Gen 5 fixed frequency flyback controller, Gen 5 quasi-resonant flyback controller - CoolSET™, CoolMOS^{TM}, CoolGaN and CoolSiC

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April 2024

restricted

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What is CoolSET?

- An integrated device with a PWM controller and high voltage MOSFET in a single package
- To perform AC to DC power conversion – ***S***witched ***M***ode ***P***ower ***S***upply (SMPS)

PWM controller

+

High voltage MOSFET

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5th generation CoolSET™ for auxiliary SMPS

Robustness

- Integrated 700 V, 800 V or 950 V superjunction MOSFET
- Comprehensive protection features
- Auto-restart scheme to minimize interruption

Ease of design

- Numerous design examples covering both indoor and outdoor aircon
- Design tools, guide and application note
- Reference designs

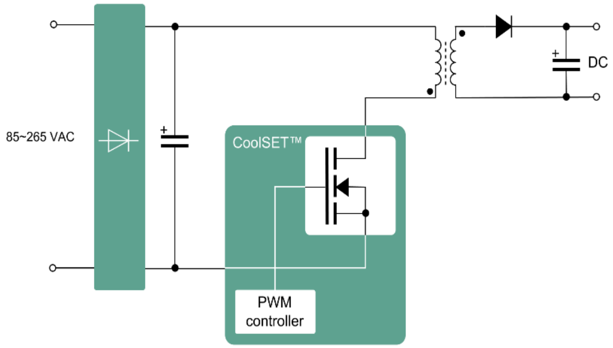
Broad portfolio

- Choice of fixed- frequency or quasi-resonant switching scheme
- Isolated flyback or non-isolated buck topology
- Highest power delivery up to 43 W
- Available in DIP-7 or SMD DSO-12 package

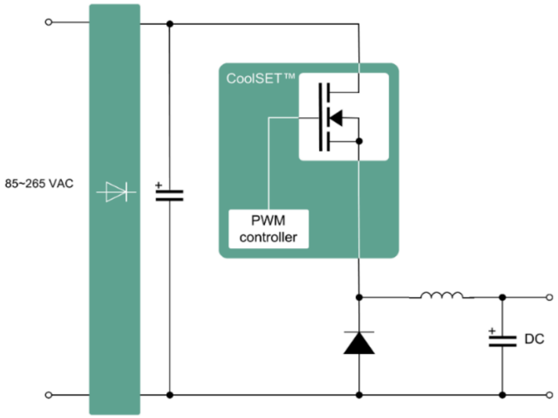
AUX power

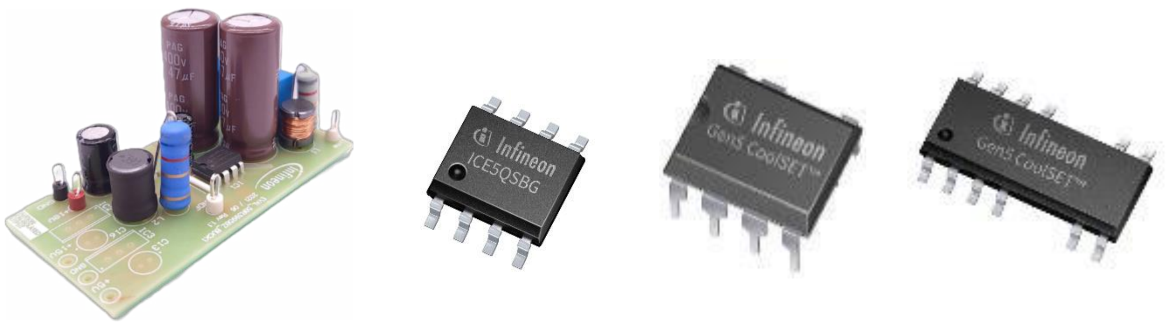
Auxiliary SMPS in Flyback or buck topology to perform AC/DC power conversion to power the various system blocks in home appliances.

Flyback



Buck





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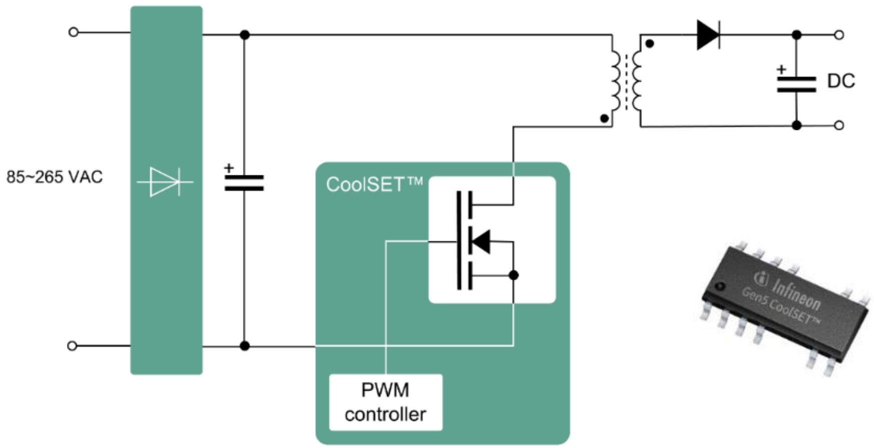
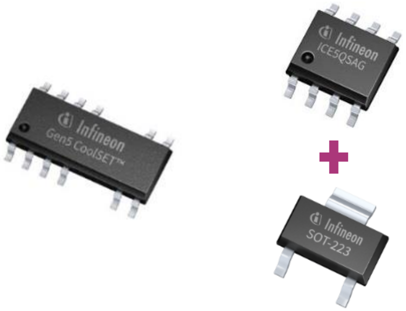
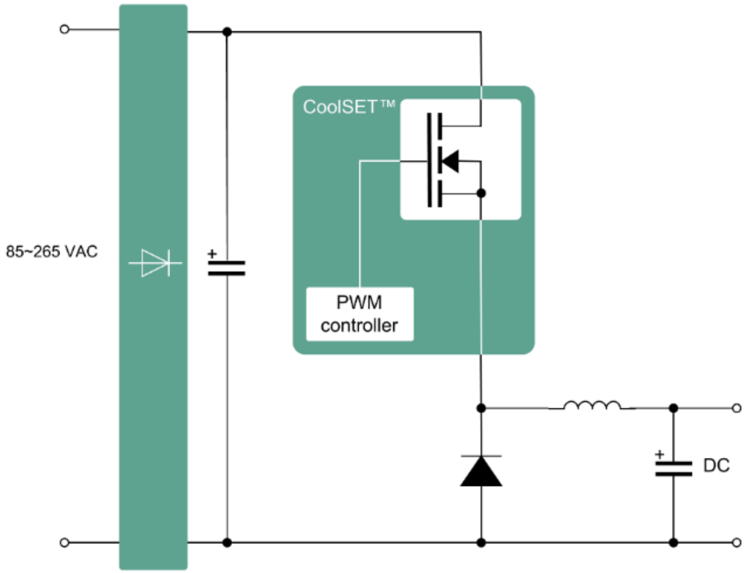
Scalable Platform – From a Few Watts to >60W

High power delivery capability in DIP-7 and DSO-12 package



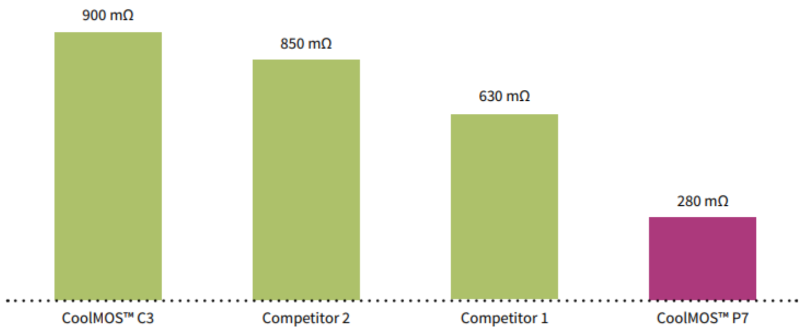


- Offline switch mode power supply
- Isolated and non-isolated Flyback topology
- Output power up to 42 W - Integrated
- >60 W with external MOSFET
- Support an output current of up to **700 mA in Buck**
- Robust **avalanche rugged CoolMOS™** inside



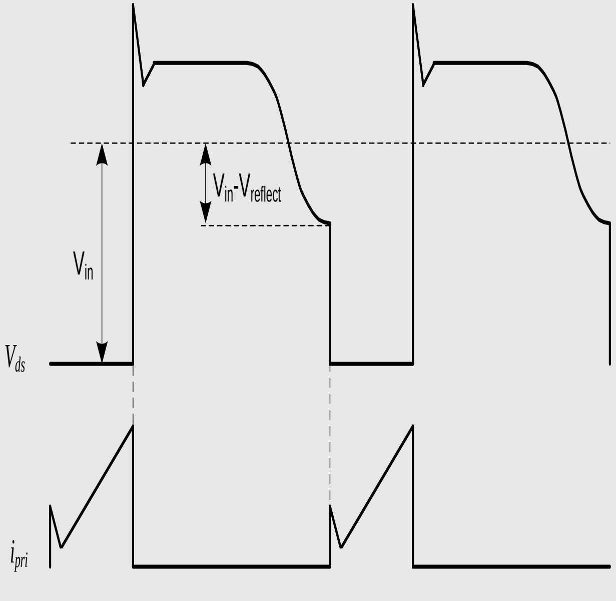
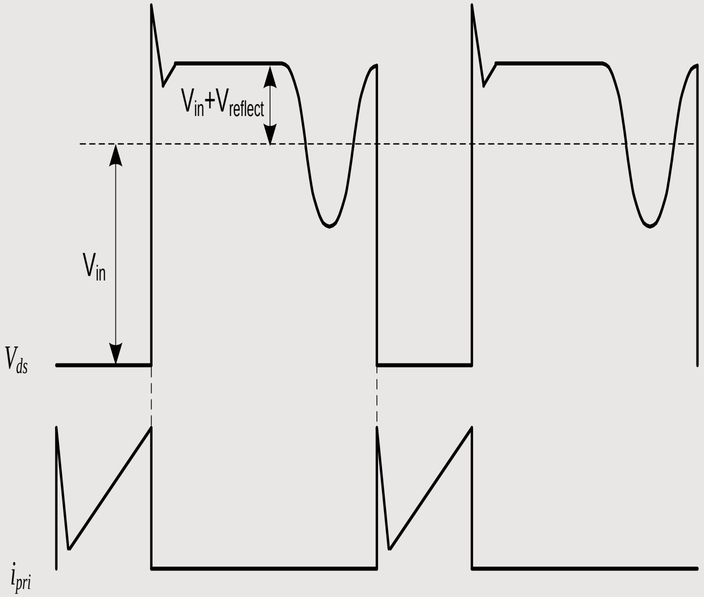
DSO12 - 2024

Overview of lowest DPAK $R_{DS(on)}$ for 800 V superjunction MOSFETs



800 V CoolMOS™ P7 sets benchmark in best-in-class DPAK $R_{DS(on)}$

CoolSET™ Switching Scheme

	Quasi-resonant	Fixed frequency
MOSFET turn ON		
	$P_{SW\_on} = \frac{1}{2} C_{o(er)} (V_{IN} - V_{reflection})^2 f_{SW}$	$P_{SW\_on} = \frac{1}{2} C_{o(er)} (V_{IN} + V_{reflection})^2 f_{SW}$
Frequency	Selectable (based on inductance value)	Fixed frequency @ 65 kHz, 100 kHz or 125 kHz
Operation	QRM	DCM or CCM
Valley Detection	Digital frequency reduction up to 10th valley	Not applicable

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Gen 5 fixed frequency flyback controller versus Gen 5 quasi-resonant flyback controller - CoolSET™

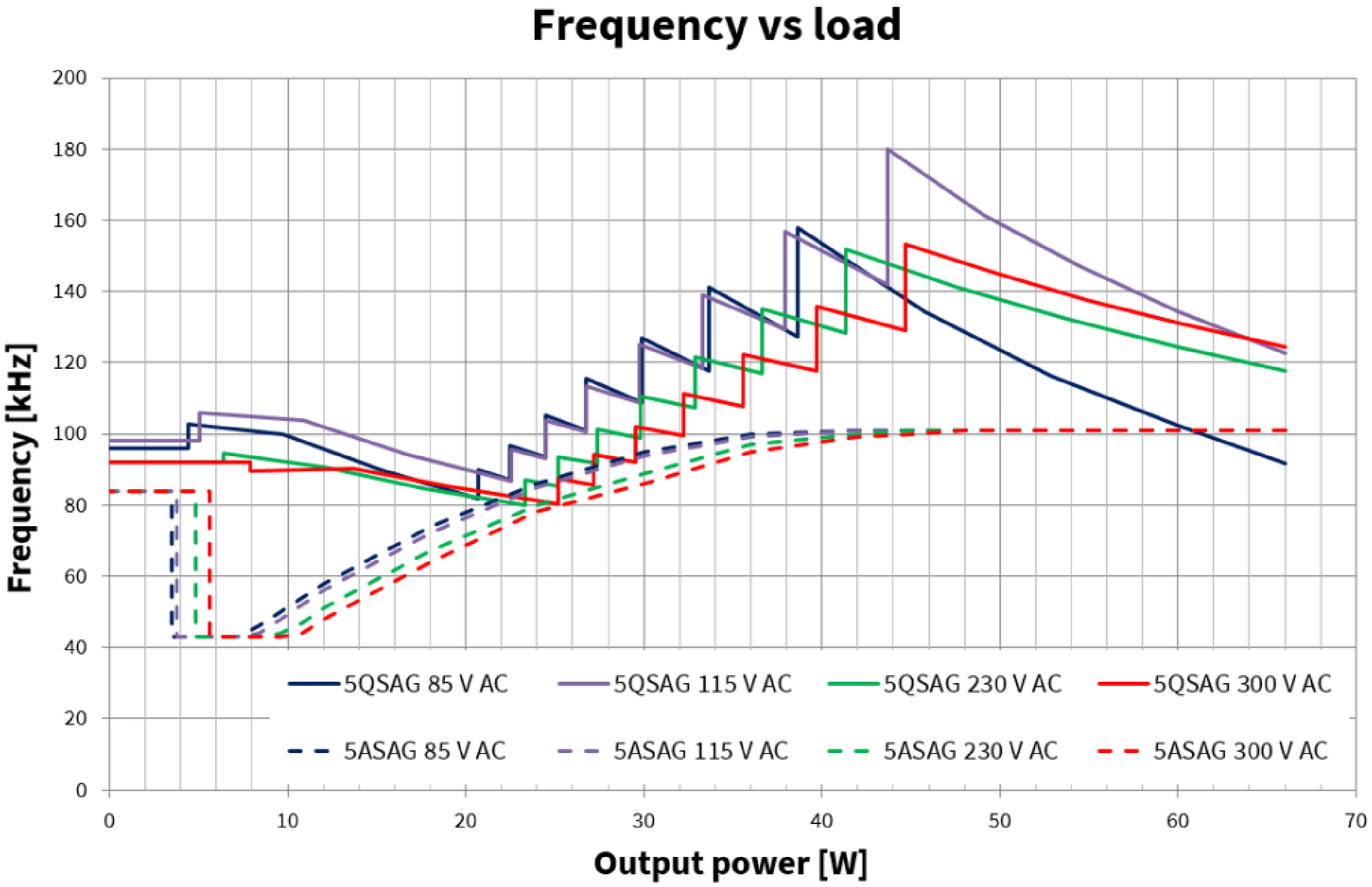
QR

- Lower losses – higher power
- Higher efficiency at full load
- Wider spread in frequency

SAME FAMILY
SIMILAR FEATURE SET

FF

- Allows CCM operation (lower output ripple)
- Integrated Op Amp – Simple resistor divider feedback



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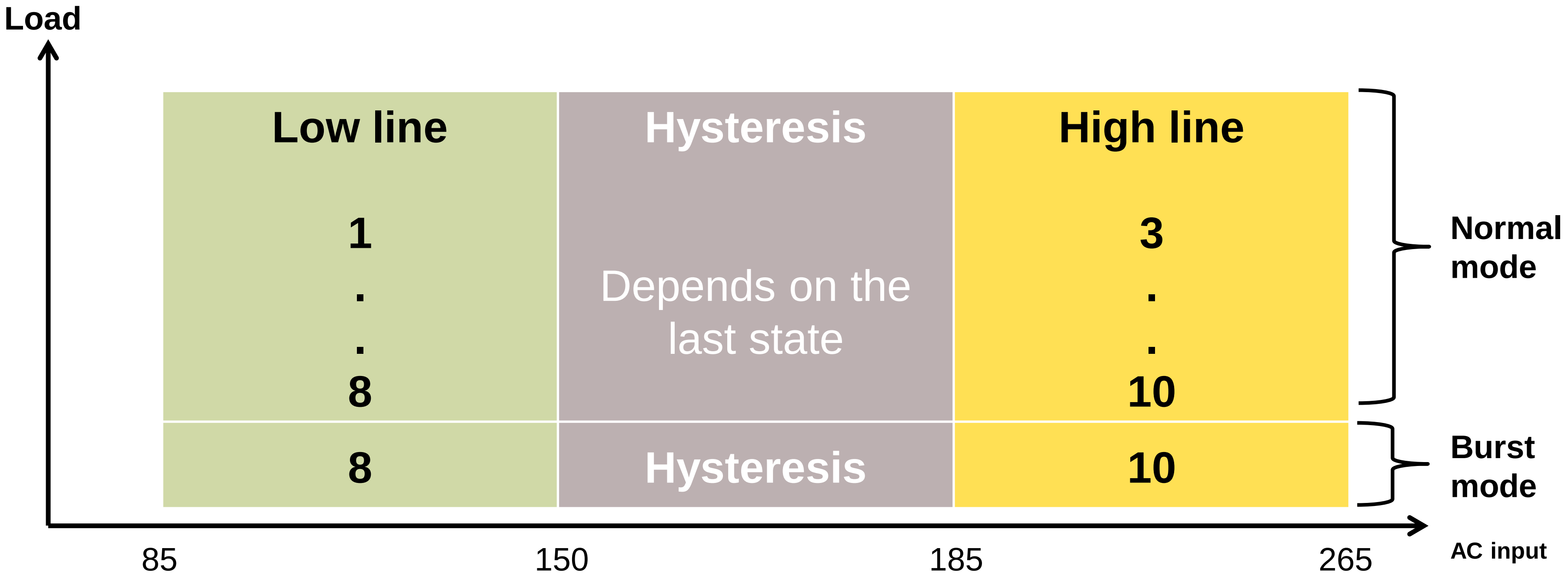
Novel Quasi-Resonant (Patented)



Load

	Low line	Hysteresis	High line	
	1 . . 8	Depends on the last state	3 . . 10	Normal mode
	8	Hysteresis	10	Burst mode

85 150 185 265 AC input

- Using the V_{IN} pin, the controller is able to differentiate between high/low AC line input to set the boundary of ZC counter operation → V_{VIN_REF}
- For low line, the zero crossing counter is allow to work within 1~8 count
- For high line, the zero crossing counter is allow to work within 3~10 count
- The hysteresis region is determine by Rl1 and Rl2 settings

Goal: To increase efficiency @ high line and reduce switching frequency spread between high/low line

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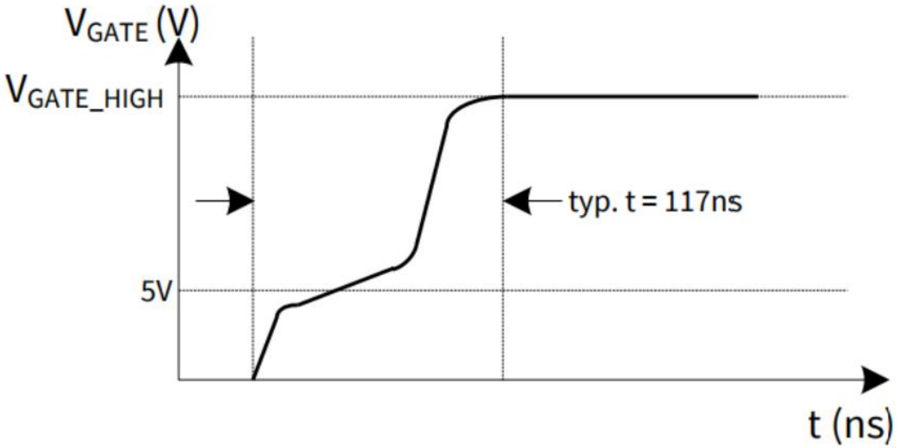
Modulate Gate Drive and Propagation Delay function



- The drive-stage is optimized for EMI
- The switch-on speed slows down before it reaches the CoolMOS™ turn on threshold.
- The leading switch spike during turn-on is minimized

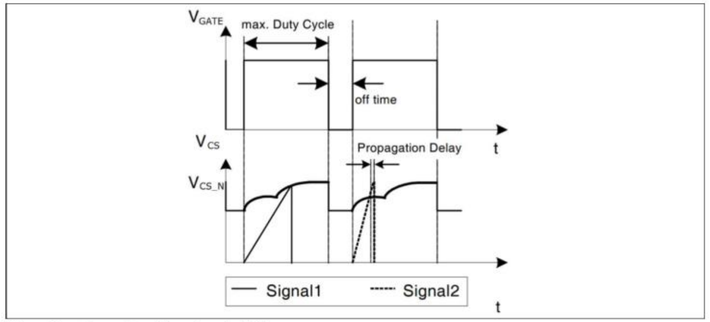


Figure 11 Dynamic voltage threshold V_{CS_N}

$$P_{out} = \eta P_{in} = \frac{1}{2}\eta L_P I_{peak}{}^2 f_S$$

Functional description

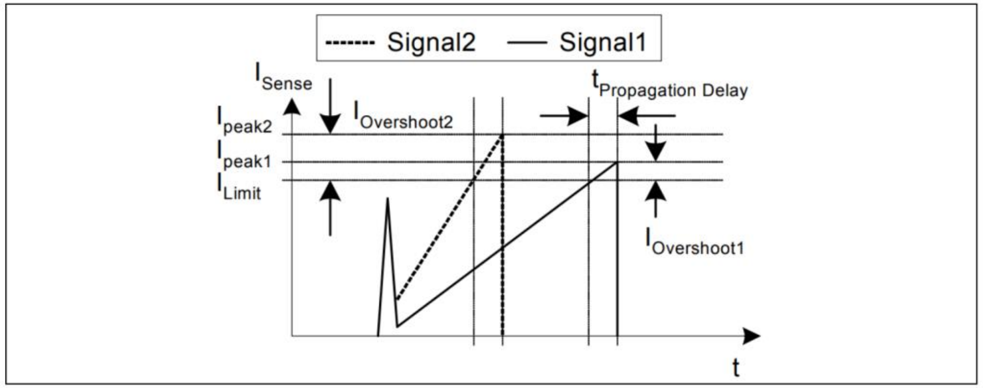


Figure 10 Current limiting

Propagation delay compensation is integrated to reduce the overshoot due to dI/dt of the rising primary current. The Current limiting becomes more accurate which will result in a minimum difference of overload protection triggering power between low and high AC line input voltage.

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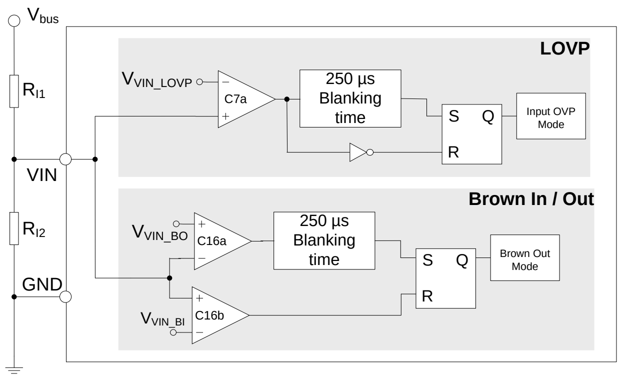
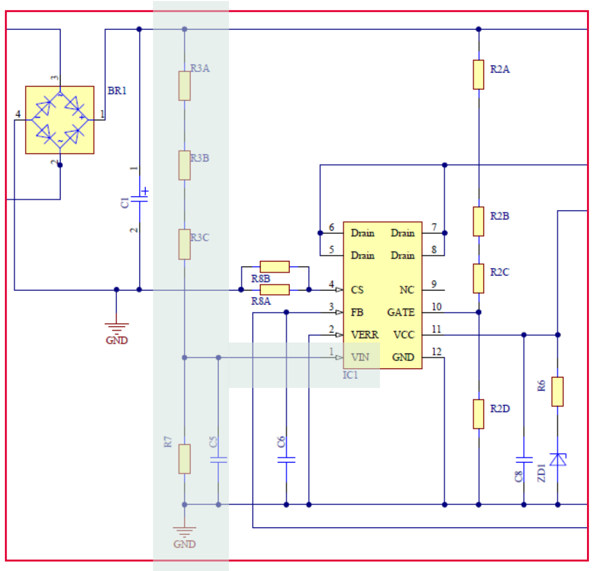
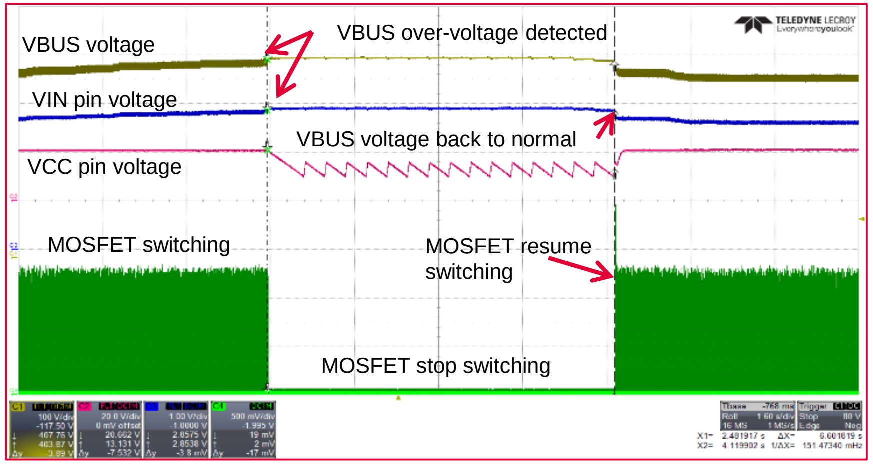
Dedicated Pin for Line Over/Under-voltage Protection





- V_{IN} **pin** senses the VBUS voltage
- Line over-voltage protection (LOVP) triggering point **adjustable** through series resistors



- Once LOVP is triggered, MOSFET will stop switching but continue to **monitor** line condition **right after VCC_ON**
- The IC will enter into **soft-start** if line voltage resumes normal state

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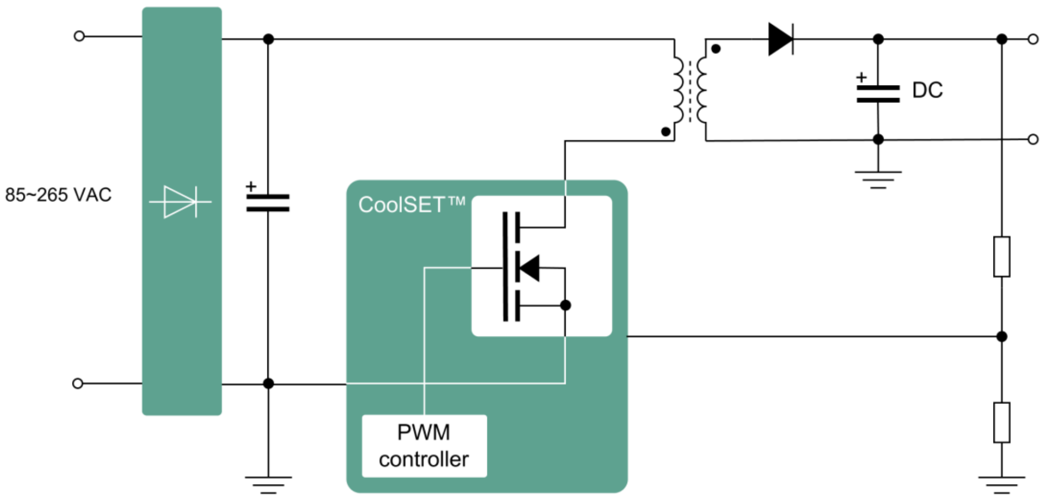
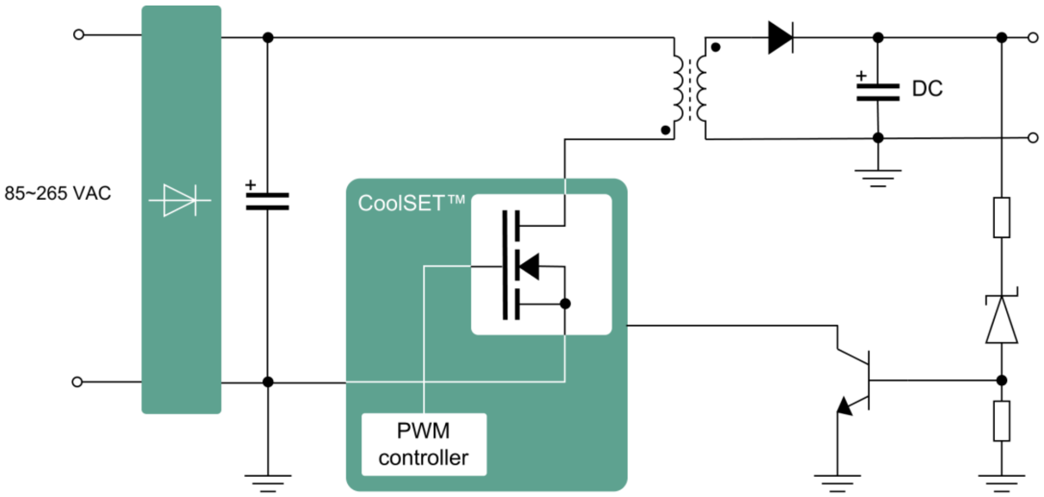
Key feature: BOM savings and ease of design with integrated error amplifier for non-isolated topologies

With integrated error amplifier



Without integrated error amplifier



- Ease of design with integrated error amplifier for non-isolated configuration
- BOM savings (e.g. 1x NPN transistor and 1x Zener diode)
- Higher and consistent (e.g. across temperature) regulation accuracy

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Fixed-frequency 800 V / 950 V CoolSET™
Absolut maximum ratings

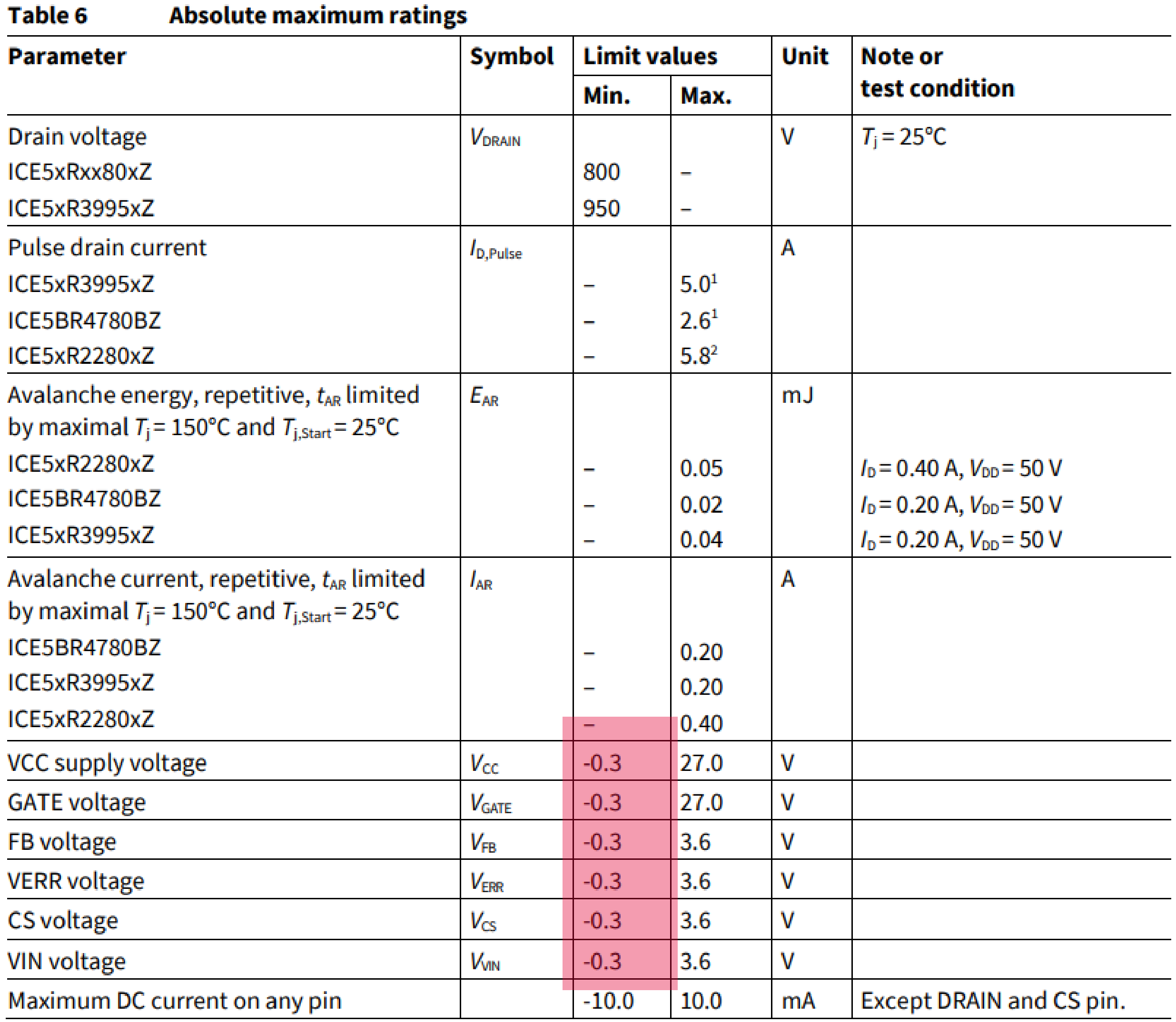

Table 6 Absolute maximum ratings

Parameter	Symbol	Limit values		Unit	Note or test condition
		Min.	Max.		
Drain voltage	V_{DRAIN}			V	$T_j = 25°C$
ICE5xRxx80xZ		800	–		
ICE5xR3995xZ		950	–		
Pulse drain current	$I_{D,Pulse}$			A	
ICE5xR3995xZ		–	5.0[1]		
ICE5BR4780BZ		–	2.6[1]		
ICE5xR2280xZ		–	5.8[2]		
Avalanche energy, repetitive, t_{AR} limited by maximal $T_j = 150°C$ and $T_{j,Start} = 25°C$	E_{AR}			mJ	
ICE5xR2280xZ		–	0.05		$I_D = 0.40$ A, $V_{DD} = 50$ V
ICE5BR4780BZ		–	0.02		$I_D = 0.20$ A, $V_{DD} = 50$ V
ICE5xR3995xZ		–	0.04		$I_D = 0.20$ A, $V_{DD} = 50$ V
Avalanche current, repetitive, t_{AR} limited by maximal $T_j = 150°C$ and $T_{j,Start} = 25°C$	I_{AR}			A	
ICE5BR4780BZ		–	0.20		
ICE5xR3995xZ		–	0.20		
ICE5xR2280xZ		–	0.40		
VCC supply voltage	V_{CC}	-0.3	27.0	V	
GATE voltage	V_{GATE}	-0.3	27.0	V	
FB voltage	V_{FB}	-0.3	3.6	V	
VERR voltage	V_{ERR}	-0.3	3.6	V	
CS voltage	V_{CS}	-0.3	3.6	V	
VIN voltage	V_{VIN}	-0.3	3.6	V	
Maximum DC current on any pin		-10.0	10.0	mA	Except DRAIN and CS pin.

