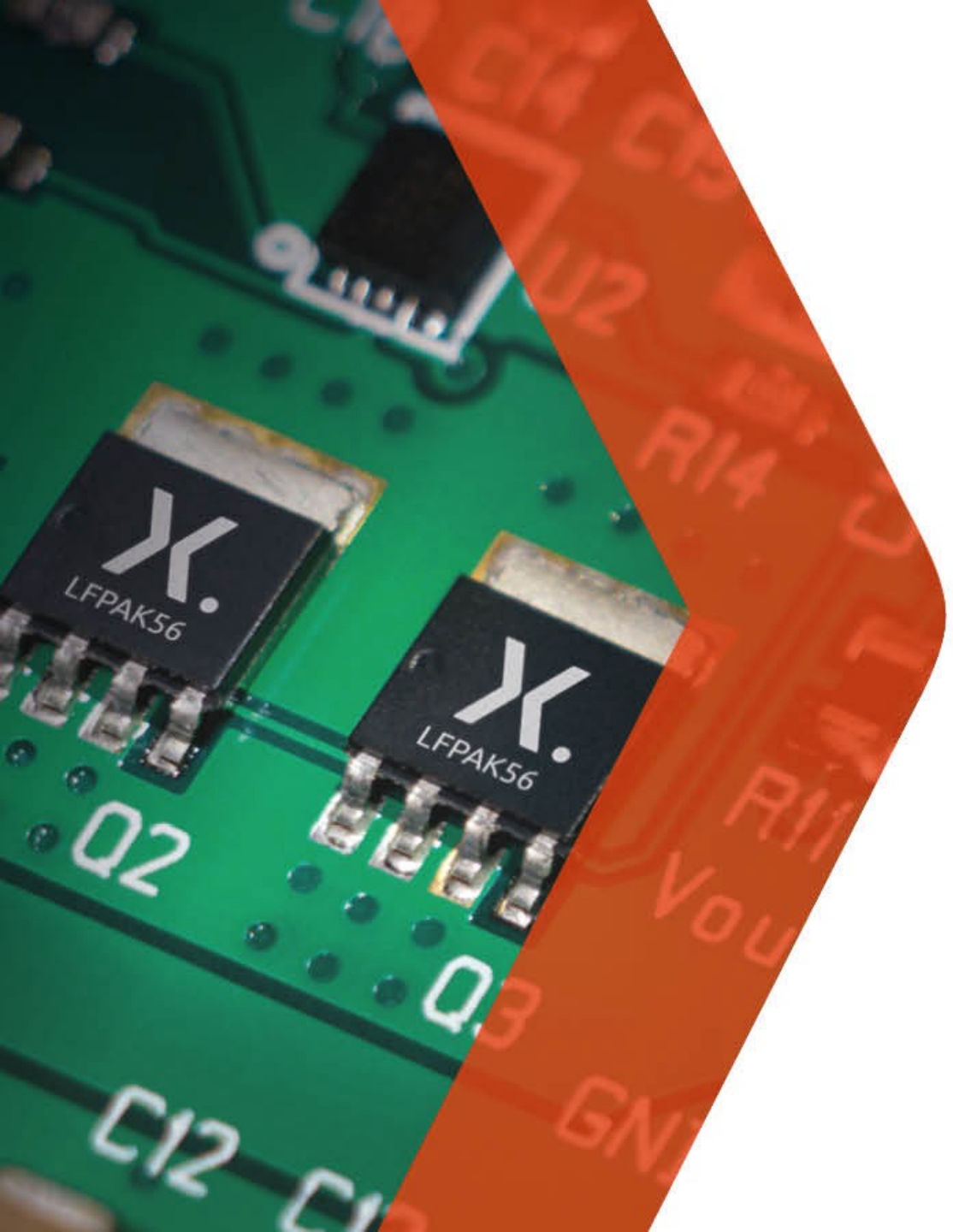

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MOSFET Body-Diode Behaviour Benefits of Low Qrr & Low VSD in switching applications

September 2021

Introduction

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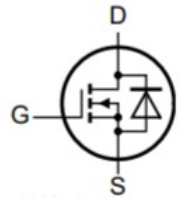
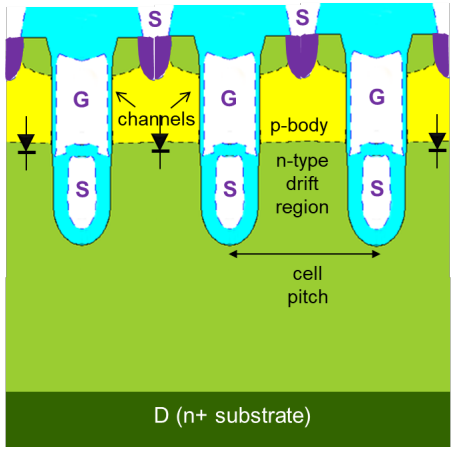
MOSFET body diode behaviour

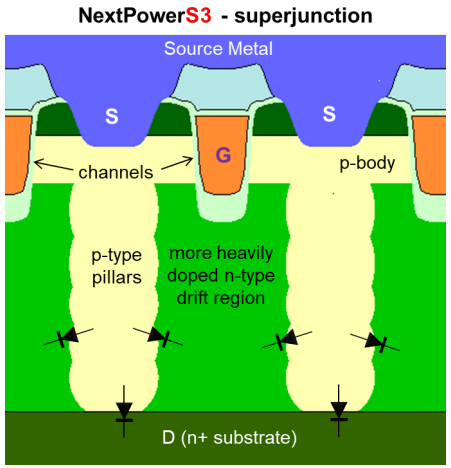
Body Diode - Introduction





A Body diode occurs in ALL MOSFETs at the junction between P-N doped silicon

- Unavoidable part of the MOSFET's structure - Essential part of mosfet behaviour
- Designers exploit the body-diode in synchronous & freewheeling applications
- Allows "inductive" load current to circulate without creating voltage spikes



Like any other diode, there are limitations & losses associated with the body diode

- V_F (or V_{SD}) is the voltage drop across the diode (MOSFET) when it is forward biased
- Q_{RR} describes the amount of stored charge, due to trapped charge carriers which accumulate around the P-N junction when the diode is forward-biased

