Low cost 100 W sensorless FOC fan motor drive solution

Agenda

1. Fan market overview
2. The 100 W demo introduction
3. Key component highlights
4. More support

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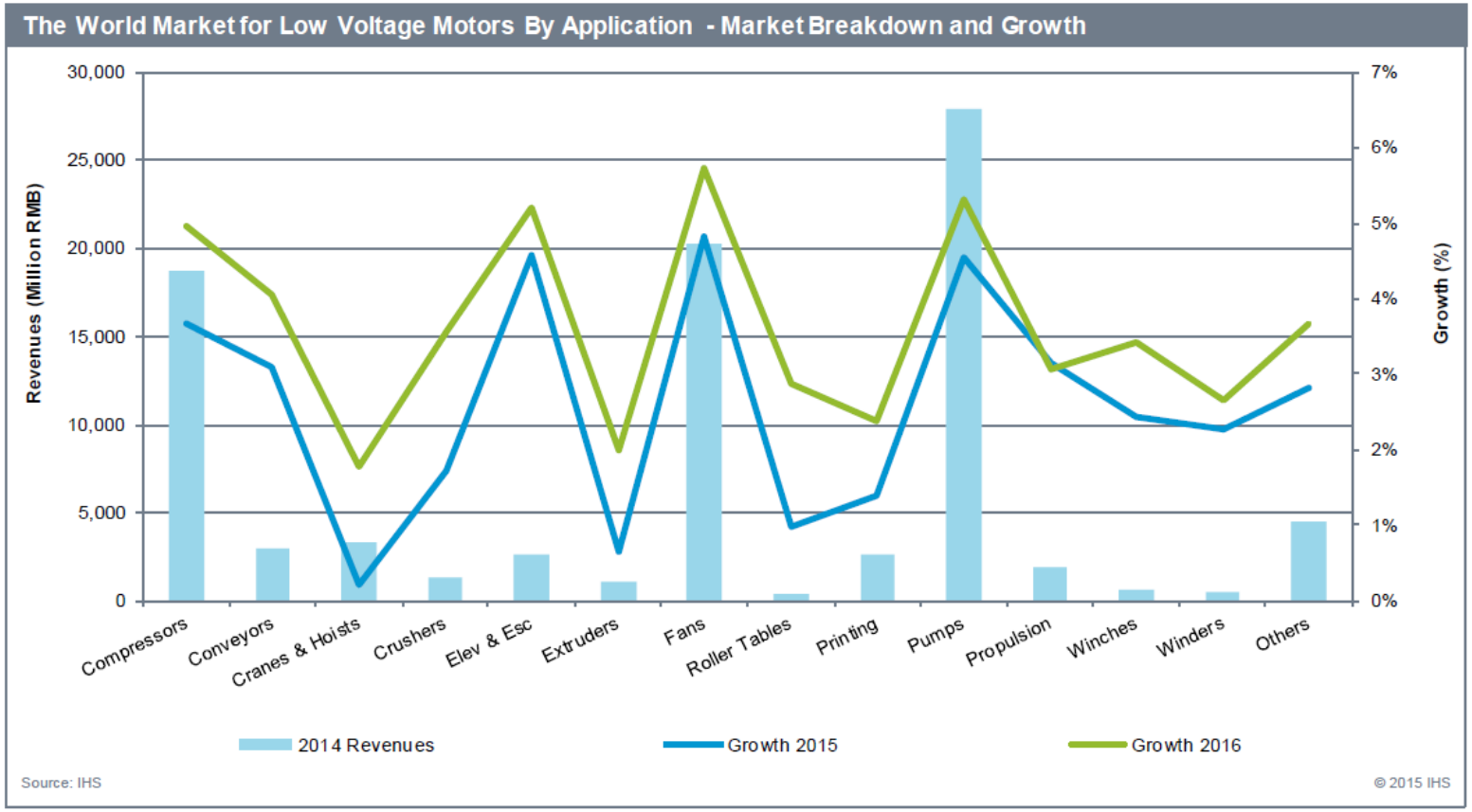
Pumps, fans and compressors are dominating worldwide motor shipments annually



- Market size for pumps, fans and compressors is around 90BUSD, accounting 75% if worldwide low-voltage motor shipments anually
- In year of 2014, fans sales revenue is 20BRMB, estimated 6% increase in 2016
- OEMs are being pushed for whole system efficiency improvement

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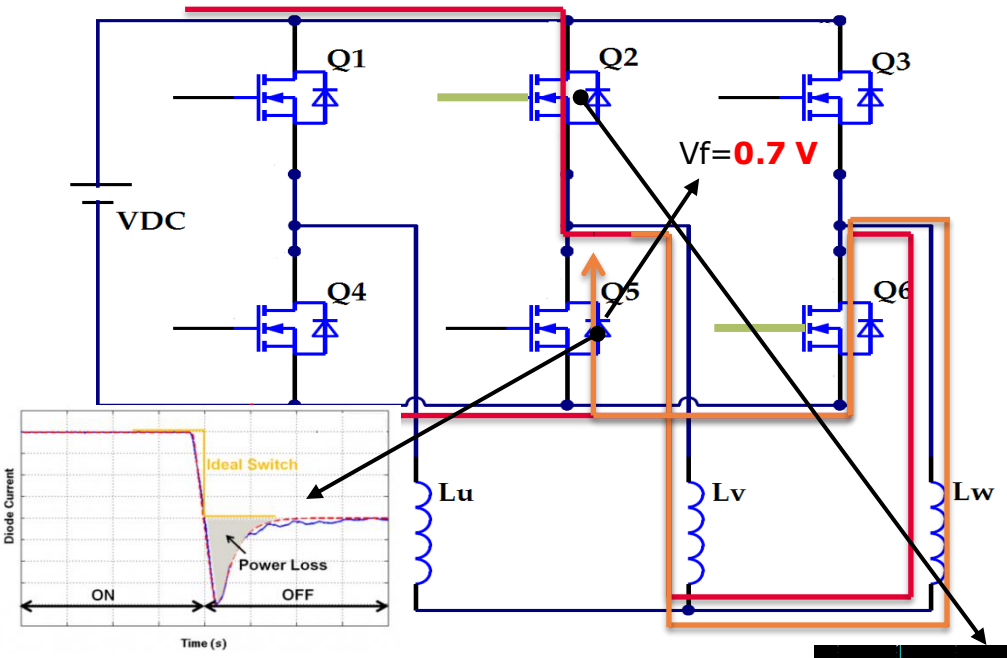
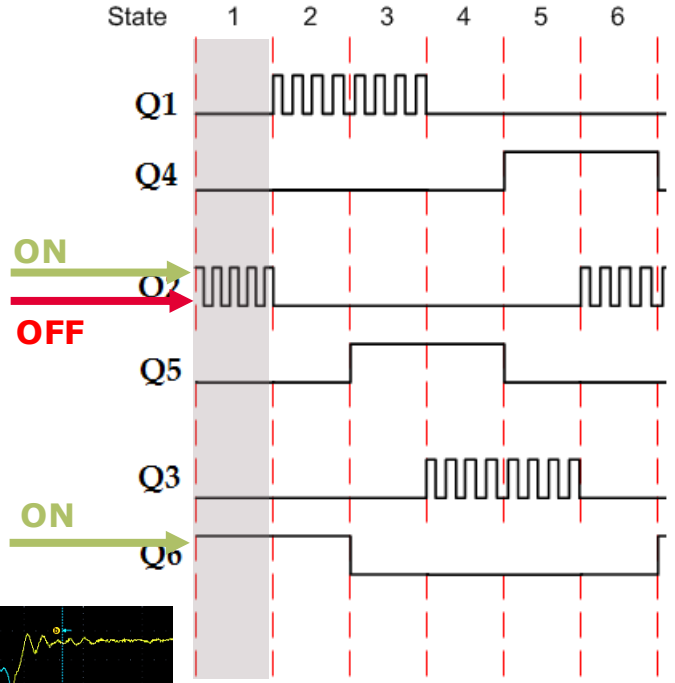
Big switching loss and reverse current conduct in tradiontal 3 phase half-bridge drive

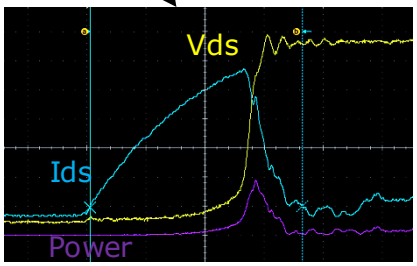


BLDC Motor driving circuit



Gate signal

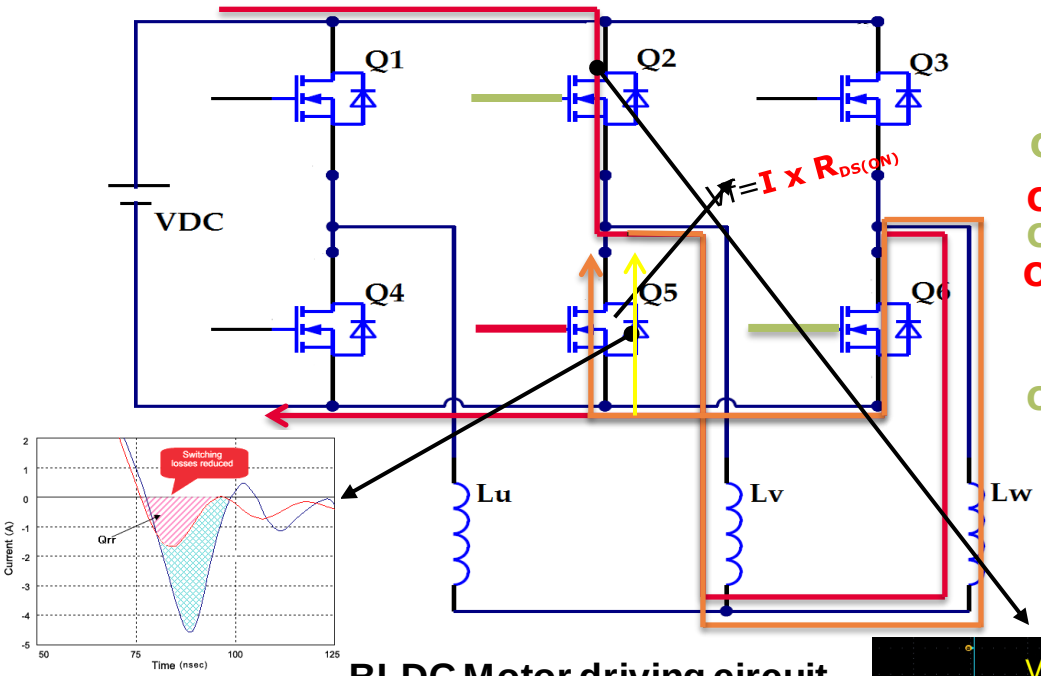
- In each stage two switches are gated
- One switch is modulating while the other switch is continuously ON



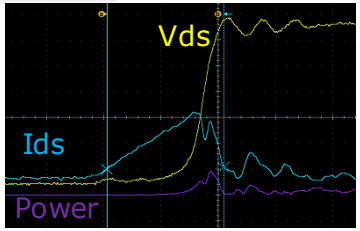
PWM of 360° motor rotation

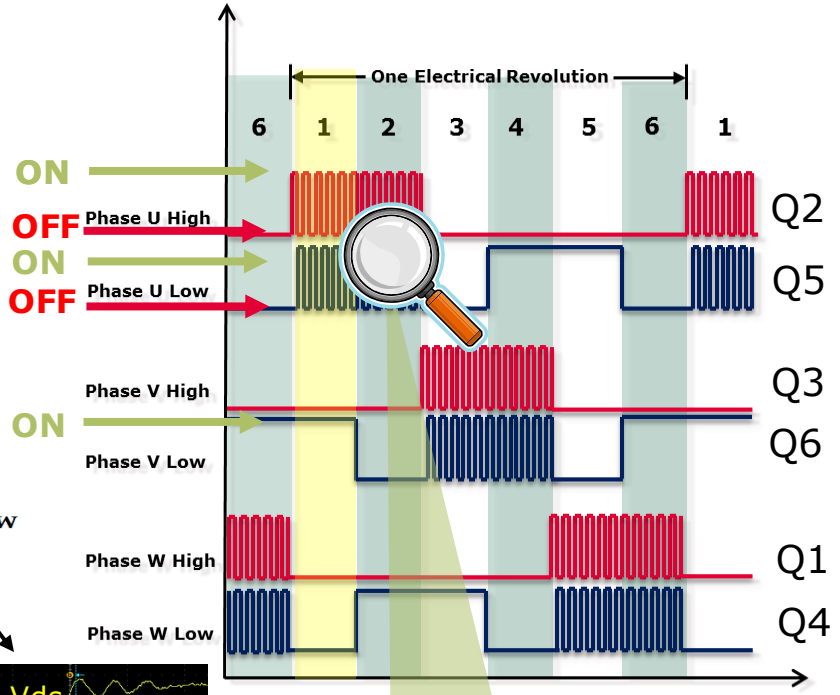
Can we further improve this situation?