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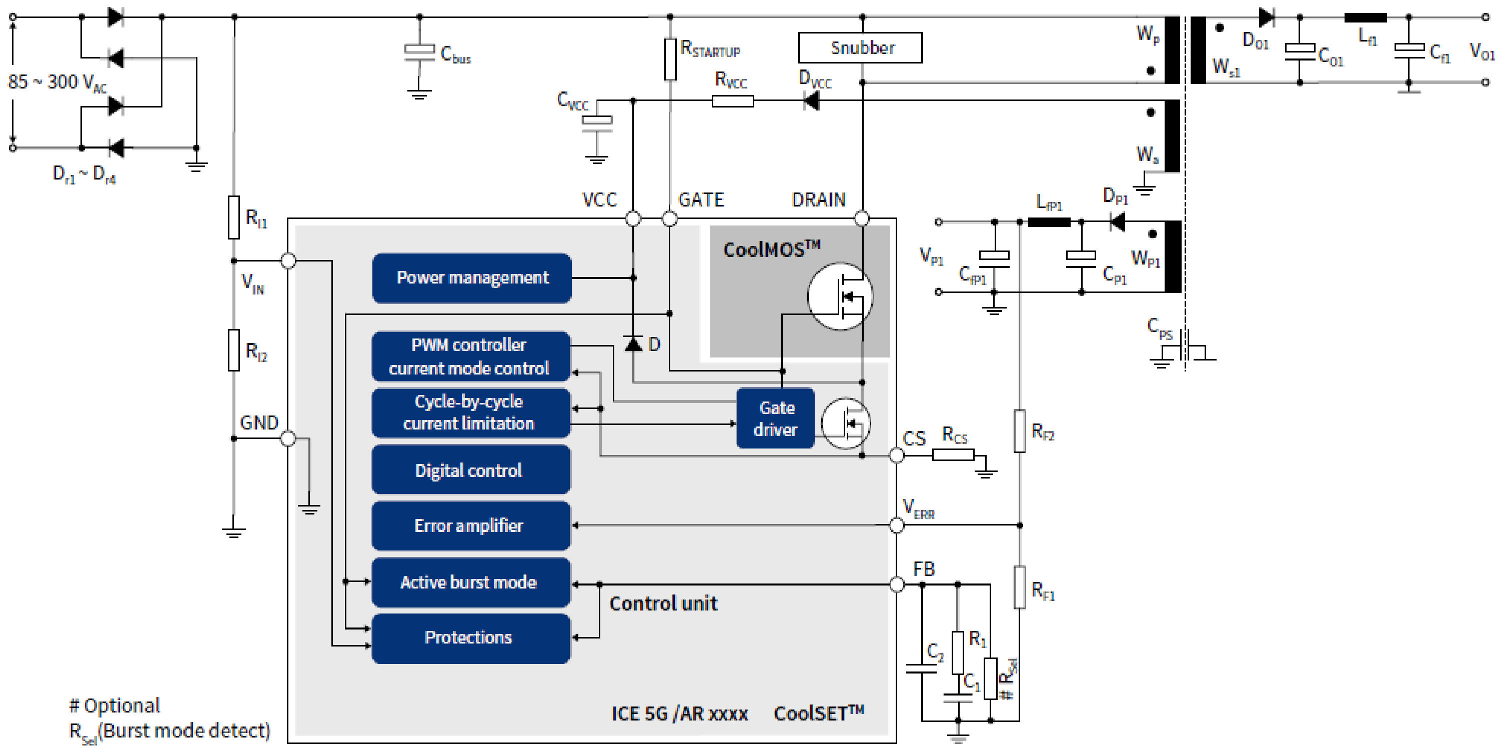
Product and system overview

5th generation: Fixed frequency flyback controllers and integrated power stages

System / application overview



Descriptions

The latest iteration of fixed frequency flyback controller and CoolSET^{TM} offering high level of integration with an enhanced, comprehensive suite of protection features.

Key features

- Rapid and robust start-up
- Improve efficiency with frequency reduction
- 65 kHz, 100 kHz and 125 kHz switching frequency variant
- Supports both isolated and non-isolated flyback and buck topology
- Additional protection features
- Auto-restart mode
- High power integration with CoolMOS™ P7

Washing Machine

Aircon

Fridge

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Typical application as isolated flyback and non-isolated flyback converter

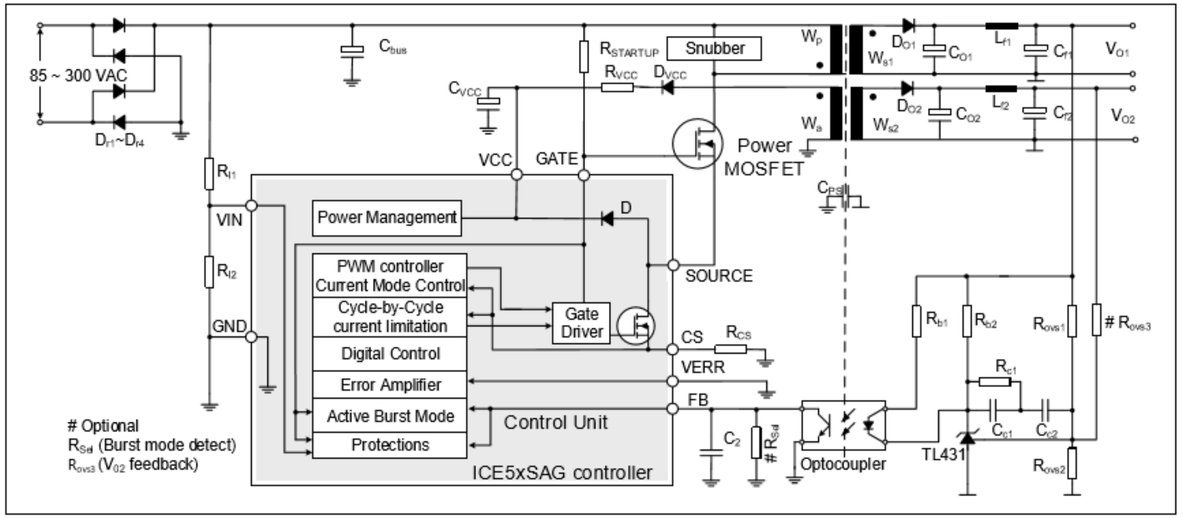


Figure 1 Typical application in isolated flyback using TL431 and optocoupler

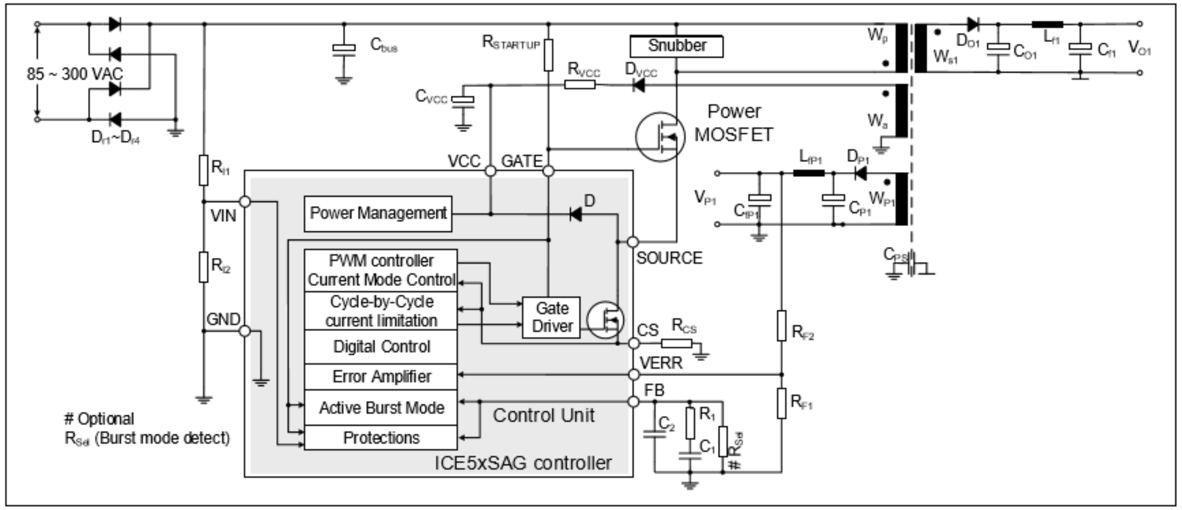
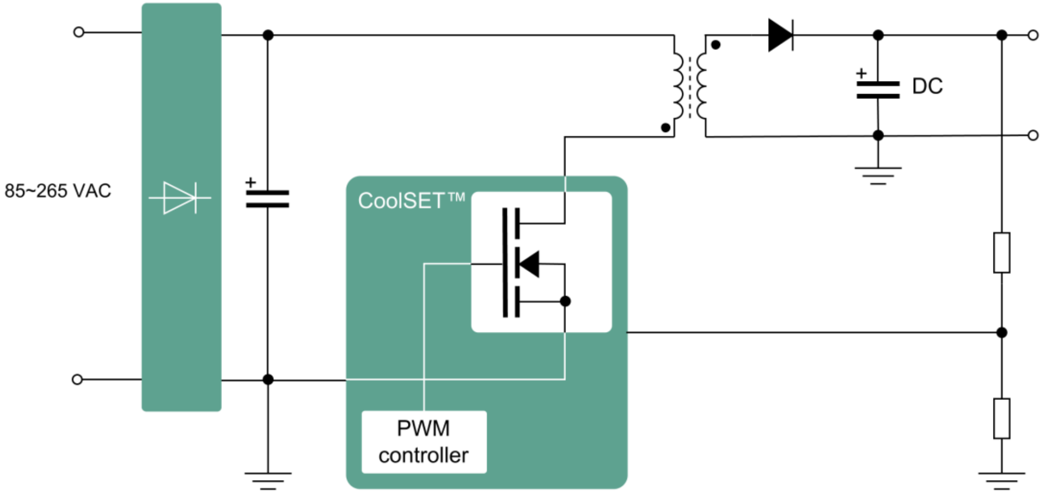
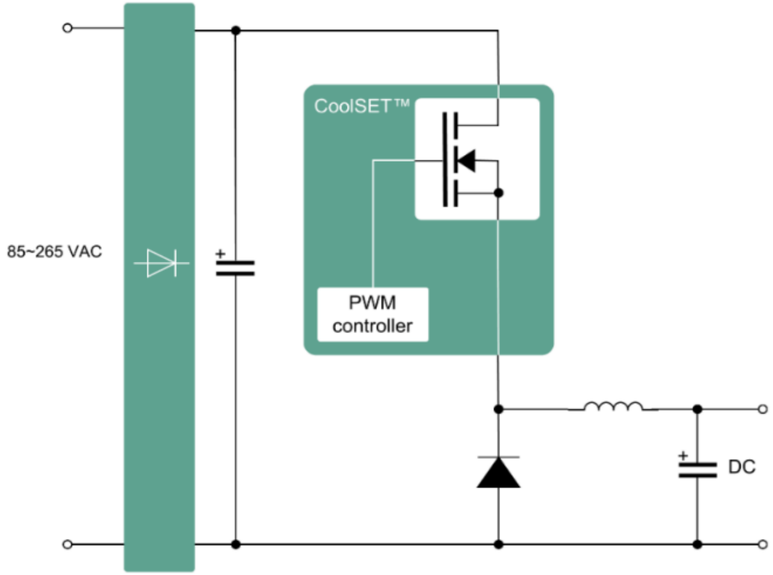


Figure 2 Typical application in non-isolated flyback utilizing integrated error amplifier





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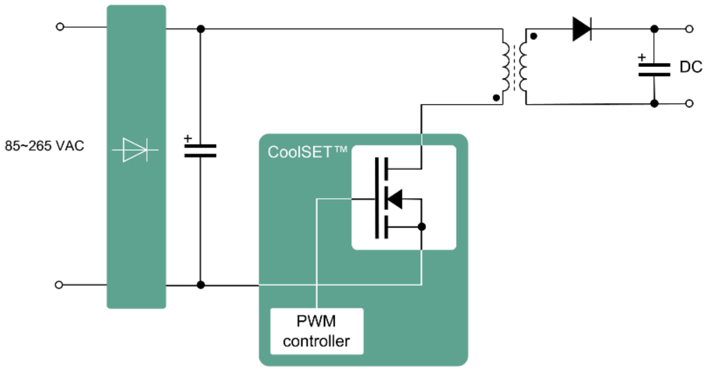
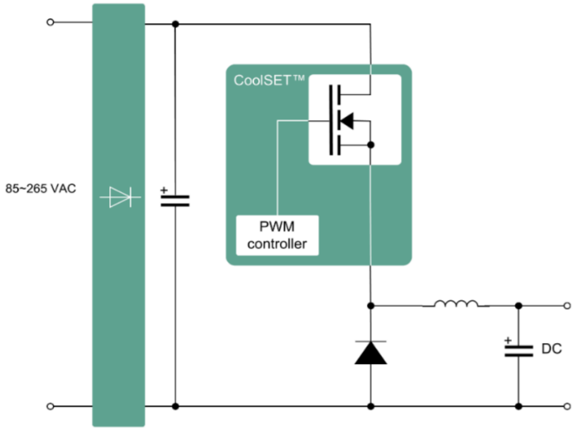
Target applications

Isolated/non-isolated flyback



Non-isolated buck



AC-DC

Main power SMPS

- Adapter
- Industrial SMPS
- Set Top Box
- Water Purifier
- TV
- PoE

AUX power

Aux power SMPS

- Server
- PC Power
- Fridge
- Aircon
- Audio
- Heating

- Offline auxiliary / bias power supply
- Isolated and non-isolated flyback topology (up to 60 W)
- Non-isolated buck topology (up to 700 mA)

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Key features

5th generation: Fixed frequency flyback controllers and integrated power stages

- **Key features**
  - 65 kHz, 100 kHz and 125 kHz switching frequency
  - Improved EMI performance with frequency jittering
  - Fixed frequency with frequency reduction (up to 2.35x)
  - Integrated error amplifier for non-isolated flyback and buck topology (optional)
  - Selectable active burst mode entry/exit profile (optional)
  - DCM/CCM current control mode
  - Cascode configuration for fast & robust start-up operation
  - CoolSET™ offering with both 700 V, 800 V and 950 V CoolMOS™

- **Protection (Auto-restart)**
  - Adjustable line input OVP
  - Adjustable brown IN (optional)
  - VCC over/under voltage
  - VCC short to ground protection
  - Open loop / overload / output short circuit protection
  - OTP with hysteresis

- **Package**
  - Standalone controller – DSO-8
  - CoolSET™ – DSO-12 and DIP-7

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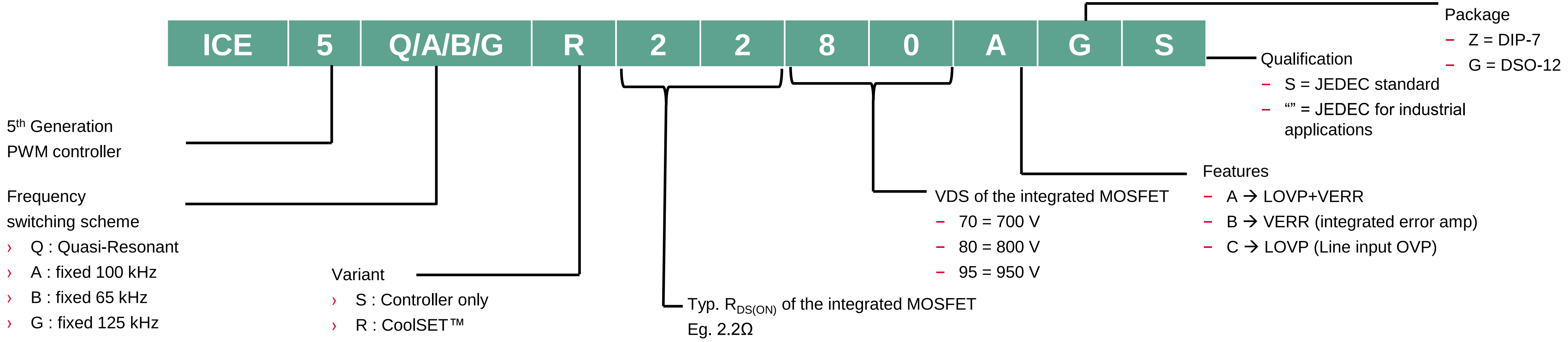
Portfolio

5th generation: Fixed frequency flyback controllers and integrated power stages

Max P_{out} 85~300 V_{AC} T_a=50ºC		15 W	17 W	23 W	27 W	40 W	60 W
External	DSO-8						ICE5ASAG ICE5GSAG
700 V	DIP-7	ICE5AR4770BZS					
	DSO-12	ICE5AR4770AG					
800 V	DIP-7	ICE5AR4780BZS ICE5BR4780BZ		ICE5AR2280CZ ICE5BR2280BZ		ICE5AR0680BZS	
	DSO-12	ICE5GR4780AG		ICE5GR2280AG	ICE5GR1680AG	ICE5AR0680AG	
950 V	DIP-7		ICE5BR3995BZ ICE5BR3995CZ				



5th Generation
PWM controller

Frequency
switching scheme

- Q : Quasi-Resonant
- A : fixed 100 kHz
- B : fixed 65 kHz
- G : fixed 125 kHz

Variant

- S : Controller only
- R : CoolSET™

Typ. $R_{DS(ON)}$ of the integrated MOSFET
Eg. 2.2Ω

VDS of the integrated MOSFET

- 70 = 700 V
- 80 = 800 V
- 95 = 950 V

Features

- A → LOVP+VERR
- B → VERR (integrated error amp)
- C → LOVP (Line input OVP)

Qualification

- S = JEDEC standard
- “” = JEDEC for industrial applications

Package

- Z = DIP-7
- G = DSO-12

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Gen5-FF Product Portfolio Extensions with 950V Integrated MOSFET– Buck and 3-Phase Designs

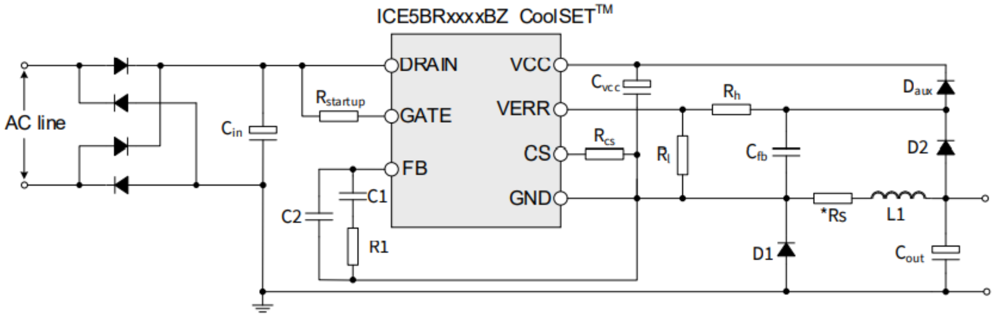
Max P_{out} 85~300 V_{AC} T_a=50°C	Max switching frequency	15 W	23 W	40 W
700 V	100 kHz	ICE5AR4770BZS		
800 V	100 kHz	ICE5AR4780BZS	**ICE5AR2280CZ**	ICE5AR0680BZS
	65 kHz	**ICE5BR4780BZ**	**ICE5BR2280BZ**	
950 V	**65 kHz**	**ICE5BR3995BZ**		
		ICE5BR3995CZ		

NEW!

- ICE5**A**RxxxxxZx → 100 kHz
- ICE5**B**RxxxxxZ → 65 kHz

- ICE5xRxxxx**C**Z
  - Line input over voltage protection

- 65kHz for Buck topologies



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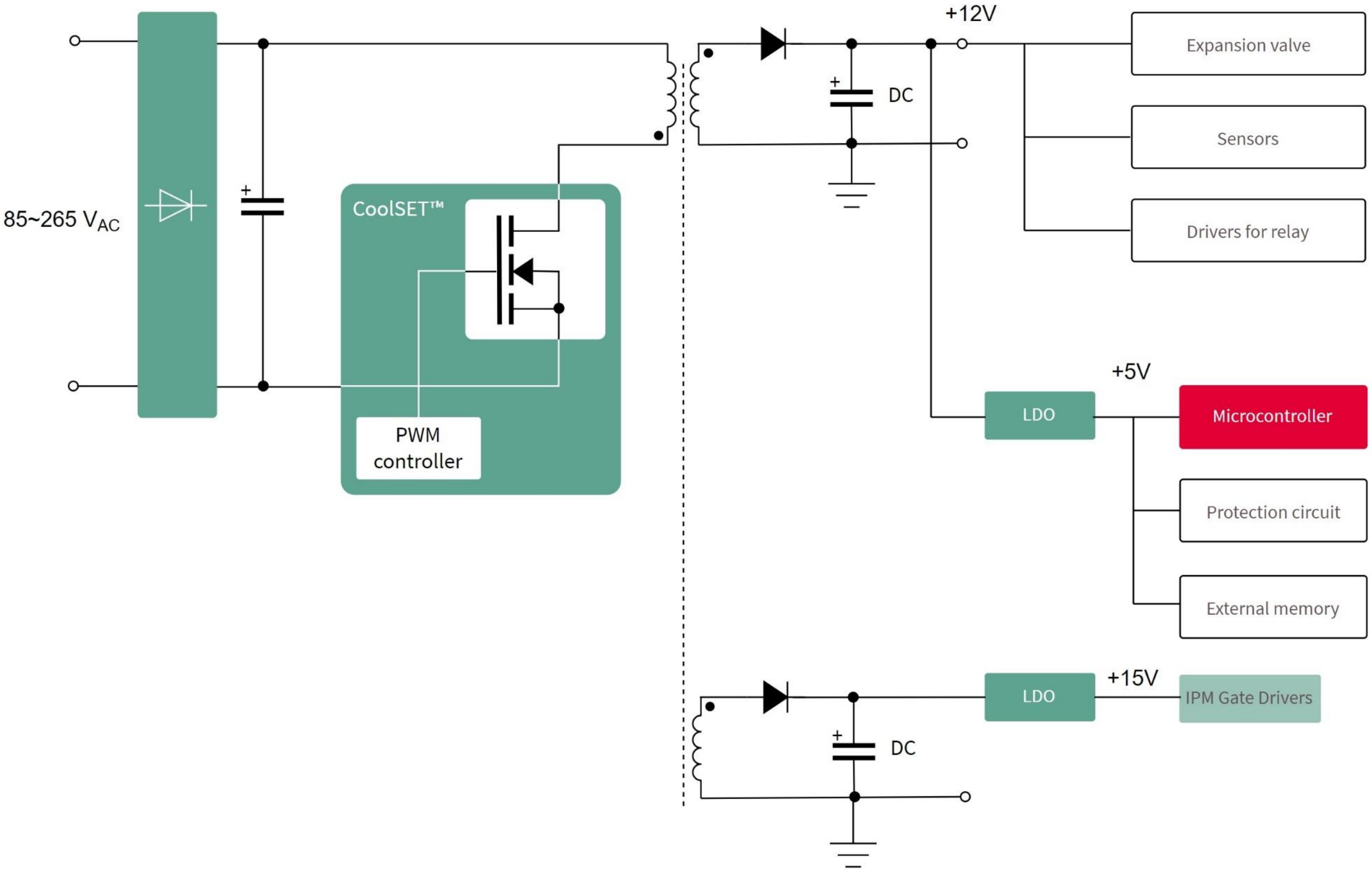
Application example: residential air-condition (Outdoor)



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Why 5th generation fixed frequency CoolSET™ ?

