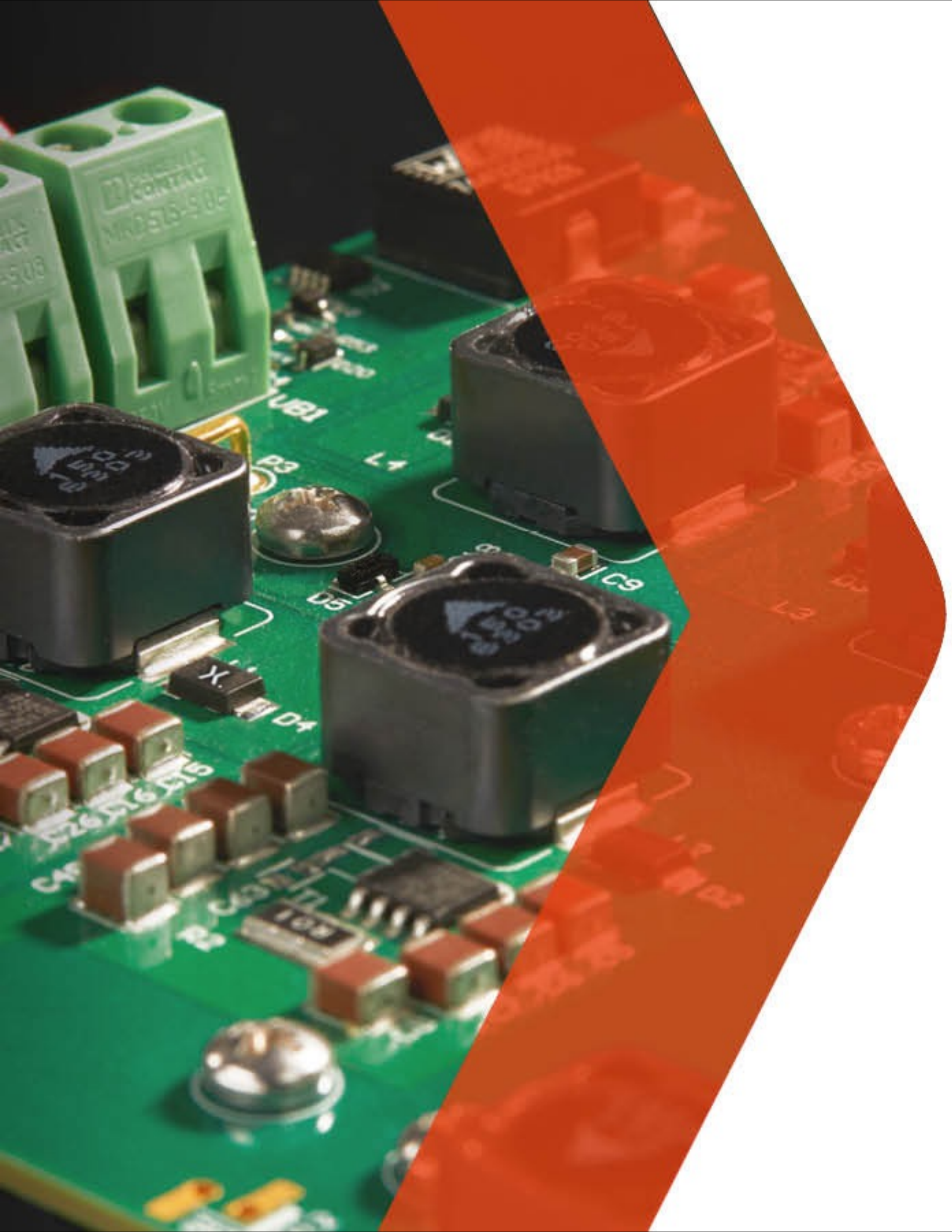


nexperia

Schottky, Silicon Germanium or Recovery (PN) rectifiers?

How to achieve extra efficiency and reliability in LED drivers or solenoid drives by choosing the most suitable power diode