Optimization one: Synchronization to reduce hard communication spikes



BLDC Motor driving circuit

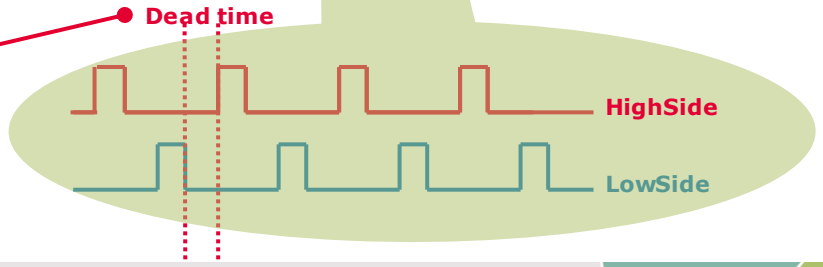




Gate signal

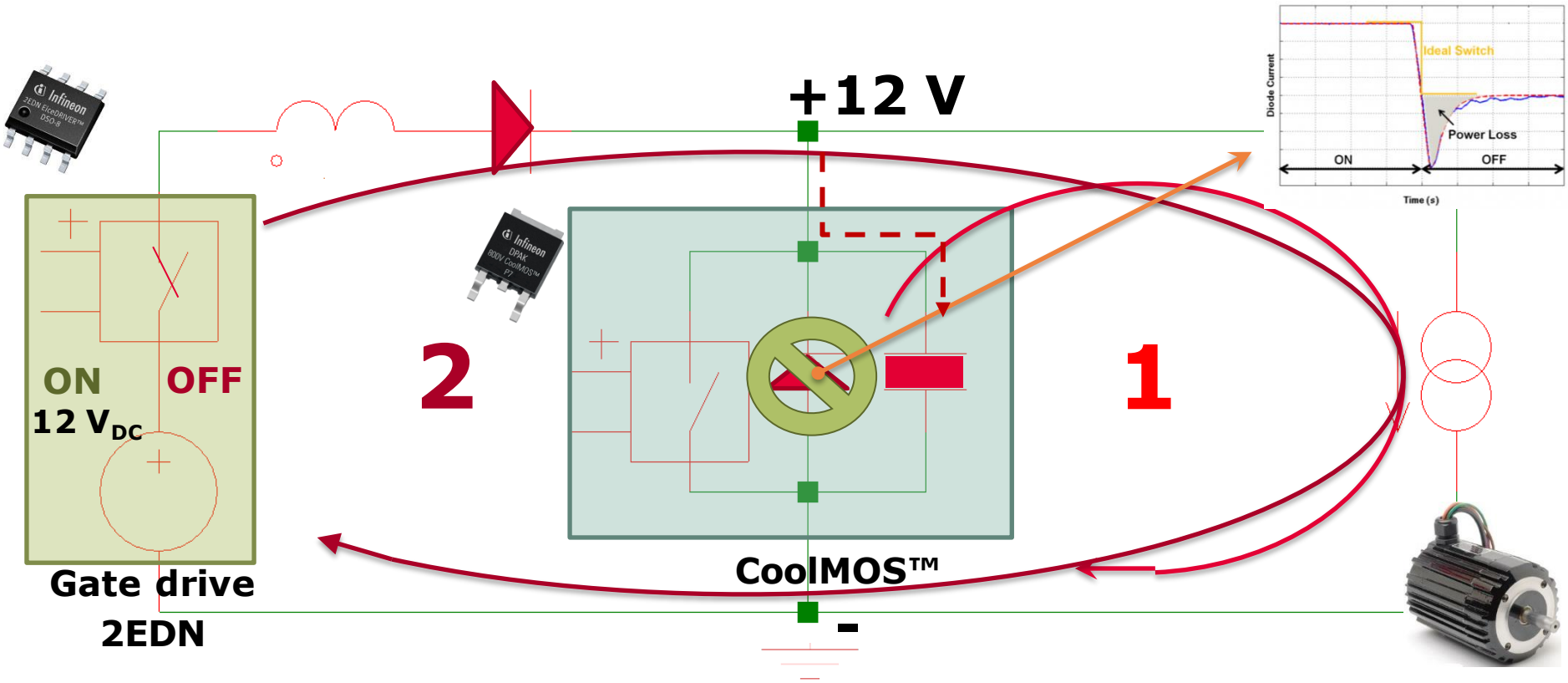
PWM of 360° motor rotation

- In each stage three switches are gated
- two switches are modulating at the same phase while the other switch is continuously ON



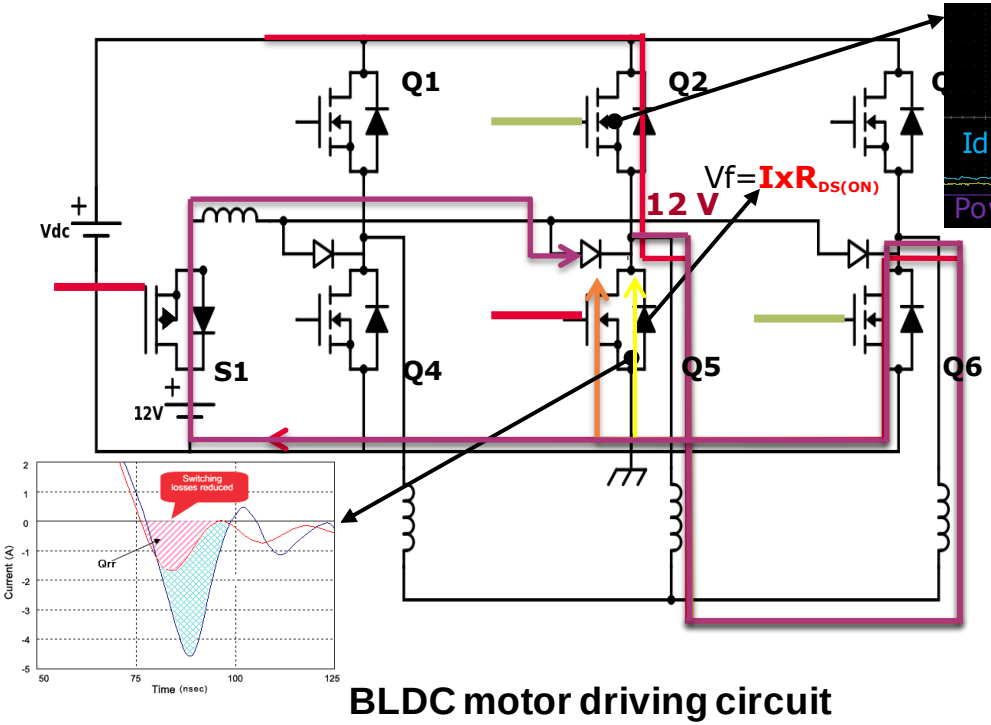
During dead time body diode has to handle the full load current

New proposed solution
Body diode recovery and pre charging circuit

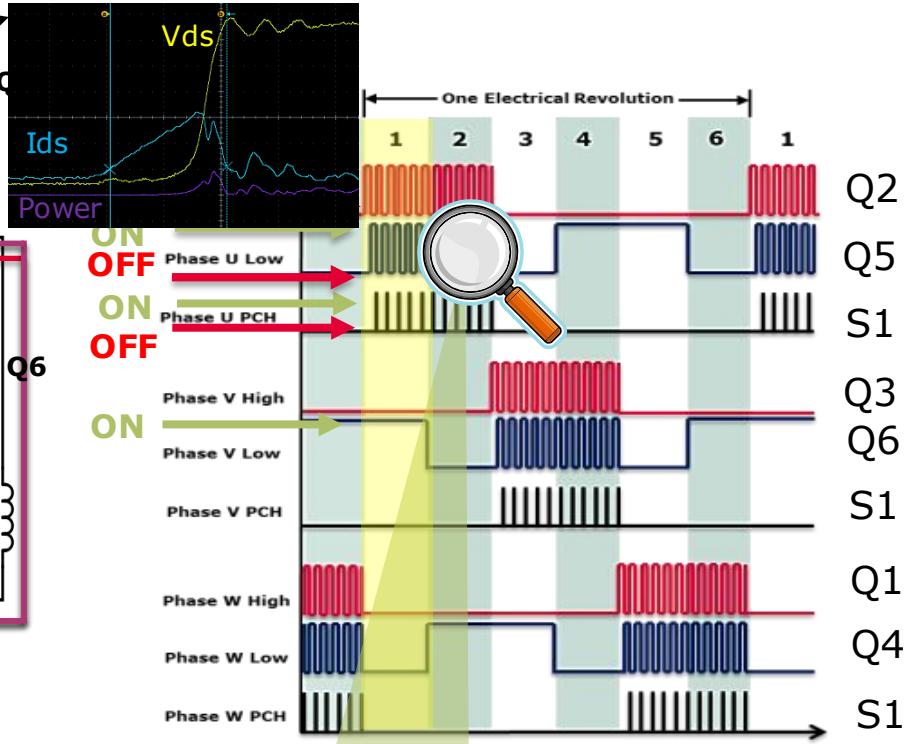


1. Current is flowing throw the body diode of the CoolMOS™ at dead time.
2. When turning ON S1 the current starts to flow through D2
   - Body diode has 12 V potential (reversed biased)
   - Body diode recovered before turn on of high side switch
   - Part of the current charge the output cap of lowside switch (faster switching)

