Improve satellite system efficiency with superjunction rad hard FETs

Space Power Workshop 2022

IOR HiRel
An Infineon Technologies Company

Representing IR HiRel

IR HiRel
An Infineon Technologies Company

Oscar Mansilla
oscar.mansilla@infineon.com
Product Marketing Director, Space Discretes & ICs

Infineon & IR HiRel: trusted supplier for space applications

- Solution provider for memories, RF and power electronics for tough applications
- Long history of providing power management electronics to the space community
- Reputation of providing the highest quality and reliable products depends upon radiation-hardened designs and manufacturing process controls
- Users of our products can count on an excellent level of service from technical pre-sales engineering, through post-sales quality support

Satellite trends: more digital loads need power

- Increased need for on-board data processing and storage elements
  - Satellites designs are fully digital for modularity
  - Software defined radio (SDR) architectures to support multiple band frequencies
    - Capable of in-orbit reconfigurability
- Changes in the distributed voltages of the power system
  - Reduces wire size and system mass
  - Increases efficiency in the power system
  - May need different converter topologies

Satellite power architecture

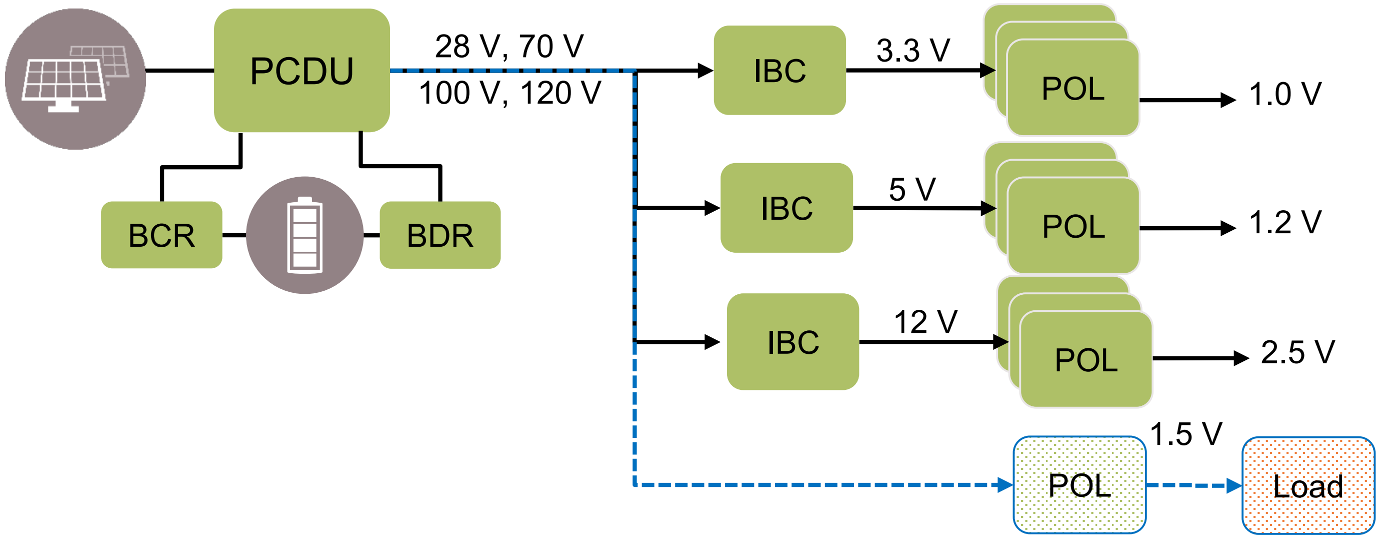
› Intermediate bus converters (IBCs) remain the backbone

› Inherently heavier

› More expensive

› Less efficient

› Require isolation



Future trend, Isolation?