	Features	Benefits	Addressed customers’ needs
Strong arguments	Integrated LOVP, brown IN protection & error amplifier	**BOM savings**	› Save more than 10 components for implementation via discrete components ~USD 0.05
	Frequency reduction	**High efficiency at mid and light load**	› Reduced switching frequency at mid & light load to achieve higher efficiency
	Slope compensation for CCM	**High power delivery**	› Highest power delivery in the market of up to 43 W with 800 V CoolSET™
	V_{CC} pin short to ground protection & enhanced OTP	**Robust system protection**	› Avoid permanent damage to controller due to vital pins shorted to ground › Avoid looping of protection mode due to absence of hysteresis during OTP
	Integrated P7 flyback optimized CoolMOS™	**Run cooler with P7 CoolMOS™**	› Simplified and enhanced thermal performance
Medium arguments	Cascode configuration	**Fast & robust startup**	› Utilizing the integrated CoolMOS™ to facilitate start-up with higher charging current enable faster start-up time
	Selectable active burst mode Entry/eExit profile	**Optimize standby power**	› Flexibility in optimizing standby and light load performance with dual active burst node entry/exit profile to choose from
Soft arguments	Platform support	**Fast time to market**	› High design reusability & interoperability across various power & regional requirements for fastest time-to-market

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Demo board availability

Generation 5-FF

(1/2)

S/N	Part number	P_{out}	Output	Isolated	App note	Available @ ISAR
1	REF_5AR4770AG_3W1	3 W	5 V	Yes	Internet	Yes
2	EVAL_5BR3995BZ_BUCK1	5.4 W	18 V	No	Internet	Yes
3	EVAL_5BR4780BZ_450mA1	6.7 W	15 V	No	Internet	Yes
4	REF_5AR4770BZS_8W1	8 W	12 V, 5 V	Yes	Internet	Yes
5	REF_5BR2280BZ_700mA1	10.5 W	15 V	No	Internet	Yes
6	REF_5AR4770AG_13W1	13 W	12 V, 15 V	No	Internet	Yes
7	DEMO_5AR4770AG_14W1	14 W	15 V, 5 V	No	Internet	Yes
8	DEMO_5GR4780AG_14W1	14 W	15 V, 5 V	No	Internet	Yes
9	DEMO_5AR4780BZS_14W1	14 W	15 V, 5 V	No	Internet	Yes
7	REF_5AR4770BZS_15W1	15 W	12 V	Yes	Internet	Yes
8	REF_5AR4770AG_15W1	15 W	12 V, 15V	Yes / No	Internet	Yes
9	REF_5BR4780BZ_15W1	15 W	15 V, 12 V, 5 V	No	Internet	Yes
10	REF_5BR3995BZ_16W1	16 W	15 V, 12 V, 5 V	No	Internet	Yes
11	REF_5BR3995CZ_16W1	16 W	12 V, 5 V, 5 V	Yes	Internet	Yes
12	REF_5GSAG_18W1	18 W	12 V	Yes	Internet	Yes

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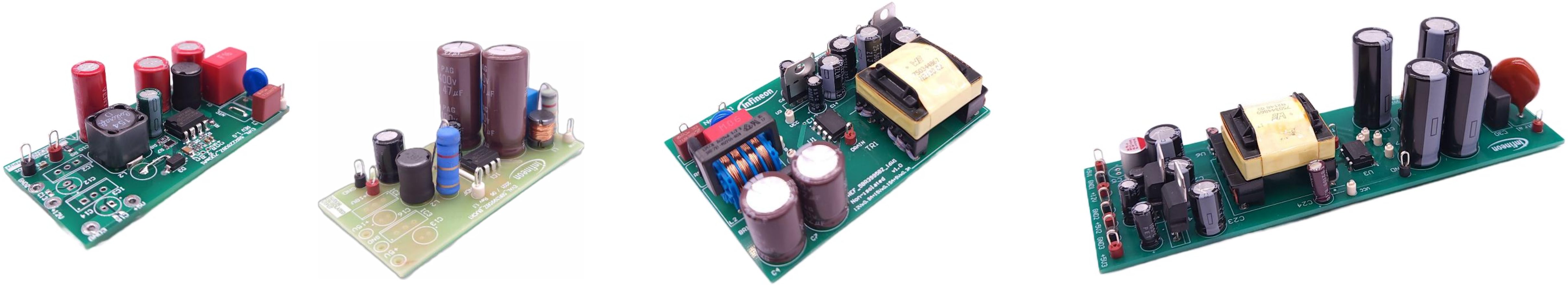
Demo board availability

Generation 5-FF

(2/2)

S/N	Part number	P_{out}	Output	Isolated	App note	Available @ ISAR
13	DEMO_5GR2280AG_22W1	22 W	12 V, 5 V	Yes	Internet	Yes
14	REF_5GR2280AG_22W1	22 W	15 V, 12 V, 20 V	No / Yes / Yes	Internet	Yes
15	REF_5BR2280BZ_22W1	22 W	15 V, 12 V, 5 V	No / Yes / Yes	Internet	Yes
16	REF_5AR2280CZ_22W1	22 W	15 V, 12 V, 5 V	No / Yes / Yes	Internet	Yes
17	DEMO_5GR1680AG_27W1	27 W	12 V, 5 V	Yes	Internet	Yes
18	DEMO_5AR0680AG_44W1	44 W	12 V	Yes	Internet	Yes
19	DEMO_5AR0680BZS_44W1	44 W	12 V	Yes	Internet	Yes
20	DEMO_5ASAG_60W1	60 W	12 V, 5 V	Yes	Internet	Yes
21	DEMO_5GSAG_60W1	60 W	19 V	Yes	Internet	Yes



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Infineon 5th generation CoolSET™

Auxiliary power supply evaluation boards for RAC application

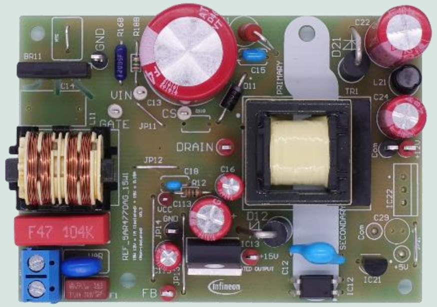
Indoor RAC (isolated except 15 V rail)

REF_5AR4770BZS_8W1

Input: 85 ~ 265 V_{AC}

Output #1: 12 V / 450 mA

Output #2: 5 V / 500 mA

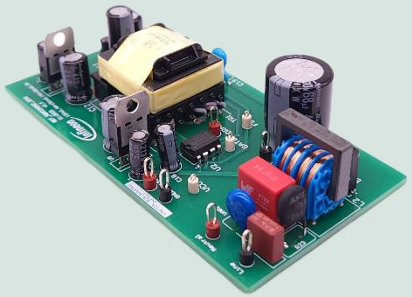


REF_5AR4770AG_15W1

Input: 85 ~ 264 V_{AC}

Output #1: 15 V / 150 mA

Output #2: 12 V / 1000 mA



REF_5BR2280BZ_22W1

Input: 85 ~ 264 V_{AC}

Output #1: 15 V / 150 mA

Output #2: 12 V / 1400 mA

Output #3: 5 V / 300 mA

Outdoor RAC (non-isolated)

REF_5AR4770AG_13W1

Input: 85 ~ 264 V_{AC}

Output #1: 15 V / 150 mA

Output #2: 12 V / 850 mA

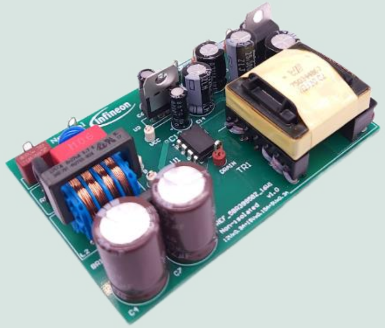
REF_5BR4780BZ_15W1

Input: 85 ~ 264 V_{AC}

Output #1: 15 V / 150 mA

Output #2: 12 V / 800 mA

Output #3: 5 V / 300 mA



REF_5BR3995BZ_16W1

Input: 85 ~ 264 V_{AC}

Output #1: 15 V / 150 mA

Output #2: 12 V / 900 mA

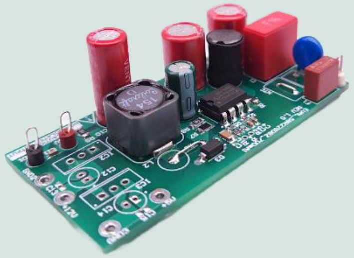
Output #3: 5 V / 300 mA

Misc (non-isolated buck)

EVAL_5BR4780BZ_450mA1

Input: 85 ~ 264 V_{AC}

Output: 15 V / 450 mA (6.7 W)



EVAL_5BR2280BZ_700mA1

Input: 85 ~ 264 V_{AC}

Output: 15 V / 700 mA (10.5 W)

EVAL_5BR3995BZ_BUCK1

Input: 85 ~ 460 V_{AC}

Output: 18 V / 300 mA (5.4 W)

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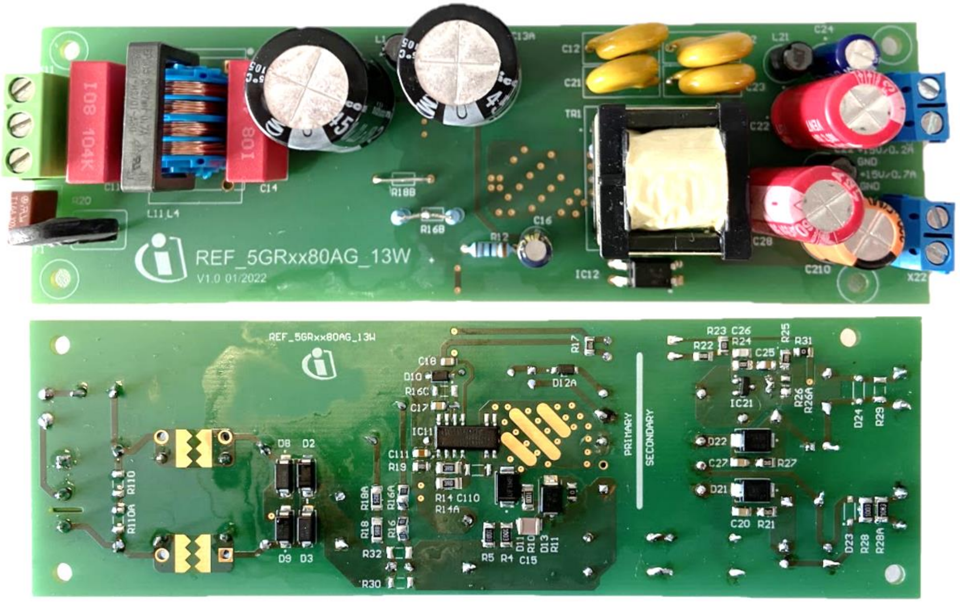
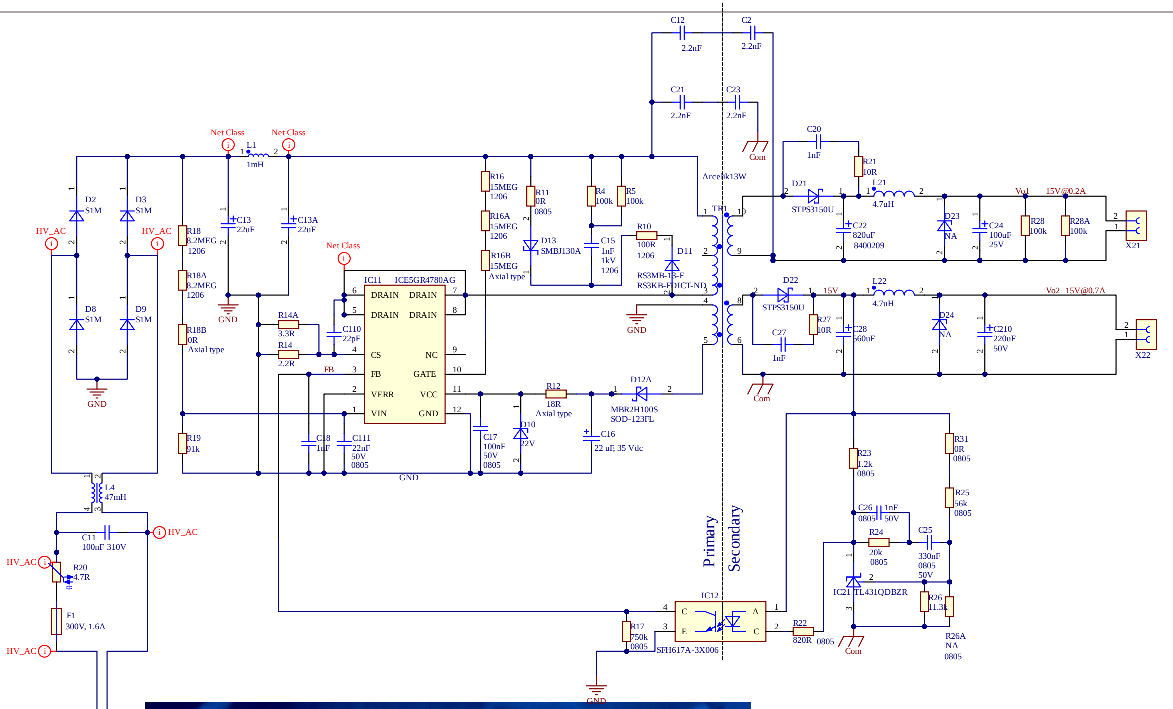
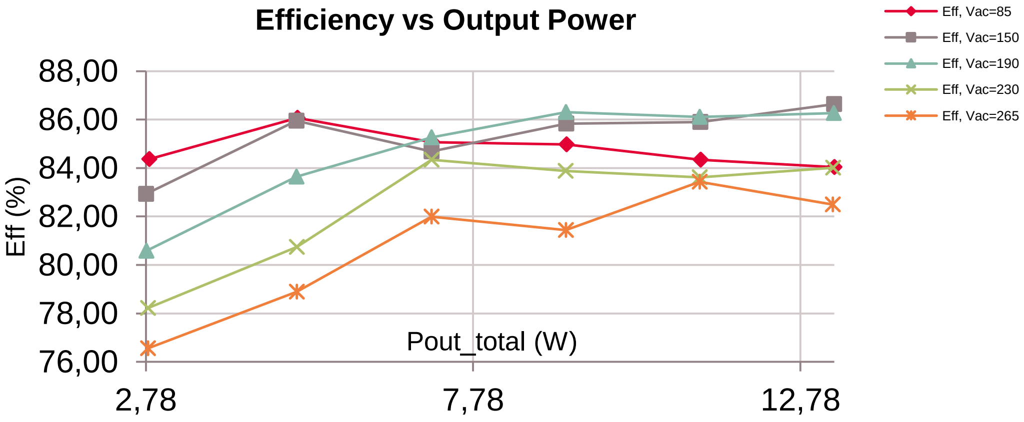
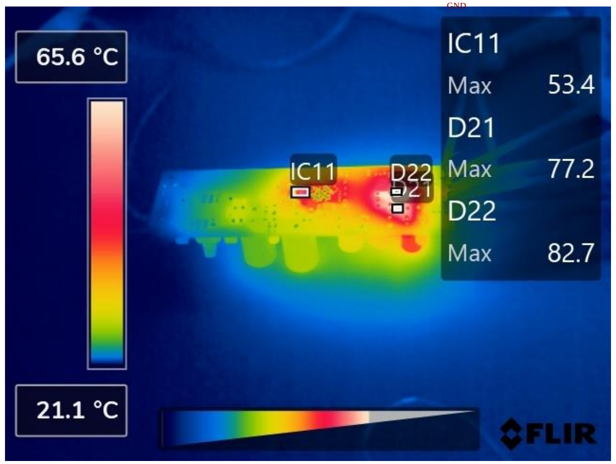
Double output 13.5W design with ICE5GR4780AG – Induction Cooking

800V MOSFET integrated









- 85~264 V_{AC} (Up to 440 VAC wrong phase connection)
- 22C Above ambient temperature
- Peak Power: 13.5 W
- Isolated output: 15 V / 700 mA
- Isolated output: 15 V / 200 mA)
- Standby < 50 mW

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Summary

- **Comprehensive suite of protections**
  - Robust line input and pin protection
  - Auto-restart recovery mode
- **High performance**
  - Frequency reduction for high efficiency at mid and light load conditions
  - Integrated CoolMOS™ P7 superjunction MOSFET
- **High power delivery**
  - Highest power delivery (without heatsink) in the market with 800 V SMD CoolSET™ of up to 60 W
  - Highest non-isolated buck output current support up to 700 mA among top tier suppliers
  - Integrated slope compensation to support CCM operation
- **High integration**
  - Integrated error amplifier to support direct feedback for non-isolated flyback or buck topology design
- **Wide portfolio**
  - Choice of 700 V, 800 V and 950 V integrated MOSFET
  - Infineon’s first CoolSET™ with 125 kHz switching frequency (on top of 65 kHz and 100 kHz)

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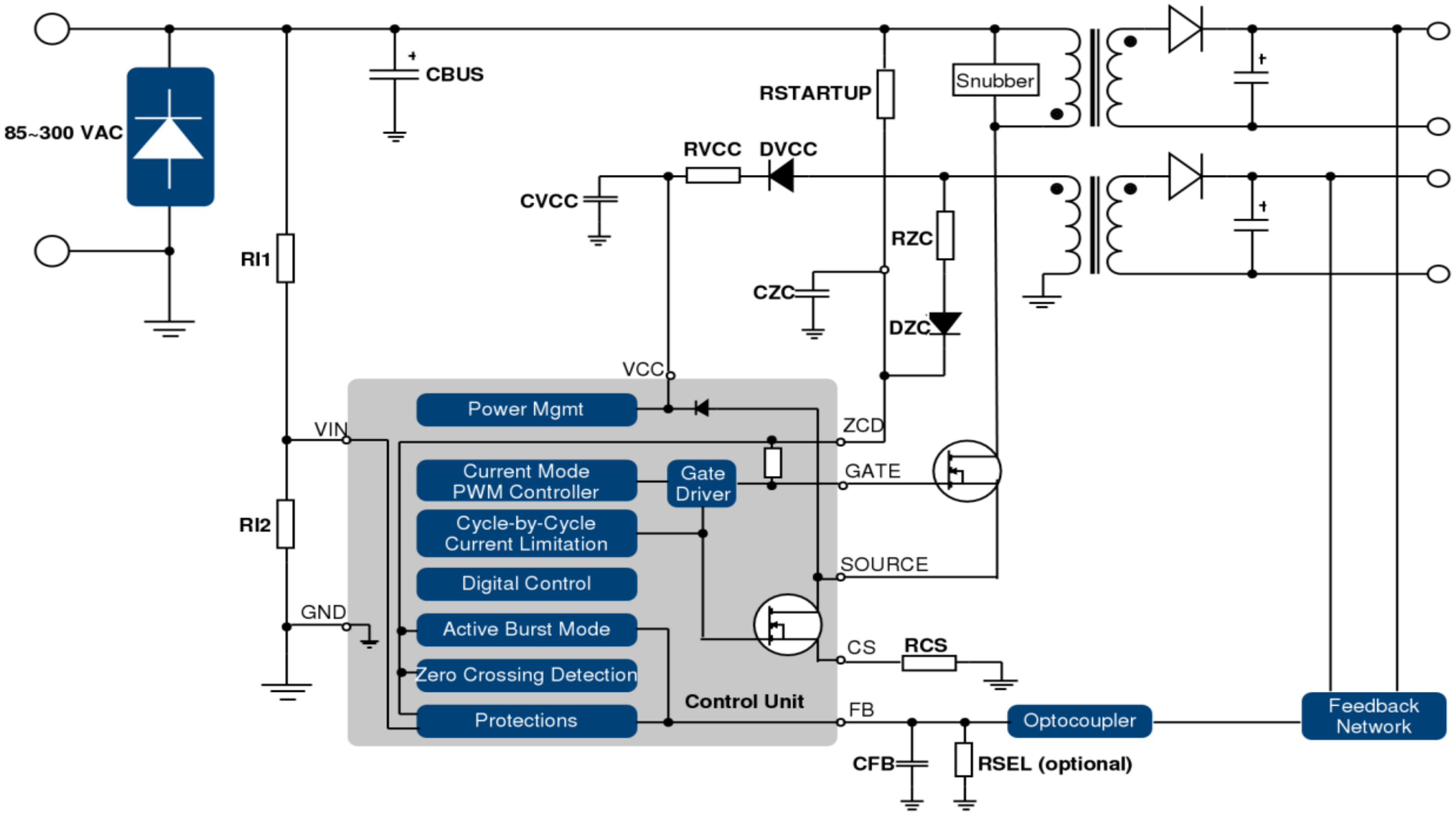
5th generation quasi-resonant
Product / system overview

System / application overview



Descriptions

- Latest iteration of quasi resonant flyback controller offering high level of integration with enhanced and comprehensive suite of protection

Key Features

- Rapid and robust start-up
- Improve efficiency
- Additional protection features
- Auto-restart mode
- High power integration with P7 CoolMOS^{TM}

Washing Machine

Aircon

Fridge

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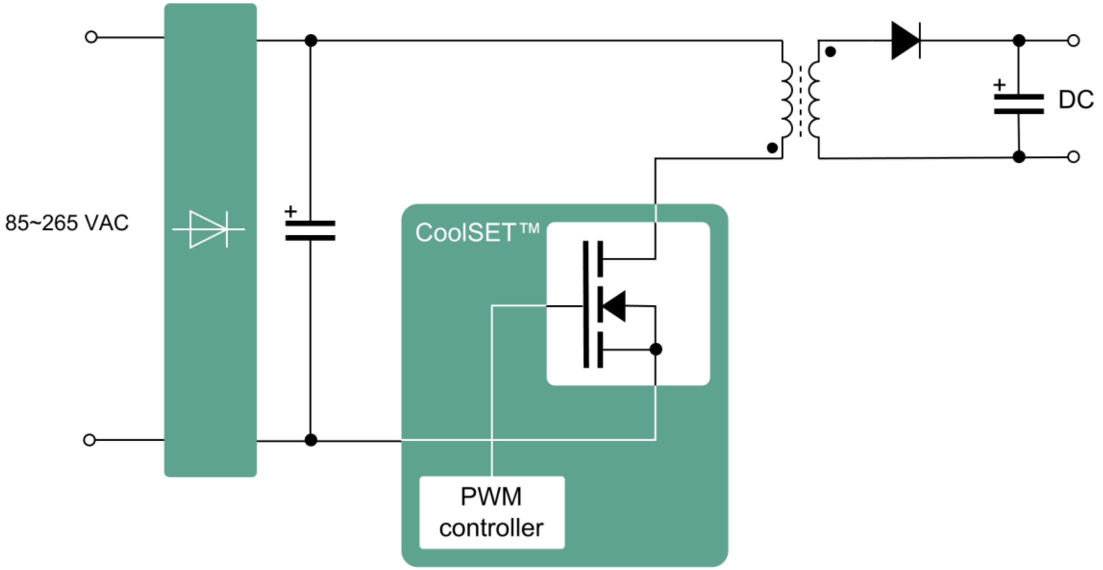
Target applications



- Offline switch mode power supply
- Isolated flyback topology
- Output power 60 W or less

AC-DC

Main power SMPS

- Adapter
- Industrial SMPS
- Set Top Box
- Water Purifier
- TV
- PoE

AUX power

Aux power SMPS

- Server
- PC Power
- Fridge
- Aircon
- Audio
- Heating

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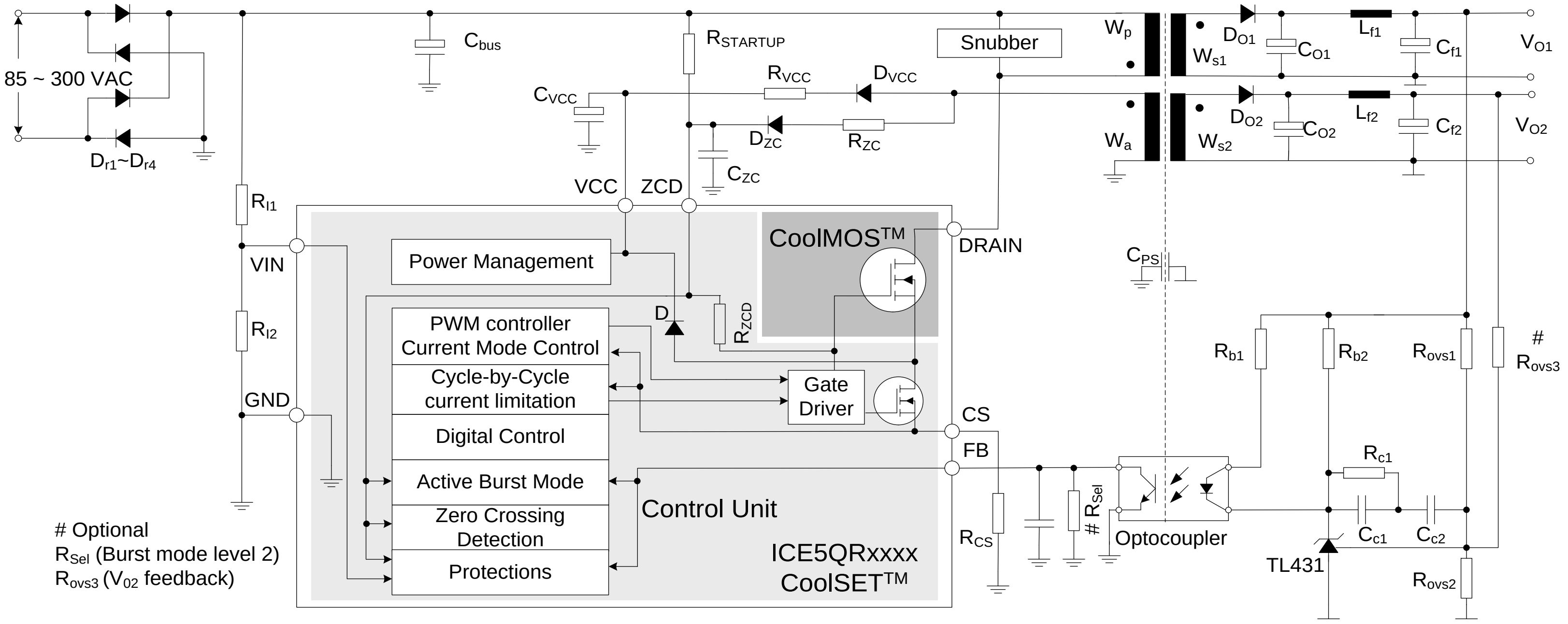
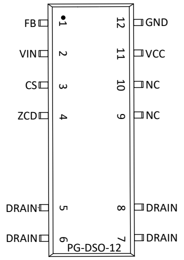
CoolSET^{TM}: ICE5QRxx80BG
Product highlights & application schematic

Proposed system approach for SMPS 10 W ~ 42 W



Optional
R_{Sel} (Burst mode level 2)
R_{ovs3} (V_{02} feedback)



Product highlights

- **800 V CoolMOS^{TM}**
- **2x fast startup** achieved with cascode configuration
- **Improved active burst mode** with **selectable entry/exit thresholds** to lower standby power
- **Novel quasi-resonant operation** and proprietary implementation **for low EMI**
- **Digital frequency reduction** up to 10th valley @ high line for better light load efficiency
- Robust line protection with **adjustable input OVP** and **brownout protection**.
- All protection to be **auto-restart**
- Comprehensive protection features to protect the IC and the system from various fault conditions

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Why gen 5 quasi resonant ?

	Features	Benefits	Addressed customers' needs
Strong arguments	Integrated LOVP & brown IN/OUT protection	BOM savings	› Save more than 10 components for implementation via discrete components ~USD 0.05
	Novel quasi resonant switching	Increase efficiency & minimize audible noise at light load	› Upsized zero crossing counters to achieve deeper frequency reduction › Narrow active burst mode entry/exit power under different line condition
	Vcc pin short to ground protection & enhanced OTP	Robust system protection	› Avoid permanent damage to controller due to vital pins shorted to ground › Avoid looping of protection mode due to absence of hysteresis during OTP
	Integrated P7 flyback optimized CoolMOS^{TM}	Run cooler with P7 CoolMOS^{TM}	› Simplified and enhanced thermal performance
Medium arguments	Cascode configuration	Fast & robust startup	› Utilizing the integrated CoolMOS^{TM} to facilitate start-up with higher charging current enable faster start-up time
	Selectable active burst mode entry/exit profile	Optimize standby power	› Flexibility in optimizing standby and light load performance with dual active burst mode entry/exit profile to choose from
Soft arguments	Integration of low $R_{DS(ON)}$ CoolMOS^{TM}	High power delivery in small form factor	› Up to 42 W offering in an integrated device and without the utilization of bulky heatsink

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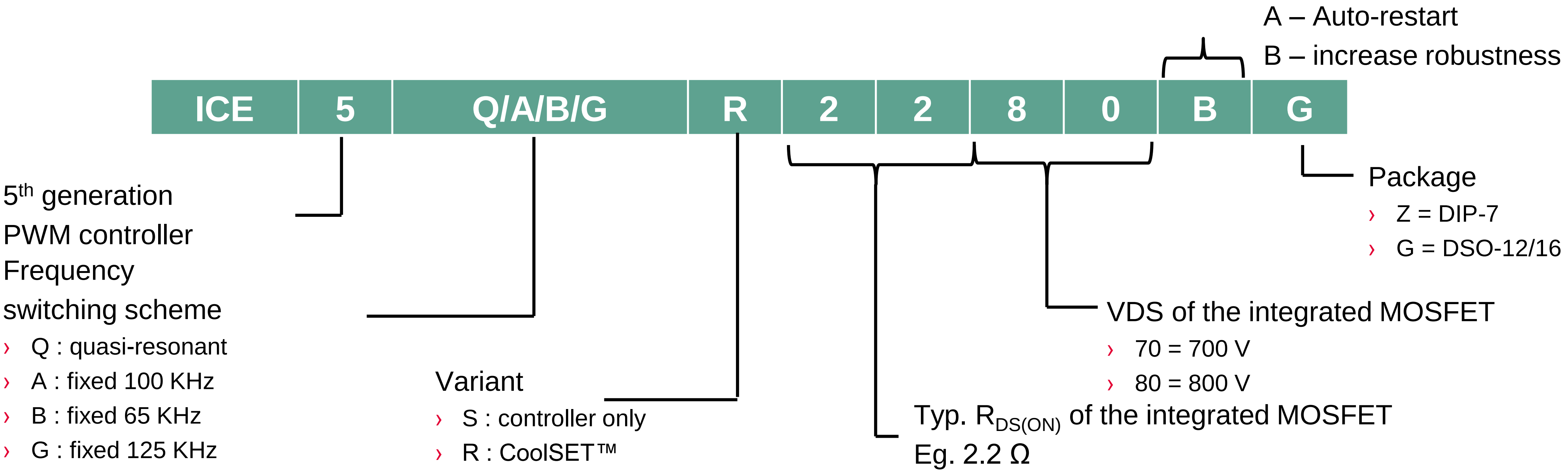
Gen 5 quasi CoolSET™ and standalone controller family

Max Pout 85~300 V_{AC} Ta=50ºC	**15 W**	**22 W**	**27 W**	**32 W**	**41-42 W**	**60 W**
DSO-8						ICE5QSAG ICE5QSBG
DSO-12	ICE5QR4780BG	ICE5QR2280BG	ICE5QR1680BG		ICE5QR0680BG	



A – Auto-restart

B – increase robustness

5th generation PWM controller

Frequency switching scheme
- Q : quasi-resonant
- A : fixed 100 KHz
- B : fixed 65 KHz
- G : fixed 125 KHz

Variant
- S : controller only
- R : CoolSET™

Typ. $R_{DS(ON)}$ of the integrated MOSFET
Eg. 2.2 Ω

VDS of the integrated MOSFET
- 70 = 700 V
- 80 = 800 V

Package
- Z = DIP-7
- G = DSO-12/16

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Gen 5 quasi resonant demoboard availability

S/N	Part number	P_{out}	App note	Available @ ISAR
1	DEMO_5QR4780BG_15W1	16 W	Internet	Yes
2	DEMO_5QR2280BG_24W1	24 W	Internet	Yes
3	DEMO_5QR1680BG_27W1	27 W	Internet	Yes
4	REF_5QSBG_33W1	33 W	Internet	Yes
5	REF_5QR1680BG_30W1	30 W	Upcoming	Upcoming
6	DEMO_5QR0680BG_42W1	42 W	Internet	Yes
7	DEMO_5QSBG_60W1	60 W	Internet	Yes

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Summary

- Gen 5 quasi resonant is the first wave of various flyback products to be launched
  - Fixed frequency variant and standard grade available to further compliment the portfolio
- Various new features introduced with gen 5 quasi resonant
  - Cascode configuration
  - Novel quasi resonant switching scheme
  - Selectable active burst mode
  - Robust line input and pin protection
  - Fully auto-restart protection scheme

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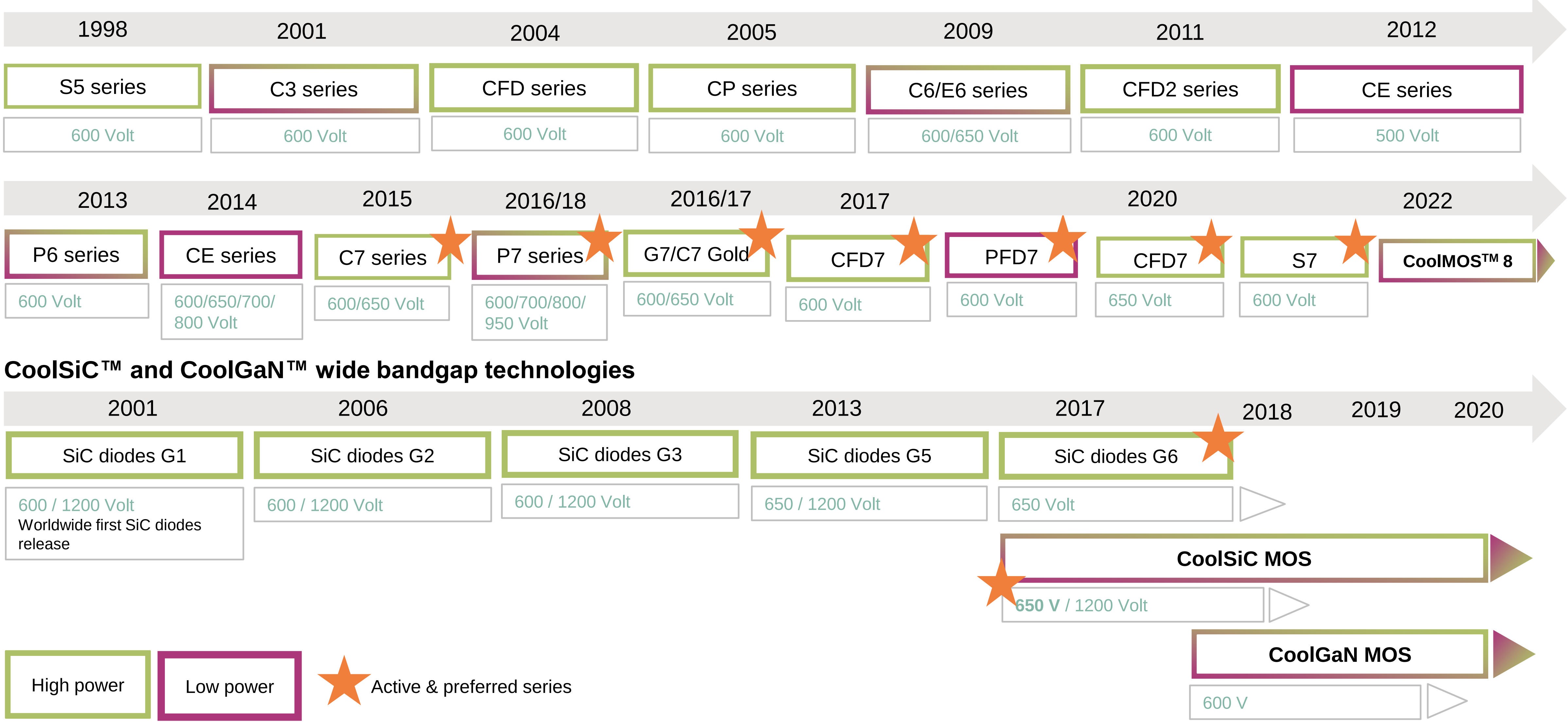
Infineon - Inventor of superjunction
Long-standing **experience for 19 years**