Optimization two: Precharge and synchronization

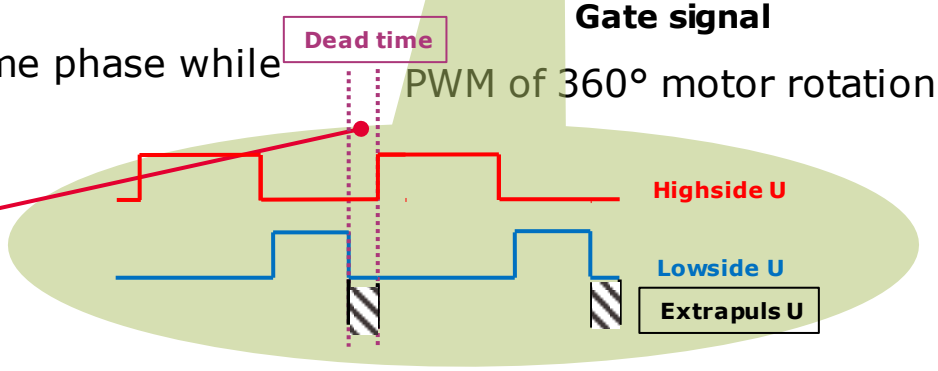


BLDC motor driving circuit



Gate signal

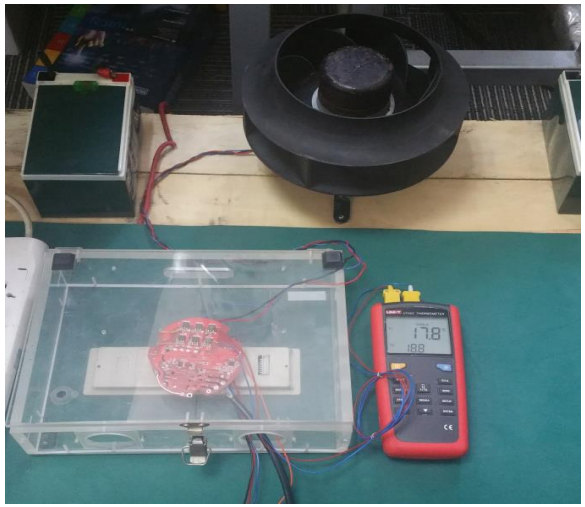
- In each stage four switches are gated
- two switches are modulating at the same phase while the other switch is continuously ON

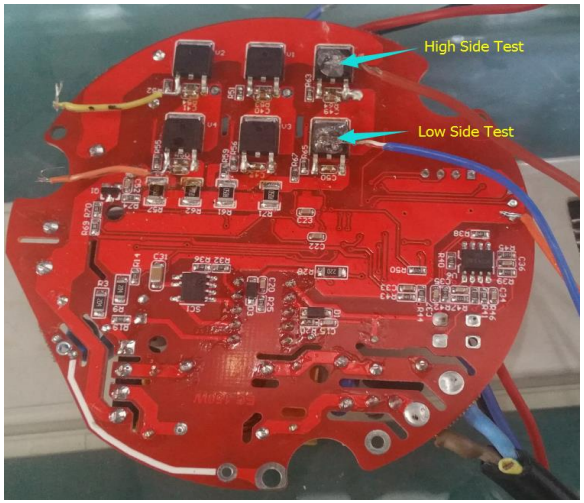


During dead time body diode no longer will handle the full load current

100 W BLDC driver board testing setup

Thermal measurement





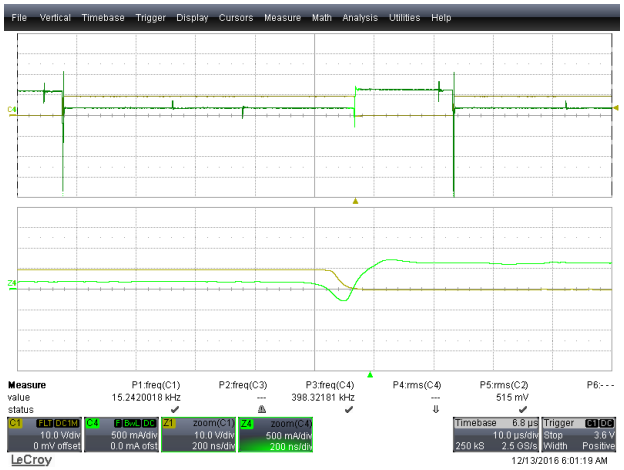
Test setup:

- Test conditions:
  - V_{in}=220 V_{ac};
  - No airflow
  - Motor basic spec: phase resistance 14.35 ohm, phase inductance 0.05 H, 2 pole pairs, 3000 rpm, reverse voltage index 105.3 V/Krpm
- Unit initially powered up at 100 W input @1500 RPM of motor speed for long time until MOSFET body temperature is stable before recoding measurement