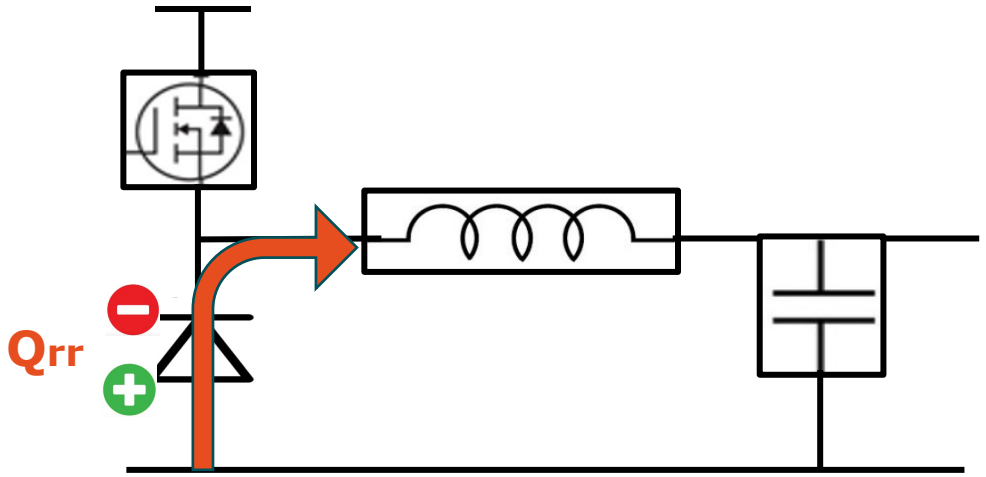
MOSFET body diode behaviour - Qrr

Example: Synchronous buck / half-bridge / full-bridge

During Dead-time - Control FET & Sync FET are turned OFF

Body diode conducts the inductive load current

Stored charge (Q_{rr}) accumulates in the body diode



MOSFET body diode behaviour - Qrr

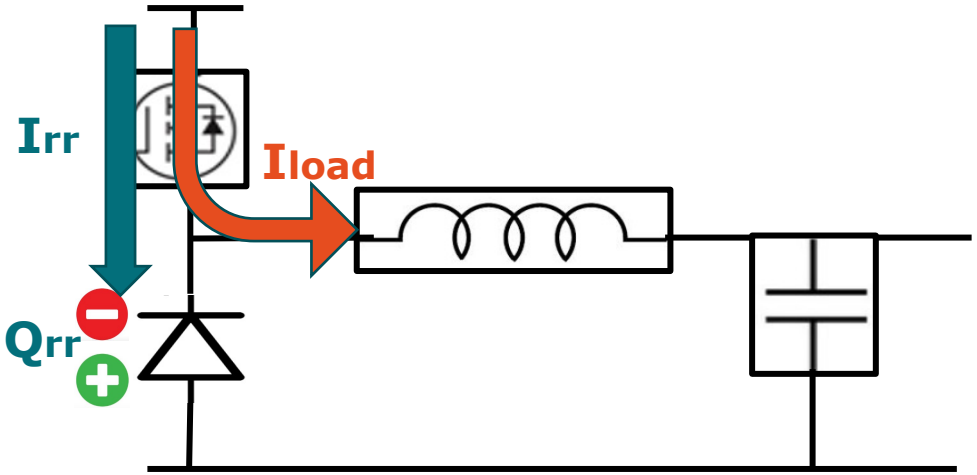
Example: Synchronous buck / half-bridge / full-bridge

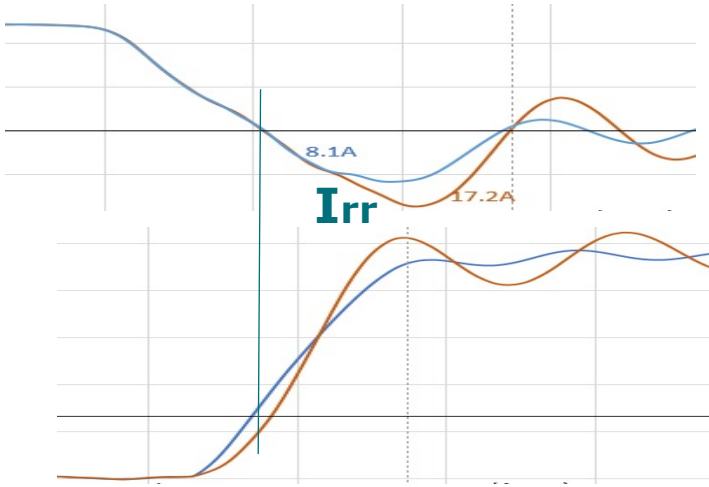
When the **Control FET turns ON**

Load current flows thru the high-side MOSFET + Spike current (I_{rr}) required to deplete stored charge (Q_{rr})

I_{rr} causes additional I^2R losses in the high-side MOSFET and other components in the application

I_{rr} interacts with parasitic inductance in PCB & MOSFET leadframe to cause voltage spike (V = L x *di/dt*)