PMAD example: digital processing unit with 50 W requirement

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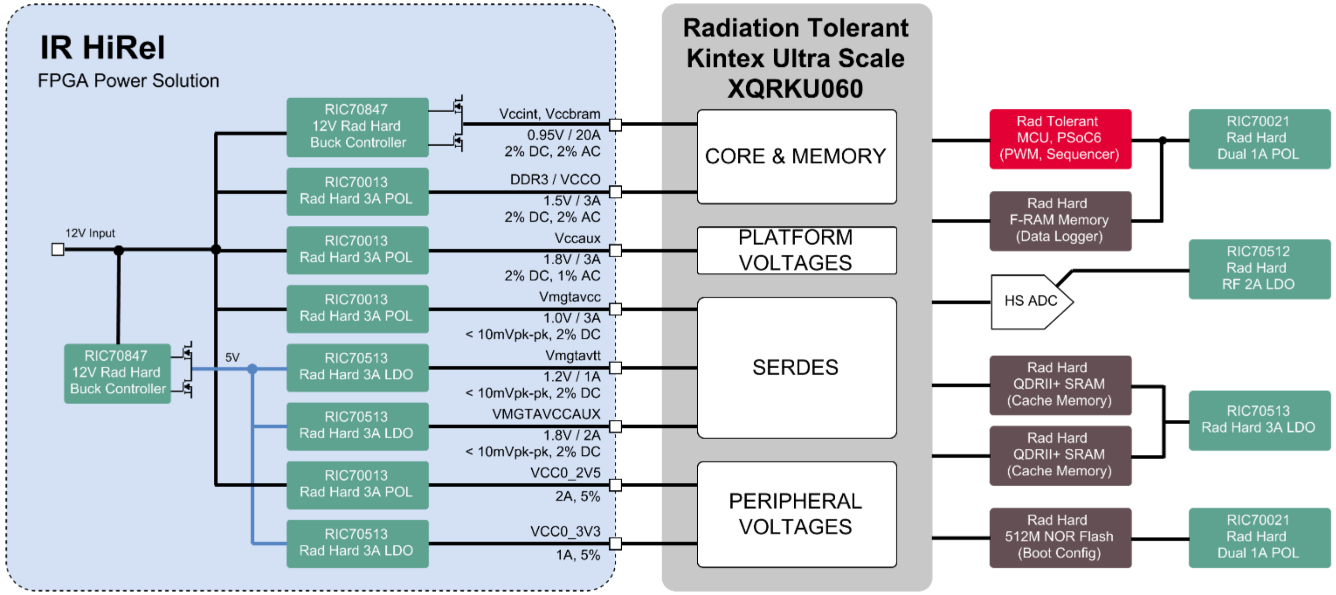
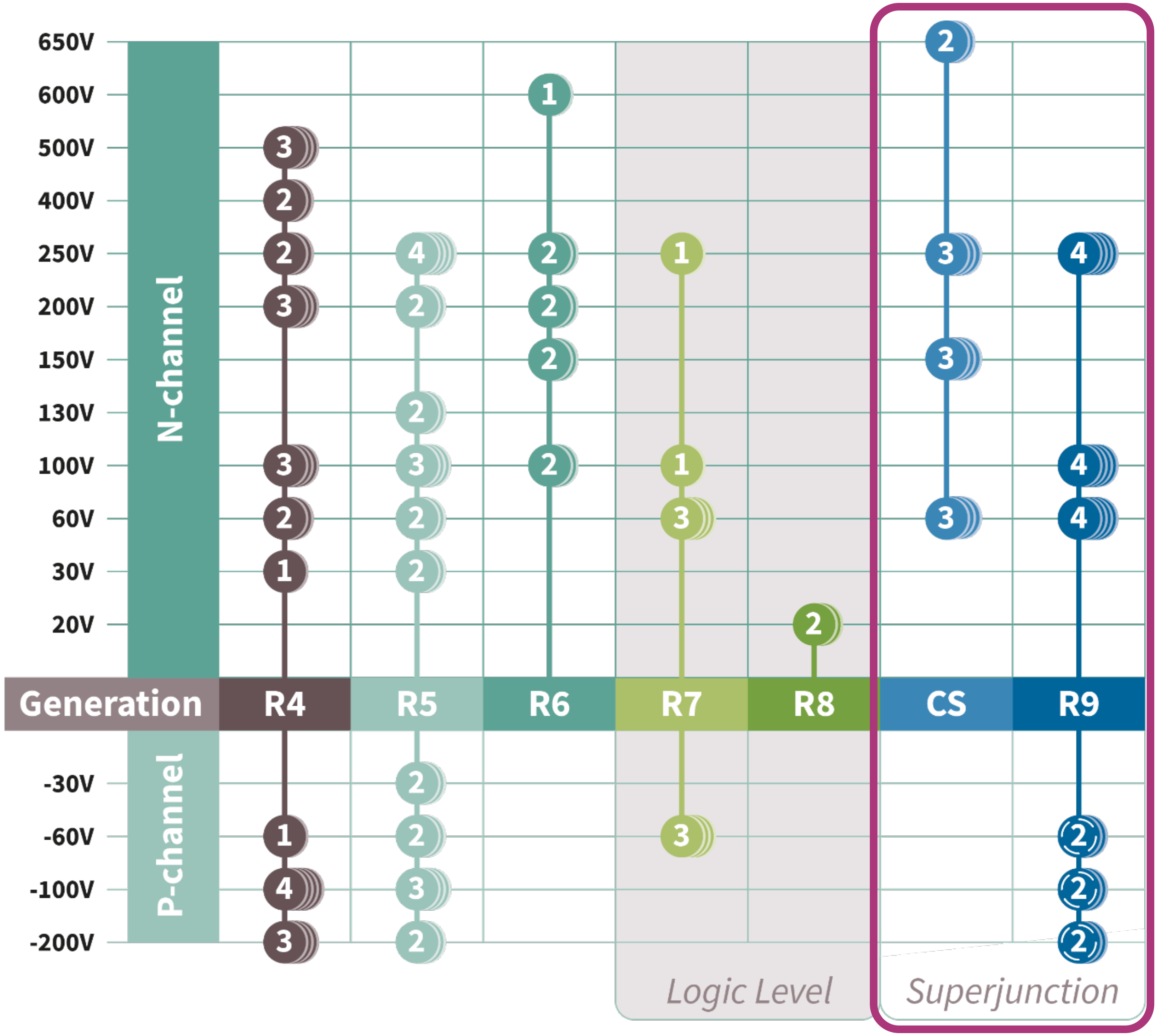
Block diagram