Stress tests show big margin of CoolMOS™

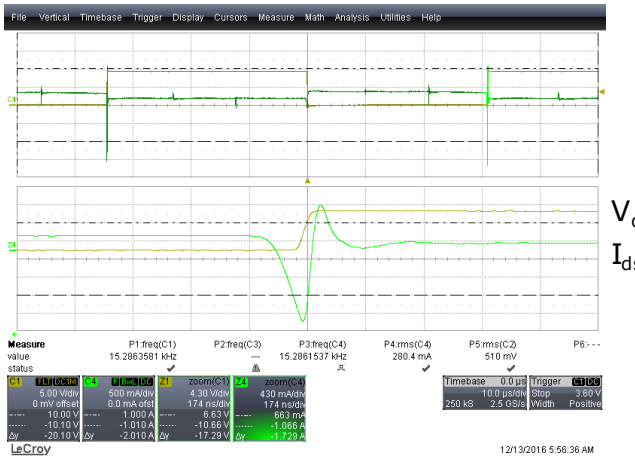
High-side switch

Turn off, V_{ds} and I_{ds} waveform



V_{ds} peak : 300 V
I_{ds} peak : 0.94 A

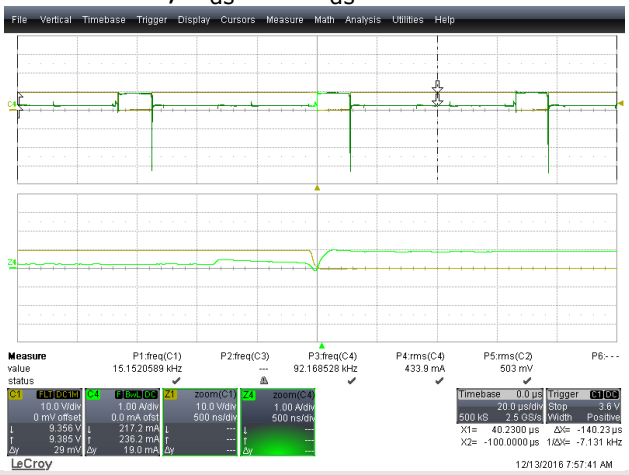
Turn on, V_{ds} and I_{ds} waveform



V_{ds} peak : 302 V
I_{ds} peak : 6.4 A

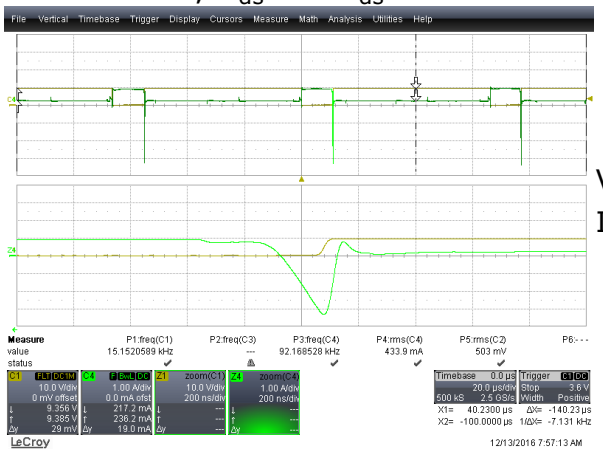
Low-side switch

Turn off, V_{ds} and I_{ds} waveform



V_{ds} peak : 301 V
I_{ds} peak : 1.1 A

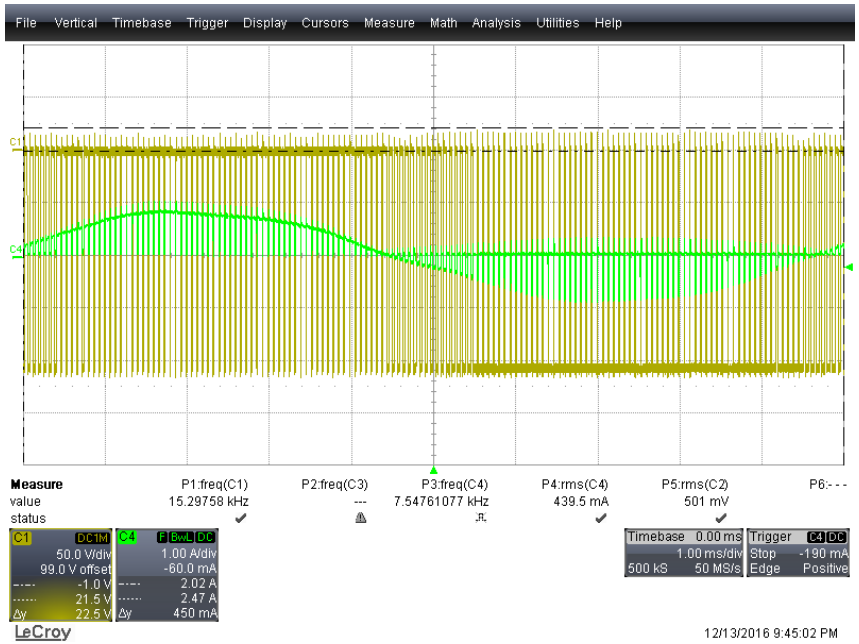
Turn on, V_{ds} and I_{ds} waveform



V_{ds} peak : 301 V
I_{ds} peak : 4.1 A

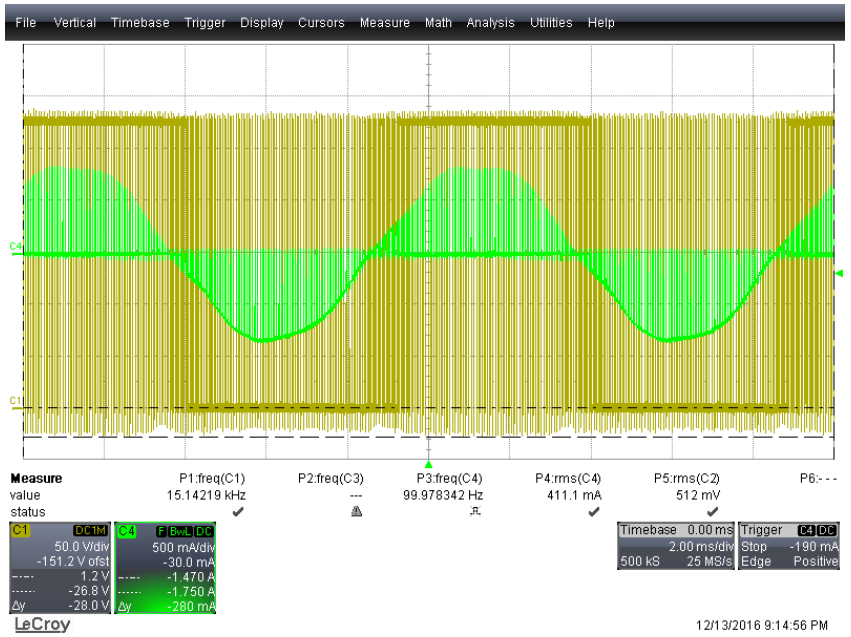
More stress tests

High-side switch



MOS body temperature is 74.6°C

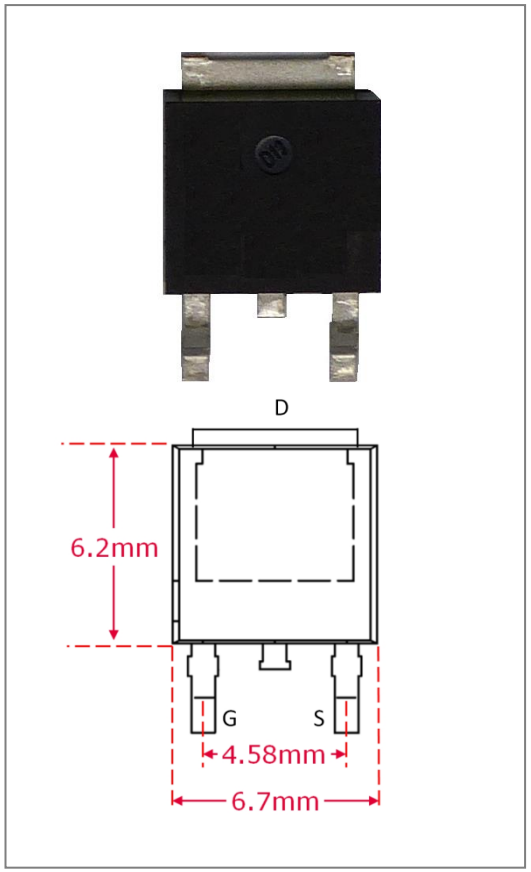
Low-side switch



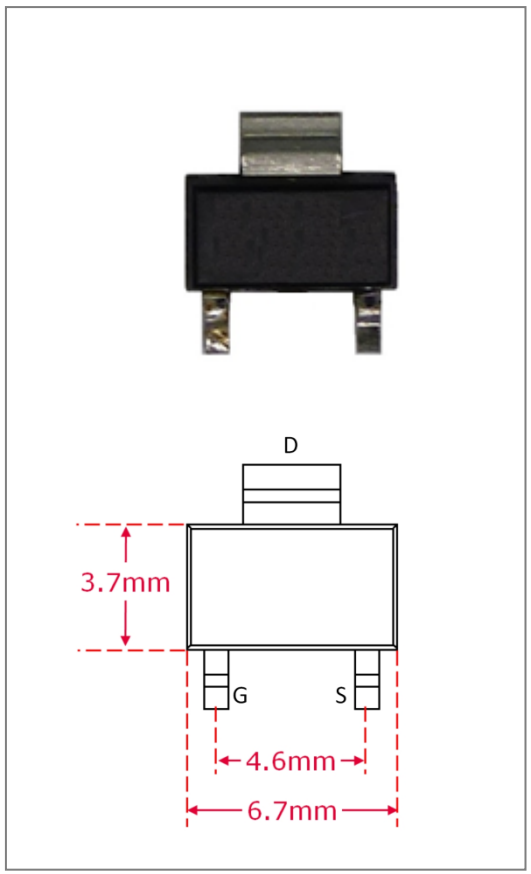
MOS body temperature is 74.1°C

SOT-223 offers smaller footprint while being pin-to-pin compatible with DPAK

DPAK



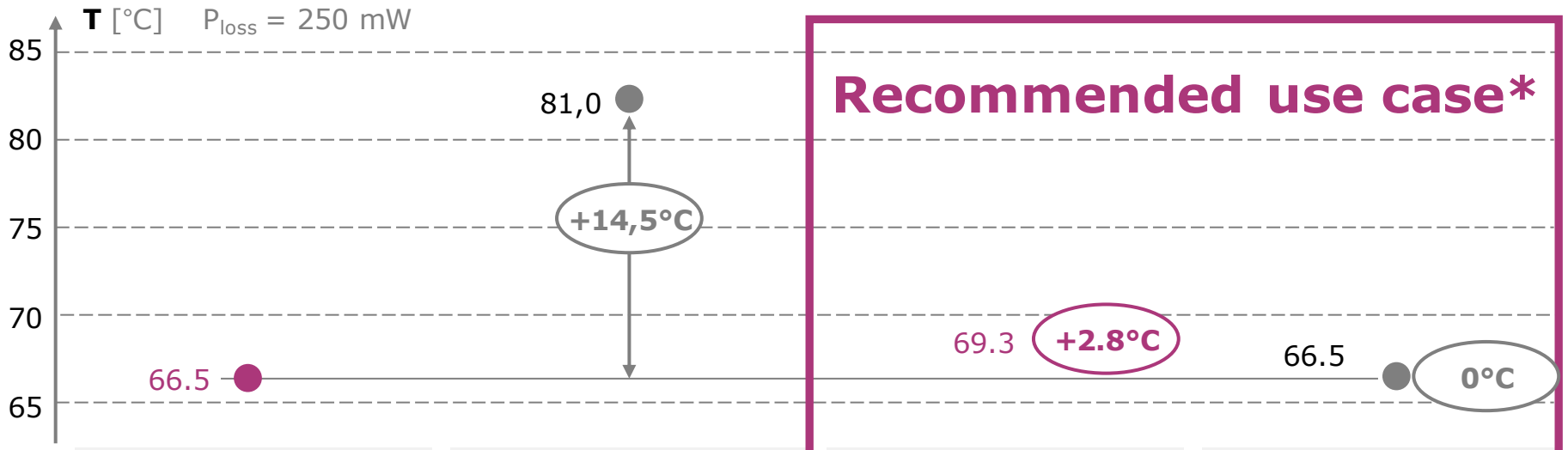
SOT-223



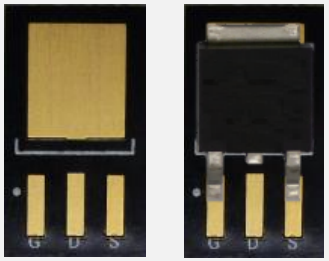
Use cases for SOT-223

- **One-on-one DPAK replace-ment** for reducing cost
- **Space savings** in compact designs (thermal limitations, please see next pages)

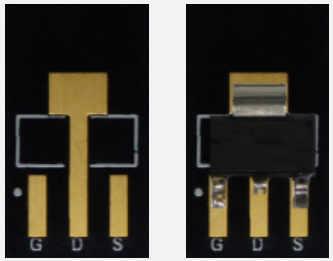
Only slight increase in temperature – add. offer area around footprint is essential



DPAK on DPAK footprint (reference)

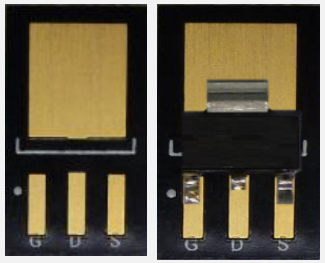


SOT-223 on SOT-223 footprint



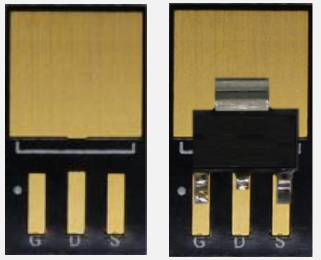
- Good for **low power levels**
- Footprint savings vs DPAK

SOT-223 on DPAK footprint



- Drop-in replace-ment for DPAK
- Good for **designs with thermal margin**

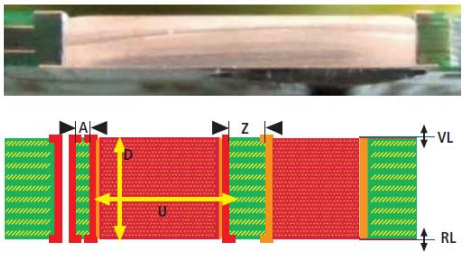
SOT-223 on Foot-print of DPAK + 20 mm² Cu



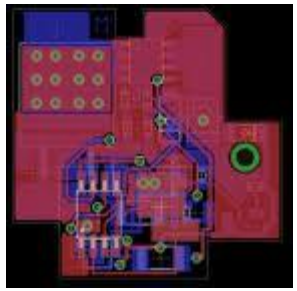
- Replacement for DPAK
- Good for **designs with sufficient cooling area**

Recommendation for SMD cooling

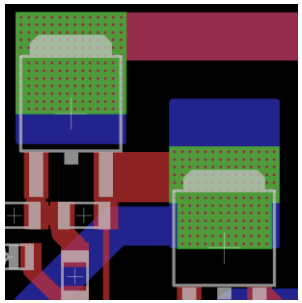
- Concept can follow several methods
  - *Copper inlays* (production limited and quite expensive concept)
  - *Thermal Vias filled with synthetic resin* to avoid solder voids at RC-drives Leadframe due to a flow through the vias
  - *Small drill holes* (between 0.2 and 0.4 mm) for the thermal vias that are filled during galvanization to avoid solder flow
- Infineon recommend the small drill hole concepts since it's the most cost effective solution due to easy production and adequate thermal behavior



Copper Inlays (Ruwel GmbH)



Classical Thermal Vias with resin



Thin-Via-Concept (Small drill holes)

Tested and proven reference design allows better project management to extend success

Driver IC

Main component(s)	Infineon's product offering
› Half bridge	› IRS2103

Power management

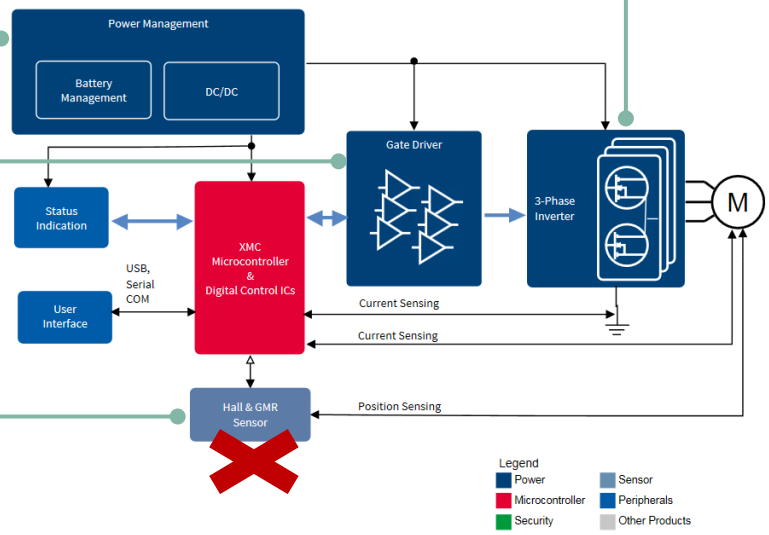
Main component(s)	Infineon's product offering
› LDO	› IFX2931GV50

Sensorless control

Simplified design, cost optimization

Power Switch

Main component(s)	Infineon's product offering
› CoolMOS™ CE	› IPD60R650CE



Your advantage

- Accelerate time-to-market
- Lower initial investment
- Ease of use

We can bring more values …

Value proposition	The solution can provide…
Cost & efforts reduction	› Productive solution, save development efforts and cost, fast time to market › CoolMOS™ CE used as the replacement of IPM or IGBT, also no need of Hall sensor, can save >10% BOM cost › One-stop-shop solution, optimization for purchasing efforts and cost
High efficiency	› Thanks of CoolMOS™ CE lower switching & conductive loss, and with XMC1302 algorithm to reduce reverse current loss, the efficiency improved quite a lot, particularly during light load situation › Comparing with discrete IGBT, the CoolMOS™ can reduce body temperature (up to 20°C))
Delivery capacity insurance	› Commonditve components used, esay for purchasing › Infineon has the world largest power semi capacity, has 3 front-end sites for silicon manufacturing and >5 back-end plants packaging › Flexible multi-source program, improve the business response › Fast stock replenishment to shorten CoolMOS™ CE delivery lead time, less than 5weeks
High reliability and quality	› Infineon offers highly ruggedized performance and proven reliability › CoolMOS™ offers unrivalled quality in the industry only 38 fails from >1.6 billion shipped parts