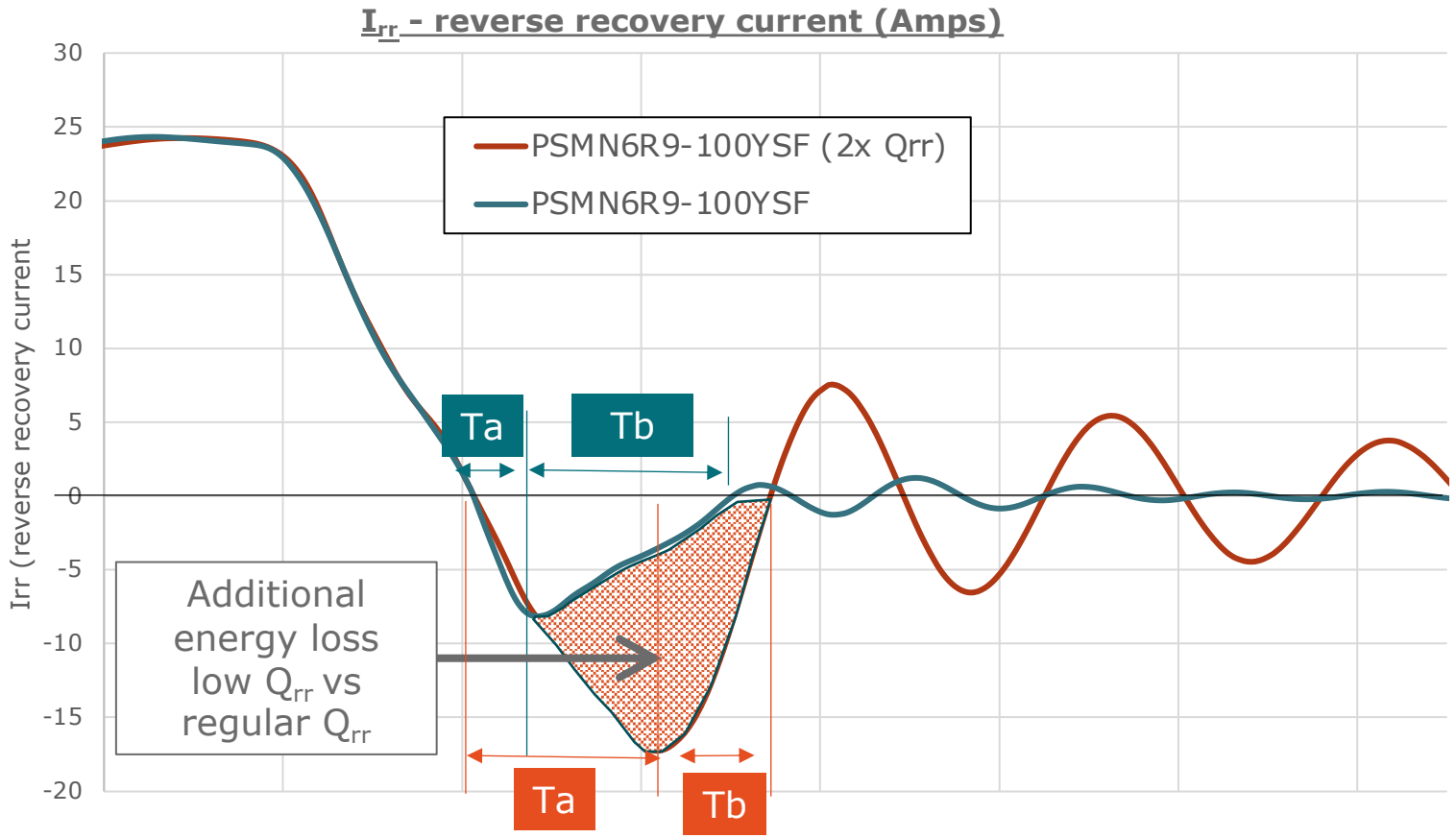
Spike voltage
V = L x *di/dt*

Low Qrr MOSFET reduces I^2R losses in the high-side MOSFET

Low Qrr MOSFET reduces the spike voltage

MOSFET body diode behaviour - Qrr

Simulating the effects of 50% lower Q_{rr}

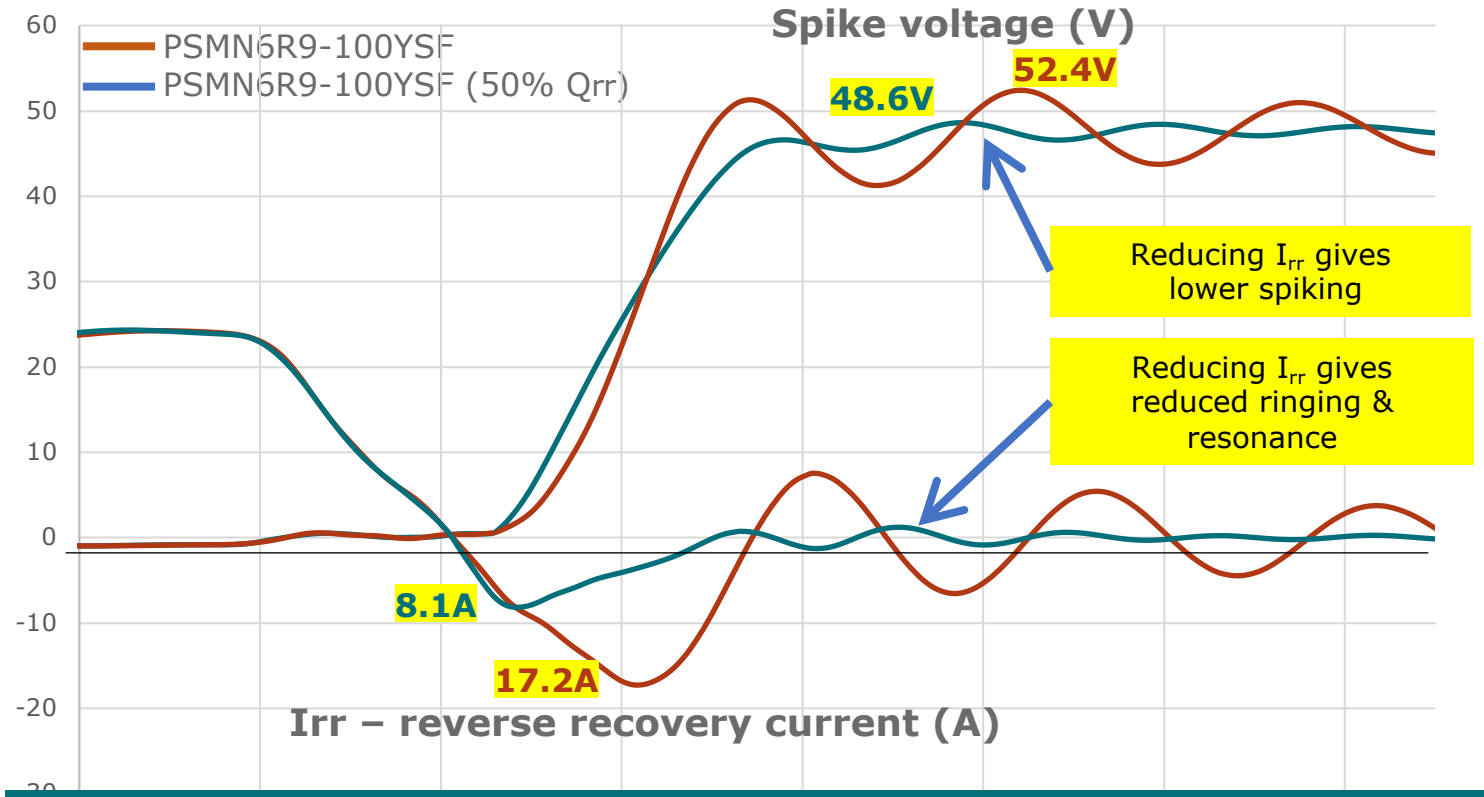


- Spice simulations show the benefits of low Q_{rr} in switching applications
- Reducing Qrr by 50% gives lower current spike & lower voltage spike
- Improved softness factor (Ta/Tb) gives reduced ringing & resonance
- Shaded area represents the additional energy loss for parts with 2x Q_{rr}
- Lower I_{rr} ringing & resonance also contributes to lower EMI emissions
- Can result in shorter dead-time in some applications

Low Q_{rr} MOSFET's + optimised damping = reduced current spiking (I_{rr})

MOSFET body diode behaviour - Qrr

Simulating the effects of 50% lower Q_{rr}



The body diode's reverse recovery current (I_{rr}) interacts with parasitic inductance in the PCB & MOSFET leadframe resulting in a voltage spike