September 2021

Introduction

- Dr.-Ing. Reza Behtash
- Application Marketing Manager

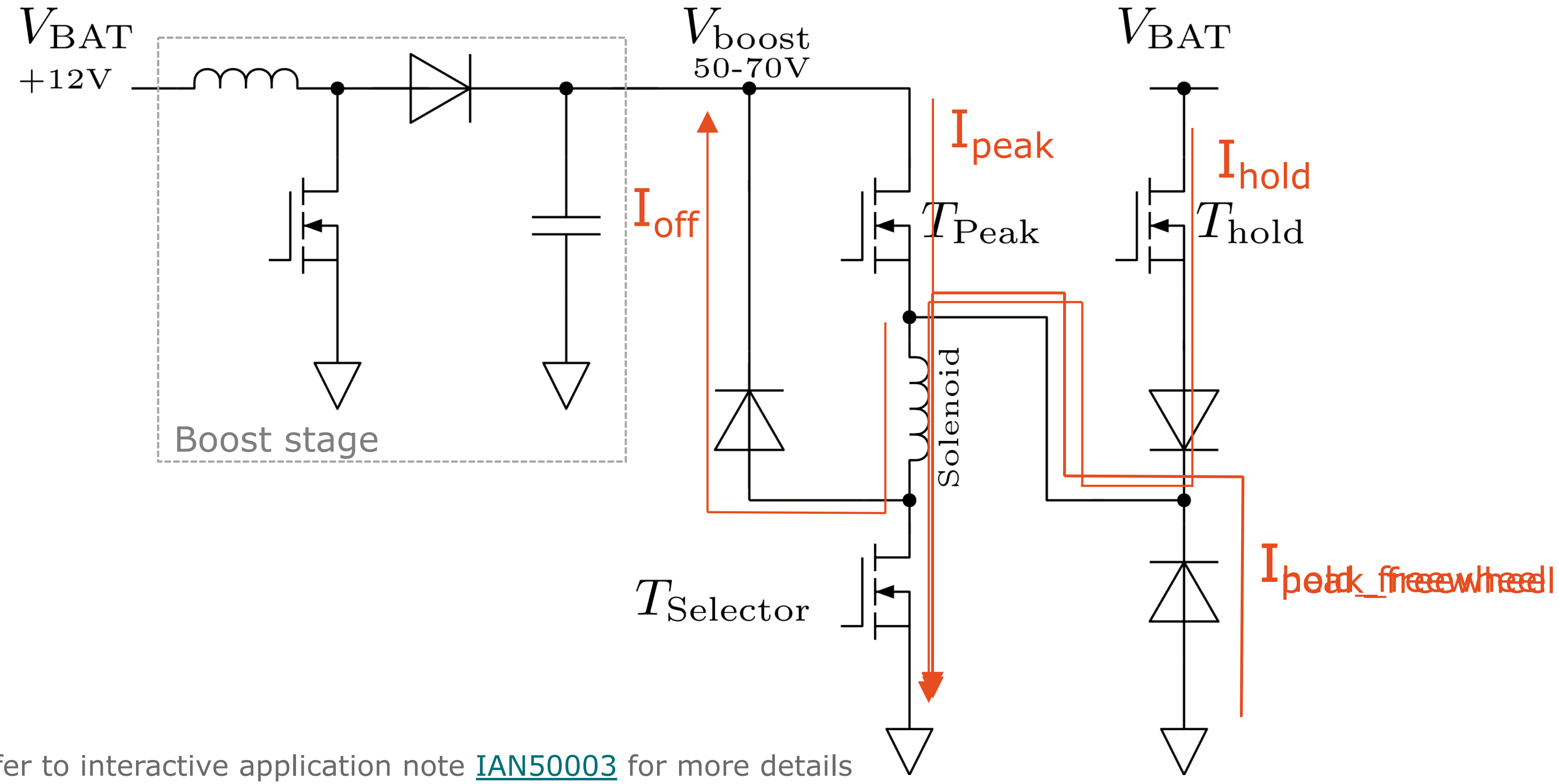
Agenda:

- Diodes in solenoid drivers
- Diodes in LED drivers

Diodes in solenoid drivers

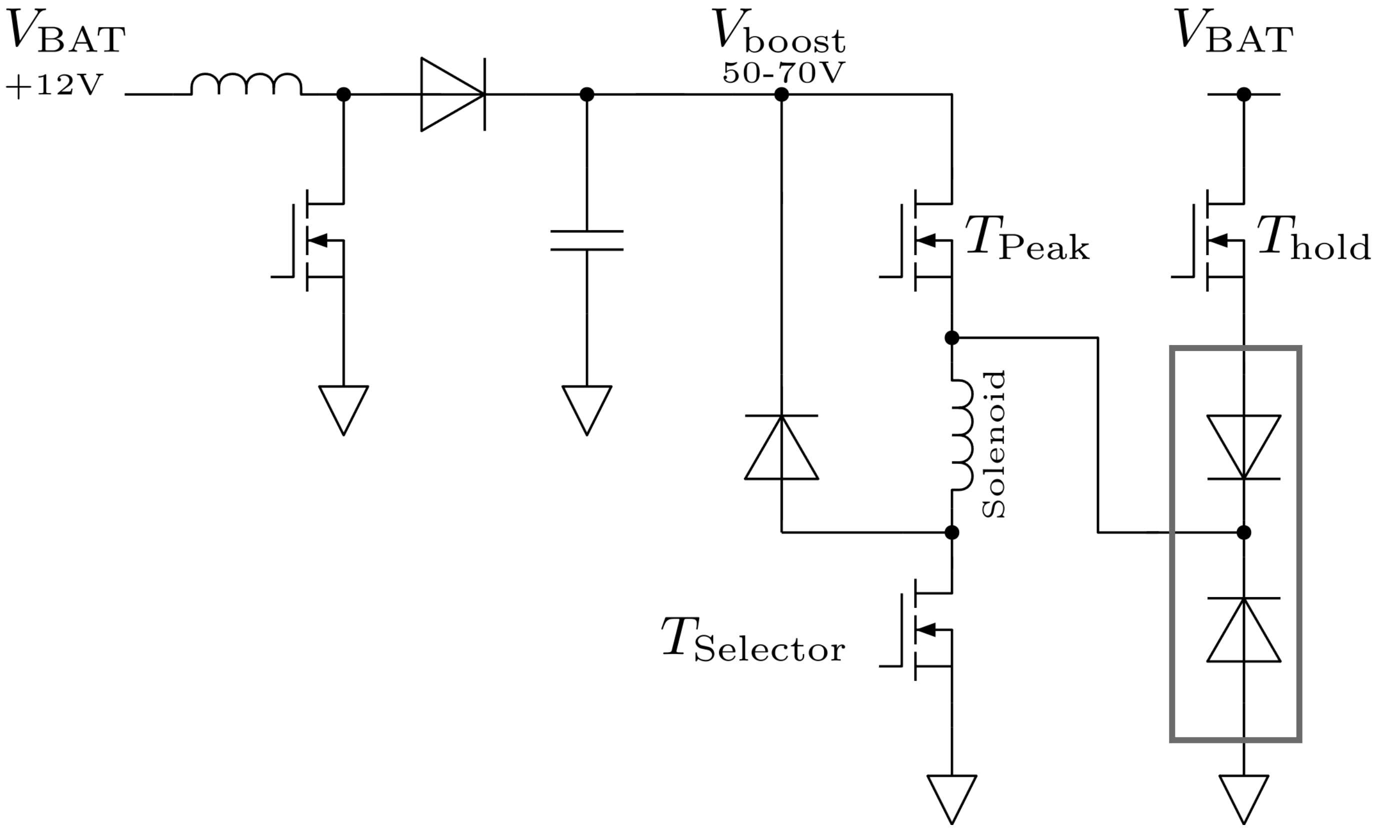
Solenoid driver

With boost converter in a fuel injection system



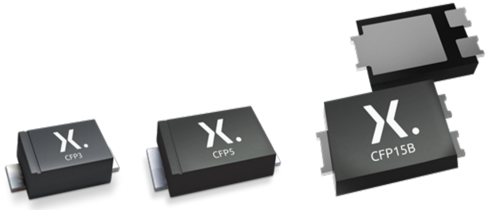
Please refer to interactive application note IAN50003 for more details

What are the requirements for the diodes?



- Dual die configuration
- Low V_f for low power dissipation (Peak currents ~ 3-10 A)
- Very low leakage at high ambient temperature (≪ 500 uA at 130 °C)
- At least 100 V blocking voltage
- Switching losses not dominating
- High IFSM robustness
- Wide SOA
- High reliability

Recovery Rectifiers | Product Portfolio

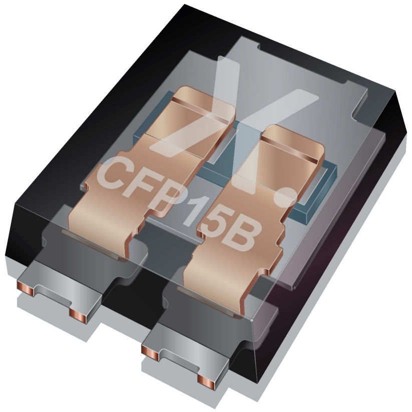


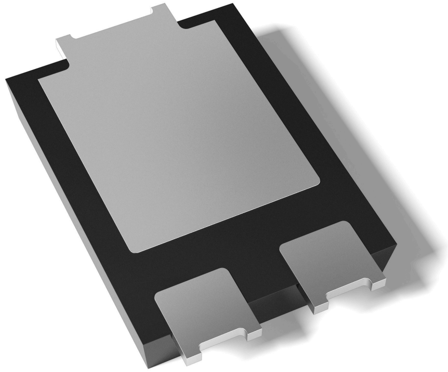
Nexperia’s has a complete 200V portfolio and building the 650V portfolio

Type	Package	V_R max [V]	$I_{f\,(AV)}$ max [A]	V_f max @ $I_{F(AV)}$ [mV]	I_R max [µA]	t_{rr} typ [ns]	Configu-ration	$T_{j\,(max)}$ [°C]	AEC-Q101
PNE20010ER	CFP3	200	1	930	0.2	10	single	175	✓
PNE20020ER	CFP3	200	2	980	0.2	10	single	175	✓
PNE20020EP	CFP5	200	2	950	1	10	single	175	✓
PNE20030EP	CFP5	200	3	980	1	13	single	175	✓
PNE20040CPE	CFP15B	200	2 x 2	960	1	13	dual, cc	175	✓
PNE20060CPE	CFP15B	200	2 x 3	940	1	13	dual, cc	175	✓
PNE20080CPE	CFP15B	200	2 x 4	930	1	12	dual, cc	175	✓
PNE200100CPE	CFP15B	200	2 x 5	950	1	12	dual, cc	175	✓
PNU650V10ER	CFP3	650	1	1250	5	35	single	175	✓
PNU650V10EP	CFP5	650	1	1250	5	35	Single	175	✓

Recovery Rectifiers in CFP15B package

Highly reliable clip bonded Flatpower package CFP15B





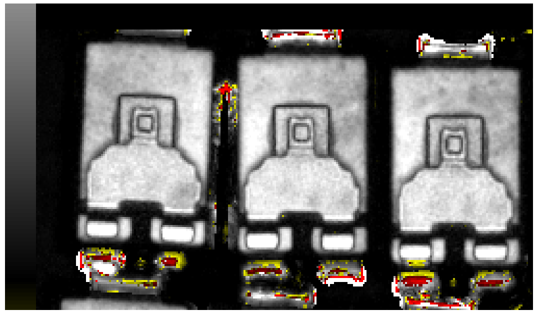
- Solid copper clip:
  - low parasitic inductance
  - high surge robustness (IFSM)
- Exposed heat sink for best thermal performance
- Single and dual die configuration
- 60% space saving on PCB compared to DPAK
- Tin-plated lead ends optimized for AOI

Reliability beyond AEC-Q101

- Extended reliability testing – 2 times AEC-Q101 qualified
- Zero delamination
- Board level reliability tested:
  - bending test
  - vibration test
  - power temperature cycling
  - drop test