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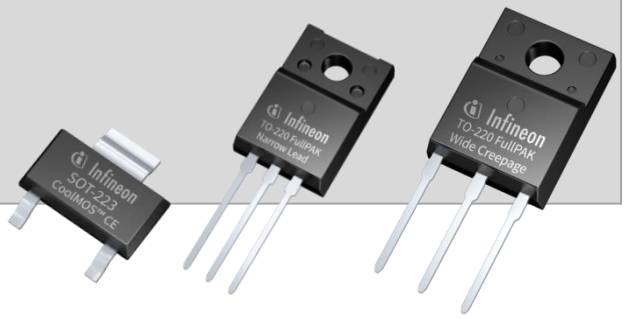
Infineon addresses customer needs with CoolMOS™ CE on product level & as a supplier

Product benefits of CoolMOS™ CE

1. **Superjunction MOSFET** technology with improved switching
2. Better **efficiency and thermals**
3. **Innovative packages** resulting in BOM cost savings



Benefits from supplier Infineon

4. **Supply security** from 3 front-end sites (silicon manufacturing) and >5 back-end plants (packaging)
5. **Unrivalled quality** in the industry:
   - Proven track record
   - Highest testing level
6. **Fast quoting and lead time**
   - Multisource business model
   - Fast stock replenishment

1 CoolMOS™ CE is a Superjunction MOSFET technolog that offers improved switching and is rapidly growin

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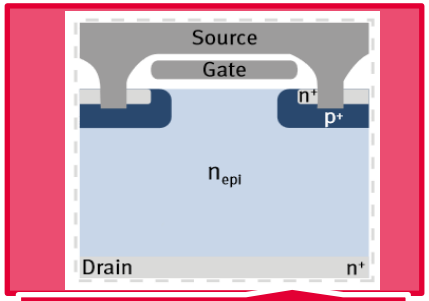
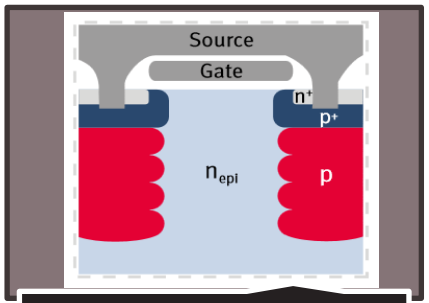
Planar MOSFET



Standard MOSFET

Superjunction MOSFET



CoolMOS™

Example 650 V:

$R_{DS(on)}$	1300	1500	[mΩ]
Q_{g*}	33	10.5	[nC]
E_{oss**}	1.6	0.78	[µJ]
C_{oss***}	60	18	[pF]

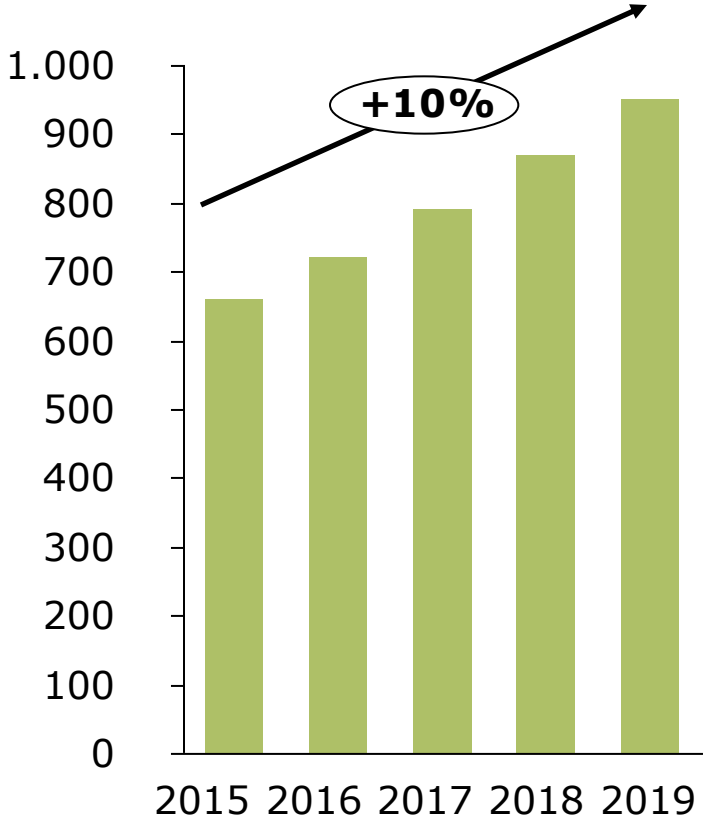
- Lateral structure
- Larger die size, thus larger capacitance
- Higher switching loss

- Vertical structure
- Smaller die size, thus smaller capacitance
- Lower switching loss

Better switching vs. planar (conventional) FET

Superjunction MOSFET forecast

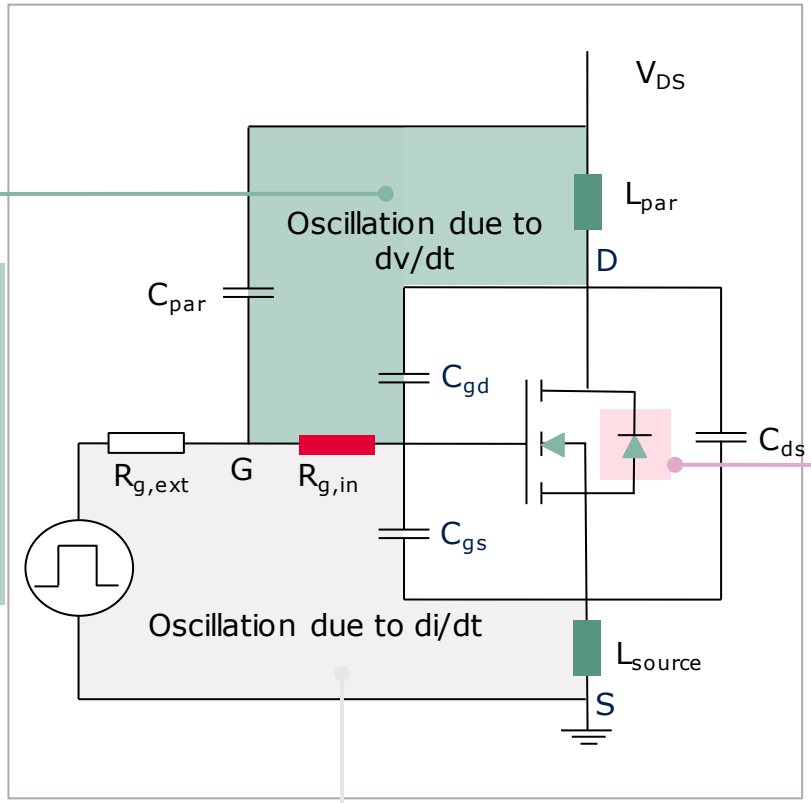
(mio USD, Yole Développement)



Rapid growth projected

2 Optimization for ease of use and addresses typical design challenges

Design challenges and value offered by CoolMOS™ CE



2

Challenges in motor switching:

- V_{GS} out of spec
- High switching loss
- High device stress

CoolMOS™ CE optimized for improved oscillation

1

Challenges from fast switching:

- EMI and oscillations from high di/dt

CoolMOS™ CE with good controllability for ease-of-use

3

Challenges in motor drive
Body diode hard commutation

- High voltage overshoot
- High current spike
- High device stress

CoolMOS™ CE with good commutation ruggedness

L_{par}: layout parasitic inductance
C_{par}: layout parasitic capacitance

3 CoolMOS™ CE brings a package innovation addressing consumer markets – selected examples

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 **IPAK SL mold stopper**	› Defined stand-off between package body and PCB › Higher production yield as no residue after cleaning
 **TO-220 FullPAK Narrow Lead**	› Reduced stand-off height › Lower height for semi slim adapters as MOSFET can be fully inserted into the PCB
 **TO-220 FullPAK Wide Creepage**	› Increased creepage distance (4.25 vs. 2.54 mm) between legs › No arching and no electrical failure even if dust and dirt comes into the power supply
 **SOT-223**	› Lower cost DPAK replacement › Enabled by smaller dies of superjunction MOSFET

Innovative package solutions… → **… enable customer BOM savings**

4 CoolMOS™ CE offers supply security – production in 3 frontend (silicon) and >5 backend locations (packaging

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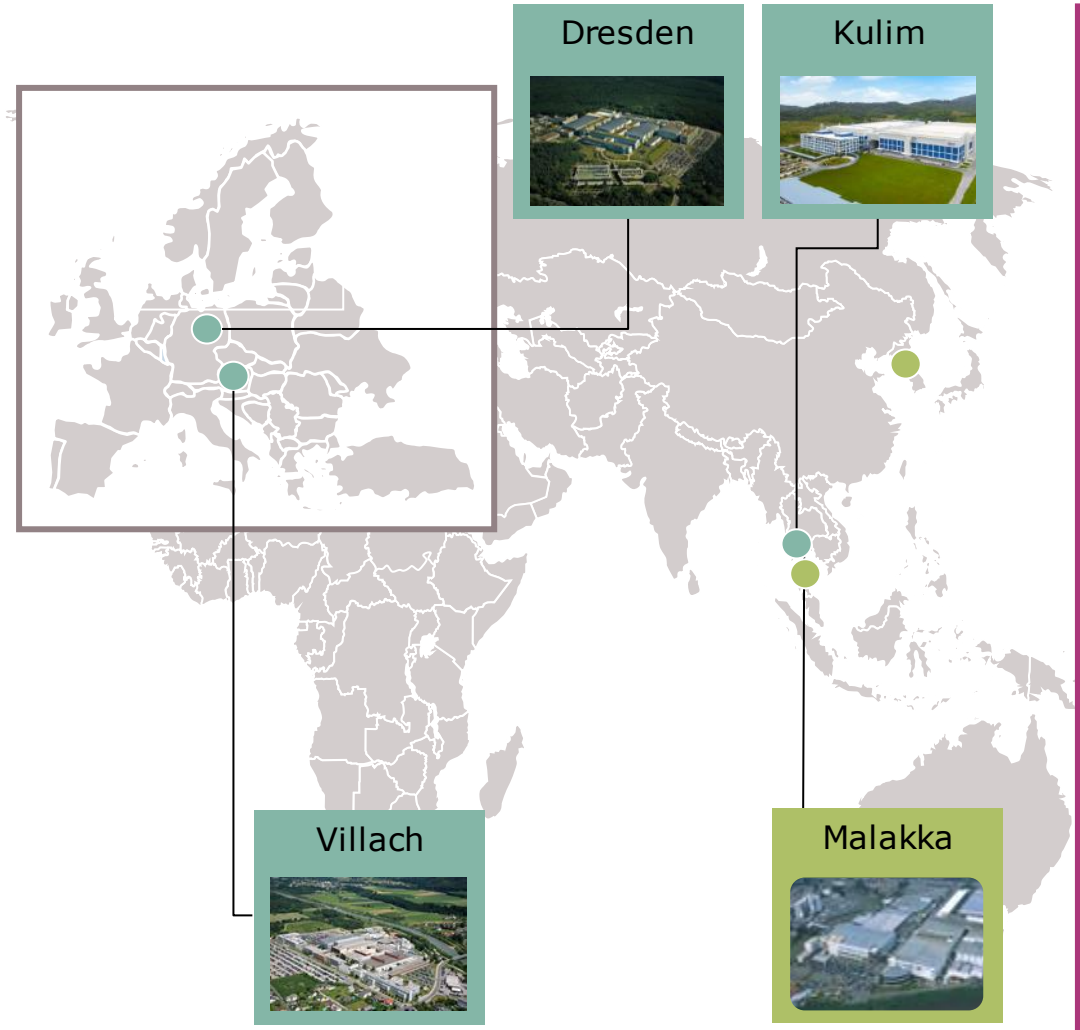