Lower I_{rr} current also results in lower I^2R losses in other parts of the application (eg in the high-side MOSFET)

50% lower Q_{rr} results in around 8% reduced spike voltage

Qrr	Irr (Amps)	Spike Voltage (V)
100%	17.2	52.4
50%	8.1	48.6

Reducing I_{rr} delivers reduced voltage spikes

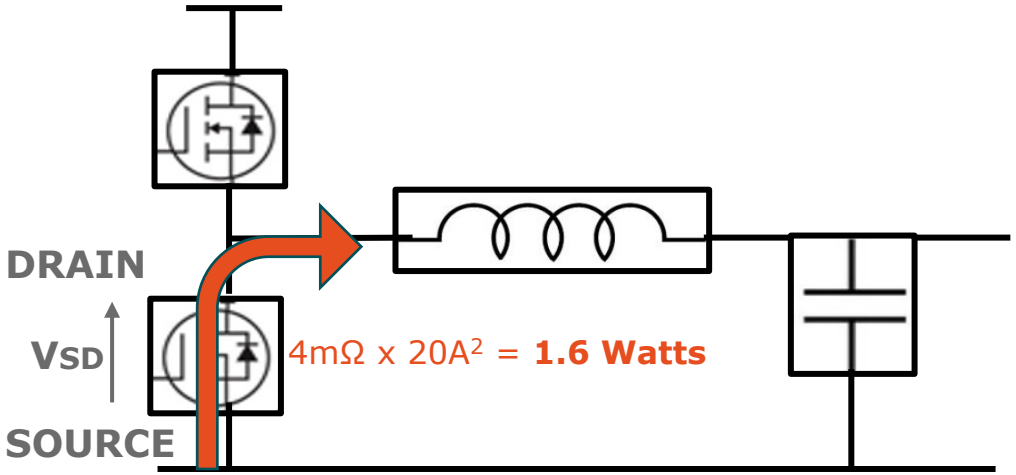
Optimised damping (*Ta/Tb*) delivers lower ringing & resonance

MOSFET body diode behaviour – VF (VSD)

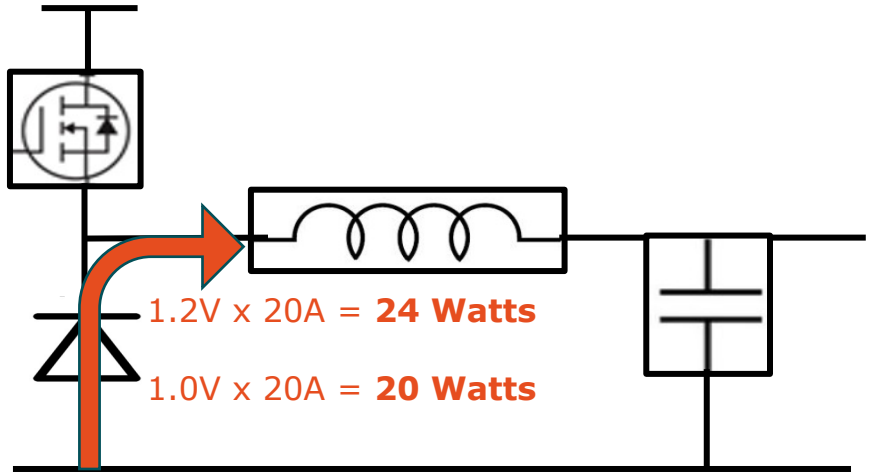
Example: Synchronous buck/ half-bridge with dead-time of 80nS

Consider an ideal mosfet with RDSon=4mΩ
conducting 20A for 80nS
I^2R losses = 20^2 x 0.004 = 1.6 Watts

MOSFET Energy loss (80nS) = 128nJ



Consider a mosfet's body diode
conducting 20A for 80nS
Power loss = Vf x I(load) = 1.2 x 20 = 24 Watts
Power loss = Vf x I(load) = 1.0 x 20 = 20 Watts
DIODE Energy loss (80nS) = 1920nJ



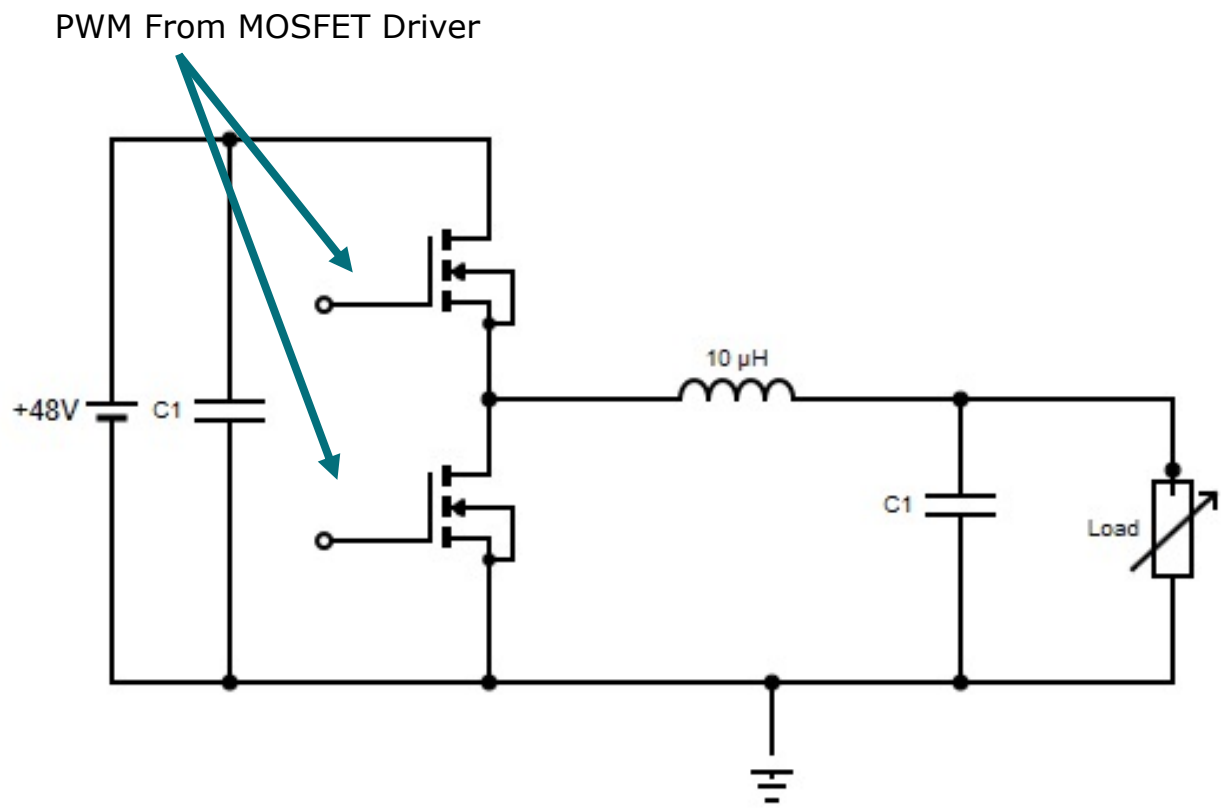
Body diode losses can be x12 ~ x15 higher than when the mosfet conducts
Reducing the diode's Vf results in significant efficiency gains (4 Watts)