12mm bending

Zero delam after MSL



*MSL: Moisture Sensitivity Level Testing

Recovery Rectifiers | Product Portfolio

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PNE20010ER	CFP3	200	1	930	0.2	10	single	175	✓
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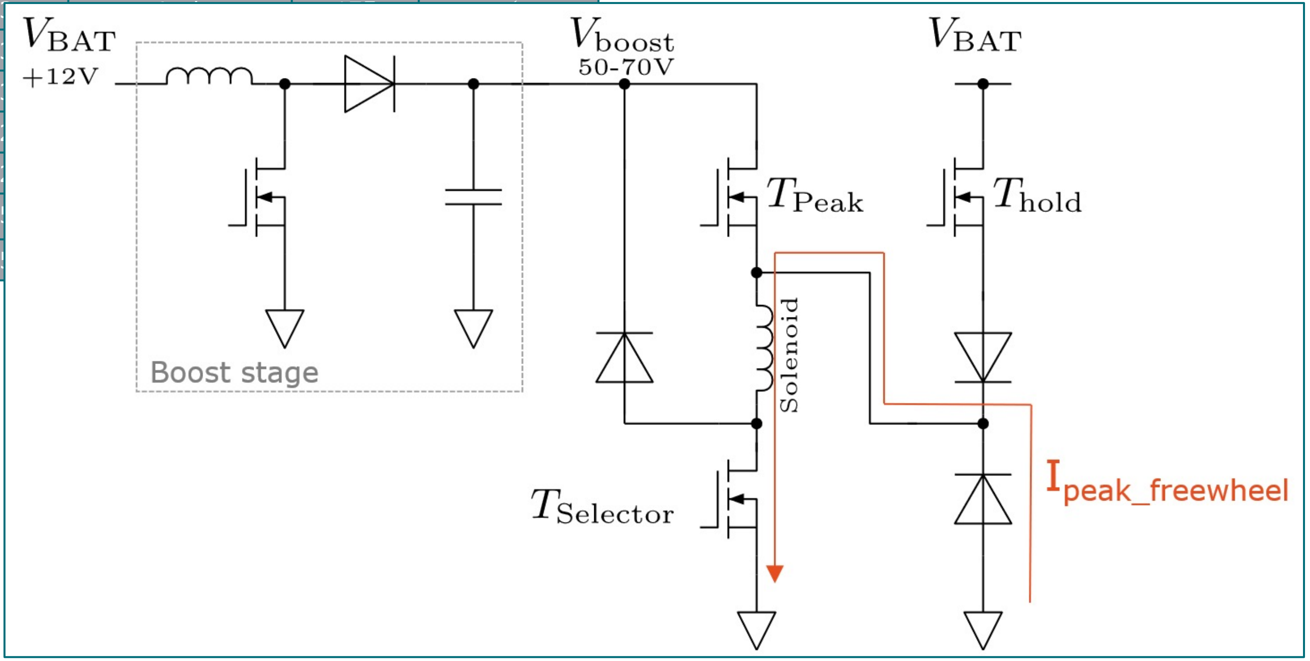
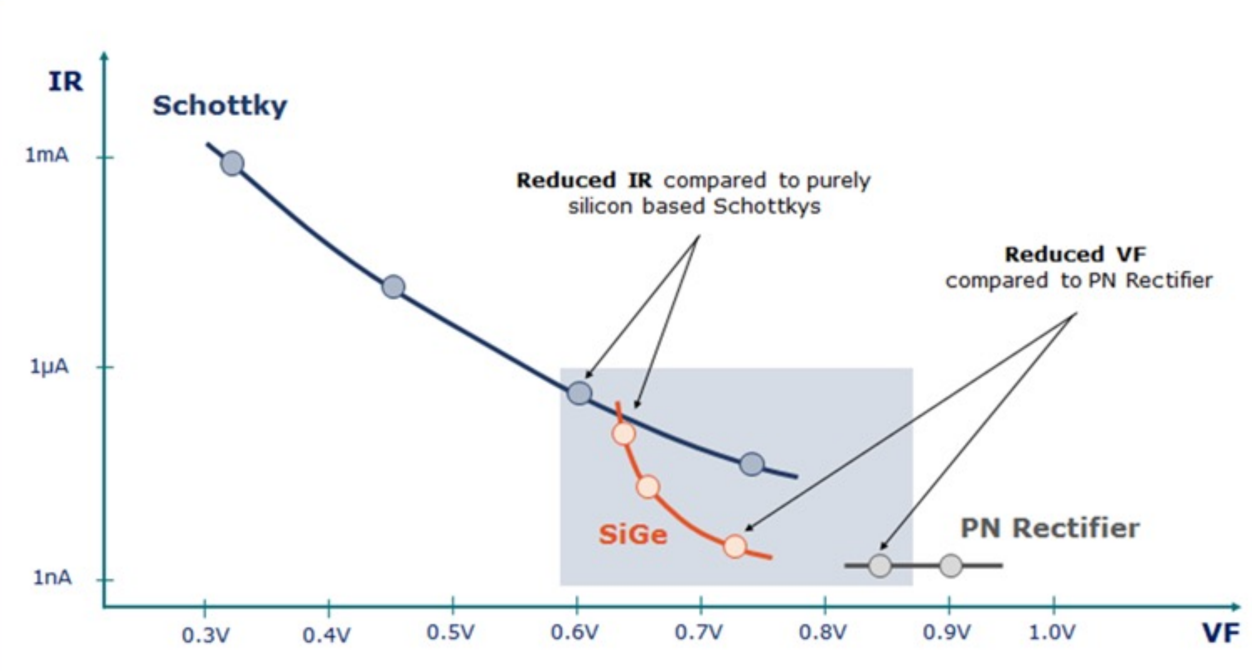
PNE20020EP	CFP5	200	2	950	1	10	single	175	✓
PNE20030EP	CFP5	200	3	980	1	[illegible]	[illegible]	[illegible]	[illegible]
PNE20040CPE	CFP15B	200	2 x 2	960	1	[illegible]	[illegible]	[illegible]	[illegible]
PNE20060CPE	CFP15B	200	2 x 3	940	1	[illegible]	[illegible]	[illegible]	[illegible]
PNE20080CPE	CFP15B	200	2 x 4	930	1	[illegible]	[illegible]	[illegible]	[illegible]
PNE200100CPE	CFP15B	200	2 x 5	950	1	[illegible]	[illegible]	[illegible]	[illegible]
PNU650V10ER	CFP3	650	1	1250	5	[illegible]	[illegible]	[illegible]	[illegible]
PNU650V10EP	CFP5	650	1	1250	5	[illegible]	[illegible]	[illegible]	[illegible]