300 mm (12 inch) production in Dresden

- World's largest power semicon production facility
- World's first volume production of power semis on 12"
- State-of-the art equipment from former DRAM maker, highest precision
- CoolMOS™ main volume, flexible upside capacity

5 CoolMOS™ offers unrivalled quality in the industry
Only 38 fails from >1.6 bn shipped parts

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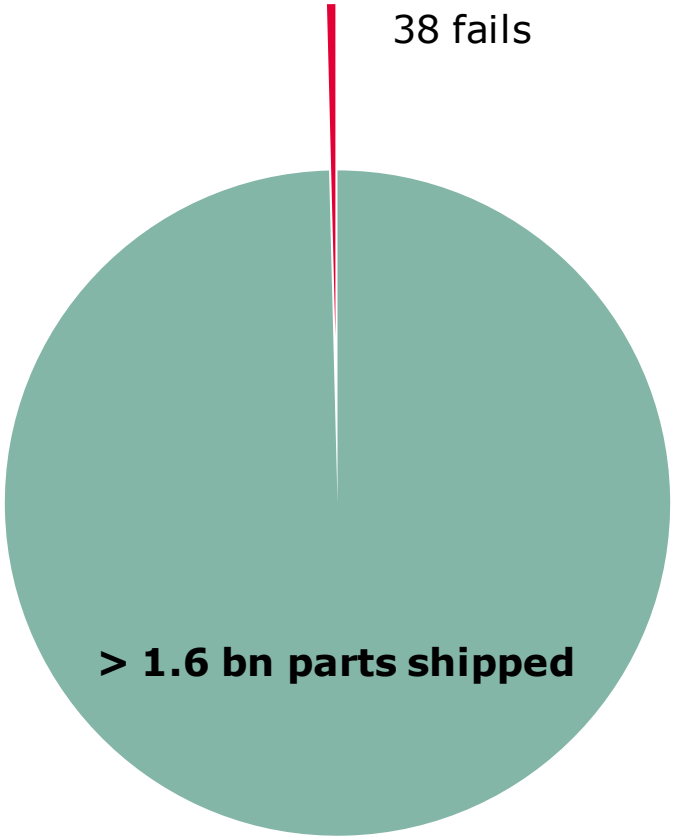

All CoolMOS™ technologies

- 0.03 DPM on average
- Only 38 fails over 1.6 bn parts shipped

Quality leadership in power MOSFETs – no other vendor offers such reliable parts

5 CoolMOS™ offers unrivalled quality in the industry Infineon keeps its quality promise – competitors b

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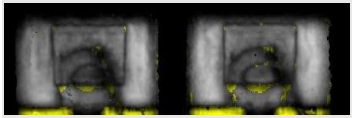
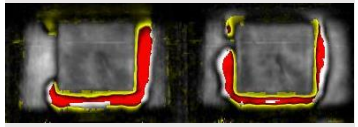
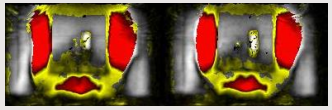
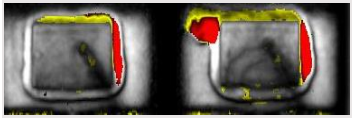
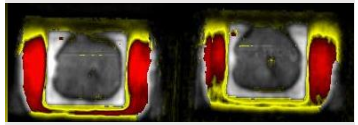
	Infineon	Competitor A	Competitor B
Initial	 5/5 PASS	 5/5 show die pad delamination	 5/5 show die pad delamination
TC 500c	 1/5 show die pad delamination	 5/5 show die pad delamination	 5/5 show die pad delamination

Competitors with large delamination:

- Risk of electrical failure
- Not keeping promised reliability

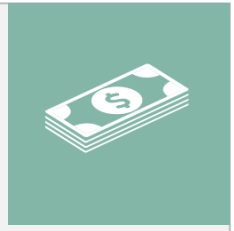
Infineon invests into high reliability

- Selection of higher grade package BOM
- Regular quality monitoring after stressing

Quality leadership in power MOSFETs – no other vendor offers such reliable parts

6 CoolMOS™ CE offers ease of business via fast quoting and low lead times

- **Fast quote & price response**
- Larger pricing freedom for distributor via multisource price list
- Fast quote response from business manager
  - Target < 24 hrs for >80% requests
  - Up to 3 days in exceptions



- **Short lead time**
- Faster than normal inventory replenishment to secure certain buffer level
- 4-6 weeks lead time for large orders

Business model for CoolMOS™ CE tailored for speed & ease of business

Where to find more: www.infineon.com/ce

- Product information (parts, selection, x-reference, …)
- Application information (benefits, demo boards, …)

32-bit XMC1000 industrial microcontroller ARM® Cortex®-M0

ARM® Cortex®-M4 **(with FPU)**

- **Core up to 48 MHz/ peripherals up to 96 MHz**
- **PWM Timers CCU4**
- 2 serial channels
- 12 Bit ADC
- **-40 to 105°C**

>70% Performance Increase

XMC1100
up to 64 kB Flash
16-40 pins

XMC1200
up to 200 kB Flash /
16-40 pins

- 9ch LED control
- 3 analog comparators

XMC1300
up to 200 kB Flash /
16-40 pins

- Math co-processor
- CCU8 PWM timer
- Hall and encoder I/F

XMC1400
up to 200 kB Flash /
40-64 pins

- 2x CAN
- 2x CCU8
- Pp to 4 serial channel
- 4x analog converters

TSSOP-16/28/38 - VQFN-24/40/ 64 - LQFP-64

Wide supply voltage range 2.0 V to 5.5 V

Secure boot leader – ensure IP protection

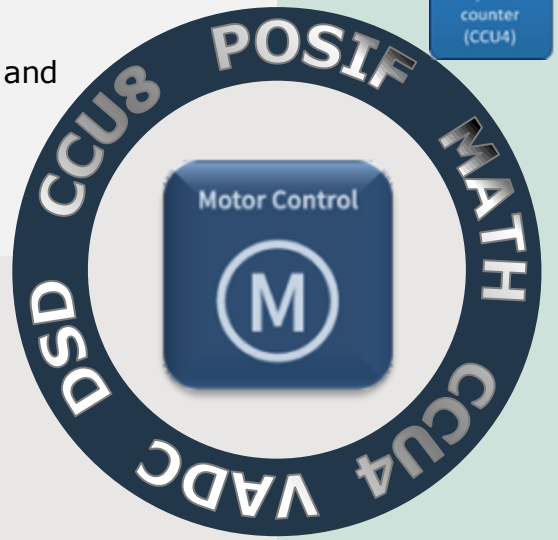
Application specific peripherals

MATH co-processor	**ERU Event request unit**	**High performance analog converters**	**PWM timer for motor control (CCU8)**	**LED brightness color control unit**

XMC1000/4000 Motor Control - beyond standard core…

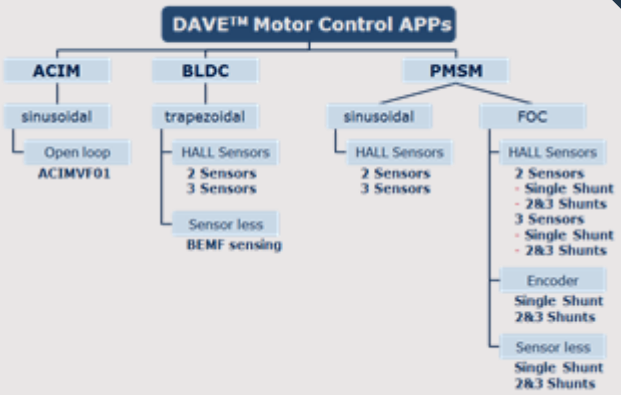
Dedicated motor control peripherals for various control and feedback schemes

- Fast and sophisticated 12-bit ADC (up to 2MSPS)
- Position interfaces for HALL sensors, incremental encoders and resolvers for higher integration
- PWM unit tailored for sinusoidal and trapezoidal commutation pattern
- Event Request Unit (ERU) enables
  - interconnection between analog, PWM and
  - sensor interface peripherals
- Ideal for FOC control, both low-end and high-performance

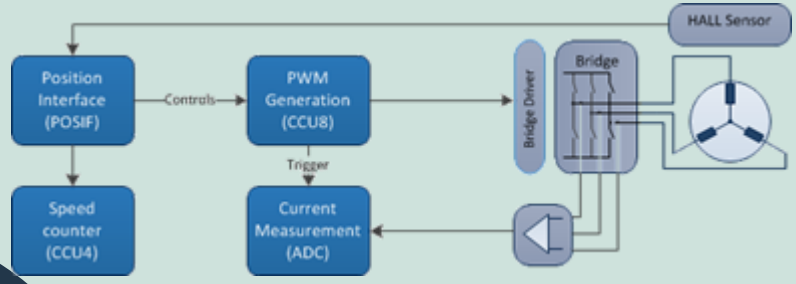


DAVE™ APPs support

Comprehensive and growing APPs support for different types of motors and motor control schemes.