NextPower 80V/100V

Benchmark testing

Topology used for evaluation

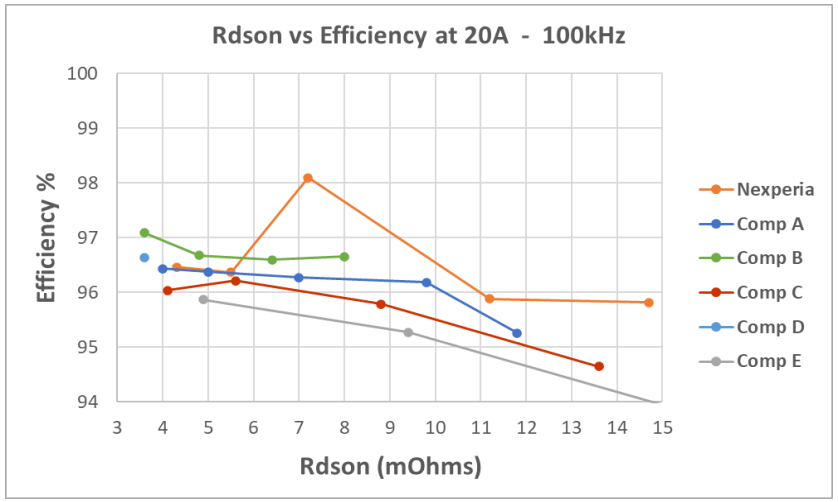
Simplistic Buck Convertor – 48V to 12V

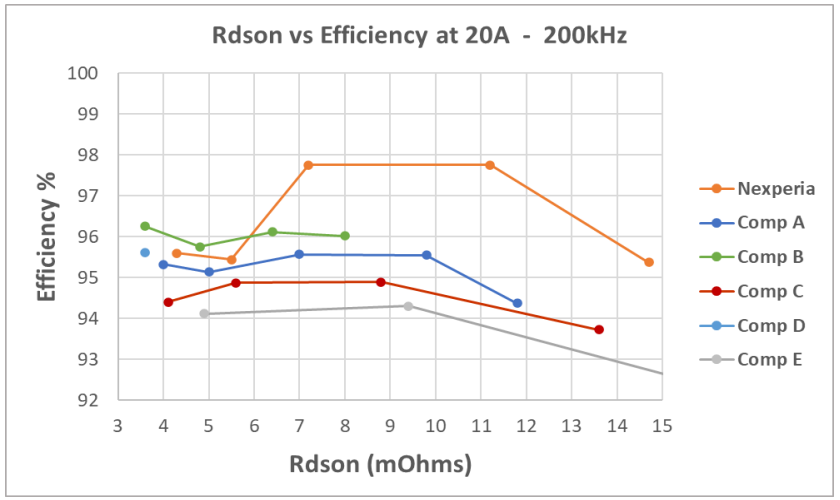


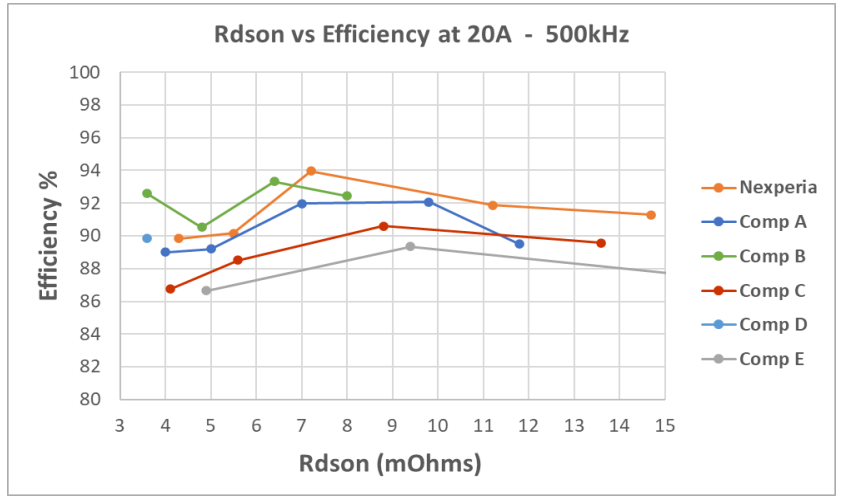
- **Simple Design – highlights MOSFET behaviour**
  - Minimal additional components or tuning to give unbiased results
  - Same MOSFET used in high-side & low-side
  - Fixed inductor (10uH)
  - Fixed gate resistor values (0 Ohms)
  - Fixed deadtime across all product groups
  - CCM mode (constant current)
  - Sweeping load current from 2-20A
- **MOSFET Performance (100KHz-500KHz)**
  - Switch-node spiking
  - Efficiency vs load current
  - Efficiency vs switching frequency