CoolMOS™ – Silicon technologies

- 1998 – S5 series – 600 Volt
- 2001 – C3 series – 600 Volt
- 2004 – CFD series – 600 Volt
- 2005 – CP series – 600 Volt
- 2009 – C6/E6 series – 600/650 Volt
- 2011 – CFD2 series – 600 Volt
- 2012 – CE series – 500 Volt

- 2013 – P6 series – 600 Volt
- 2014 – CE series – 600/650/700/800 Volt
- 2015 – C7 series ★ – 600/650 Volt
- 2016/18 – P7 series ★ – 600/700/800/950 Volt
- 2016/17 – G7/C7 Gold ★ – 600/650 Volt
- 2017 – CFD7 ★ – 600 Volt
- 2020 – PFD7 ★ – 600 Volt
- CFD7 ★ – 650 Volt
- S7 ★ – 600 Volt
- 2022 – **CoolMOS™ 8**

CoolSiC™ and CoolGaN™ wide bandgap technologies

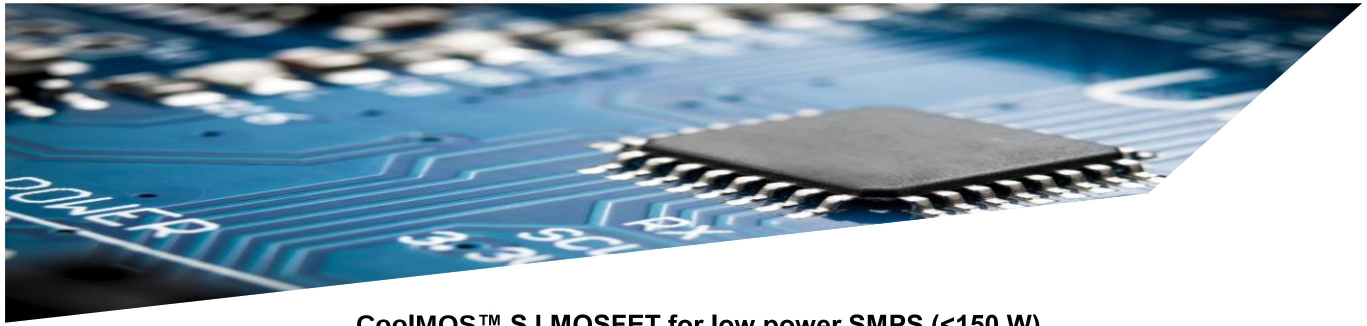
- 2001 – SiC diodes G1 – 600 / 1200 Volt
  Worldwide first SiC diodes release
- 2006 – SiC diodes G2 – 600 / 1200 Volt
- 2008 – SiC diodes G3 – 600 / 1200 Volt
- 2013 – SiC diodes G5 – 650 / 1200 Volt
- 2017 – SiC diodes G6 ★ – 650 Volt
- 2018
- 2019
- 2020
- **CoolSiC MOS** ★ – **650 V** / 1200 Volt
- **CoolGaN MOS** – 600 V

🟩 High power

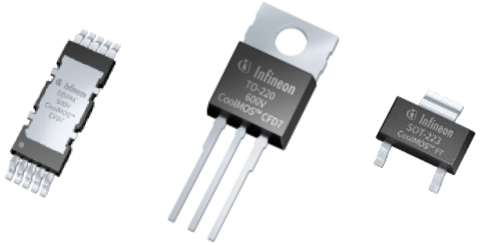
🟪 Low power

★ Active & preferred series

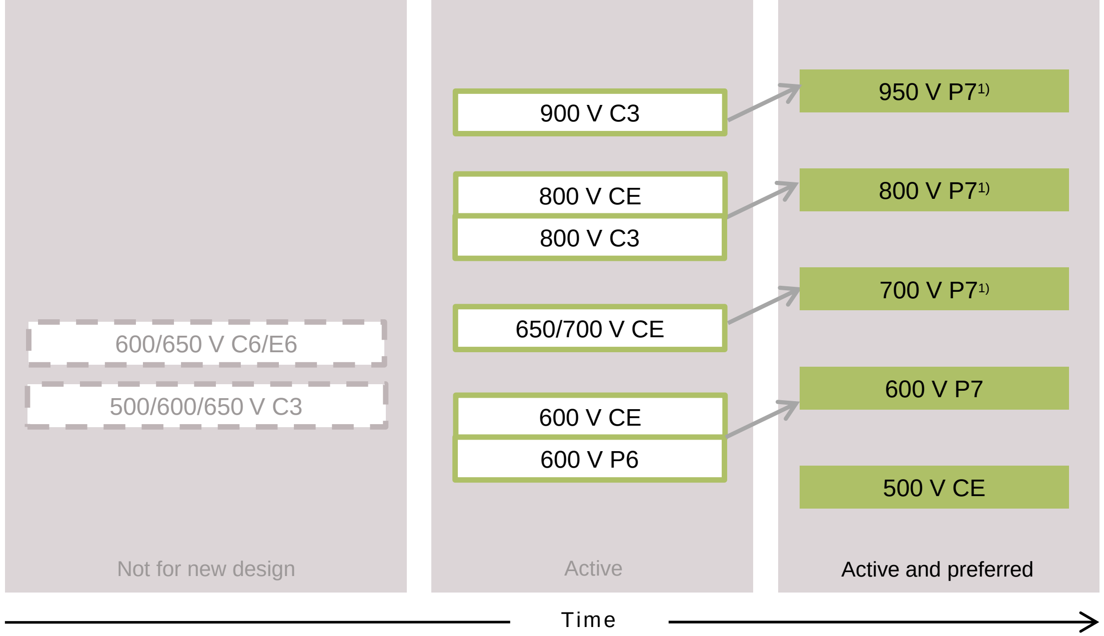
CoolMOS™ positioning within high and low power SMPS market



CoolMOS™ SJ MOSFET for low power SMPS (<150 W)



CoolMOS™ SJ MOSFET for high power SMPS (>150 W) and automotive

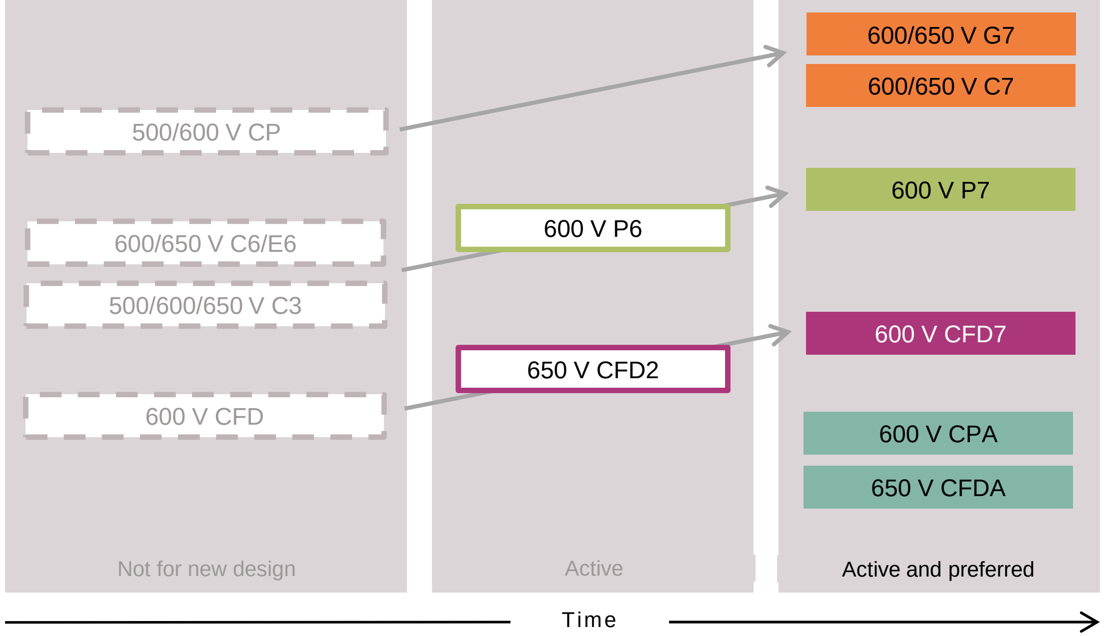


Not for new design
- 600/650 V C6/E6
- 500/600/650 V C3

Active
- 900 V C3
- 800 V CE
- 800 V C3
- 650/700 V CE
- 600 V CE
- 600 V P6

Active and preferred
- 950 V P7[1]
- 800 V P7[1]
- 700 V P7[1]
- 600 V P7
- 500 V CE

Time



Not for new design
- 500/600 V CP
- 600/650 V C6/E6
- 500/600/650 V C3
- 600 V CFD

Active
- 600 V P6
- 650 V CFD2

Active and preferred
- 600/650 V G7
- 600/650 V C7
- 600 V P7
- 600 V CFD7
- 600 V CPA
- 650 V CFDA

Time

🟩 Price-performance 🟧 Highest performance 🟪 Fast recovery diode 🟦 Automotive

[1] Optimized for flyback topologies

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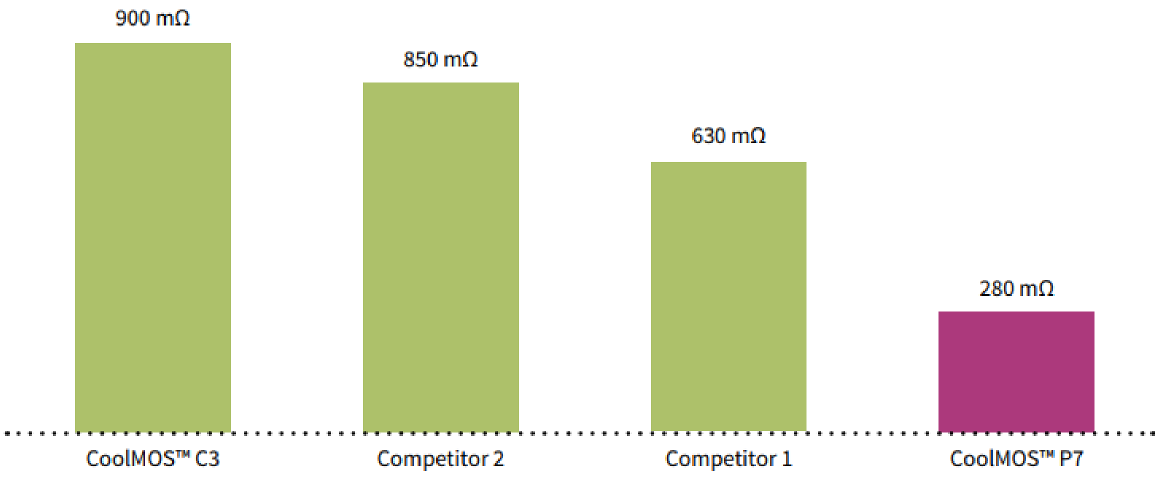
CoolMOS™ P7 – Smaller Die Size Enhances IC Cost Effectiveness

Best in Class MOSFET

- 950V, 800V and 700V MOSFET
- Specified avalanche energy for increased robustness
- Best-in-class $R_{DS(on)}$ vs die size
- Best-in-class FOM $R_{DS(on)}$ * E_{oss}; reduced Q_g, C_{iss} and C_{oss}
- Best-in-class $V_{(GS)th}$ of 3 V
- Smallest $V_{(GS)th}$ variation of ± 0.5 V
- Integrated Zener Diode ESD protection up to Class 2 (HBM)

Overview of lowest DPAK $R_{DS(on)}$ for 800 V superjunction MOSFETs



800 V CoolMOS™ P7 sets benchmark in best-in-class DPAK $R_{DS(on)}$

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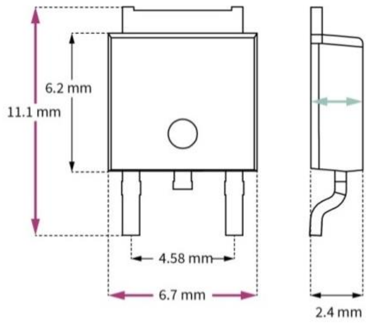
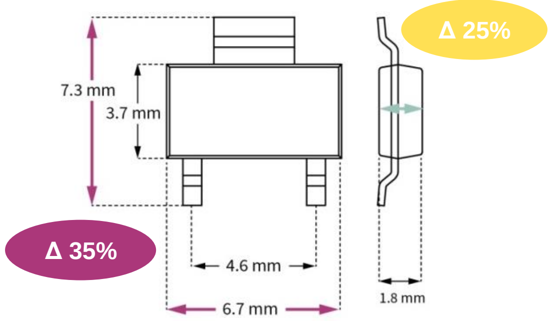
Our recommendation: the cost effective SOT-223 package offers smaller footprint while being pin-to-pin compatible with DPAK

DPAK



Area: **74.7 mm²**

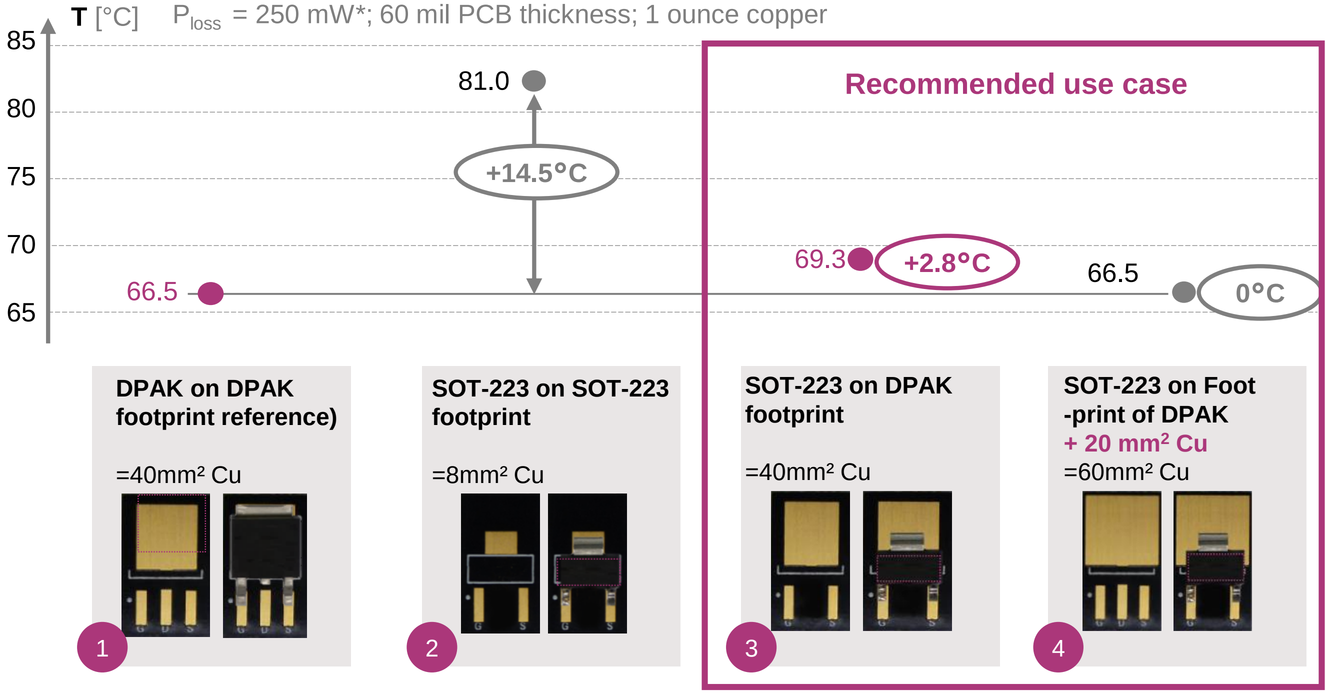
SOT-223



Area: **48.9 mm²**
at optimal usage/minimal footprint

Thermal performance similar to DPAK

- The thermal behavior of the SOT-223 depends on layout of the board and on the power dissipated:



* Evaluated on internal IFX test PCBs; results independent of technology

The SOT-223 package is a suitable drop-in replacement for DPAK at lower cost, enabling space savings in designs with low power dissipation.

Learn more: www.infineon.com/sot-223 www.infineon.com/600v-pfd7

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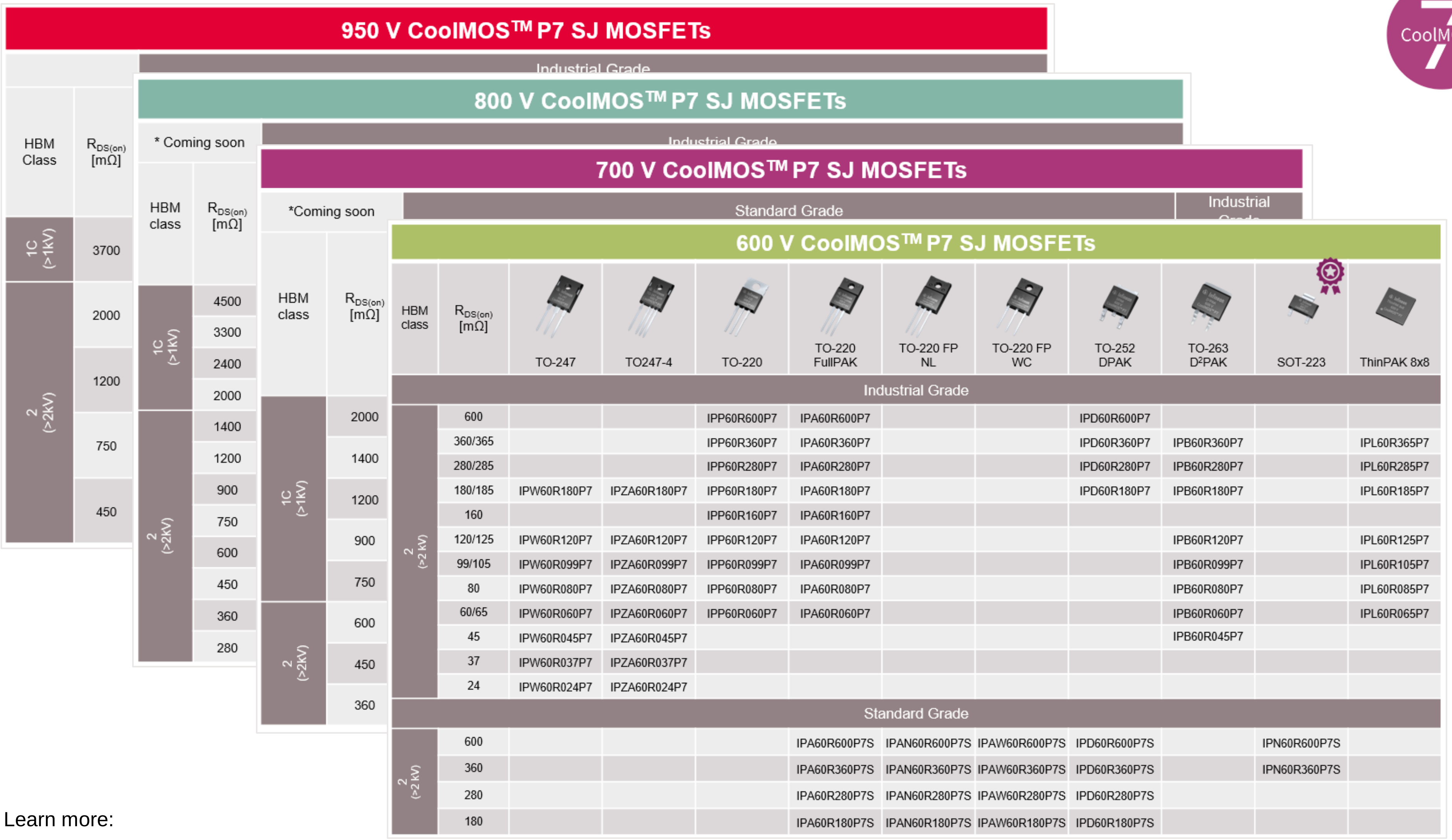
Recommended 600 - 950 V CoolMOSTM P7 SJ MOSFETs for AUX power & PFC stages in Home Appliances



950 V CoolMOS™ P7 SJ MOSFETs

HBM Class	$R_{DS(on)}$ [mΩ]	Industrial Grade
1C (>1kV)	3700	
2 (>2kV)	2000	
	1200	
	750	
	450	

800 V CoolMOS™ P7 SJ MOSFETs

* Coming soon

HBM class	$R_{DS(on)}$ [mΩ]	Industrial Grade
1C (>1kV)	4500	
	3300	
	2400	
	2000	
2 (>2kV)	1400	
	1200	
	900	
	750	
	600	
	450	
	360	
	280	

700 V CoolMOS™ P7 SJ MOSFETs

*Coming soon

HBM class	$R_{DS(on)}$ [mΩ]	Standard Grade	Industrial Grade
1C (>1kV)	2000		
	1400		
	1200		
	900		
	750		
2 (>2kV)	600		
	450		
	360		

600 V CoolMOS™ P7 SJ MOSFETs

HBM class	$R_{DS(on)}$ [mΩ]	TO-247	TO247-4	TO-220	TO-220 FullPAK	TO-220 FP NL	TO-220 FP WC	TO-252 DPAK	TO-263 D²PAK	SOT-223	ThinPAK 8x8
Industrial Grade											
2 (>2 kV)	600			IPP60R600P7	IPA60R600P7			IPD60R600P7			
	360/365			IPP60R360P7	IPA60R360P7			IPD60R360P7	IPB60R360P7		IPL60R365P7
	280/285			IPP60R280P7	IPA60R280P7			IPD60R280P7	IPB60R280P7		IPL60R285P7
	180/185	IPW60R180P7	IPZA60R180P7	IPP60R180P7	IPA60R180P7			IPD60R180P7	IPB60R180P7		IPL60R185P7
	160			IPP60R160P7	IPA60R160P7						
	120/125	IPW60R120P7	IPZA60R120P7	IPP60R120P7	IPA60R120P7				IPB60R120P7		IPL60R125P7
	99/105	IPW60R099P7	IPZA60R099P7	IPP60R099P7	IPA60R099P7				IPB60R099P7		IPL60R105P7
	80	IPW60R080P7	IPZA60R080P7	IPP60R080P7	IPA60R080P7				IPB60R080P7		IPL60R085P7
	60/65	IPW60R060P7	IPZA60R060P7	IPP60R060P7	IPA60R060P7				IPB60R060P7		IPL60R065P7
	45	IPW60R045P7	IPZA60R045P7						IPB60R045P7		
	37	IPW60R037P7	IPZA60R037P7								
	24	IPW60R024P7	IPZA60R024P7								
Standard Grade											
2 (>2 kV)	600				IPA60R600P7S	IPAN60R600P7S	IPAW60R600P7S	IPD60R600P7S		IPN60R600P7S	
	360				IPA60R360P7S	IPAN60R360P7S	IPAW60R360P7S	IPD60R360P7S		IPN60R360P7S	
	280				IPA60R280P7S	IPAN60R280P7S	IPAW60R280P7S	IPD60R280P7S			
	180				IPA60R180P7S	IPAN60R180P7S	IPAW60R180P7S	IPD60R180P7S			

CoolMOS™

Home appliance

Small home appliance

Low power drives

PFC

AUX power

Recommendation: SOT-223, the cost-effective drop-in replacement for DPAK

Learn more:
www.infineon.com/coolmos

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600 V CoolMOS^{TM} P7 portfolio

	$R_{DS(ON)}$ [mΩ] Max.	 DPAK	 D^{2}PAK	 ThinPAK 8x8	 TO220 FullPAK	 TO220	 TO220 FP NL	 TO220 FP WC	 TO247	 TO247-4	 SOT223
Industrial Grade	600	IPD60R600P7			IPA60R600P7	IPP60R600P7					
	360/365	IPD60R360P7	IPB60R360P7	IPL60R365P7	IPA60R360P7	IPP60R360P7					
	280/285	IPD60R280P7	IPB60R280P7	IPL60R285P7	IPA60R280P7	IPP60R280P7					
	180/185	IPD60R180P7	IPB60R180P7	IPL60R185P7	IPA60R180P7	IPP60R180P7			IPW60R180P7	IPZA60R180P7	
	160				IPA60R160P7	IPP60R160P7					
	120/125		IPB60R120P7	IPL60R125P7	IPA60R120P7	IPP60R120P7			IPW60R120P7	IPZA60R120P7	
	99/105		IPB60R099P7	IPL60R105P7	IPA60R099P7	IPP60R099P7			IPW60R099P7	IPZA60R099P7	
	80		IPB60R080P7	IPL60R085P7	IPA60R080P7	IPP60R080P7			IPW60R080P7	IPZA60R080P7	
	60/65		IPB60R060P7	IPL60R065P7	IPA60R060P7	IPP60R060P7			IPW60R060P7	IPZA60R060P7	
	45		IPB60R045P7						IPW60R045P7	IPZA60R045P7	
	37								IPW60R037P7	IPZA60R037P7	
	24								IPW60R024P7	IPZA60R024P7	
Standard Grade	600	IPD60R600P7S			IPA60R600P7S		IPAN60R600P7S	IPAW60R600P7S			IPN60R600P7S
	360	IPD60R360P7S			IPA60R360P7S		IPAN60R360P7S	IPAW60R360P7S			IPN60R360P7S
	280	IPD60R280P7S			IPA60R280P7S		IPAN60R280P7S	IPAW60R280P7S			
	180	IPD60R180P7S			IPA60R180P7S		IPAN60R180P7S	IPAW60R180P7S			

HBM : over 2kV

Charger Adapter Lighting TV PC Power Server Solar Telecom EV-Charging

- Large $R_{DS(on)}$ and package variety
- Offering through hole and SMD packages
- Suitable for a wide variety of applications and power ranges

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700 V CoolMOS™ P7 product portfolio Recommended for PFC/flyback topologies**

700 V CoolMOS™ P7 SJ MOSFETs

HBM class	$R_{DS(on)}$ [mΩ]	Standard grade						Industrial grade
		 **TO-220 FullPAK**	 **TO-220 FP narrow lead**	 **TO-251 IPAK SL**	 **TO-251 IPAK SL w/ ISO lead standoff**	 **TO-252 DPAK**	 **SOT-223**	 **ThinPAK 5x6**
1C (>1 kV)	2000				IPSA70R2K0P7S		IPN70R2K0P7S	IPLK70R2K0P7*
	1400			IPS70R1K4P7S	IPSA70R1K4P7S	IPD70R1K4P7S	IPN70R1K4P7S	IPLK70R1K4P7*
	1200				IPSA70R1K2P7S		IPN70R1K2P7S	IPLK70R1K2P7*
	900	IPA70R900P7S	IPAN70R900P7S	IPS70R900P7S	IPSA70R900P7S	IPD70R900P7S	IPN70R900P7S	IPLK70R900P7*
	750	IPA70R750P7S	IPAN70R750P7S		IPSA70R750P7S		IPN70R750P7S	IPLK70R750P7*
2 (>2 kV)	600	IPA70R600P7S	IPAN70R600P7S	IPS70R600P7S	IPSA70R600P7S	IPD70R600P7S	IPN70R600P7S	IPLK70R600P7*
	450	IPA70R450P7S	IPAN70R450P7S		IPSA70R450P7S		IPN70R450P7S	
	360	IPA70R360P7S	IPAN70R360P7S	IPS70R360P7S	IPSA70R360P7S	IPD70R360P7S	IPN70R360P7S	

** Excluding half and full bridge configurations

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800 V CoolMOS^{TM} P7 product portfolio Recommended for PFC/flyback topologies**

800 V CoolMOS^{TM} P7 SJ MOSFETs

NEW package

HBM class	$R_{DS(on)}$ [mΩ]	Industrial grade								
		 TO-247	 TO-220	 TO-220 FullPAK	 TO-220 FullPAK narrow lead	 TO-251 IPAK LL	 TO-251 IPAK SL	 TO-252 DPAK	 SOT-223	 ThinPAK 5x6
1C (>1kV)	4500					IPU80R4K5P7		IPD80R4K5P7	IPN80R4K5P7	
	3300					IPU80R3K3P7		IPD80R3K3P7	IPN80R3K3P7	
	2400					IPU80R2K4P7	IPS80R2K4P7	IPD80R2K4P7	IPN80R2K4P7	
	2000					IPU80R2K0P7	IPS80R2K0P7	IPD80R2K0P7	IPN80R2K0P7	IPLK80R2K0P7*
2 (>2kV)	1400		IPP80R1K4P7	IPA80R1K4P7		IPU80R1K4P7	IPS80R1K4P7	IPD80R1K4P7	IPN80R1K4P7	IPLK80R1K4P7*
	1200		IPP80R1K2P7	IPA80R1K2P7		IPU80R1K2P7	IPS80R1K2P7	IPD80R1K2P7	IPN80R1K2P7	IPLK80R1K2P7*
	900		IPP80R900P7	IPA80R900P7		IPU80R900P7	IPS80R900P7	IPD80R900P7	IPN80R900P7	IPLK80R900P7*
	750		IPP80R750P7	IPA80R750P7		IPU80R750P7	IPS80R750P7	IPD80R750P7	IPN80R750P7	IPLK80R750P7*
	600		IPP80R600P7	IPA80R600P7		IPU80R600P7	IPS80R600P7	IPD80R600P7	IPN80R600P7	IPLK80R600P7*
	450		IPP80R450P7	IPA80R450P7	IPAN80R450P7			IPD80R450P7		
	360	IPW80R360P7	IPP80R360P7	IPA80R360P7	IPAN80R360P7			IPD80R360P7		
	280	IPW80R280P7	IPP80R280P7	IPA80R280P7	IPAN80R280P7			IPD80R280P7		

A wide range of products ensure to easily cover all target applications!