How to improve Vf without sacrificing advantages of recovery rectifiers (low leakage, thermal stability)?

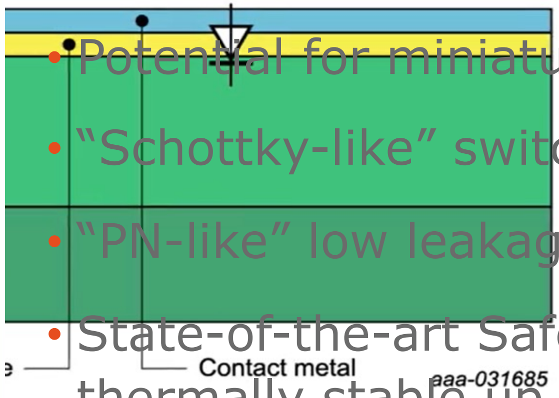


SiGe Rectifiers | An Innovative Technology

Silicon germanium (SiGe) – a technology with unique value propositions



- Excellent I_r/V_f trade-off – reducing conduction losses



- Potential for miniaturization
- “Schottky-like” switching
- “PN-like” low leakage current
- State-of-the-art Safe Operation Area – thermally stable up to almost T_A = 175 °C
- 2x AEC-Q101 qualified portfolio

SOA – SiGe technology

Life comparison to same class Schottky rectifier

Experiment set up:

- Schottky and SiGe diode (120 V) in reverse bias
- Chuck temperature is increased, and the leakage currents are monitored

Result:

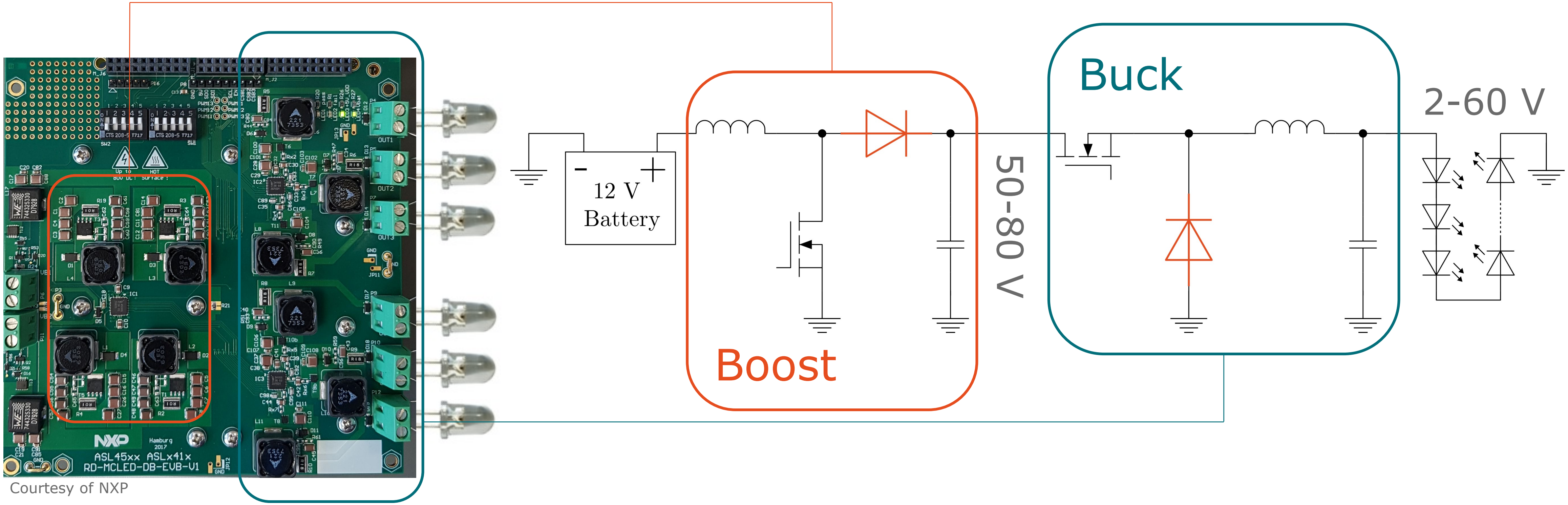
- SiGe diode offering an extremely wide SOA
- SiGe diodes leakage current orders of magnitude less than Schottky counterpart