Next Power 100V - Efficiency @20A vs competitors

Nexperia vs Leading competitor types – 100V 3mOhm to 15mOhm





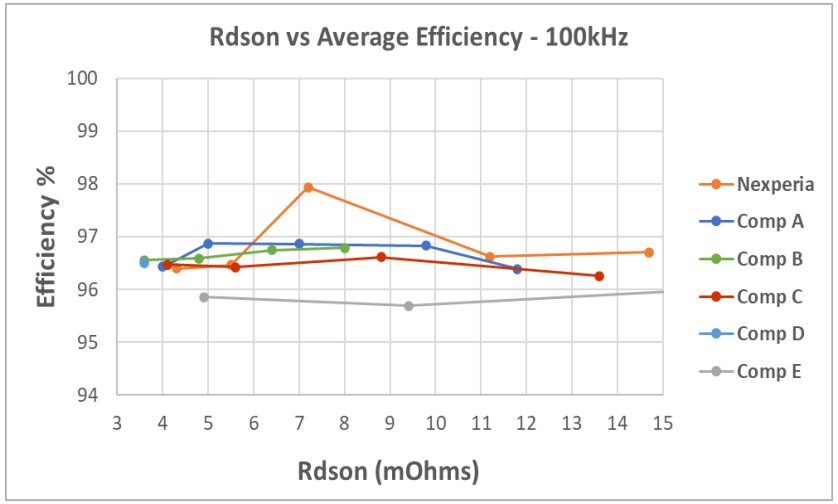


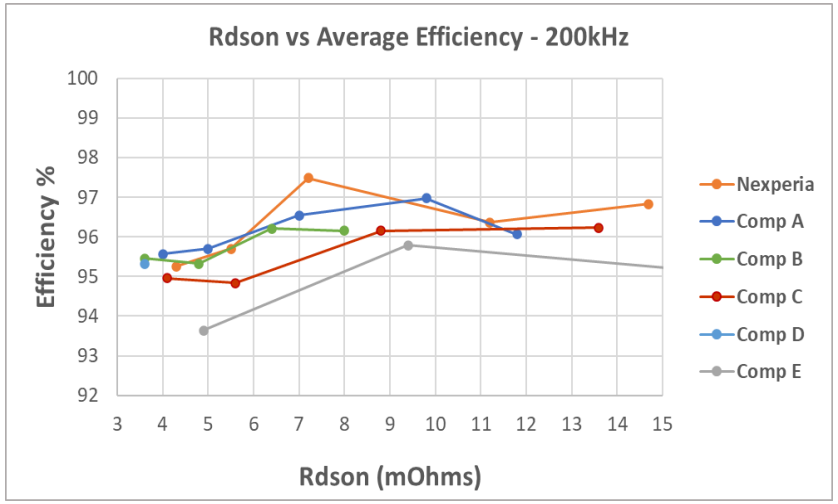
Consistently strong ‘efficiency @20A’ from 100KHz to 500KHz

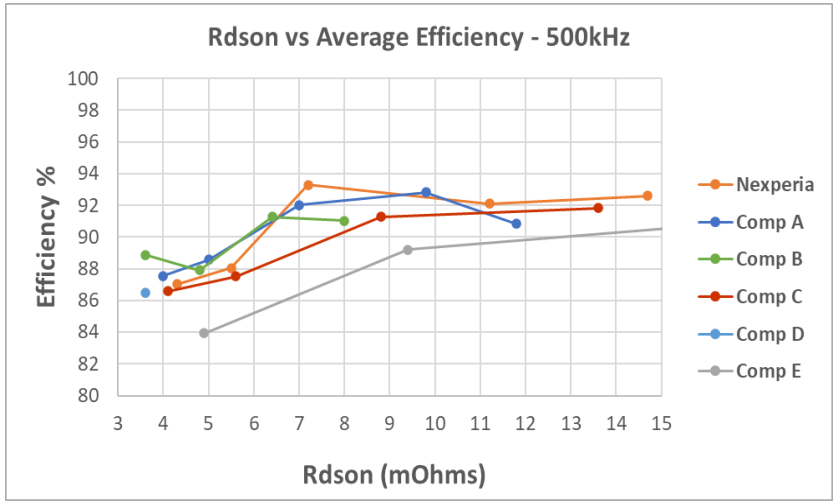
Nexperia’s 12mR~15mR are on-par with competitor 7mR~10mR

Next Power 100V - Average Efficiency vs competitors

Nexperia vs Leading competitor types – 3mOhm to 15mOhm







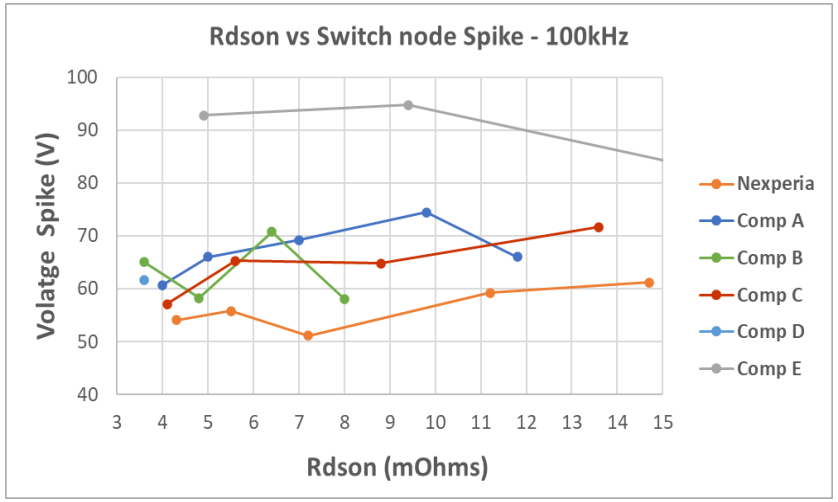
Average efficiency measured at 2A,4A,10A,20A load current

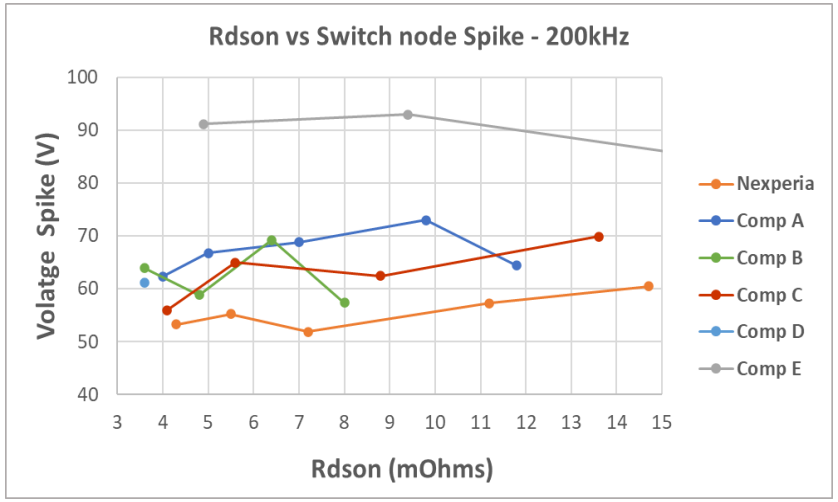
Consistently strong 'average efficiency' from 100KHz to 500KHz