* Coming soon

** Excluding half and full bridge configurations

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950 V CoolMOS™ P7 SJ MOSFETs product portfolio

950 V CoolMOS^{TM} P7 SJ MOSFETs

		Industrial grade			
HBM class	$R_{DS(on)}$ [mΩ]	 TO-220 FullPAK	 TO-251 IPAK LL	 TO-252 DPAK	 SOT-223
1C (>1 kV)	3700		IPU95R3K7P7		IPN95R3K7P7
2 (>2 kV)	2000		IPU95R2K0P7	IPD95R2K0P7	IPN95R2K0P7
	1200	IPA95R1K2P7	IPU95R1K2P7	IPD95R1K2P7	IPN95R1K2P7
	750	IPA95R750P7	IPU95R750P7	IPD95R750P7	
	450	IPA95R450P7	IPU95R450P7	IPD95R450P7	

Adapter

Charger

AUX power

AC-DC

Smart metering

Industrial SMPS

Lighting

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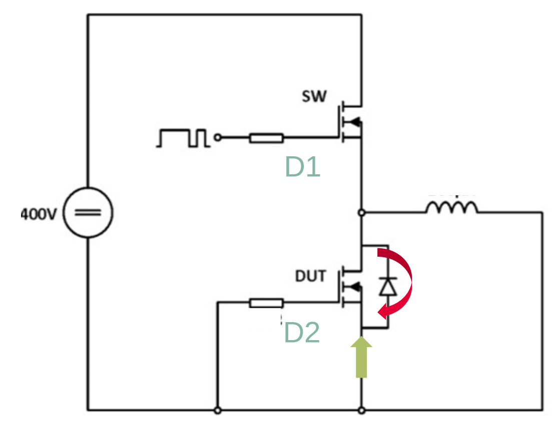
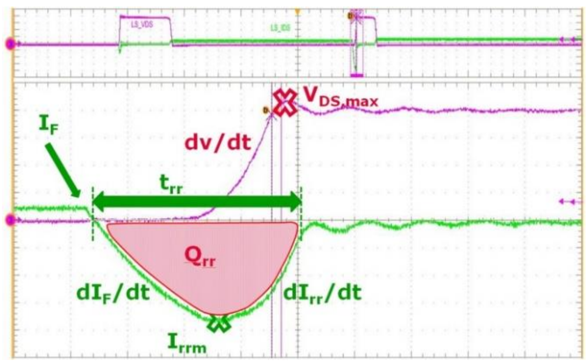
CoolMOS™ CFD7/PFD7 family offers excellent hard commutation ruggedness thanks to outstanding body diode parameters

Body diode hard commutation challenge in LLC/ZVS



Hard commutation in ZVS/LLC …

- Inductor drives reverse current through the body diode of D2 (free wheeling)
- As D1 is switched on again, high-side current leads to commutation of the low-side body diode
- High di/dt and voltage overshoot significantly stress D2
- Stress leading up to destruction in repeated hard commutation



… requires fast body diode (Q_{rr}, t_{rr})

Fast body diode

- **Reduces stress on device** while the body diode is not fully recovered
- Provides an **extra safety margin** for repetitive hard commutation and reduces design-in effort

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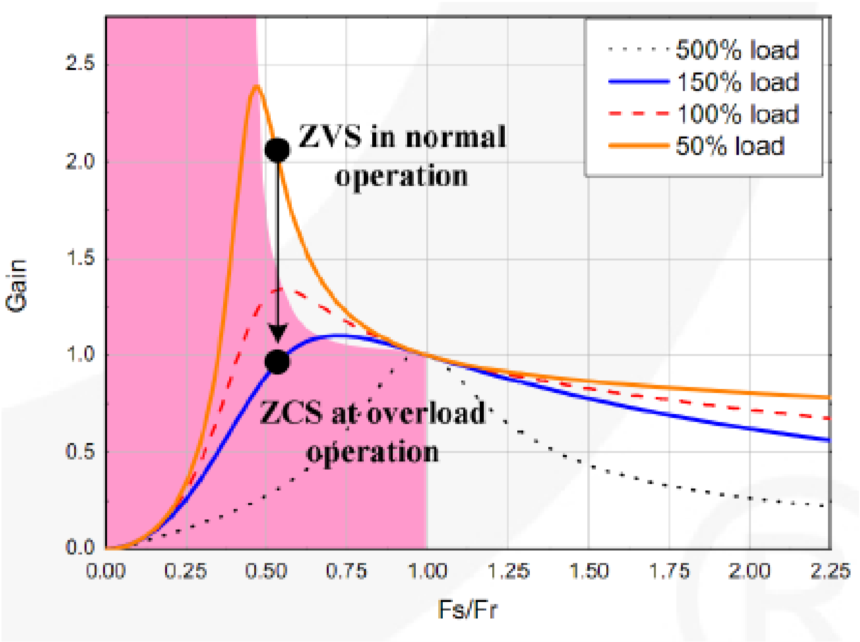
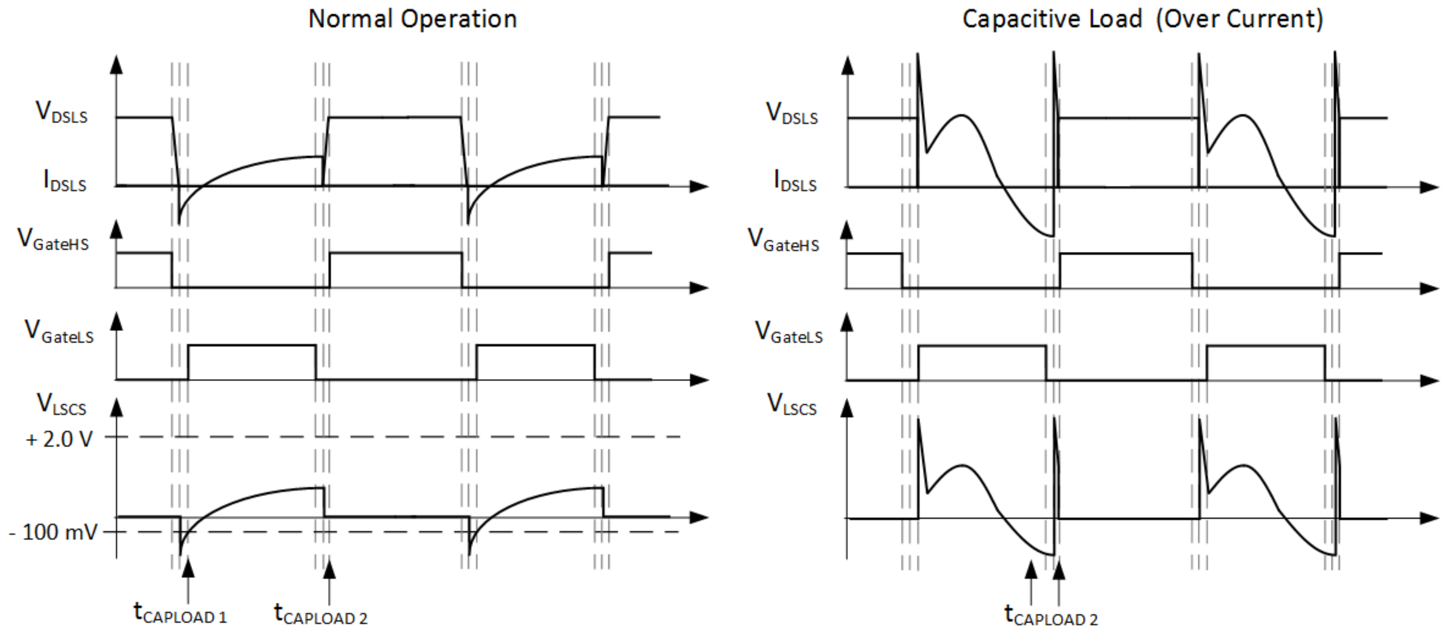
Hard commutation in LLC topology





Resonant converters work in capacitive mode when their switching frequency falls below a critical value that depends on the loading conditions and the input-to-output voltage ratio.

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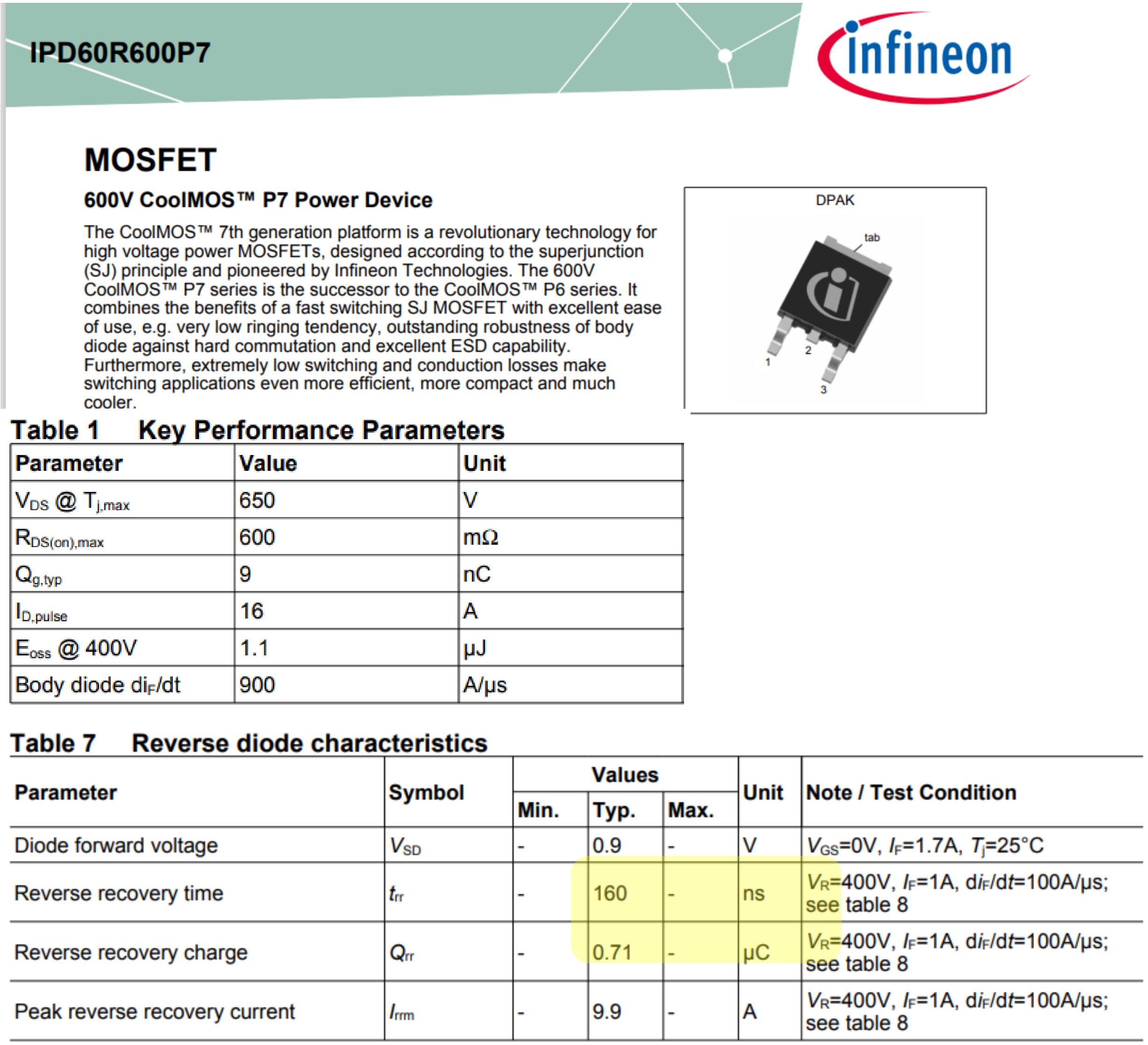
Difference of the internal body diode from the CoolMos family CoolMos 600V P7 and PFD7



IPD60R600P7

MOSFET

600V CoolMOS™ P7 Power Device

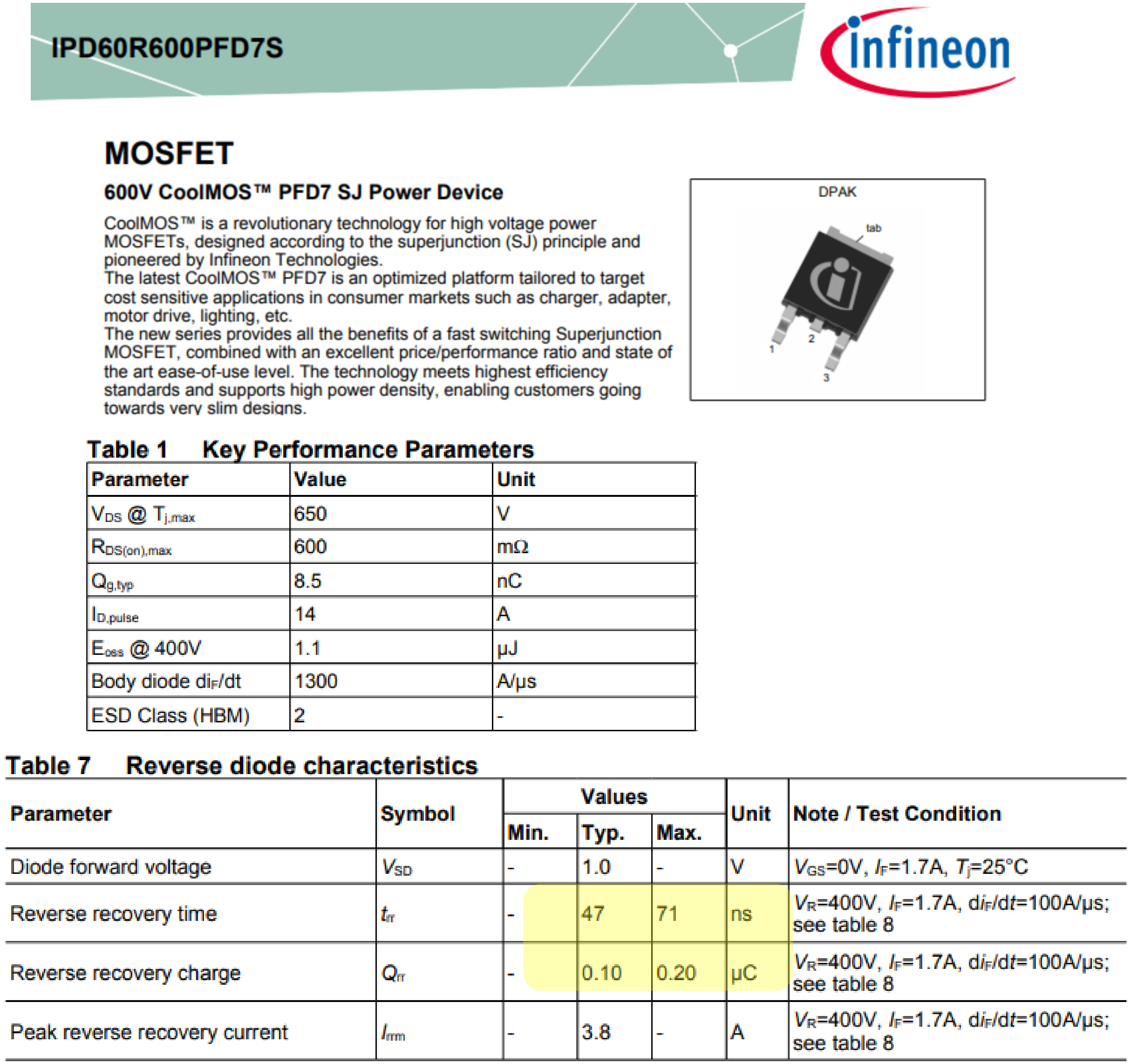
The CoolMOS™ 7th generation platform is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies. The 600V CoolMOS™ P7 series is the successor to the CoolMOS™ P6 series. It combines the benefits of a fast switching SJ MOSFET with excellent ease of use, e.g. very low ringing tendency, outstanding robustness of body diode against hard commutation and excellent ESD capability. Furthermore, extremely low switching and conduction losses make switching applications even more efficient, more compact and much cooler.

Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS} @ $T_{j,max}$	650	V
$R_{DS(on),max}$	600	mΩ
$Q_{g,typ}$	9	nC
$I_{D,pulse}$	16	A
E_{oss} @ 400V	1.1	µJ
Body diode di_F/dt	900	A/µs

Table 7 Reverse diode characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	V_{SD}	-	0.9	-	V	V_{GS}=0V, I_F=1.7A, T_j=25°C
Reverse recovery time	t_{rr}	-	160	-	ns	V_R=400V, I_F=1A, di_F/dt=100A/µs; see table 8
Reverse recovery charge	Q_{rr}	-	0.71	-	µC	V_R=400V, I_F=1A, di_F/dt=100A/µs; see table 8
Peak reverse recovery current	I_{rrm}	-	9.9	-	A	V_R=400V, I_F=1A, di_F/dt=100A/µs; see table 8



IPD60R600PFD7S

MOSFET

600V CoolMOS™ PFD7 SJ Power Device

CoolMOS™ is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies.
The latest CoolMOS™ PFD7 is an optimized platform tailored to target cost sensitive applications in consumer markets such as charger, adapter, motor drive, lighting, etc.
The new series provides all the benefits of a fast switching Superjunction MOSFET, combined with an excellent price/performance ratio and state of the art ease-of-use level. The technology meets highest efficiency standards and supports high power density, enabling customers going towards very slim designs.

Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS} @ $T_{j,max}$	650	V
$R_{DS(on),max}$	600	mΩ
$Q_{g,typ}$	8.5	nC
$I_{D,pulse}$	14	A
E_{oss} @ 400V	1.1	µJ
Body diode di_F/dt	1300	A/µs
ESD Class (HBM)	2	-

Table 7 Reverse diode characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	V_{SD}	-	1.0	-	V	V_{GS}=0V, I_F=1.7A, T_j=25°C
Reverse recovery time	t_{rr}	-	47	71	ns	V_R=400V, I_F=1.7A, di_F/dt=100A/µs; see table 8
Reverse recovery charge	Q_{rr}	-	0.10	0.20	µC	V_R=400V, I_F=1.7A, di_F/dt=100A/µs; see table 8
Peak reverse recovery current	I_{rrm}	-	3.8	-	A	V_R=400V, I_F=1.7A, di_F/dt=100A/µs; see table 8

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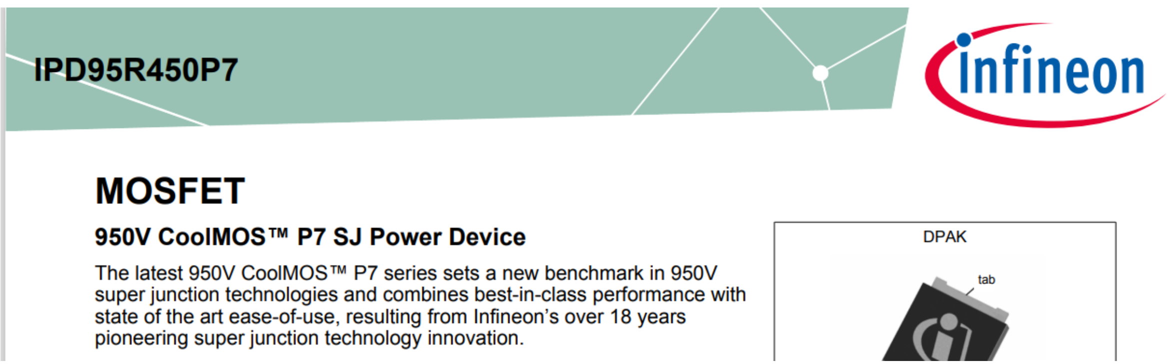
Difference of the internal body diode from the CoolMos family CoolMos 950V P7 and PFD7



IPD95R450P7

MOSFET

950V CoolMOS™ P7 SJ Power Device

The latest 950V CoolMOS™ P7 series sets a new benchmark in 950V super junction technologies and combines best-in-class performance with state of the art ease-of-use, resulting from Infineon's over 18 years pioneering super junction technology innovation.

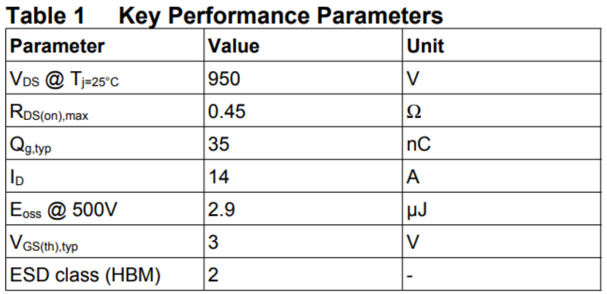
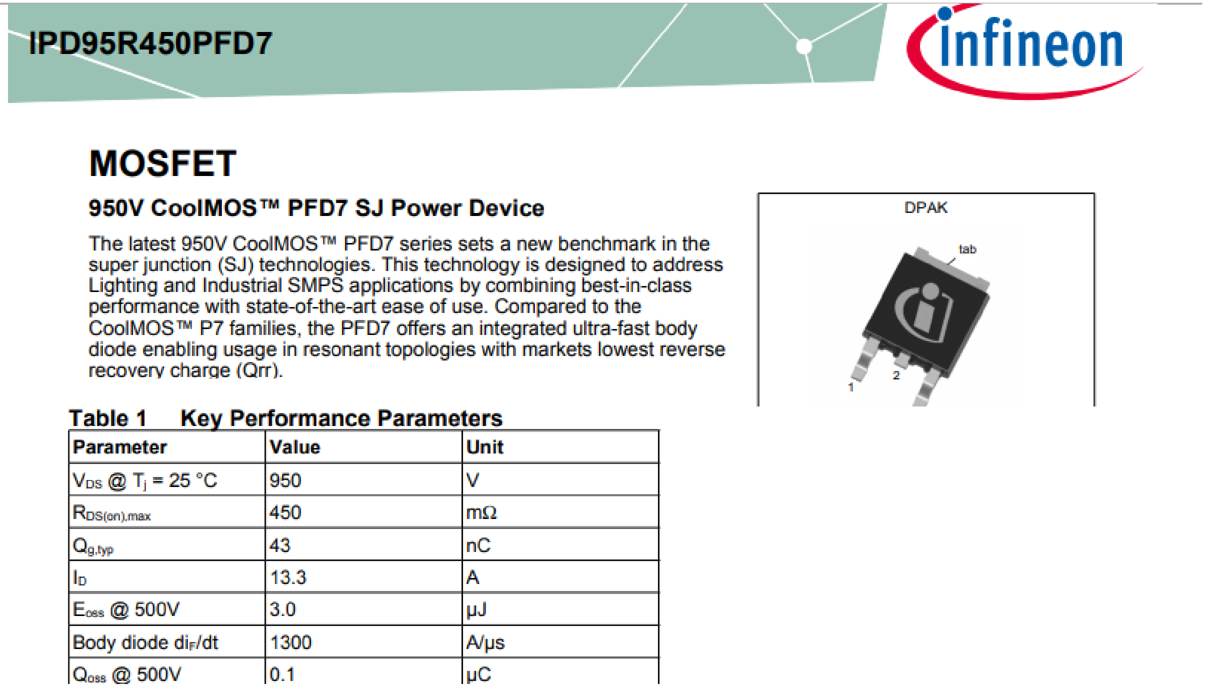


Table 1 Key Performance Parameters

Parameter	Value	Unit
V_{DS} @ $T_{j=25°C}$	950	V
$R_{DS(on),max}$	0.45	Ω
$Q_{g,typ}$	35	nC
I_D	14	A
E_{oss} @ 500V	2.9	µJ
$V_{GS(th),typ}$	3	V
ESD class (HBM)	2	-



IPD95R450PFD7

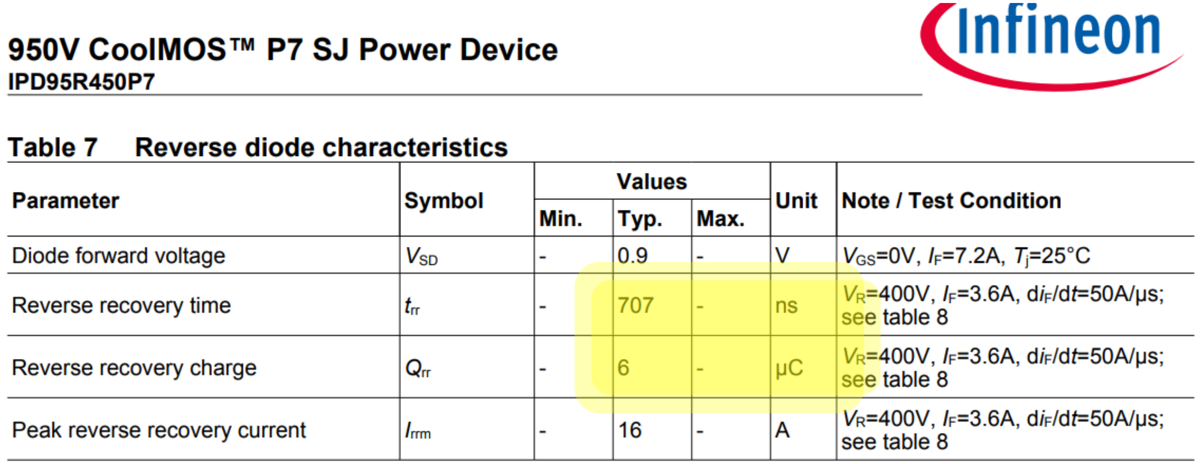
MOSFET

950V CoolMOS™ PFD7 SJ Power Device

The latest 950V CoolMOS™ PFD7 series sets a new benchmark in the super junction (SJ) technologies. This technology is designed to address Lighting and Industrial SMPS applications by combining best-in-class performance with state-of-the-art ease of use. Compared to the CoolMOS™ P7 families, the PFD7 offers an integrated ultra-fast body diode enabling usage in resonant topologies with markets lowest reverse recovery charge (Qrr).

Table 1 Key Performance Parameters

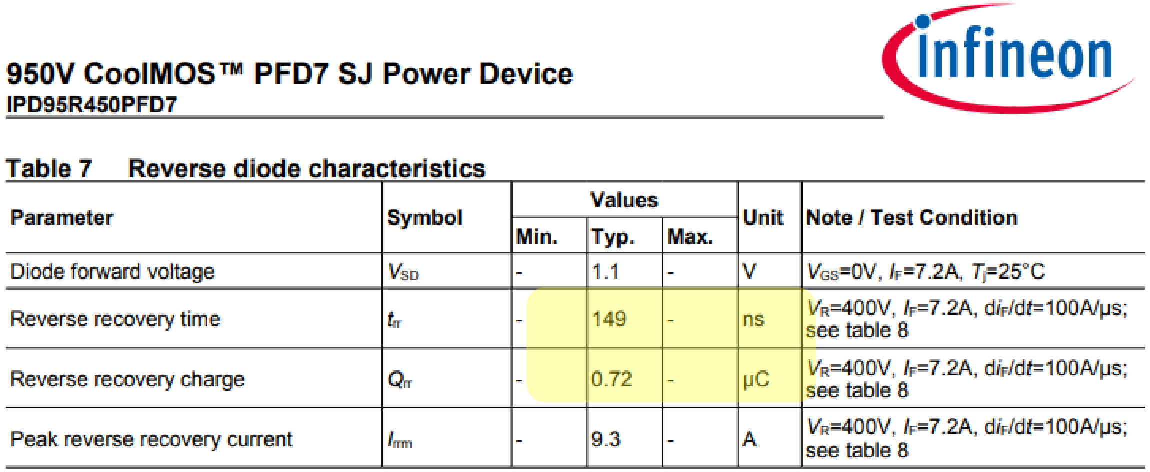
Parameter	Value	Unit
V_{DS} @ T_j = 25 °C	950	V
$R_{DS(on),max}$	450	mΩ
$Q_{g,typ}$	43	nC
I_D	13.3	A
E_{oss} @ 500V	3.0	µJ
Body diode di_F/dt	1300	A/µs
Q_{oss} @ 500V	0.1	µC



950V CoolMOS™ P7 SJ Power Device
IPD95R450P7

Table 7 Reverse diode characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	V_{SD}	-	0.9	-	V	V_{GS}=0V, I_F=7.2A, T_j=25°C
Reverse recovery time	t_{rr}	-	707	-	ns	V_R=400V, I_F=3.6A, di_F/dt=50A/µs; see table 8
Reverse recovery charge	Q_{rr}	-	6	-	µC	V_R=400V, I_F=3.6A, di_F/dt=50A/µs; see table 8
Peak reverse recovery current	I_{rrm}	-	16	-	A	V_R=400V, I_F=3.6A, di_F/dt=50A/µs; see table 8



950V CoolMOS™ PFD7 SJ Power Device
IPD95R450PFD7

Table 7 Reverse diode characteristics

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	V_{SD}	-	1.1	-	V	V_{GS}=0V, I_F=7.2A, T_j=25°C
Reverse recovery time	t_{rr}	-	149	-	ns	V_R=400V, I_F=7.2A, di_F/dt=100A/µs; see table 8
Reverse recovery charge	Q_{rr}	-	0.72	-	µC	V_R=400V, I_F=7.2A, di_F/dt=100A/µs; see table 8
Peak reverse recovery current	I_{rrm}	-	9.3	-	A	V_R=400V, I_F=7.2A, di_F/dt=100A/µs; see table 8

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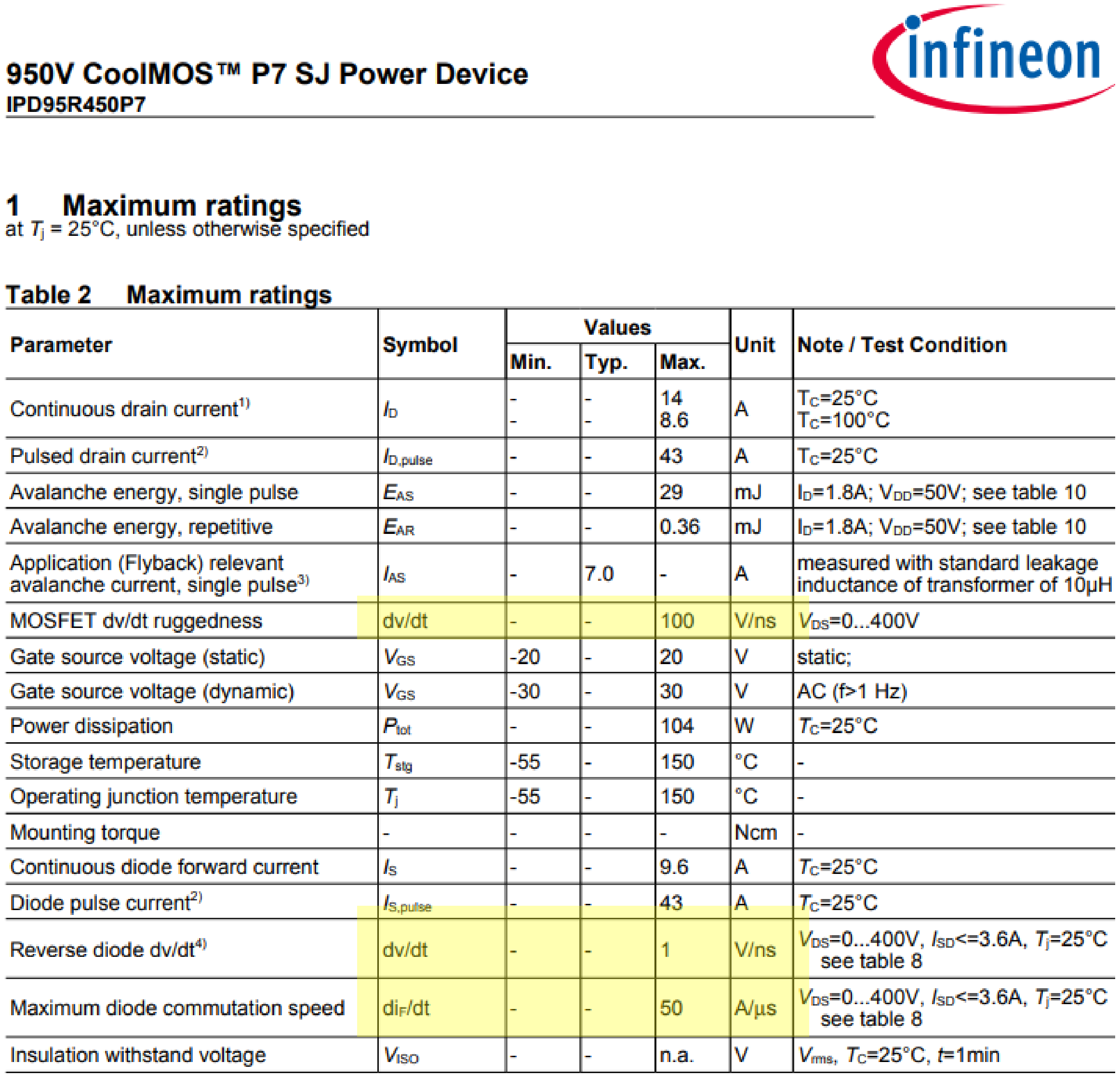
Differences of the maximum ratings mosfet ruggedness dv/dt