Diodes in LED drivers

Asynchronous LED drivers

Switched-mode converter

For instance, asynchronous boost / buck stage of a LED driver



Courtesy of NXP

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Switched-mode converter

Requirements concerning the rectifiers in the boost and buck stage

- **Low reverse recovery charge Q_{rr} :** for every switching cycle the reverse recovery charge Q_{rr} is dissipated in the MOSFET, a major contribution to the switching losses of the converter
- **High thermal stability:** in high power density applications, rectifiers with a broad Safe operating area (SOA) are needed. Thermal runaway of the rectifier must not happen
- **Low electromagnetic emission:** the rectifier is supposed to have minimal impact on the conducted and radiated electromagnetic emission levels of the converter
- **Low forward voltage-drop:** voltage forward drop of the rectifier impacting the conduction losses – though not dominating the overall efficiency

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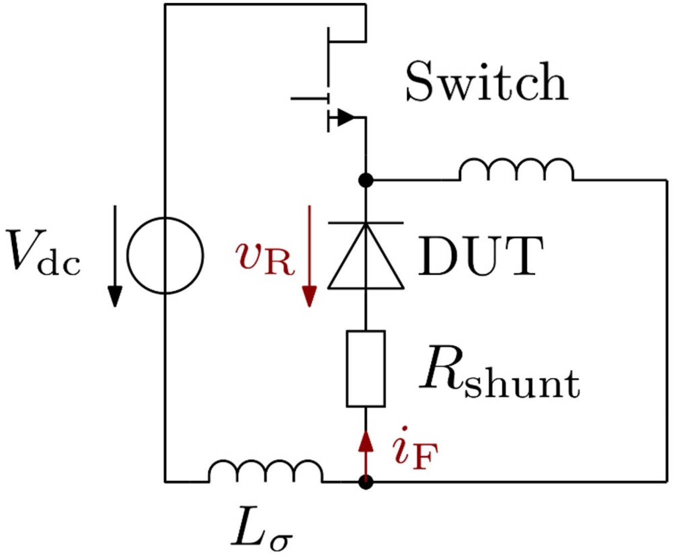
Double pulse test circuit

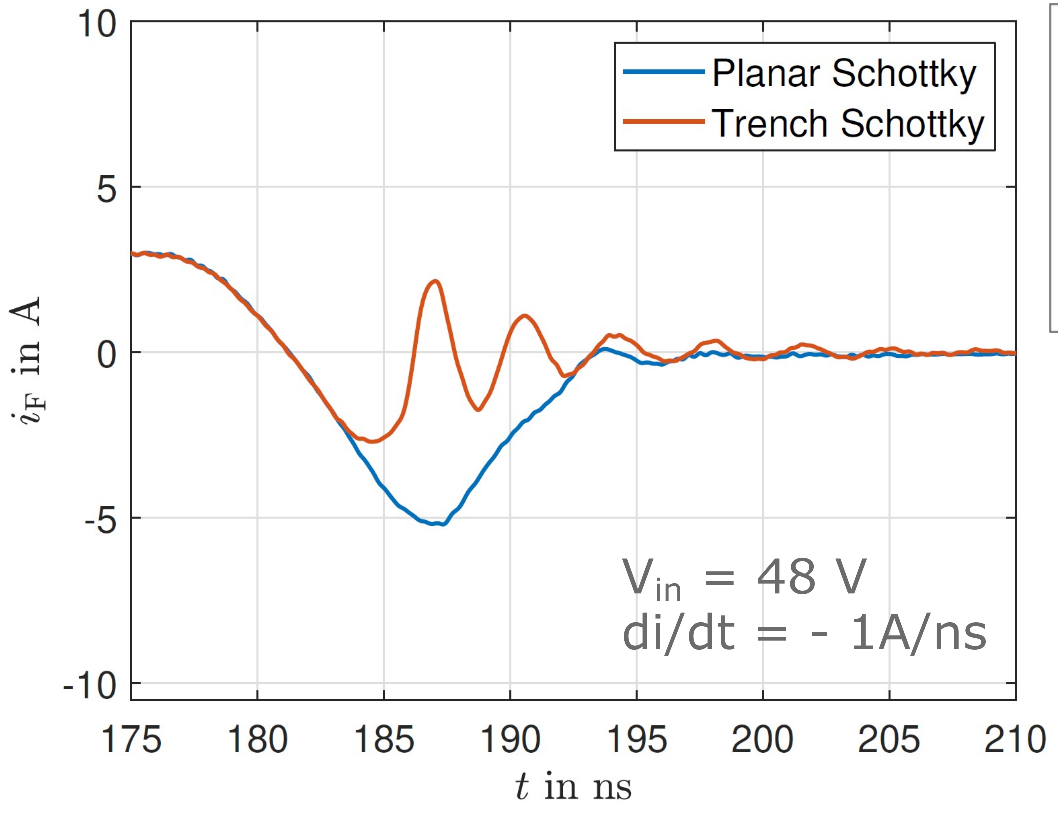
Standard method for measuring the switching performance

- Collaboration with Helmut-Schmidt-University in Hamburg
- A double pulse test characterizes all switching phases of the DUT:
  - First pulse characterizes the turn-on behavior
  - Second pulse characterizes the turn-off behavior
- High di/dt (-1A/ns) – V_{DC}=48 V
- DUT at defined temperature
- Optimized design to keep Ls minimal (~5 nH)