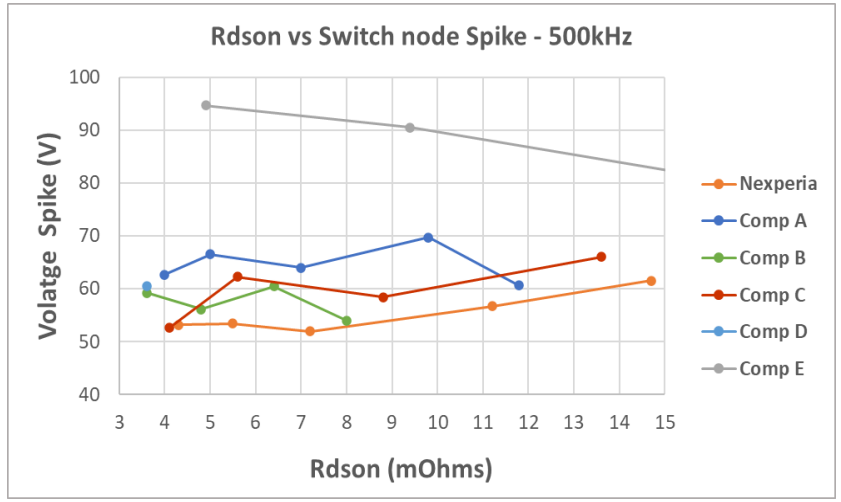
Nexperia's 12mR~15mR are on-par with competitor 7mR~10mR

Next Power 100V - Switch-node Spiking vs competitors

Nexperia vs Leading competitor types – 3mOhm to 15mOhm







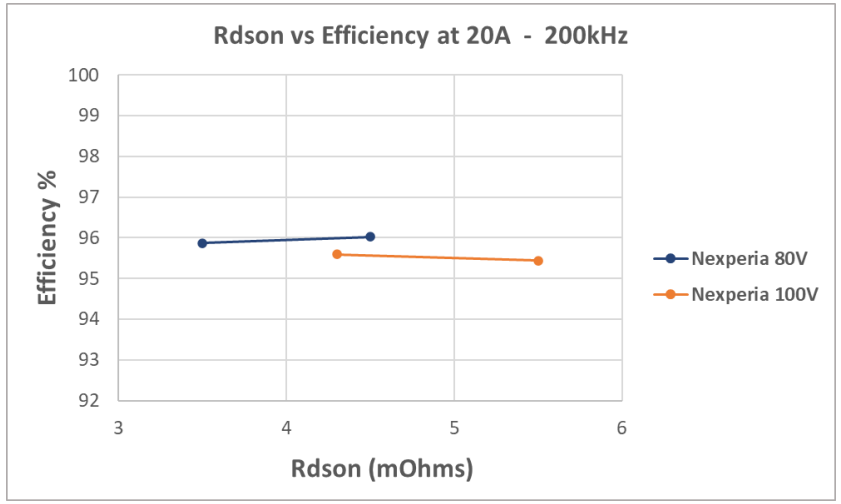
Lowest spiking across all competitors

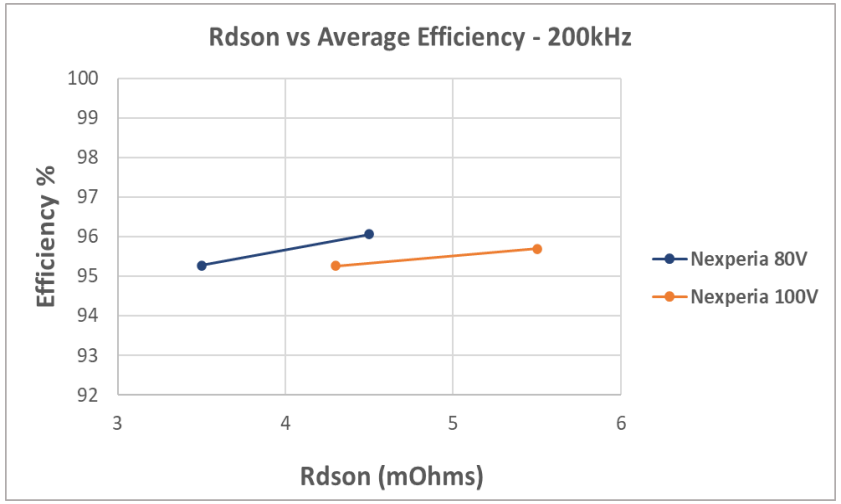
Spike voltage is not dependent on switching frequency

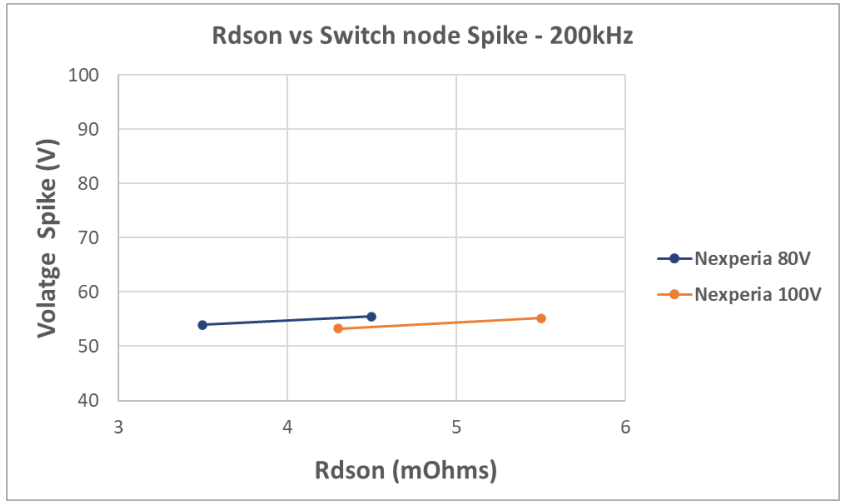
Low Q_{rr} body diode may also give reduced EMI emissions in many applications