System power

Component	Rail	Voltage (V)	Current	Power (W)
KU060	VCCINT	0.99	30	29.70
	VCCBRAM	0.356	0.334	0.12
	VCCAUX	1.812	0.736	1.33
	VCCAUX_IO	1.813	0.44	0.80
	VCCO	1.522	0.914	1.39
	VMGTVCCAUX	1.805	0.064	0.12
	VMGTAVCC	1.01	1.509	1.52
	VMGTAVTT	1.213	0.677	0.82
	VCCADC	1.833	0.02	0.04
	VREFP	1.25	0.01	0.01
RT MCU	VDDA/VDDD	1.8	0.046	0.08
F-RAM MEMORY	VDD	3.3	0.02	0.07
HS ADC 3.2 GHz	VA/VD	2	2.4	4.80
HS ADC 3.2 GHz	VA/VD	2	2.4	4.80
CACHE MEMORY	VDD	1.8	1.275	2.30
	VDDQ	1.8	0.05	0.09
CACHE MEMORY	VDD	1.8	1.275	2.30
	VDDQ	1.8	0.05	0.09
			TOTAL POWER	**50.37**

Infineon & IR HiRel rad hard MOSFETs



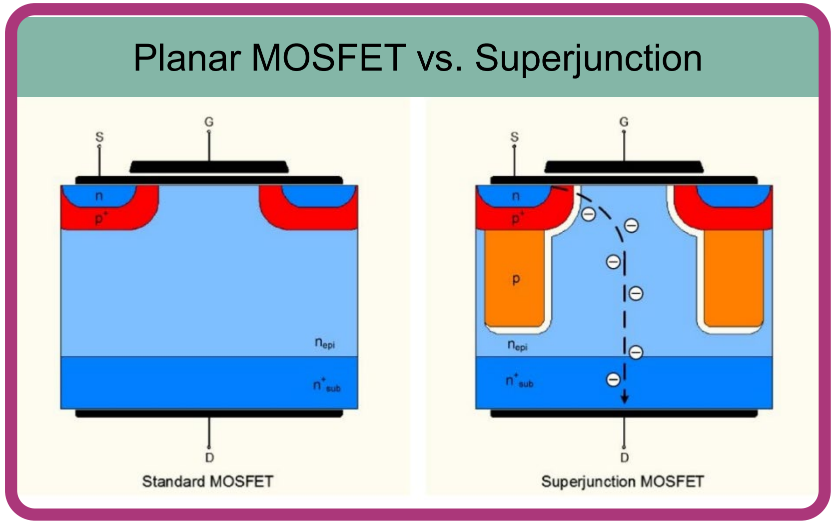
N-Channel: 20 V to 650 V
P-Channel: -30 V to -200 V