Superior switching performance with Trench Schottky

Double pulse measurements at T_{amb} = 85°



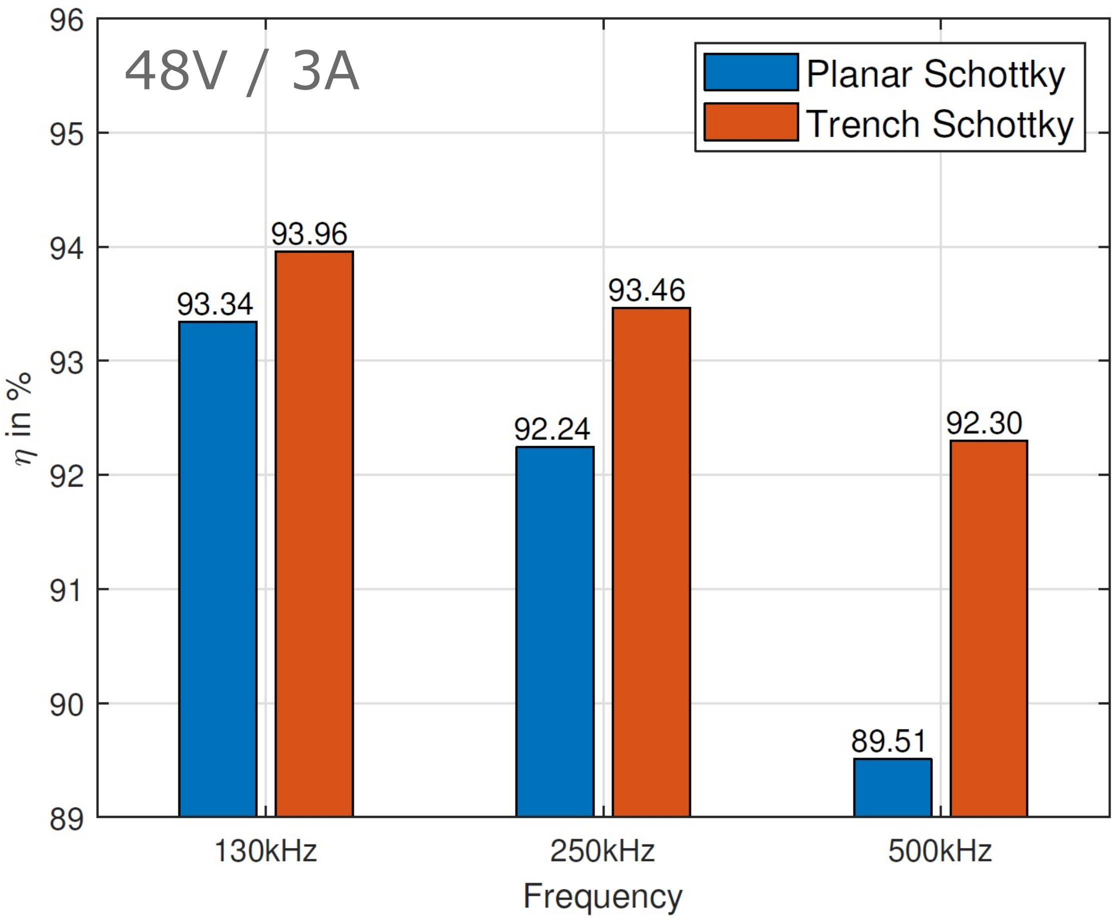
	$Q_{rr}^{T_c=25°C}$ [nC]	$Q_{rr}^{T_c=85°C}$ [nC]	$I_{rrm}^{T_c=25°C}$ [A]	$I_{rrm}^{T_c=85°C}$ [A]
Trench Schottky	8.6	8.5	2.8	2.7
SiGe	19.1	25.5	4.4	4.9
Recovery A	37.3	52.1	7.1	8.1
Planar Schottky	26.3	33.5	5.2	5.2
Recovery B	33.5	44.4	8.2	8.9

Trench Schottky Vs. planar Schottky:

- Less stored charge Q_{rr} of Trench rectifier compared to planar Schottky rectifier
- No increase of Q_{rr} of Trench rectifier over temperature (25 °C → 85 °C)

Low Q_{rr} – high converter efficiency with Trench

48 V-12 V buck converter as test vehicle – 3 A rectifiers in SOD128



- Higher converter efficiency achieved with Trench rectifier compared to planar Schottky
- The higher the frequency, the higher switching losses, the bigger the Trench advantage