NextPower 80V vs NextPower 100V

NextPower 80V vs NextPower 100V







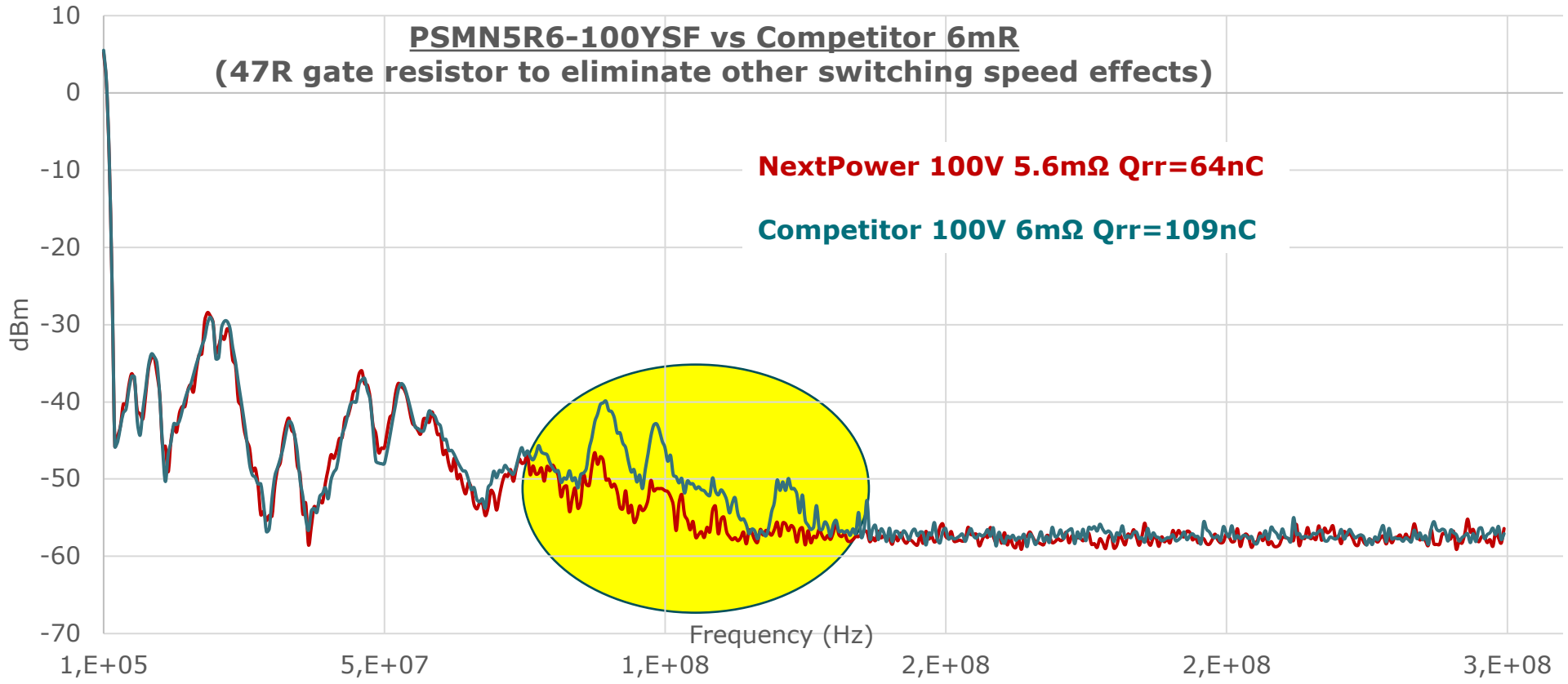
NextPower 80V – lower RDSon compared to NextPower 100V

NextPower 80V - Slight efficiency improvement especially under high load

Similar low-spiking performance as NextPower 100V

Low Q_{rr} = Lower EMI emissions

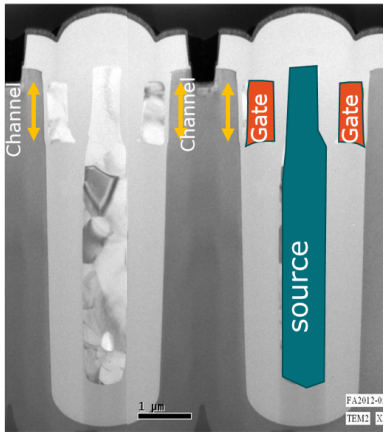
Study between high Q_{rr} (competitor) & low Q_{rr} (NextPower 100V) parts



NextPower 100V with Low Q_{rr} delivers ~10dB lower EMI emissions (80MHz ~ 150MHz)

NextPower 80V / 100V – Technology Benefits

Low Qrr & Low body-diode Vf – For high efficiency and low spiking



Features

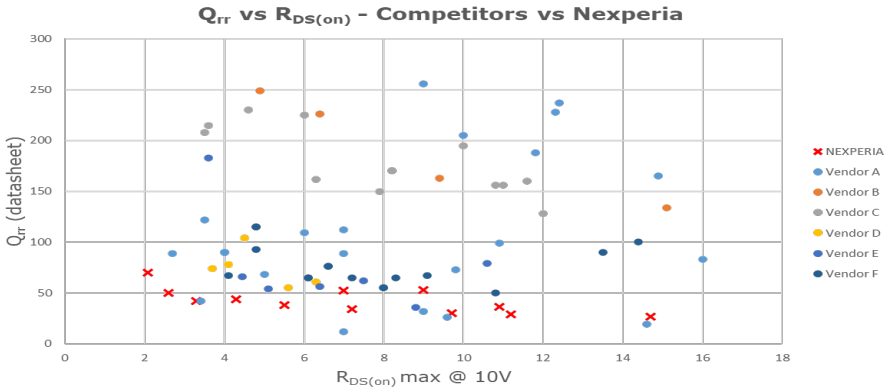
- Low $R_{DS(on)}$ – 3.5mΩ @80V & 4.3mΩ @100V in LFPAK56E
- Very low Qrr (60~70% lower than leading competitors)
- Optimised body-diode, low forward voltage - V_{SD} = 1V(max))
- Strong avalanche rating, 100% tested at I_{AS} > 50 Amps
- Optimised C_{OSS}
- T_j(max) = 175°C
- Wave-solderable LFPAK56 package

Benefits

- Low I^2R losses & high ID(max) rating
- – Efficiency gains, low-spiking & low-ringing & EMI
- Low dead-time losses in synchronous / free-wheeling application
- Rugged & reliable switching
- Low-spiking & high-efficiency
- – LFPAK types meet IPC9592 for telecom & computing applications
- – Low cost manufacturing & space-constrained PCB assembly

Suitable for a wide range of applications

- AC/DC synchronous rectifier
- DC/DC primary & secondary side switching – 48V 4G/5G telecom applications
- BLDC Motor control (e.g. Full-bridge)
- LED lighting (e.g. flyback & boost applications)



Design-in resources

Request samples for Evaluation

- Speak to your local sales representative or distributor
- Buy online from the Nexperia shop - https://www.nexperia.com/shop.html

Interactive Parametric search tool

- Choose a MOSFET by voltage, package, RDS(on)
  https://www.nexperia.com/products/mosfets/power-mosfets/#parametrics

Datasheet & Application Data available.

- Visit the Nexperia.com for more information
  https://www.nexperia.com/products/mosfets/family/NEXTPOWER-80-100V-MOSFETS/

Hints and tips and guidance on MOSFET's & GAN products.

- Request a free copy of Nexperia application Handbook in digital and hardback form
  https://efficiencywins.nexperia.com/efficient-products/mosfet-and-gan-fet-application-handbook.html

Please share your questions and insights

EFFICIENCY WINS.