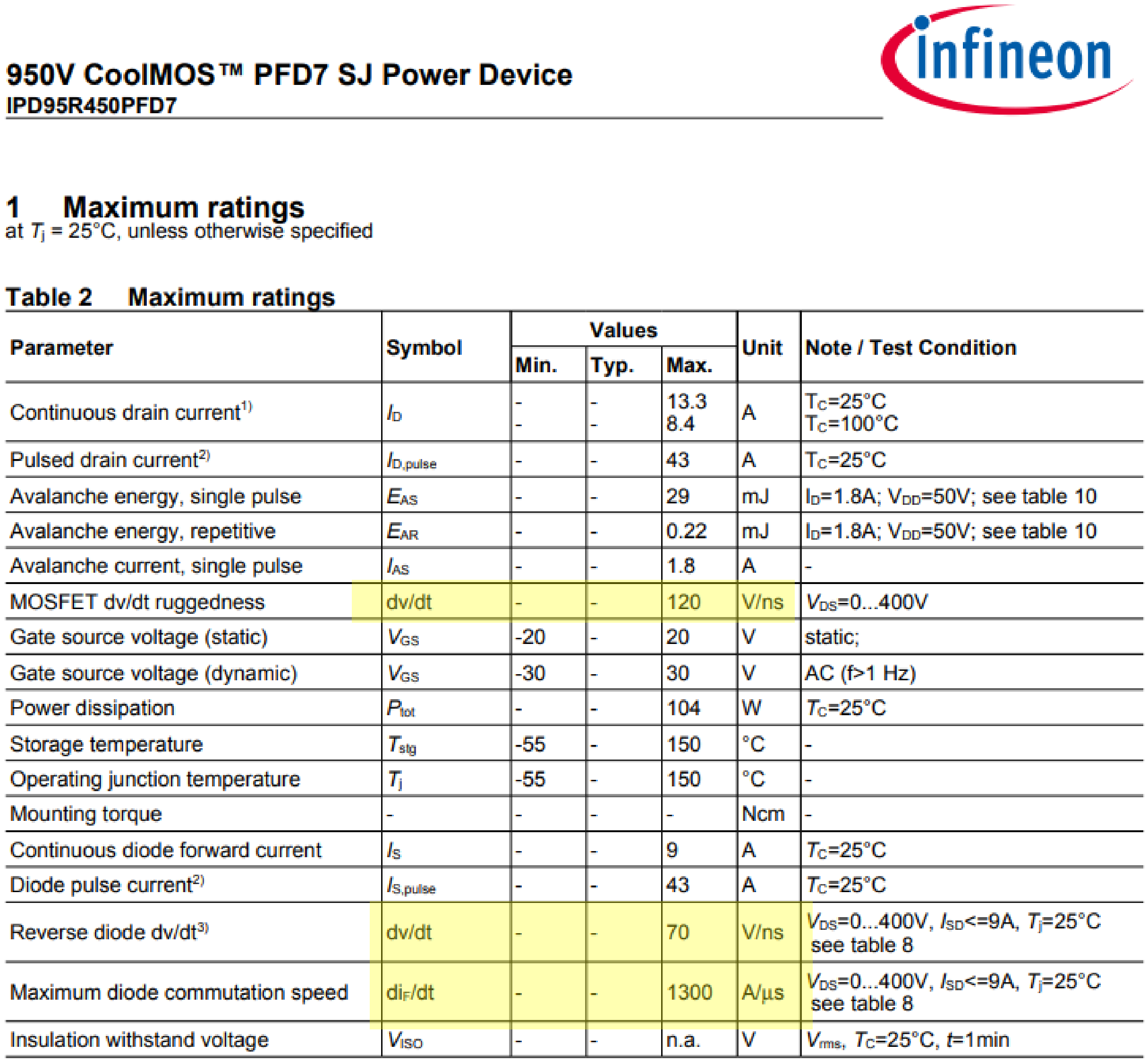
950V CoolMOS™ P7 SJ Power Device
IPD95R450P7

1 Maximum ratings

at T_j = 25°C, unless otherwise specified

Table 2 Maximum ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Continuous drain current[1]	I_D	- -	- -	14 8.6	A	T_C=25°C T_C=100°C
Pulsed drain current[2]	$I_{D,pulse}$	-	-	43	A	T_C=25°C
Avalanche energy, single pulse	E_{AS}	-	-	29	mJ	I_D=1.8A; V_{DD}=50V; see table 10
Avalanche energy, repetitive	E_{AR}	-	-	0.36	mJ	I_D=1.8A; V_{DD}=50V; see table 10
Application (Flyback) relevant avalanche current, single pulse[3]	I_{AS}	-	7.0	-	A	measured with standard leakage inductance of transformer of 10µH
MOSFET dv/dt ruggedness	dv/dt	-	-	100	V/ns	V_{DS}=0...400V
Gate source voltage (static)	V_{GS}	-20	-	20	V	static;
Gate source voltage (dynamic)	V_{GS}	-30	-	30	V	AC (f>1 Hz)
Power dissipation	P_{tot}	-	-	104	W	T_C=25°C
Storage temperature	T_{stg}	-55	-	150	°C	-
Operating junction temperature	T_j	-55	-	150	°C	-
Mounting torque	-	-	-	-	Ncm	-
Continuous diode forward current	I_S	-	-	9.6	A	T_C=25°C
Diode pulse current[2]	$I_{S,pulse}$	-	-	43	A	T_C=25°C
Reverse diode dv/dt[4]	dv/dt	-	-	1	V/ns	V_{DS}=0...400V, I_{SD}<=3.6A, T_j=25°C see table 8
Maximum diode commutation speed	di_F/dt	-	-	50	A/µs	V_{DS}=0...400V, I_{SD}<=3.6A, T_j=25°C see table 8
Insulation withstand voltage	V_{ISO}	-	-	n.a.	V	V_{rms}, T_C=25°C, t=1min



950V CoolMOS™ PFD7 SJ Power Device
IPD95R450PFD7

1 Maximum ratings

at T_j = 25°C, unless otherwise specified

Table 2 Maximum ratings

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Continuous drain current[1]	I_D	- -	- -	13.3 8.4	A	T_C=25°C T_C=100°C
Pulsed drain current[2]	$I_{D,pulse}$	-	-	43	A	T_C=25°C
Avalanche energy, single pulse	E_{AS}	-	-	29	mJ	I_D=1.8A; V_{DD}=50V; see table 10
Avalanche energy, repetitive	E_{AR}	-	-	0.22	mJ	I_D=1.8A; V_{DD}=50V; see table 10
Avalanche current, single pulse	I_{AS}	-	-	1.8	A	-
MOSFET dv/dt ruggedness	dv/dt	-	-	120	V/ns	V_{DS}=0...400V
Gate source voltage (static)	V_{GS}	-20	-	20	V	static;
Gate source voltage (dynamic)	V_{GS}	-30	-	30	V	AC (f>1 Hz)
Power dissipation	P_{tot}	-	-	104	W	T_C=25°C
Storage temperature	T_{stg}	-55	-	150	°C	-
Operating junction temperature	T_j	-55	-	150	°C	-
Mounting torque	-	-	-	-	Ncm	-
Continuous diode forward current	I_S	-	-	9	A	T_C=25°C
Diode pulse current[2]	$I_{S,pulse}$	-	-	43	A	T_C=25°C
Reverse diode dv/dt[3]	dv/dt	-	-	70	V/ns	V_{DS}=0...400V, I_{SD}<=9A, T_j=25°C see table 8
Maximum diode commutation speed	di_F/dt	-	-	1300	A/µs	V_{DS}=0...400V, I_{SD}<=9A, T_j=25°C see table 8
Insulation withstand voltage	V_{ISO}	-	-	n.a.	V	V_{rms}, T_C=25°C, t=1min

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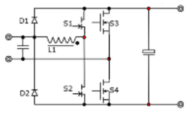
600 V/650 V CoolMOS™, CoolSiC™, and CoolGaN™ FOMs analysis

DEVICE	$V_{(BR)DSS}$ [V]	$R_{DS(on)}{*}Q_{rr}$ [mΩ * µC]	$R_{DS(on)}{*}E_{oss}$ [mΩ * µJ]	$R_{DS(on)}{*}Q_g$ [mΩ * nC]	$R_{DS(on)}{*}Q_{oss}$ [mΩ * µC]
CoolMOS^{TM} 7	600	100%	100%	100%	100%
CoolMOS^{TM} 7– fast diode	600	10%	104%	108%	104%
CoolGaN^{TM} Gen 1	600	0%	84%	6%	13%
CoolSiC^{TM} Gen 1	650	2%	133%	41%	21%

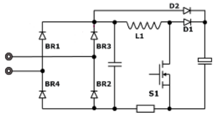
Allows WBG usage in topologies with repetitive hard commutation (e.g., CCM totem-pole PFC) → BOM savings for highest efficiency



CCM PFC totem-pole

SiC/GaN in servers, OBC

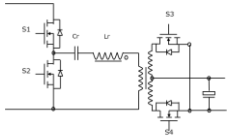
Minimum switching losses in hard-switching topologies (e.g., classic boost PFC) → higher efficiency with GaN



Classic Boost PFC

Si for best cost – performance ratio

Reduced driving losses especially at light-load conditions. Allows WBG to reach higher efficiency at increased frequency → power density increase (weight & size reduction)



Half-bridge LLC

high power density
e.g., GaN for chargers

Enables better soft-switching (e.g. half-bridge LLC), where WBG leads to higher efficiency combined with high frequencies

SiC and GaN
e.g., in telecom

Both SiC and Gan allow an easier way than Si to top efficiency

The 3 products have similar behaviour in hard-switching topologies like classic PFC

For power density, SiC is better than Si but the champion is GaN

SiC and GaN are both better than Si to reach both high efficiency and high density

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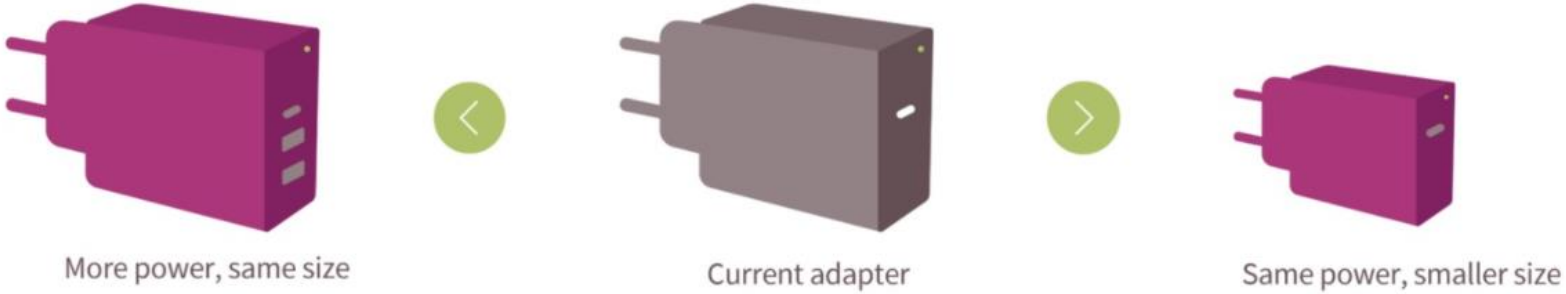
While doubling power density, CoolGaN™ is positioned to be the future of mobile charging

What higher power density means to customers



System savings

3x	**> 30%**	**20%**	**50%**	**2x**
switching frequency	energy savings	lower System Cost	higher power density	less Size & weight

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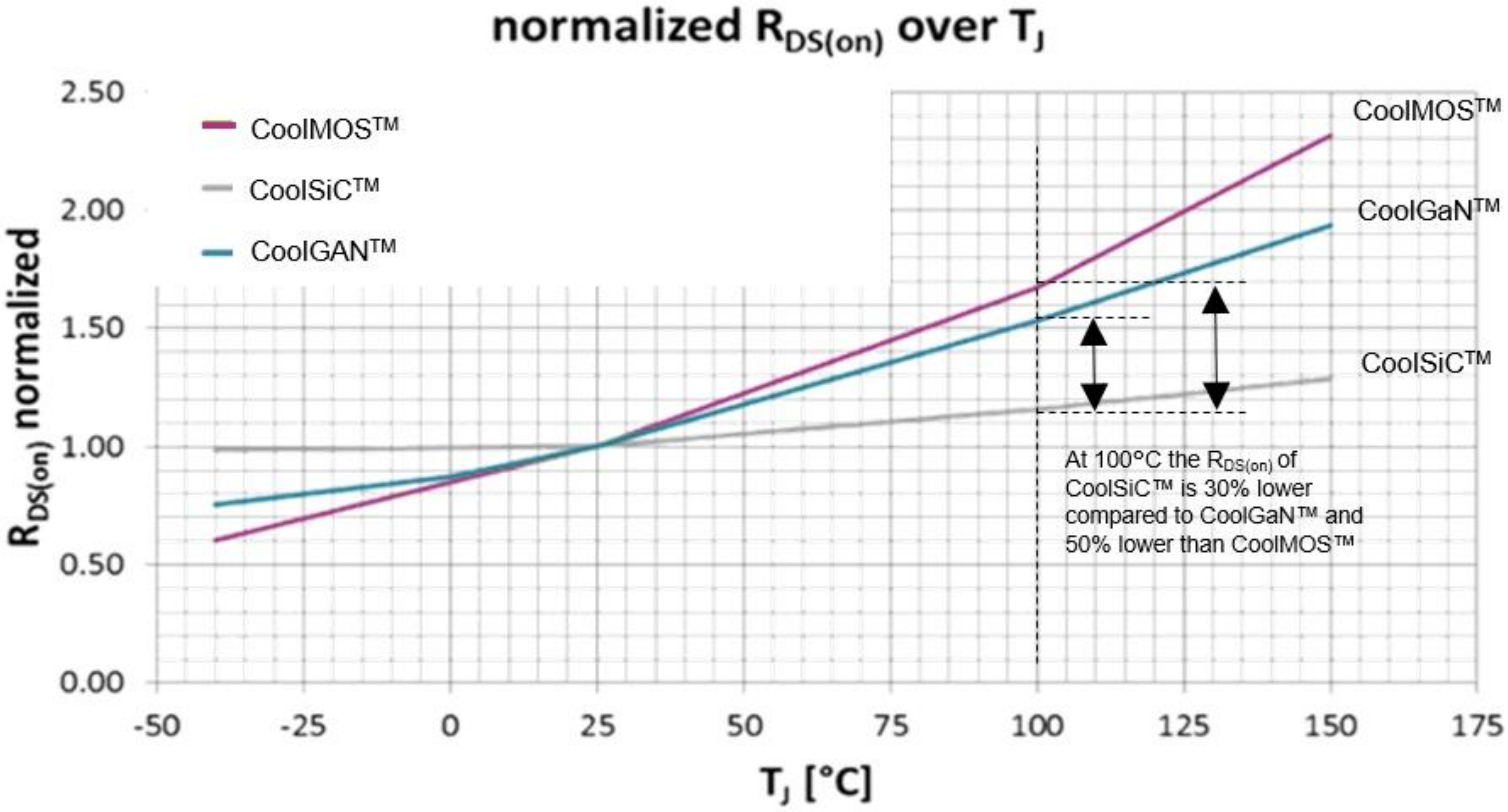
Comparison: $R_{DS(on)} = f\ (T_J)$



At 100°C the $R_{DS(on)}$ of CoolSiC™ is 30% lower compared to CoolGaN™ and 50% lower than CoolMOS™

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Infineon completes acquisition of GaN Systems, becoming a leading GaN Power House

Addressing fast-growth applications with **highly complementary strengths** in IP, application understanding, customer access and project pipeline

Significant **roadmap acceleration** through unmatched R&D resources and application expertise

Leadership in Power Systems through mastery of all relevant power technologies –
Si, SiC, GaN

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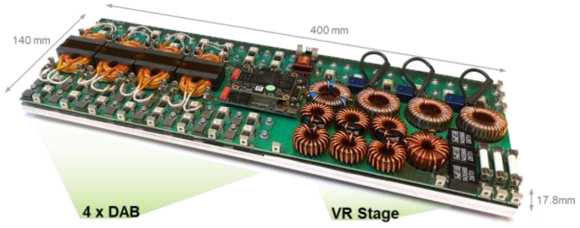
GaN brings a significant value proposition in many applications

On-board Charger



On-board charger: increasing power density from today’s 2kW/l to 10kW/l with GaN

HP SMPS

HP-SMPS for server: GaN is enabling highest power density and efficiency, to enable Accelerated- and AI computing at lowest TCO

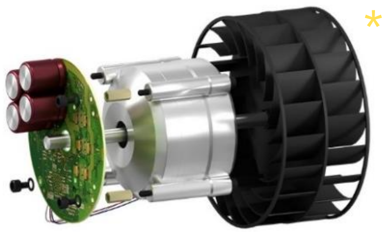
Charger & Adapter

High-density charger & adapter: GaN enables smallest form factors for multiport chargers & adapters

Renewables

ESS DCDC converter: highest efficiency and space reduction with GaN vs Si implementation

Motor Control



GaN increases of overall system efficiency by reduction of motor-current ripple and switching losses

48V DCDC

48V to ~7V/1V conversion: with GaN brings smaller form factors to Accelerated- and AI computing as well as Telecom brick converters

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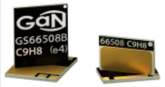
By extending our leading GaN portfolio in the segments of 100V and 650V we will provide you even more freedom to design

		GaN transistors							Int. Power Stages			Gate Driver ICs	
													
Voltage	**Rdson** (Max @ 25C)	**Die**	**GaN*PX*® Top** & Bottom cooled	**PQFN 3x5**	**PDFN 5x6**	**PDFN 8x8**	**TOLL**	**DSO** Top & Bottom cooled	**QFN 8x8** Half-Bridge	**LGA 6x8** Half-Bridge	**QFN 8x8** 1-channel	**Isolation** Functional	**Isolation** Functional
600 V and 650 V	**650**								🟩	🟩			
	570				🟦								
	340				🟩				🟩		🟩		
	260-285		🟦		🟦 🟩				🟩		🟩		
	190-195				🟦 🟩	🟦 🟩	🟩		🟩		🟩		
	130		🟦								🟩		
	110					🟦							
	90		🟦										
	63-70		🟦 **AEC**			🟦 🟩	🟩	🟩					
	42						🟩	🟩					
	32		🟦 AEC										
	13	🟦 AEC											
100 V	**22**		🟦										
	10		🟦										
	3.3			🟩									

🟩 Infineon 🟦 Former GaN Systems

AEC = option available for Automotive use

- Bringing the companies together provides a larger portfolio with more resources
- In the cases of product overlap, the products operate similarly, and customers have validated them as alternate sources for each other

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IGLR60R190D1 600V CoolGaN™ enhancement-mode Power Transistor

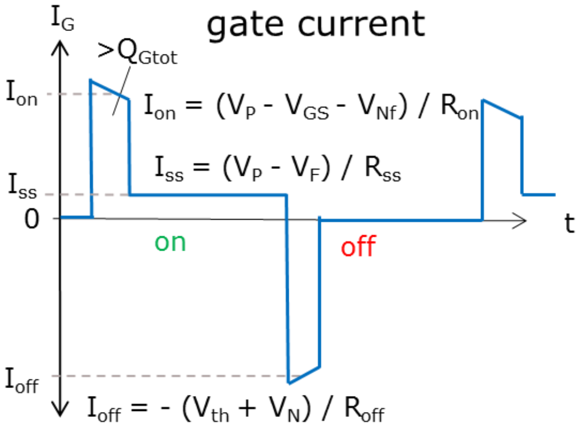
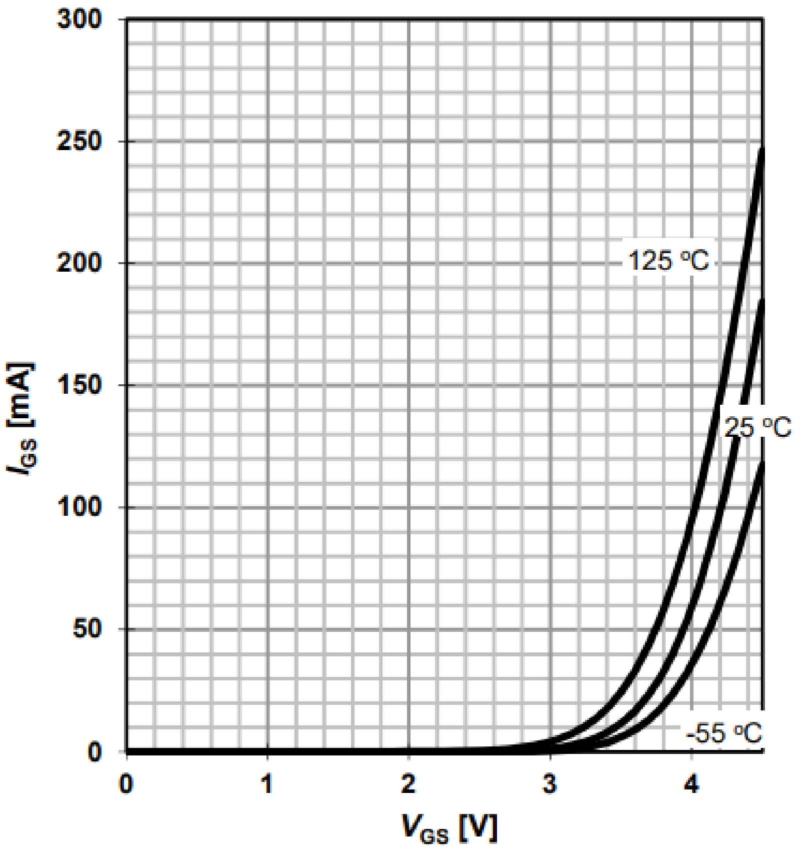
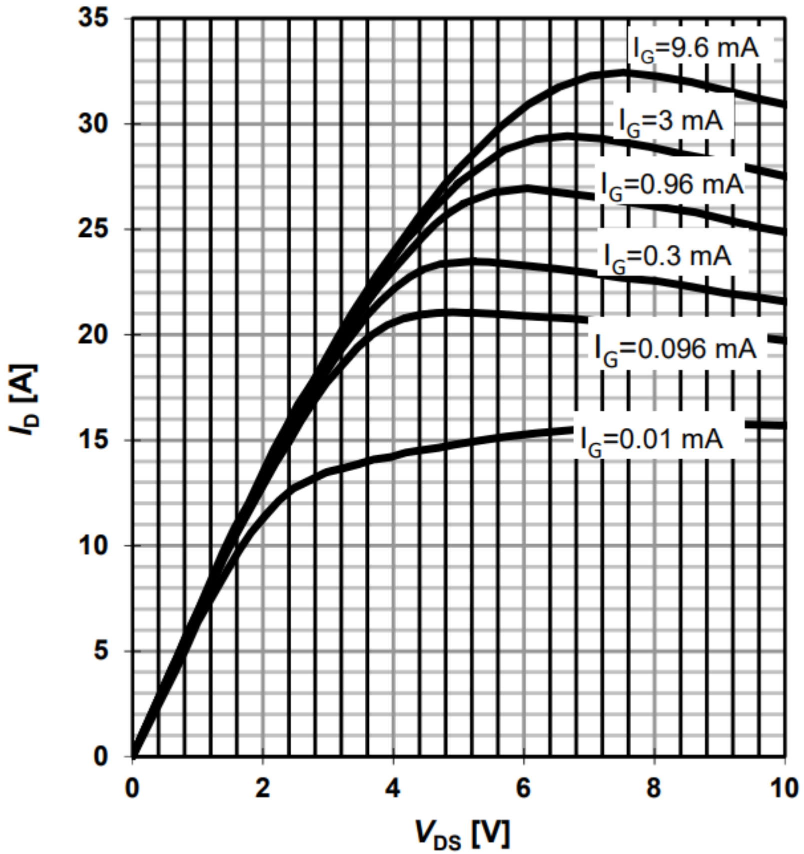


Figure 11 Typ. gate characteristics forward



$I_{GS}=f(V_{GS},T_j)$; open drain

Figure 7 Typ. output characteristics



$I_D=f(V_{DS},I_G)$; T_j = 25 °C

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GS66506T
Top-side cooled 650 V E-mode GaN transistor
Datasheet

GaN Systems 650V/90mOhm

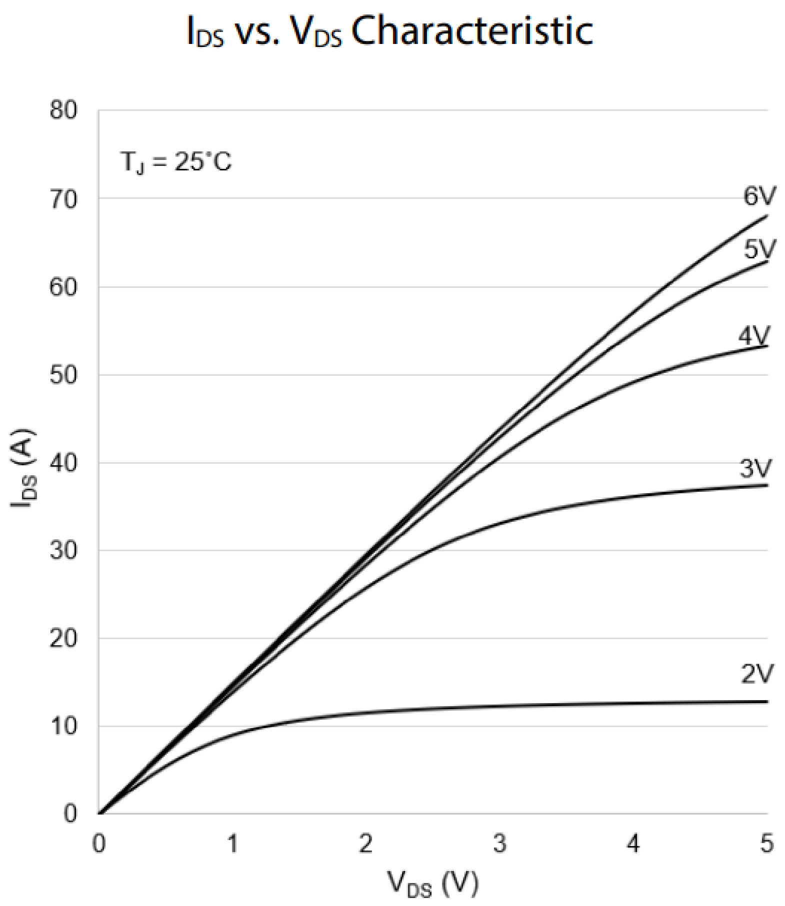

Figure 1: Typical I_{DS} vs. V_{DS} @ $T_J = 25\ ^{0}C$

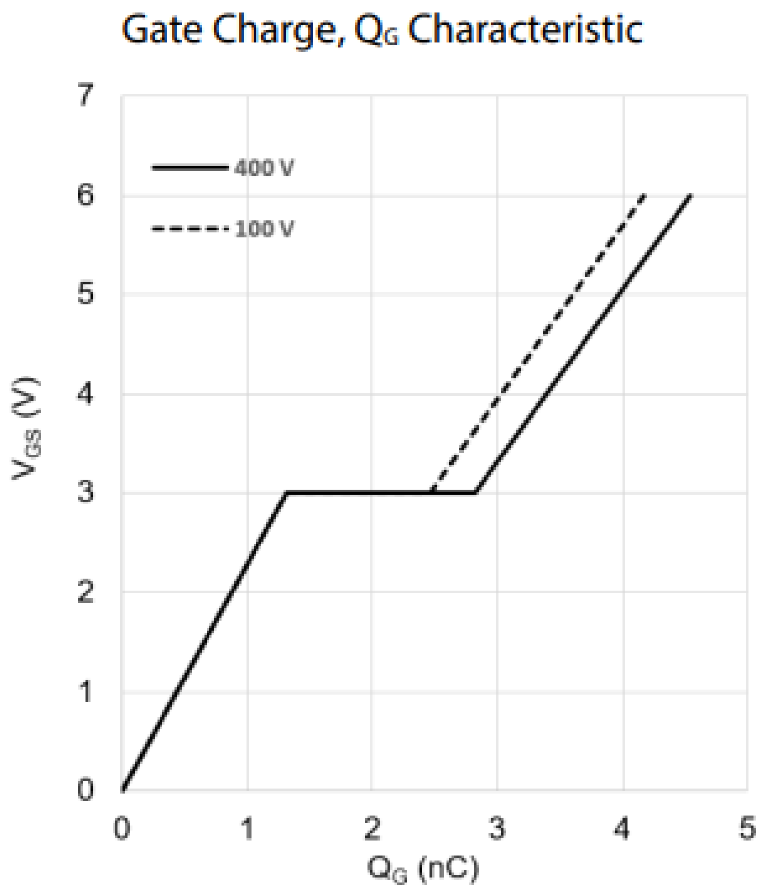

Figure 6: Typical V_{GS} vs. Q_G @ V_{DS} = 100, 400 V

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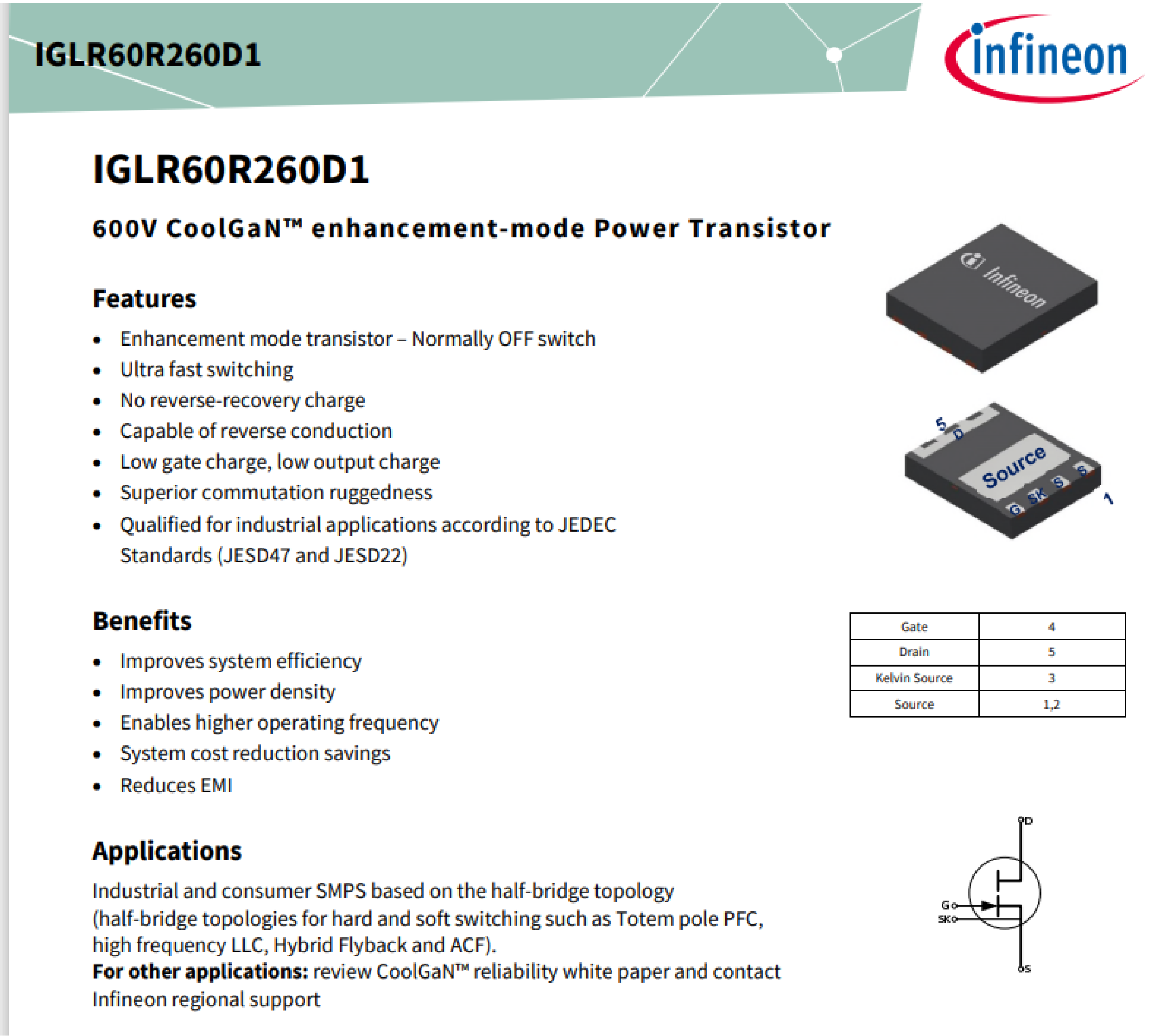
Comparison of the source connection CoolGaN versus CoolMos