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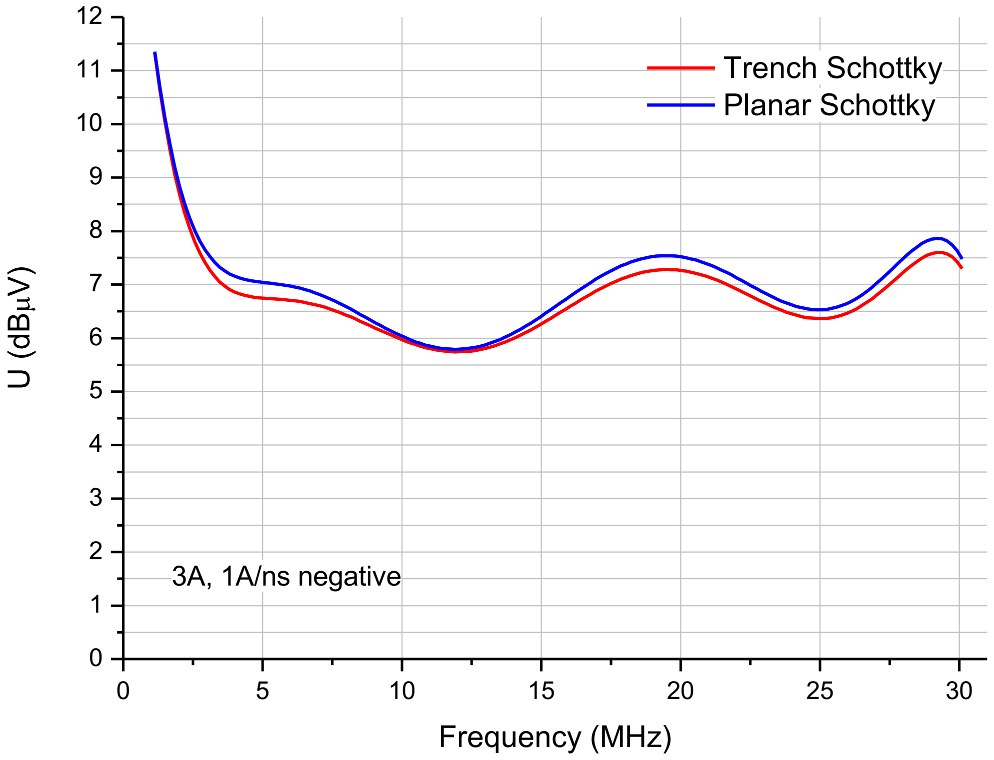
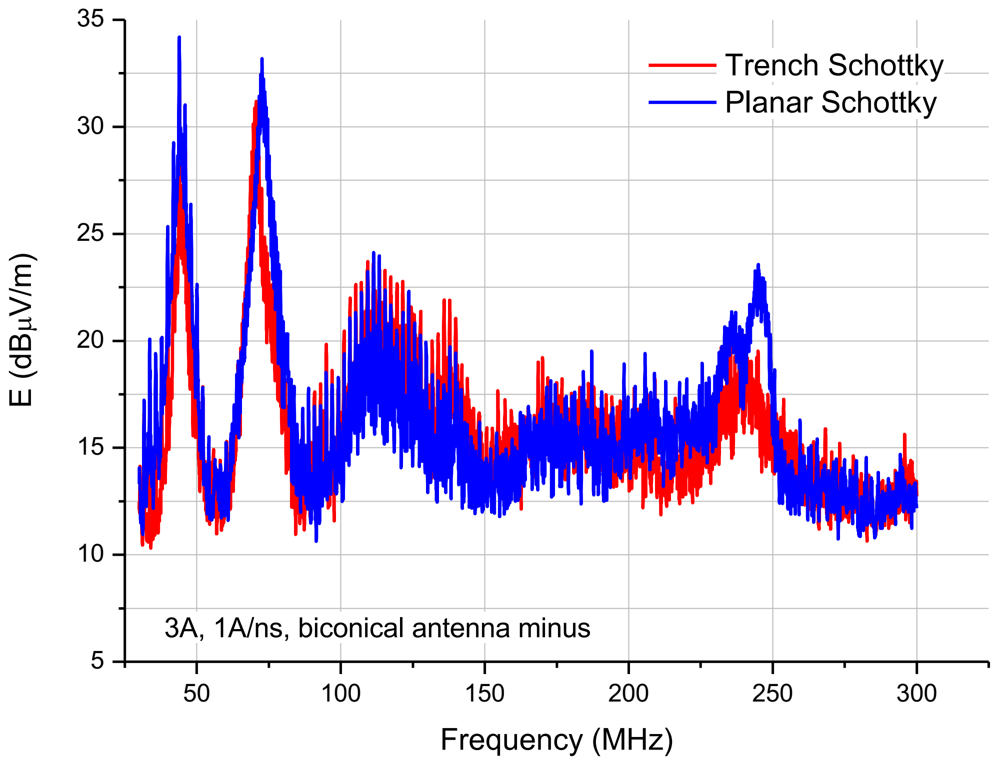
Impact on electromagnetic emission

48 V-12 V buck converter as test vehicle – 3 A rectifiers in SOD128

Conducted emission



Radiated emission



No increased electromagnetic emission levels despite observed ringing of Trench rectifier during switching

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Conclusion

- Solenoid driver:
  - Go with 200V hyper fast recovery rectifier
  - Use dual die configuration in CFP15B package for state-of-the-art reliability
  - If you want to optimize further by reducing Vf, take a look at the SiGe technology

- LED driver:
  - The best choice for highest efficiency is the Trench Schottky
  - Keep in mind Nexperia Trench Schottkys products deliver extra efficiency and thermal safety margin

How to receive more information

- Interactive application note on driving solenoids: Search IAN50003 on www.nexperia.com
- Find the suitable Trench Schottky rectifier: www.nexperia.com/trench-schottky-rectifiers
- Find out more about SiGe rectifiers: www.nexperia.com/sige-rectifiers
- Visit our *efficiencywins* blogs: https://efficiencywins.nexperia.com/ (filter: diodes)
- Contact us directly
- Sample boxes can be ordered from Power Live page

Please share your questions and insights

EFFICIENCY WINS.