Robust and intelligent motor control systems with XMC



BLDC Power Tools Block Diagram

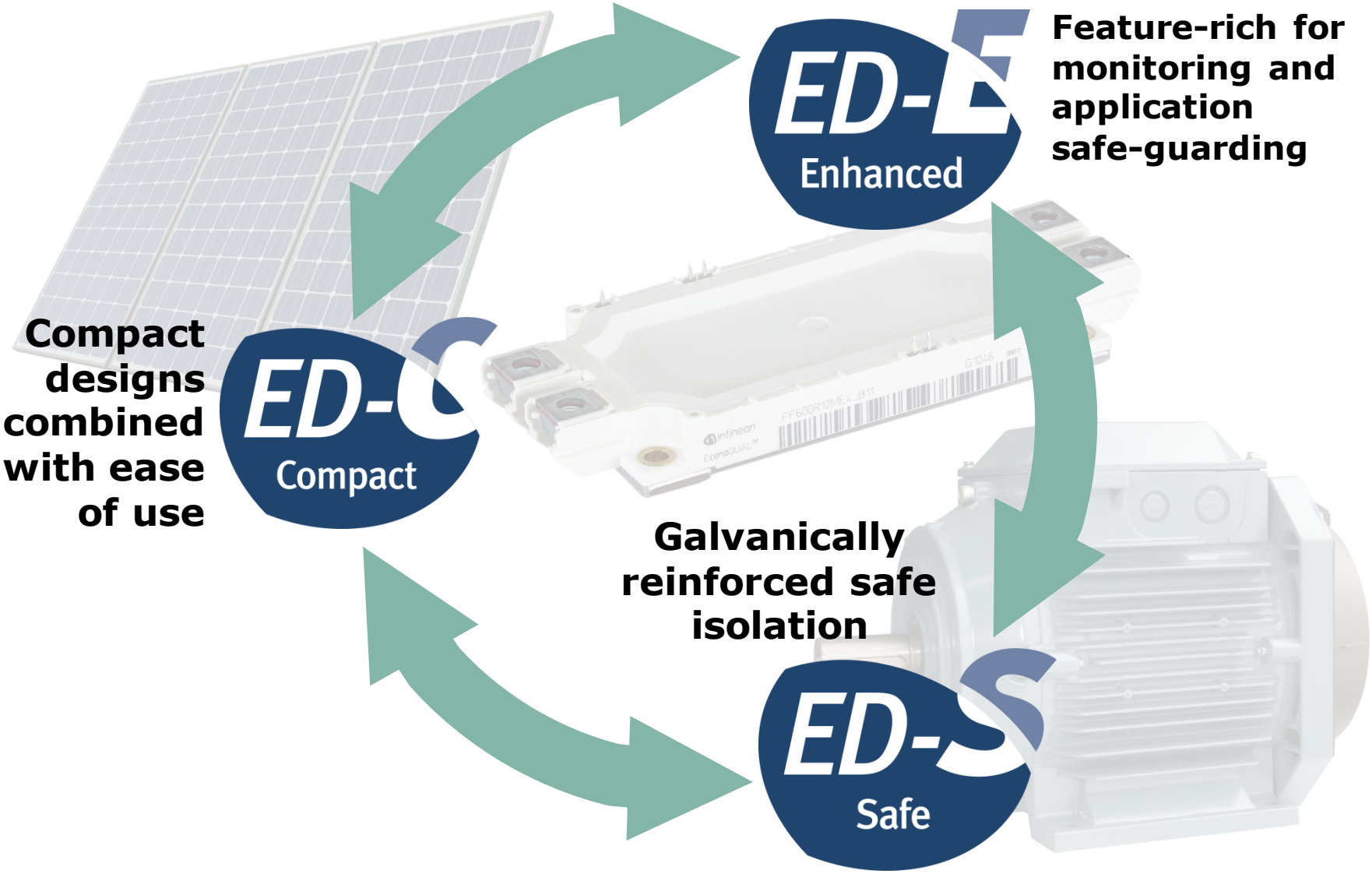
Additional HW/SW features bring your motor control system to the next level:

- Ethernet, CAN, CAN-FD (XMC1400) and serial communication
- Over-current protection (OCP) and Overvoltage protection (OVP) with fast reaction times using ADC fast compare mode (150ns conversion time)
- Over-temperature protection (w/ext. sensors)
- High temperature range (up to 125°C, XMC4000) and automotive grade flash for most robust and reliable systems
- Sophisticated PWMs allow additional synchronous rectification to increase system efficiency

XMC1000 highlighted feature for motor FOC control

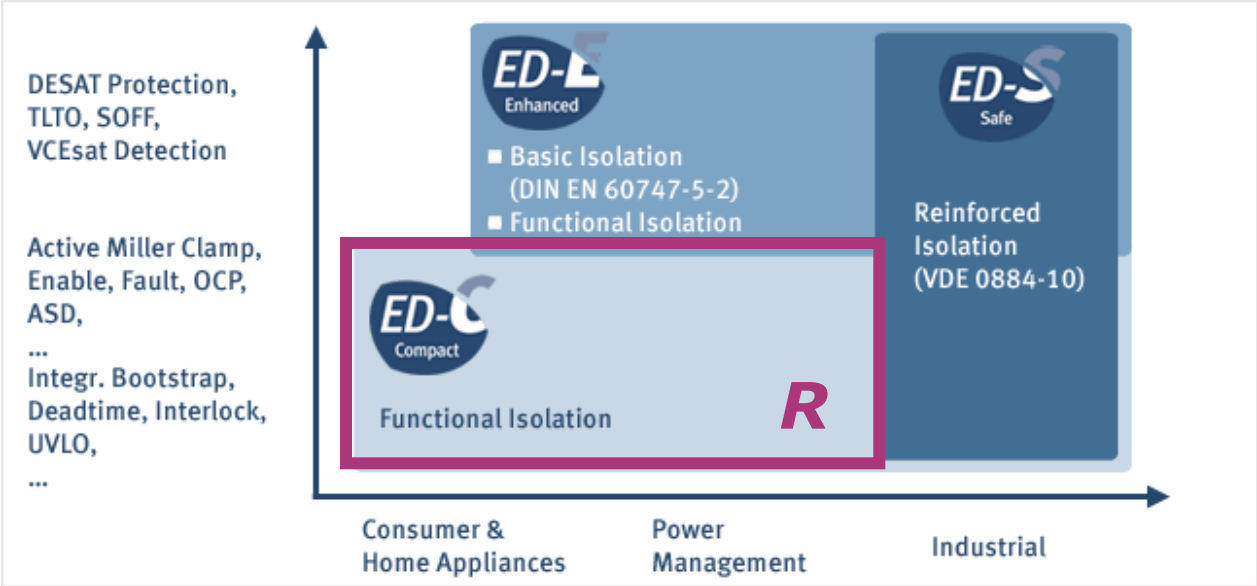
- MATH coprocessor
  - 38x faster sine, cosine and arctangent calculations
  - High-resolution Park/Inverse Park Transforms at 24-bit in less than 1 μs
  - 7x faster division compared to other ARM® Cortex®-M0 devices
- CCU8 PWM
  - Generate PWM patterns for all kind of motors
  - Interact with ADC for ADC triggering at sensorless control of motors
  - Operate always in a safe state - even in an error condition
  - Dead time control to minimum hardware effort
  - 16-bit resolution for high precision space vector PWM generation
- ADC
  - On-chip ADC gain (x1, x3, x6, or x12) to eliminate external Op-Amp
  - Simultaneously sample of multiple analog channels
  - Fast ADC reduces torque ripple due to minimized blind angle in sensorless FOC
  - Used to sense motor three phase current as feedback to the system

EiceDRIVER™ - your driver solution



EiceDRIVER™ compact - the right gate driver for all motor drives

- **highly reliable** driver ICs with **functional isolation**
- **small packages** e.g. DSO-8 or TSSOP-28
- offers highest **cost-efficiency** & **ease-of use**
- with Infineon's Coreless Transformer Technology & SOI-Level Shifter



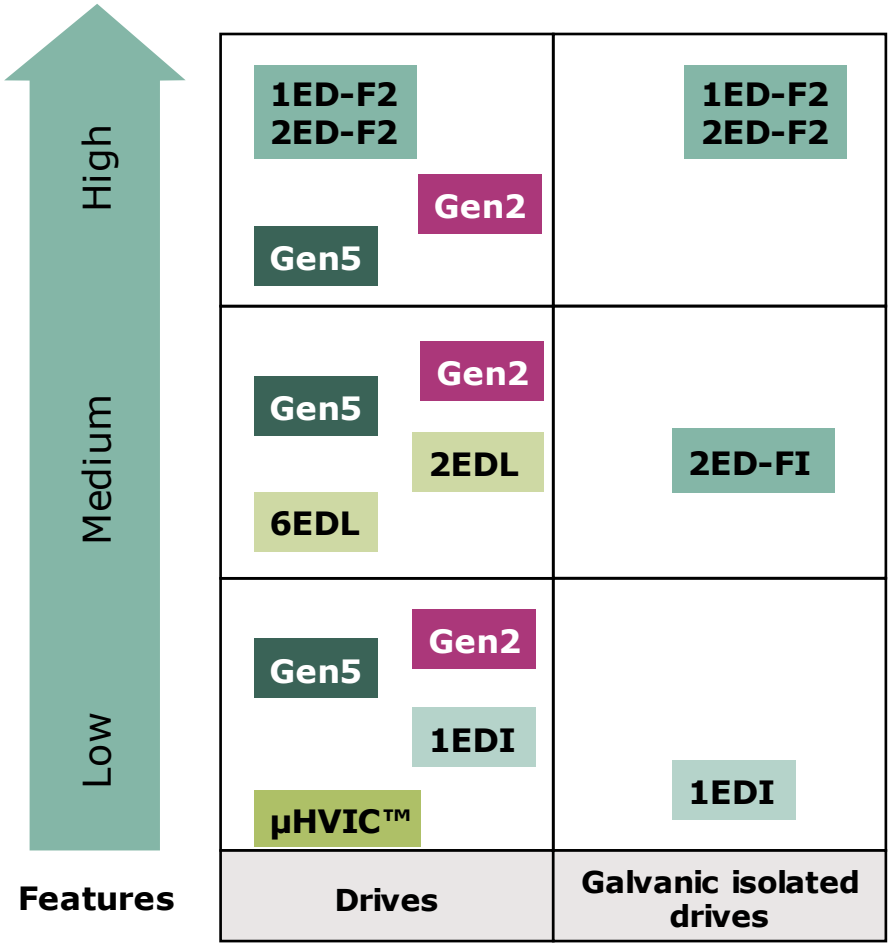
R recommended for motor drives

Using OptiMOS™ & EiceDRIVER™ C – reduces your system costs by removing ...

- HV bootstrap diode and current limiter
- External comparator and biasing for SC protection
- Enable circuit
- Gate emitter resistors

www.infineon.com/EiceDRIVER™

HV gate drivers
a broad, feature-rich portfolio



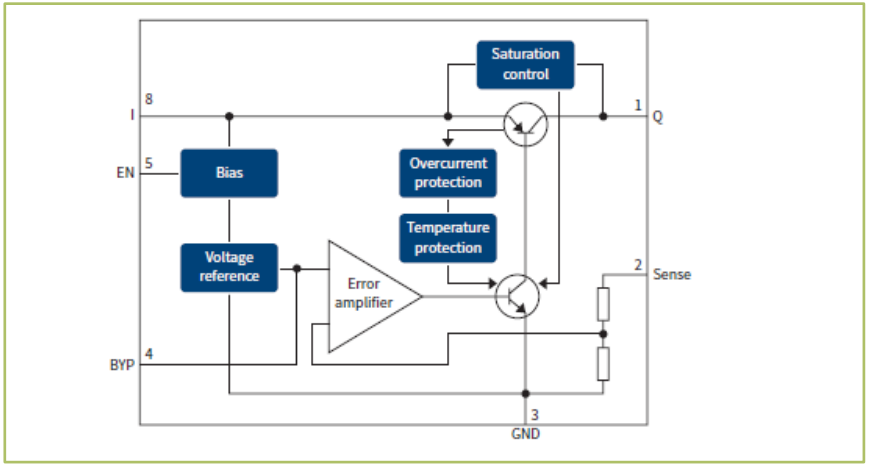
Level shift driver ICs:

- **Gen 2:** Mature process, industry benchmark for robustness, broad portfolio up to 1200 V
- **Gen 5:** Cost effective, feature rich, high accuracy mainly 600 V
- **µHVIC™:** SOT-23 building blocks
- **2EDL:** Half-Bridge, Silicon on Insulator, integrated bootstrap diode, over current protection (IRIP)
- **6EDL:** Three phase, Silicon on Insulator, integrated bootstrap diode

Cordless transformer driver ICs:

- **1EDI:** Single channel, unrivaled output current level, matching propagation delays