IGLR60R260D1

IGLR60R260D1

600V CoolGaN™ enhancement-mode Power Transistor

Features

- Enhancement mode transistor – Normally OFF switch
- Ultra fast switching
- No reverse-recovery charge
- Capable of reverse conduction
- Low gate charge, low output charge
- Superior commutation ruggedness
- Qualified for industrial applications according to JEDEC Standards (JESD47 and JESD22)

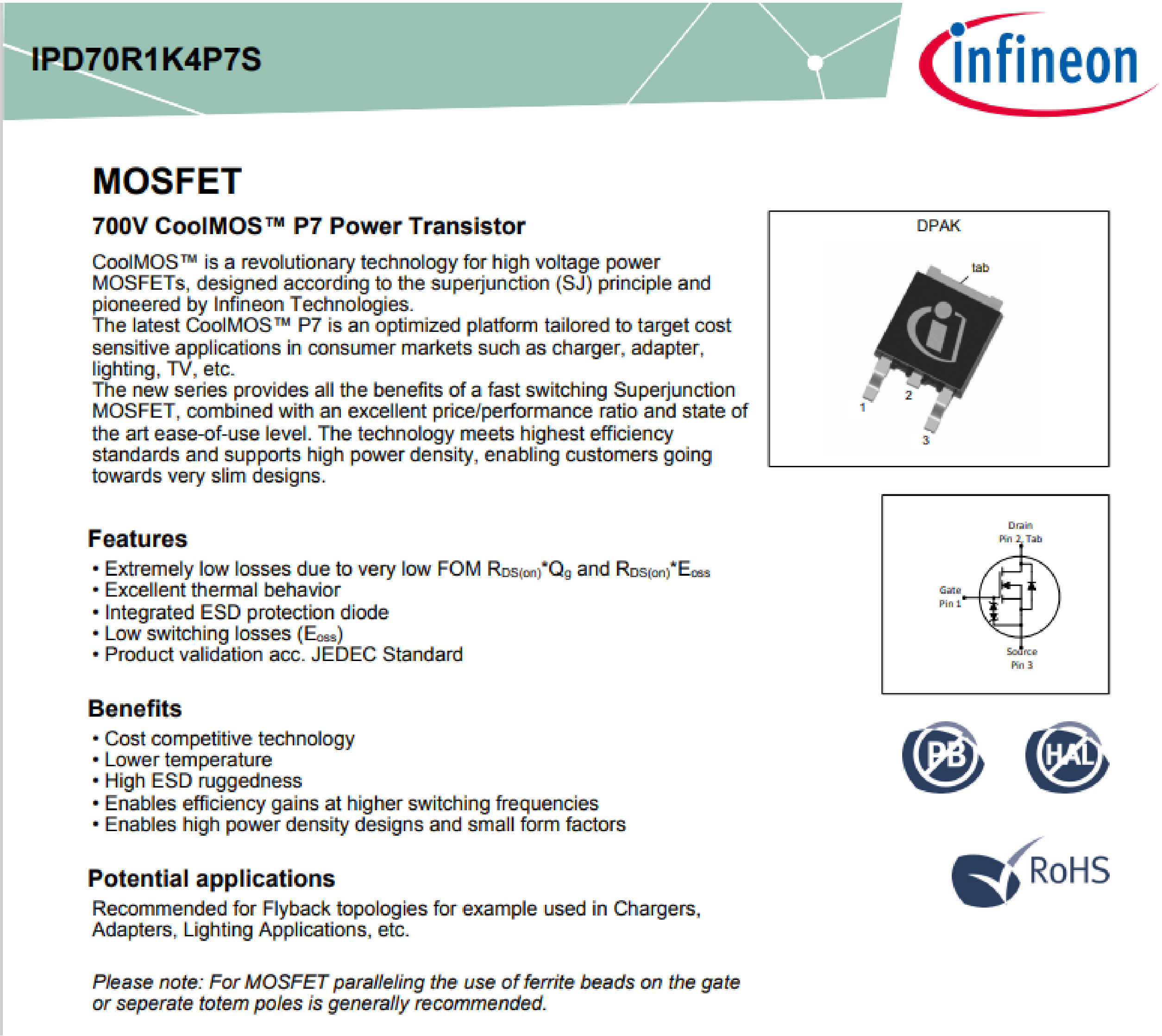
Gate	4
Drain	5
Kelvin Source	3
Source	1,2

Benefits

- Improves system efficiency
- Improves power density
- Enables higher operating frequency
- System cost reduction savings
- Reduces EMI

Applications

Industrial and consumer SMPS based on the half-bridge topology (half-bridge topologies for hard and soft switching such as Totem pole PFC, high frequency LLC, Hybrid Flyback and ACF).
For other applications: review CoolGaN™ reliability white paper and contact Infineon regional support



IPD70R1K4P7S

MOSFET

700V CoolMOS™ P7 Power Transistor

CoolMOS™ is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies.
The latest CoolMOS™ P7 is an optimized platform tailored to target cost sensitive applications in consumer markets such as charger, adapter, lighting, TV, etc.
The new series provides all the benefits of a fast switching Superjunction MOSFET, combined with an excellent price/performance ratio and state of the art ease-of-use level. The technology meets highest efficiency standards and supports high power density, enabling customers going towards very slim designs.

Features

- Extremely low losses due to very low FOM $R_{DS(on)}$*Q_g and $R_{DS(on)}$*E_{oss}
- Excellent thermal behavior
- Integrated ESD protection diode
- Low switching losses (E_{oss})
- Product validation acc. JEDEC Standard

Benefits

- Cost competitive technology
- Lower temperature
- High ESD ruggedness
- Enables efficiency gains at higher switching frequencies
- Enables high power density designs and small form factors

Potential applications

Recommended for Flyback topologies for example used in Chargers, Adapters, Lighting Applications, etc.

Please note: For MOSFET paralleling the use of ferrite beads on the gate or seperate totem poles is generally recommended.

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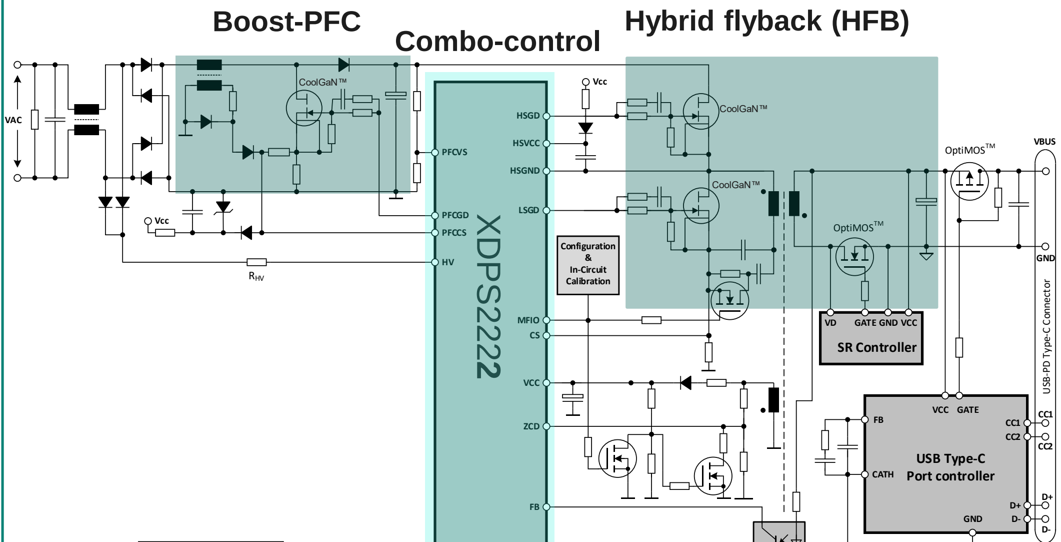
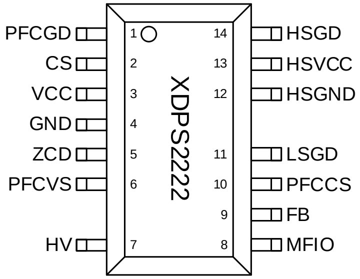
XDP™ digital power XDPS2222: PFC + hybrid flyback combo IC
Key features at a glance

Typical application





Inherent HFB topology advantages

- Low voltage stress on primary and secondary switches
- Small transformer by resonant energy transfer

Key features

- 600 V high voltage start-up cell for fast VCC charging
- Novel ZVS hybrid flyback topology (asymmetrical half-bridge) for ultra-high system efficiency
- HFB peak current control for robust and fast control
- HFB ZVS operation of high-side and low-side switch (with ZVS pulse insertion in DCM)
- PFC QRM multimode operation for improved efficiency
- Harmonized PFC and hybrid flyback control
- Burst mode operation control for lowest stand-by power
- **Supports extra wide output voltage range with MFIO switching depending on output voltage**
- Integrated gate drivers supporting GaN switches
- Configurability for protections and system performance
- DSO-14 (150mil) package

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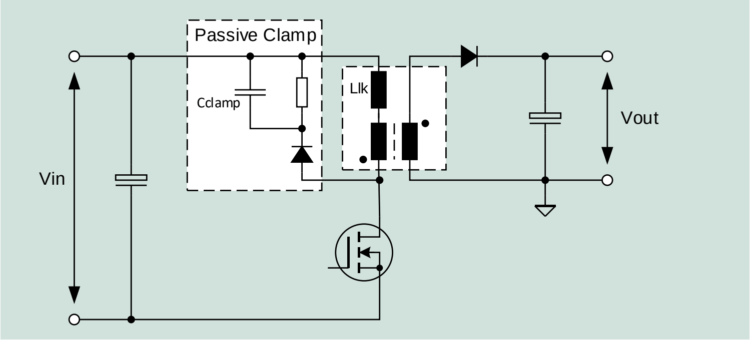
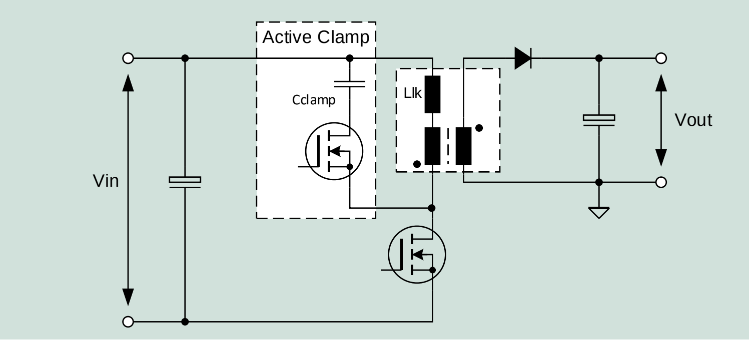
DC-DC topology comparison

Conventional flyback with snubber



- Recycling the **leakage energy for** ZVS
- But: all energy stored in transformer

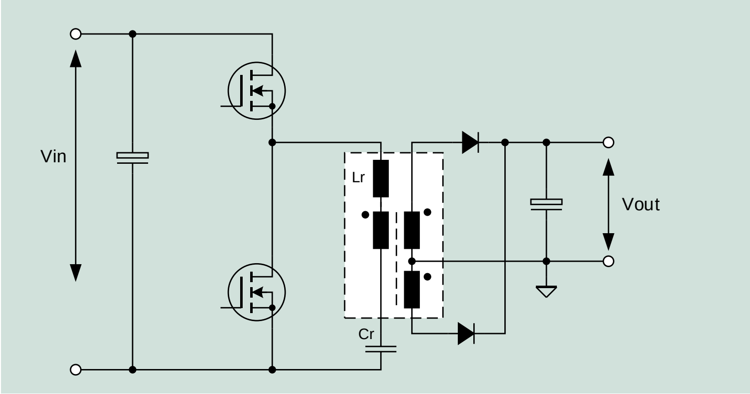
Active clamp flyback



- Using flyback principle with time separated energy storage and transmission phase

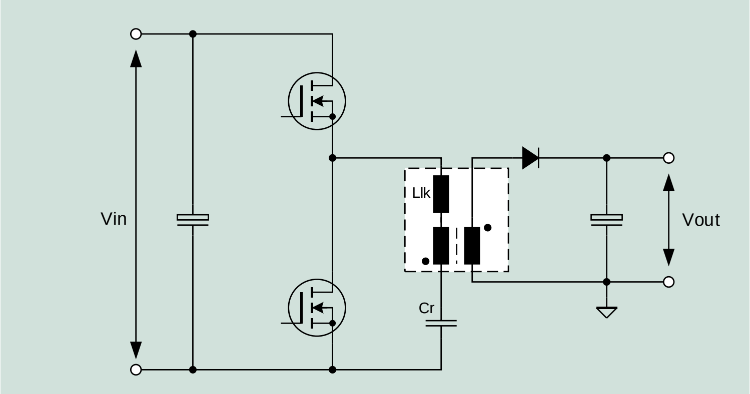
- Reduced magnetic energy for **transformer size reduction**
- **Lower breakdown voltage** requirement of **output rectifier**

LLC (Forward resonant half-bridge)



- Using resonant energy storage for **<u>substantial</u> energy transmission** and ZVS

Hybrid flyback



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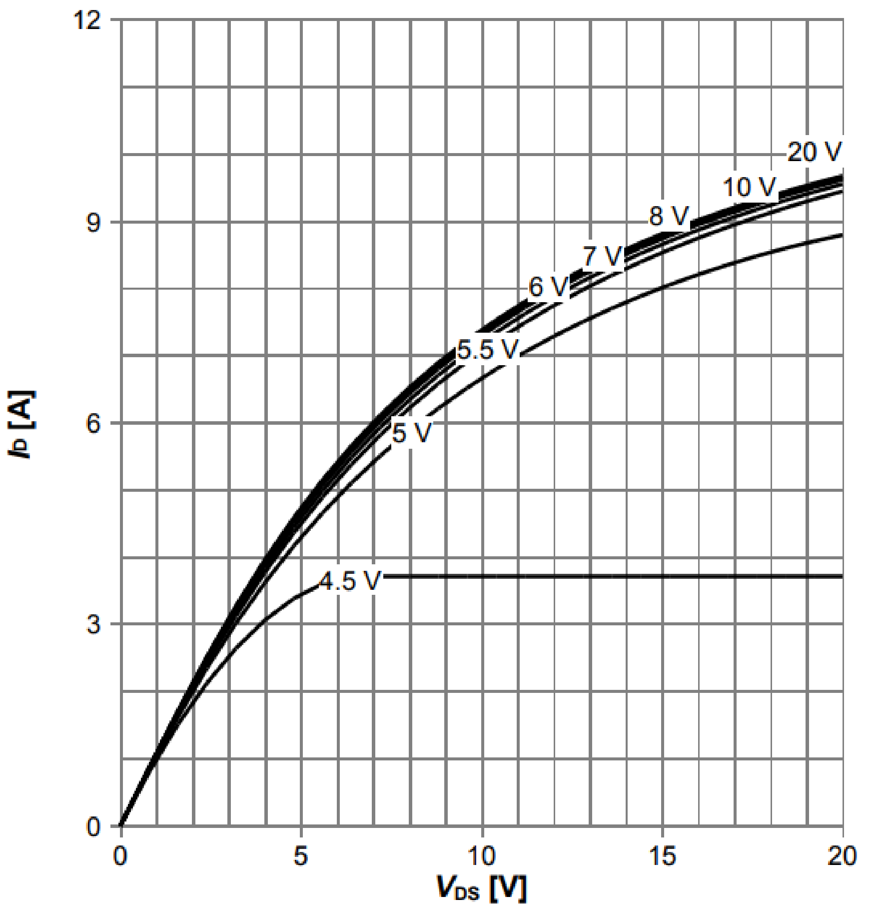
Differences of the Gate threshold CoolMos 950V versus CoolSiC 1700V

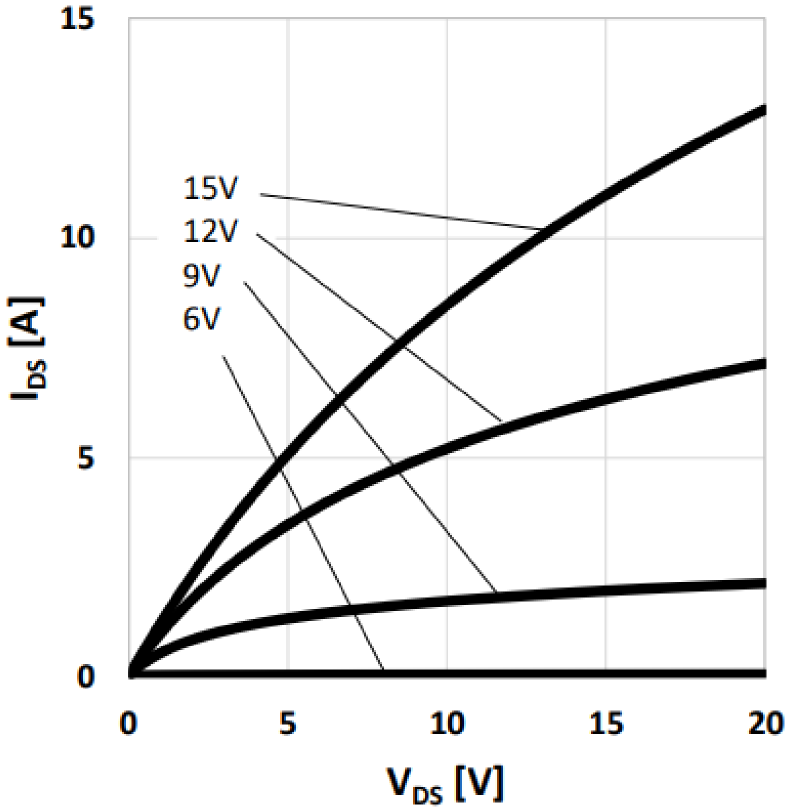
950VCoolMOS P7 SJ Power Device 1,2Ω

Diagram 5: Typ. output characteristics



I_D=f(V_{DS}); T_j=25 °C; parameter: V_{GS}

CoolSiC™ 1700V SiC Trench MOSFET 1Ω



igure 7 Typical output characteristic, V_{GS} as parameter

(I_{DS} = f(V_{DS}), T_{vj}=25°C, t_P = 20µs)

Conclusion of the required threshold voltage:

- *To turn on a CoolMos, the gate voltage should be higher than 6V and for CoolSiC higher than 12V.*
- *The typical value of the gate voltage of 3rd and 5th generation Flyback Controller from Infineon is 10V. That means a separate driver is required to drive a CoolSiC Mosfet*

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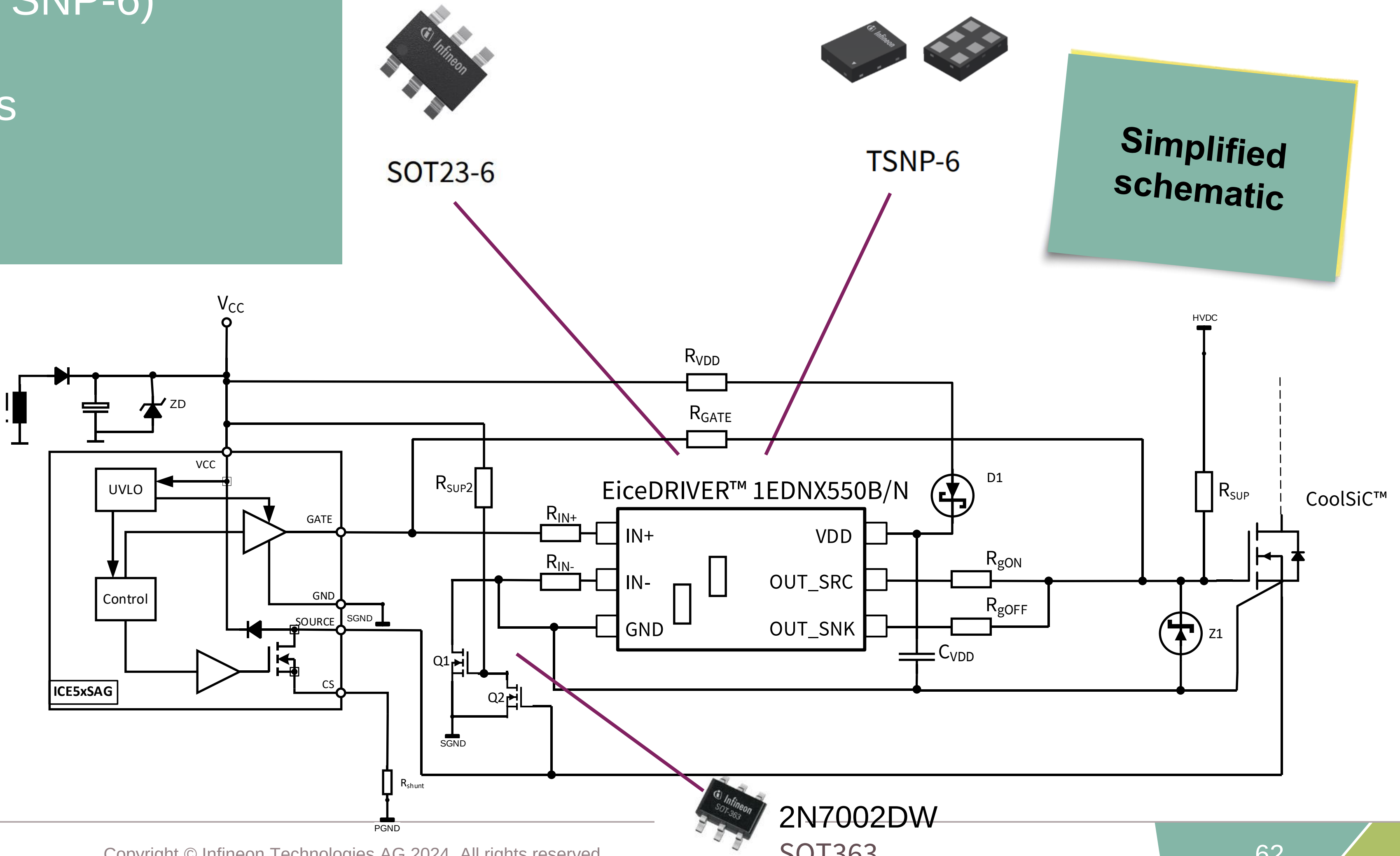
Introduction

- Enabled by EiceDRIVER™ 1EDNx550
- Small form factor (SOT23 and TSNP-6)
- Selectable UVLO
  - 12.2V & 14.9V UVLO options
- 8A/4A sink/source
- Industrial drives, EV and solar

Simplified schematic



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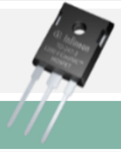
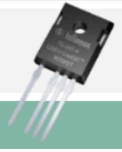
CoolSiC™ MOSFET 1200 V / 1700 V discrete

TO-247





$R_{DS(on)}$ [mΩ]	1200 V TO-247-3	1200 V TO-247-4
7	IMW120R007M1H	IMZA120R007M1H
14	IMW120R014M1H	IMZA120R014M1H
20	IMW120R020M1H	IMZA120R020M1H
30	IMW120R030M1H	IMZ120R030M1H
40 / 45	IMW120R040M1H / IMW120R045M1	IMZA120R040M1H / IMZ120R045M1
60	IMW120R060M1H	IMZ120R060M1H
90	IMW120R090M1H	IMZ120R090M1H
140	IMW120R140M1H	IMZ120R140M1H
220	IMW120R220M1H	IMZ120R220M1H
350	IMW120R350M1H	IMZ120R350M1H

SMD

$R_{DS(on)}$ [mΩ]	1200 V D^{2}PAK-7	$R_{DS(on)}$ [mΩ]	1700 V D^{2}PAK-7 high creepage
30	IMBG120R030M1H	450	IMBF170R450M1
45	IMBG120R045M1H	650	IMBF170R650M1
60	IMBG120R060M1H	1000	IMBF170R1K0M1
90	IMBG120R090M1H		
140	IMBG120R140M1H		
220	IMBG120R220M1H		
350	IMBG120R350M1H		

Solar

EV-Charging

Storage

UPS

Industrial SMPS

Drives

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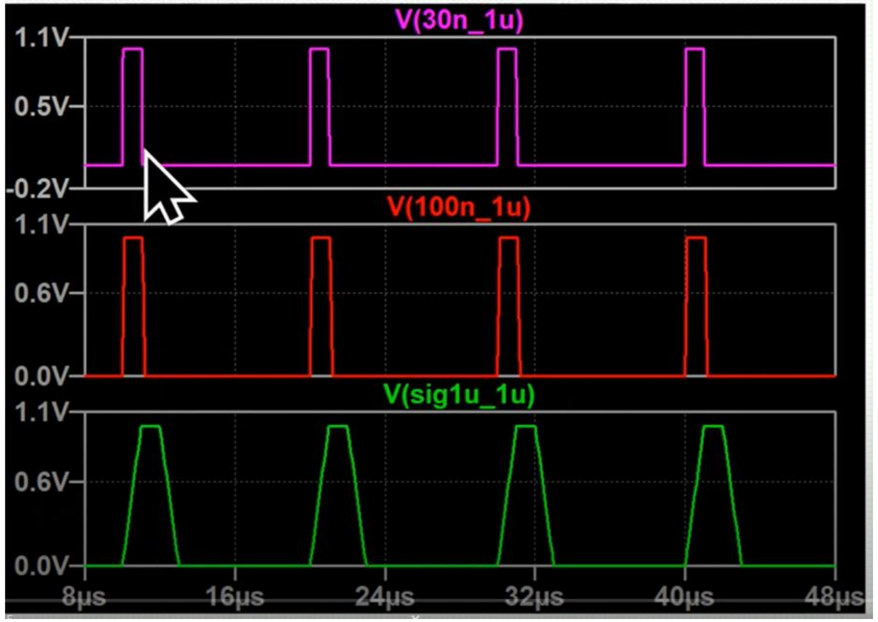
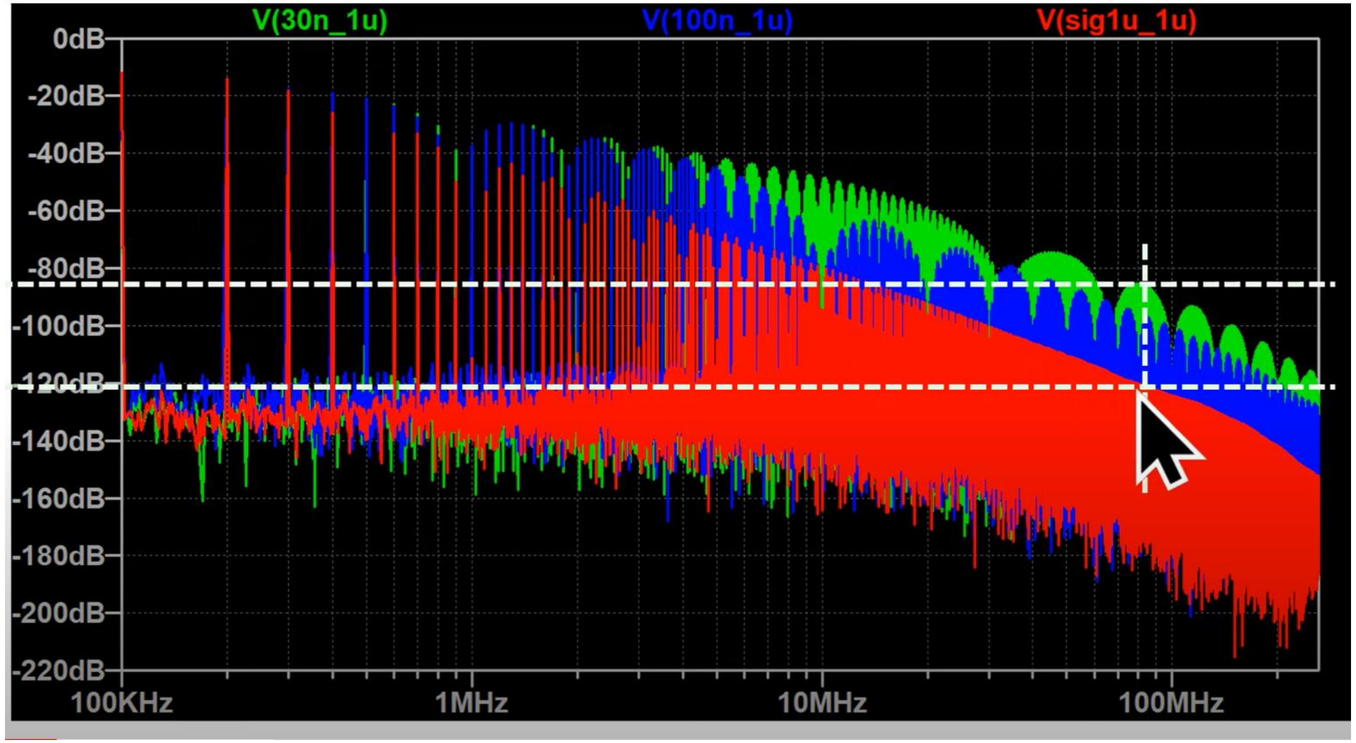
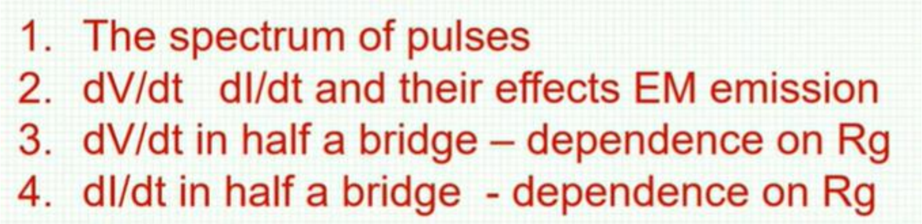
The effect of gate turn on resistor on EM emission
From Prof Sam Ben-Yaakov

dt/dV: Green 1µs/V, red = 100ns/V, violet = 30ns/V



Spectrum: Green 30ns/V, blue 100ns/V and red=1µs/V





1. The spectrum of pulses
2. dV/dt dI/dt and their effects EM emission
3. dV/dt in half a bridge – dependence on Rg
4. dI/dt in half a bridge - dependence on Rg

https://www.youtube.com/watch?v=2oYYYVu4Akk&list=PLEy5cPyMzgySUYaT0AD8rziAf6q2VEhCN&index=172

