMOTION™ Modular Application Design Kit MADK

Online simulations

- IPOSIM
- Discrete IGBT Motor Drive Simulator
- IPM 3-phase Inverter Simulator

Online forums

- Silicon Carbide forum
- IGBT modules forum
- IGBT discretes forum



We are happy to answer your questions now.

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