Linear voltage regulators for XMC™



Highlights

- Families of linear voltage regulators with fixed or adjustable output voltages
- Cost optimized ceramic capacitances applicable
- Excellent transient robustness
- Optimized to reject power supply ripples

Key Features

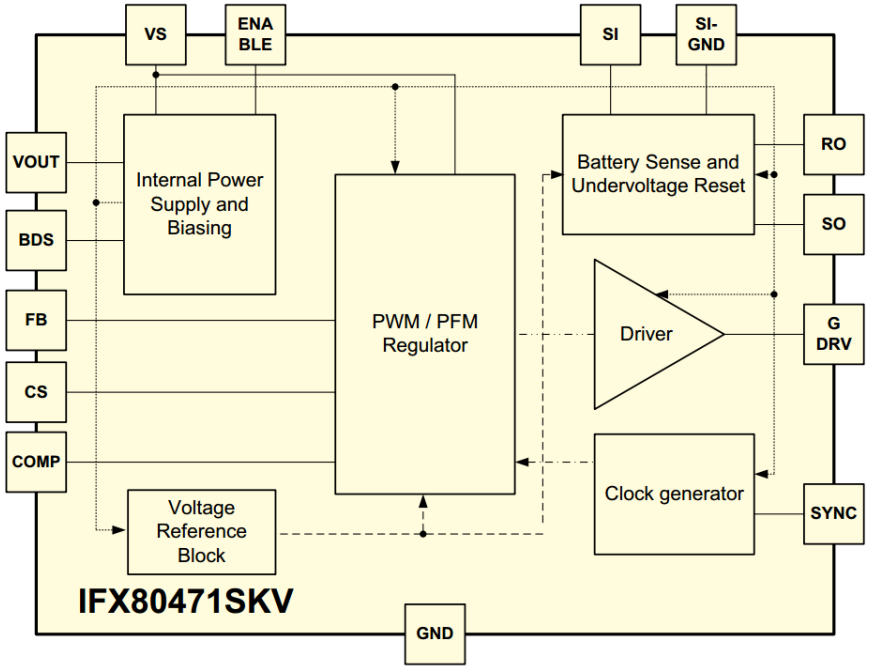
- Supplying up to 500 mA at dropout voltages of below 320 mV
- Ultra low quiescent current down to 5 µV
- Low noise characteristics

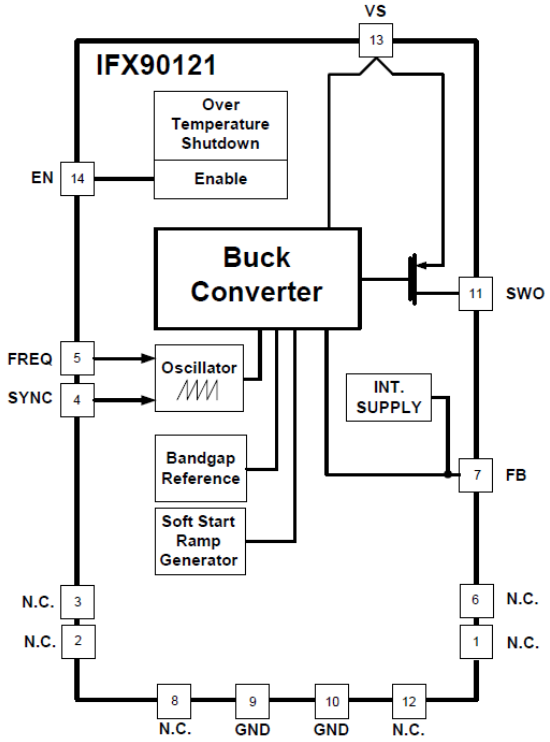
Customer Benefits

- Highest energy efficiency through ultra low quiescent currents and enable feature – helping to make your control box more efficient
- Space saving through small packages – helping to reduce the size of your control box
- Protection mechanisms avoiding system damages – ensuring safe operations of your motors

DC/DC switching regulators

Product Class	Type	Sales Name	Temperature Range	Output Voltage [V]	Output current [A]	Quiescent current [µA]	Maximum Input Voltage [V]	f_{sw} [MHz]	Accuracy Output Voltage [%]	Packages available
Unique	DC/DC Controller	**IFX80471**	-40C to 125C	5,0 / Adj	**2.3**	2	**60**	0.36	3	DSO14
	DC/DC Controller	**IFX81481**	-40C to 125C	Adj	**10**	2	**45**	0.7	2	DSO14
	DC/DC Converter	**IFX90121**	-40 to 125C	5,0	**0.5**	2	**45**	2.2	2	SSOP-14
	DC/DC Converter	**IFX91041**	-40C to 125C	3,3 / 5,0 / Adj	**1.8**	2	**45**	0.37	2	DSO8-EP

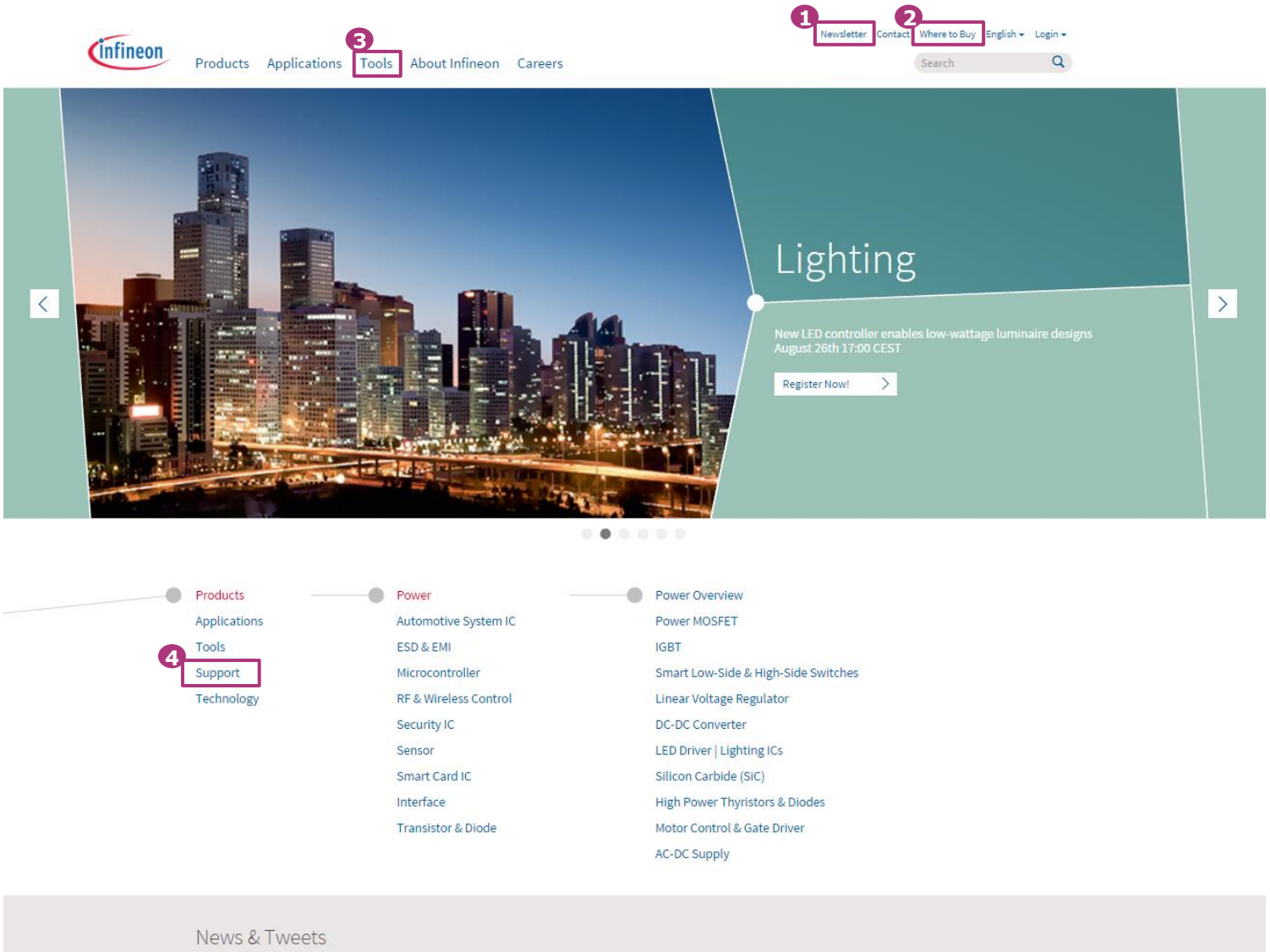




Agenda

1. Fan market overview
2. The 100 W demo introduction
3. Key component highlights
4. More support

Support
Online tools and services



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3. **Tools, Finders and Selectors**
4. **Support**

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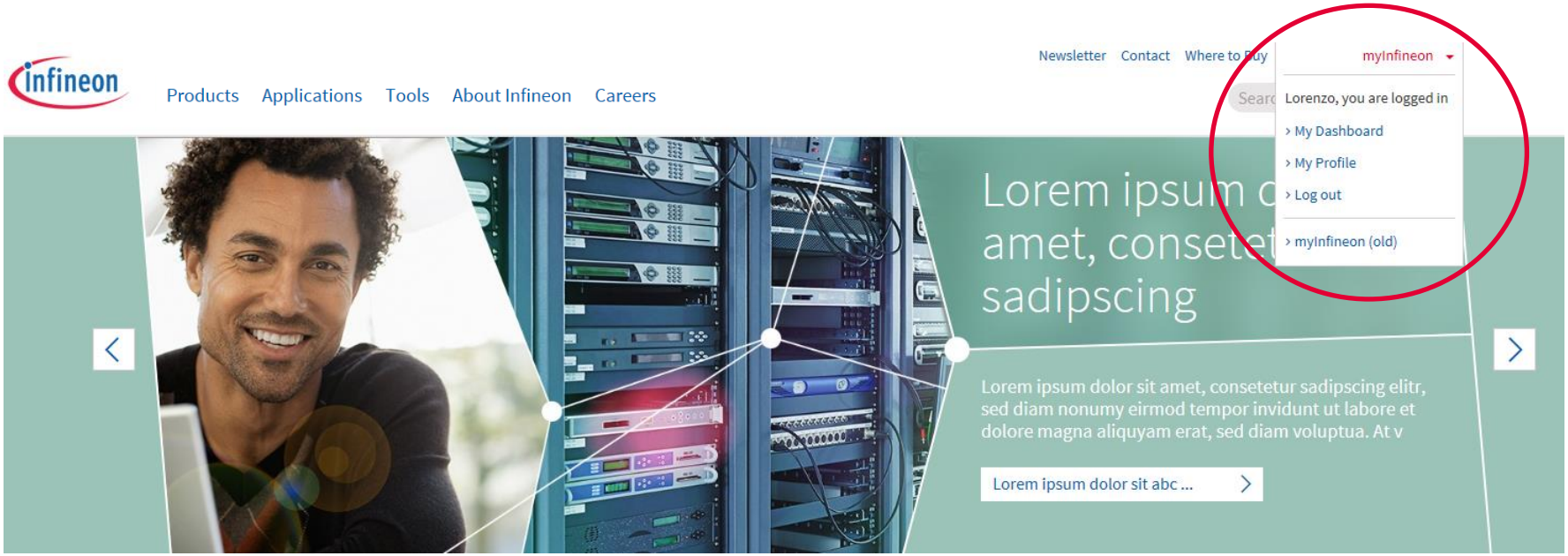

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