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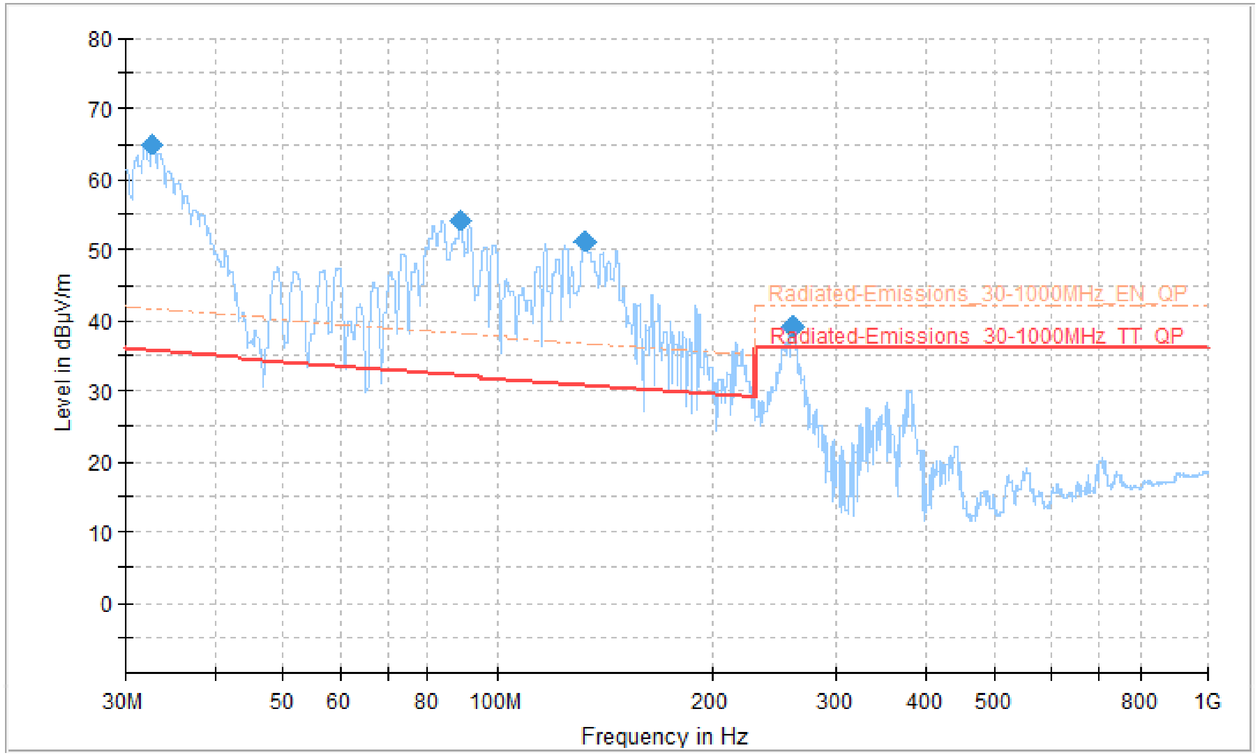
EMI requirement according to radiated emissions EN55014-1

Scan setup:

Frequencies			Receiver settings					
Start	Stop	Step	Res-BW	Detector	M- Time	Atten	Preamp	Pre-Scan Mode
30MHz	1000MHz	30kHz	120kHz	QP	1s	auto	on	Fast (TD/FFT) Repeat max hold

Final measurement:	Detector:	QP
	M-Time:	1s
	Acceptance:	6dB
	Peaks:	10



Operating mode:	5V (100mA) + 12V (1A)
Measuring distance:	3 m
Measuring hight:	1.4 m
Polarisation:	Vertical + Horizontal
Position horizontal	0° / 90° / 180° / 270°
Powersupply	230 V
EMI Test Receiver	Rohde&Schwarz ESW44
Antenna:	Rohde&Schwarz HL562e
EMC-Chamber:	Albatross M-CDC (FAR)
Powersupply:	

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Optimizing CoolMOS^{TM} based power supplies to EMI requirements
Turn-ON (dv/dt)

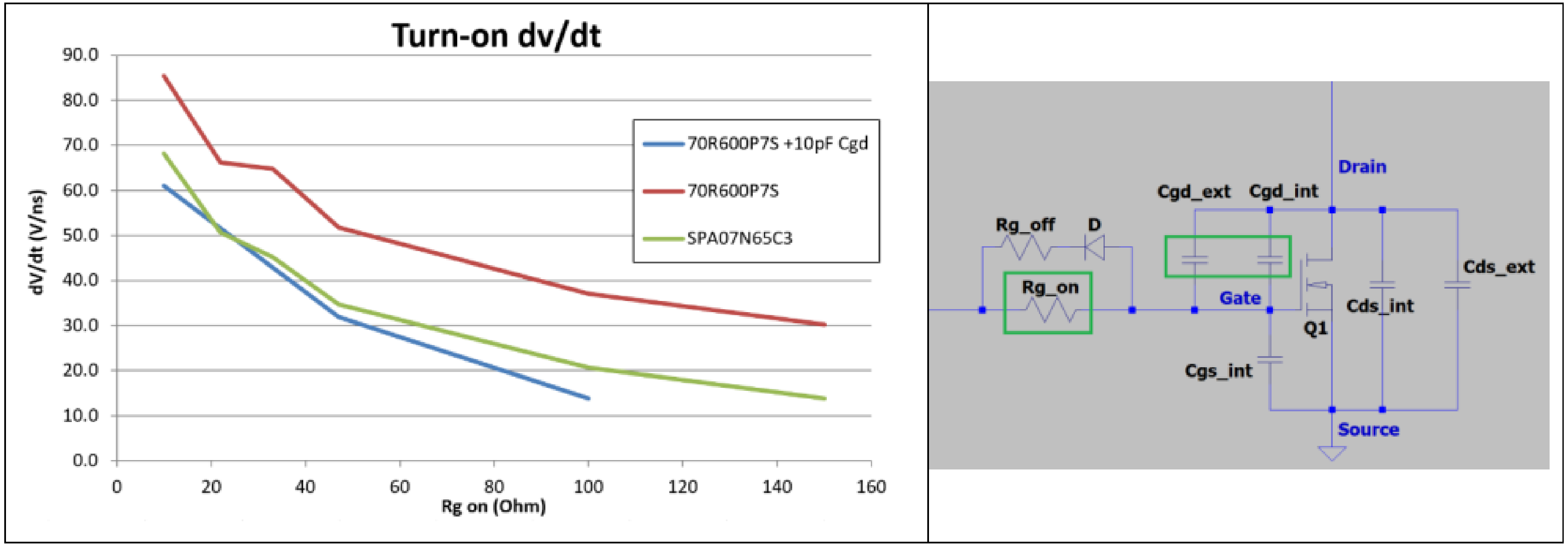

Figure 5 **Effect of R_{g_on} and C_{gd} external (C_{gd_ext}) on turn-on dV/dt**

The total gate resistance was adjusted from 10 Ω up to 150 Ω. It can be seen that as the Rg is increased the dV/dt of the system slows down. When replacing the C3 device with an IPA70R600P7S it can be seen that the dV/dt with the same Rg external is increased. The SPA07N65C3 with an Rg external of 40 Ω has a dV/dt of 40 V/ns while the P7 would need approximately 90 Ω to achieve 40 V/ns. Adding a 10 pF 1 kV ceramic capacitor as a Cgd external then makes it so the P7 device has a similar turn-on dV/dt as the C3 device, but note that this will have a negative impact on the efficiency.

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2 Gen 5 quasi-resonat flyback controller - CoolSet 26

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4 SMPS Design Tool – PowerESIM for CoolSET™ 49

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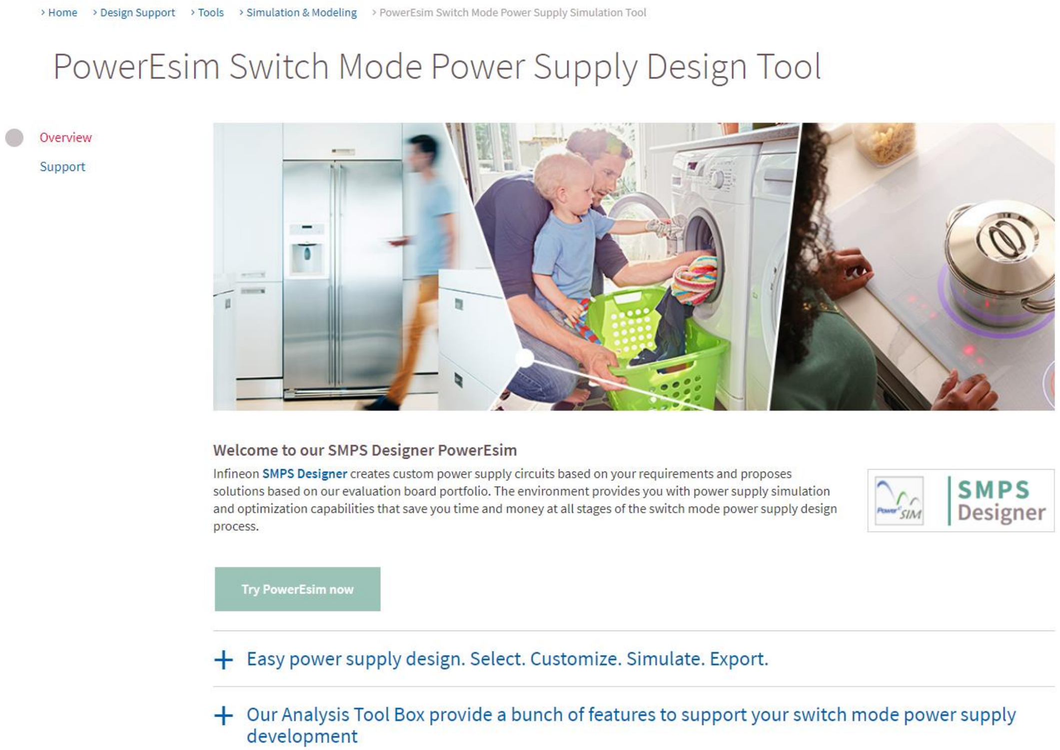
The SMPS Designer

- Web based simulator / calculator
- Support of quick and easy system design
- Loss analysis of each component during different operating points
- Eases component selection by providing all necessary information like values, component stress and voltage and current ratings
- Option to save and load designs as well and downloadable result tables
- Landing page

  https://www.poweresim.com/

  http://www.how2power.com/



PowerEsim Switch Mode Power Supply Design Tool

Welcome to our SMPS Designer PowerEsim

Infineon **SMPS Designer** creates custom power supply circuits based on your requirements and proposes solutions based on our evaluation board portfolio. The environment provides you with power supply simulation and optimization capabilities that save you time and money at all stages of the switch mode power supply design process.

+ Easy power supply design. Select. Customize. Simulate. Export.

+ Our Analysis Tool Box provide a bunch of features to support your switch mode power supply development

Calculation tool based on EXCEL:

Gen 5 fixed frequency flyback controller

https://www.infineon.com/cms/en/product/power/ac-dc-power-conversion/ac-dc-integrated-power-stage-coolset/fixed-frequency-coolset/?tab=~%27development_tools#!designsupport

Gen 5 quasi-resonant flyback controller

https://www.infineon.com/cms/en/product/power/ac-dc-power-conversion/ac-dc-integrated-power-stage-coolset/quasi-resonant-coolset/?tab=~%27development_tools#!designsupport

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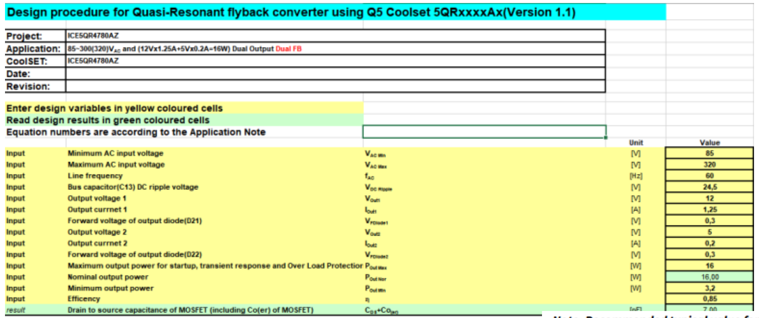
Comparison of tools

Design guide & excel tool

- Contains theory, calculation, explanations and tips
- In depth understanding of topology and IC

PowerESIM

- Online
- Very flexible transformer design



Design procedure for Quasi-Resonant flyback converter using Q5 Coolset 5QRxxxxAx(Version 1.1)

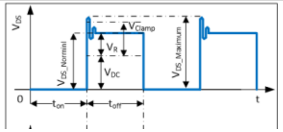
Project:	ICE5QR4780AZ
Application:	85~300(320)V_{AC} and (12Vx1.25A+5Vx0.2A=16W) Dual Output Dual FB
CoolSET:	ICE5QR4780AZ
Date:	
Revision:	

Enter design variables in yellow coloured cells

Read design results in green coloured cells

Equation numbers are according to the Application Note

			Unit	Value
Input	Minimum AC input voltage	$V_{AC\ Min}$	[V]	85
Input	Maximum AC input voltage	$V_{AC\ Max}$	[V]	320
Input	Line frequency	f_{AC}	[Hz]	60
Input	Bus capacitor(C13) DC ripple voltage	$V_{DC\ Ripple}$	[V]	24,5
Input	Output voltage 1	V_{Out1}	[V]	12
Input	Output currnet 1	I_{Out1}	[A]	1,25
Input	Forward voltage of output diode(D21)	$V_{FDiode1}$	[V]	0,3
Input	Output voltage 2	V_{Out2}	[V]	5
Input	Output currnet 2	I_{Out2}	[A]	0,2
Input	Forward voltage of output diode(D22)	$V_{FDiode2}$	[V]	0,3
Input	Maximum output power for startup, transient response and Over Load Protection	$P_{Out\ Max}$	[W]	16
Input	Nominal output power	$P_{Out\ Nor}$	[W]	16,00
Input	Minimum output power	$P_{Out\ Min}$	[W]	3,2
Input	Efficency	η		0,85
result	Drain to source capacitance of MOSFET (including Co(er) of MOSFET)	$C_{DS}+Co_{(er)}$	[nF]	7,00



Note: Recommended typical value for $R_{START-UP}$ is 50 MΩ (20 MΩ~100 MΩ), and the $R_{START-UP}$ value is directly proportional to $t_{Start-up}$ and inversely proportional to no-load standby power.

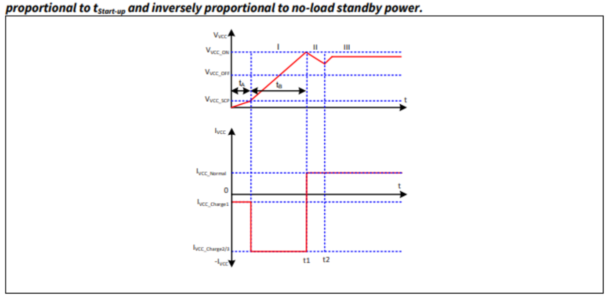
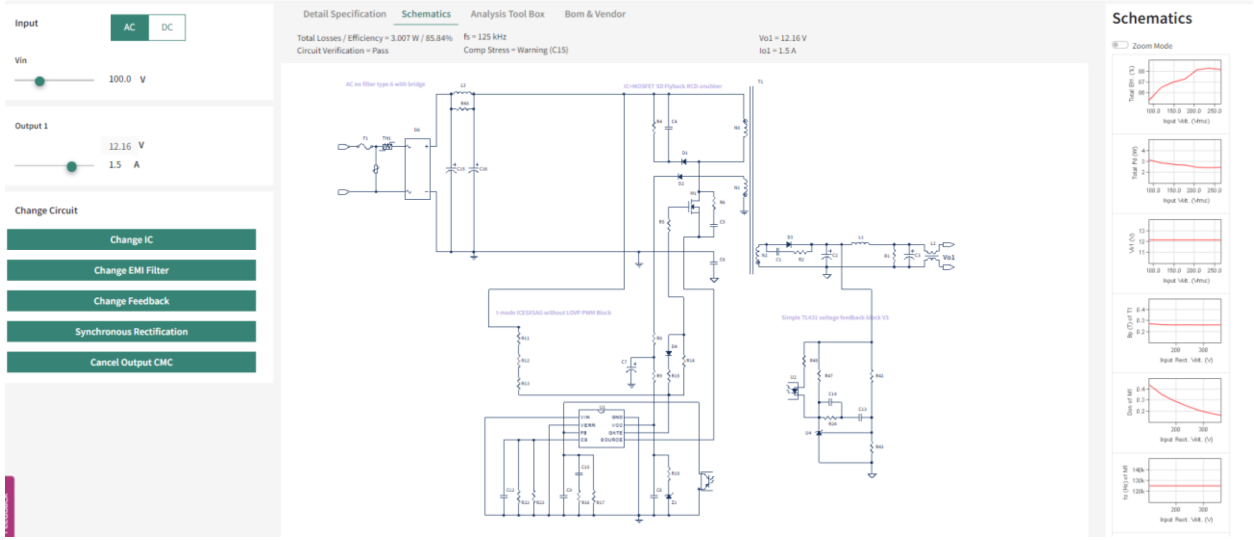


Figure 5 **V_{CC} voltage and current at start-up**

The time taken for V_{CC} pre-charging can then be approximately calculated as:

$$t_{\mathrm{StartUp}} = t_{\mathrm{A}} + t_{\mathrm{B}} = \frac{V_{VCC\_SCP} \cdot C_{VCC}}{I_{VCC\_Charge1}} + \frac{(V_{VCC\_ON} - V_{VCC\_SCP}) \cdot C_{VCC}}{I_{VCC\_Charge3}} \qquad \textbf{(Eq. 56B)}^2$$



Input: AC | DC

Vin 100.0 V

Output 1

12.16 V

1.5 A

Total Losses / Efficiency = 3.007 W / 85.84%

Circuit Verification = Pass

fs = 125 kHz

Comp Stress = Warning (C15)

Vo1 = 12.16 V

Io1 = 1.5 A

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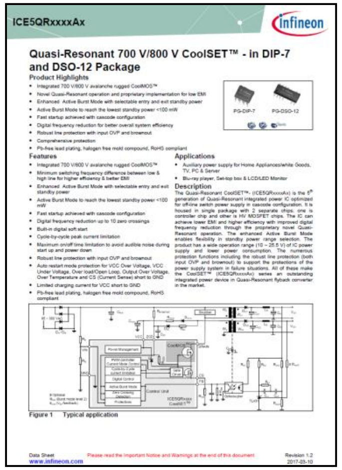
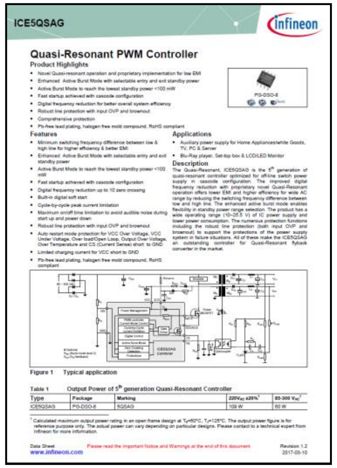
Where to get more information ?

- **Internet**
  - http://www.infineon.com/PWM
  - http://www.infineon.com/CoolSET-gen5
    - Datasheet
    - Engineering report
    - Application notes
    - Design guide
    - Calculation tool
    - Product Brief



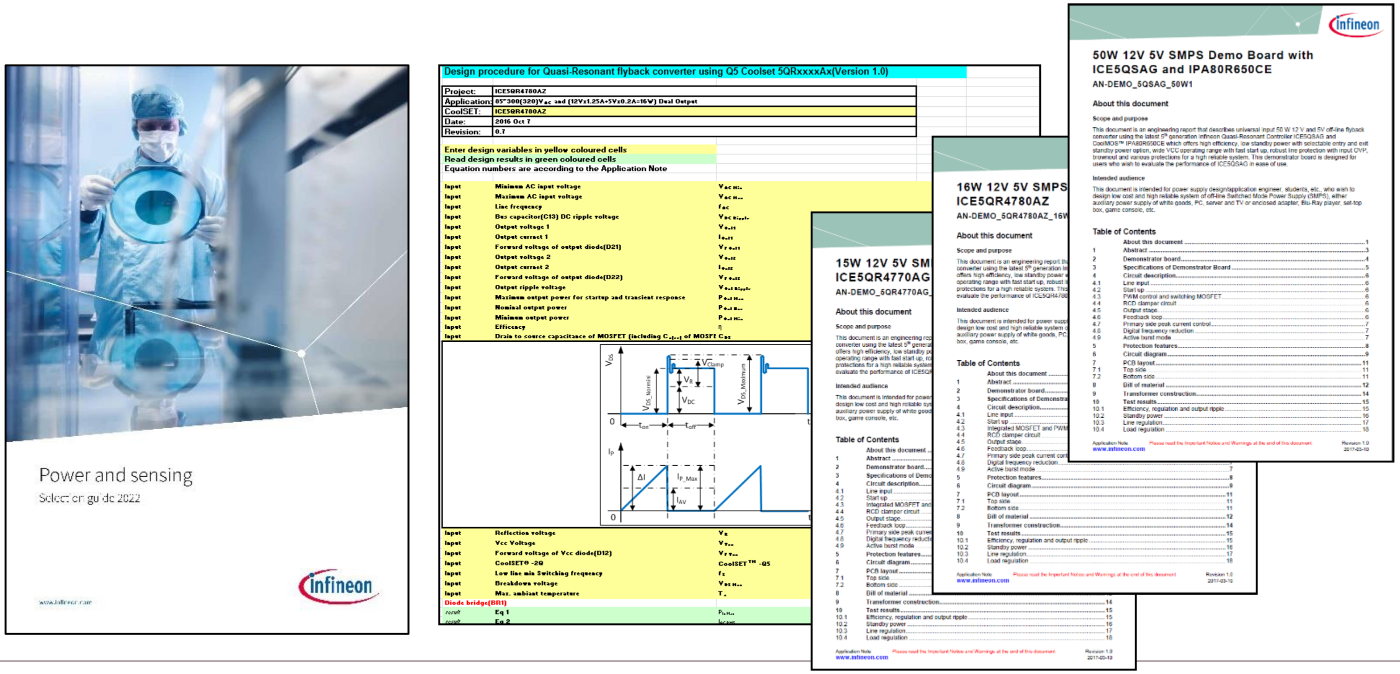
ICE5QRxxxxAx

Quasi-Resonant 700 V/800 V CoolSET™ - in DIP-7 and DSO-12 Package



ICE5QSAG

Quasi-Resonant PWM Controller



Power and sensing

Selection guide 2022

Design procedure for Quasi-Resonant flyback converter using Q5 Coolset 5QRxxxxAx(Version 1.0)

50W 12V 5V SMPS Demo Board with ICE5QSAG and IPA80R650CE

AN-DEMO_5QSAG_50W1

16W 12V 5V SMPS

ICE5QR4780AZ

15W 12V 5V SM

ICE5QR4770AG

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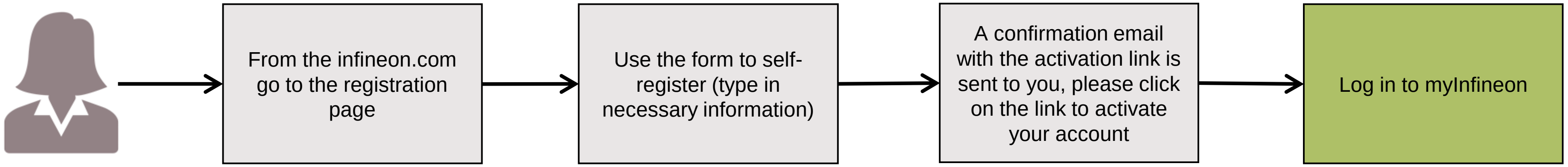

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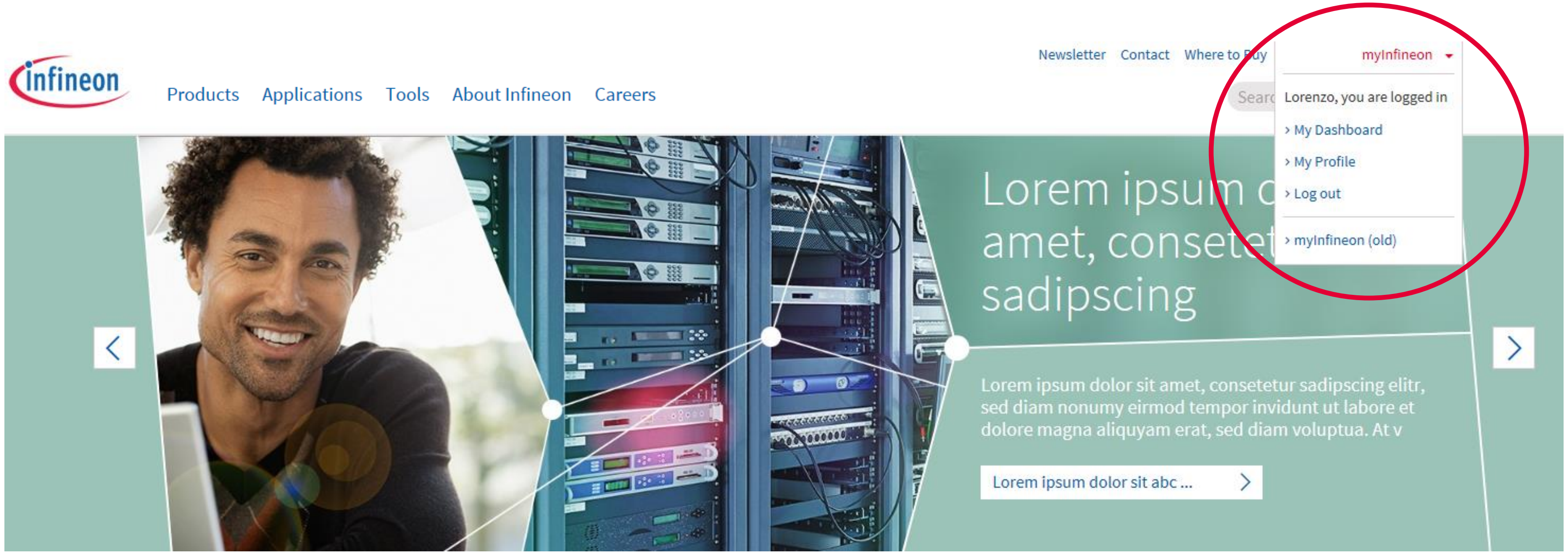

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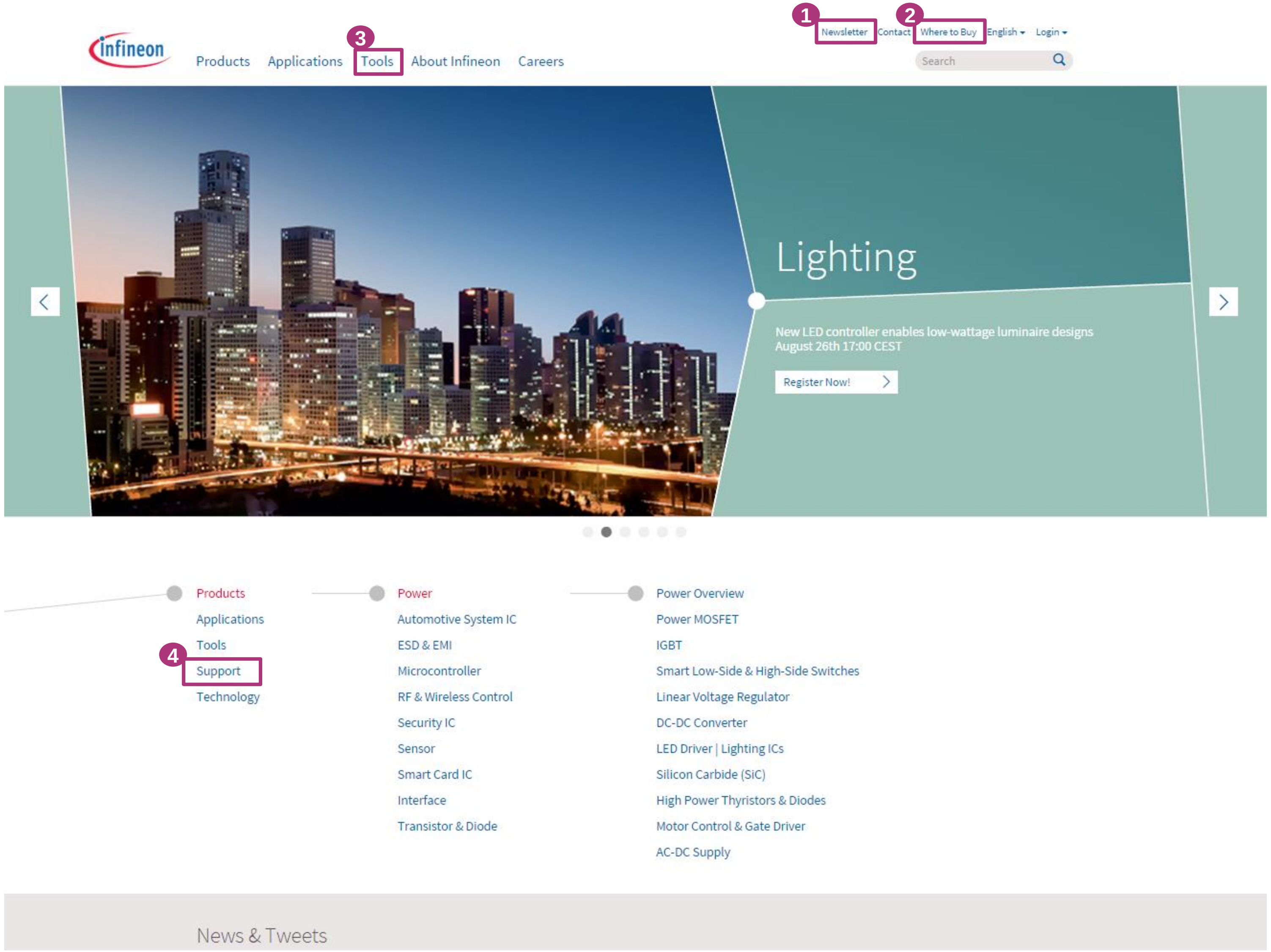

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