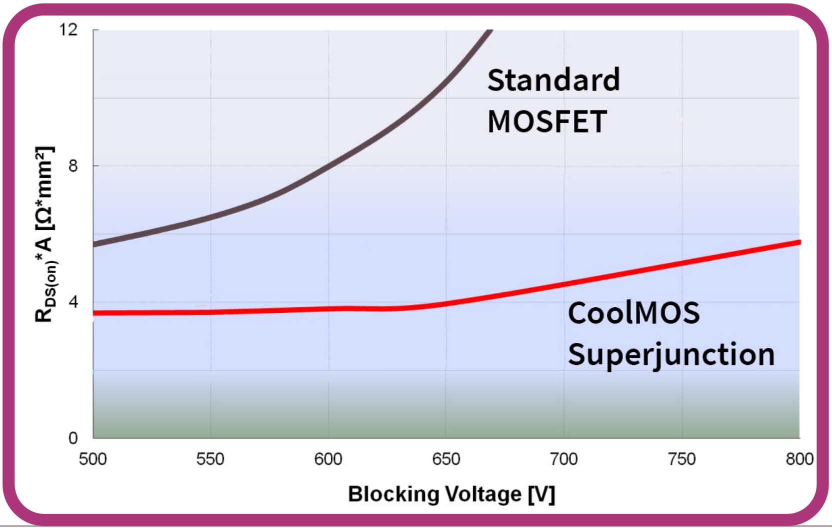
R9	Improved SWaP over prior rad hard MOSFET generations
CS	License-free, based on Infineon CoolMOS™ technology
R8	Designed for low voltage POL designs
R7	Designed for logic level gate drives
R6	Best performance for mid to high-voltage designs
R5	Optimized performance for low to mid-voltage designs
R4	All purpose MOSFET, legacy design with extensive space heritage

Die sizes available

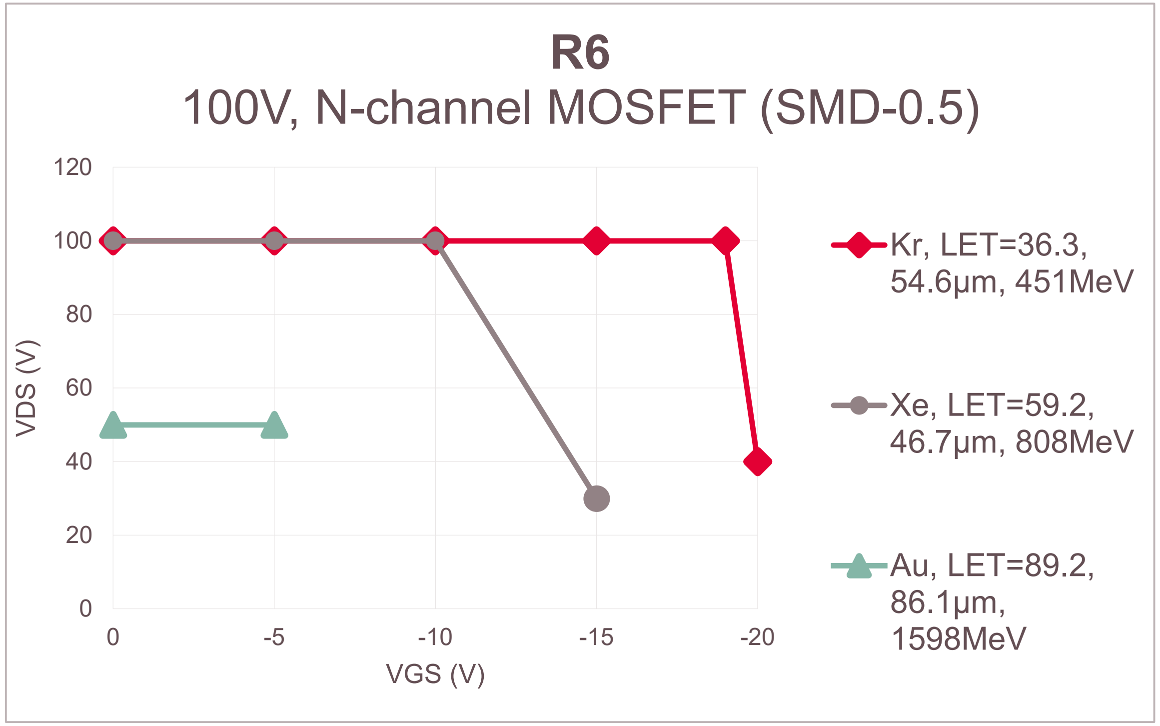
Why superjunction (SJ) technology for space applications?

- SJ over planar MOSFETs for space
  - Electrical advantage
    - Planar technology drawback: As V_{DS} increases the drift layer becomes thicker and the $R_{(DS)on}$ increases
    - SJ technology: Vertical pn junction results in low $R_{(DS)on}$
  - Radiation robustness
    - Structure of SJ technology “kills” the parasitic bipolar reducing the possibility of SEB
    - Incorporate our experience with planar technology on the gate for better SEE response
  - Structured for modularity
    - Voltage rating can scale up or down with the number of implants during fabrication

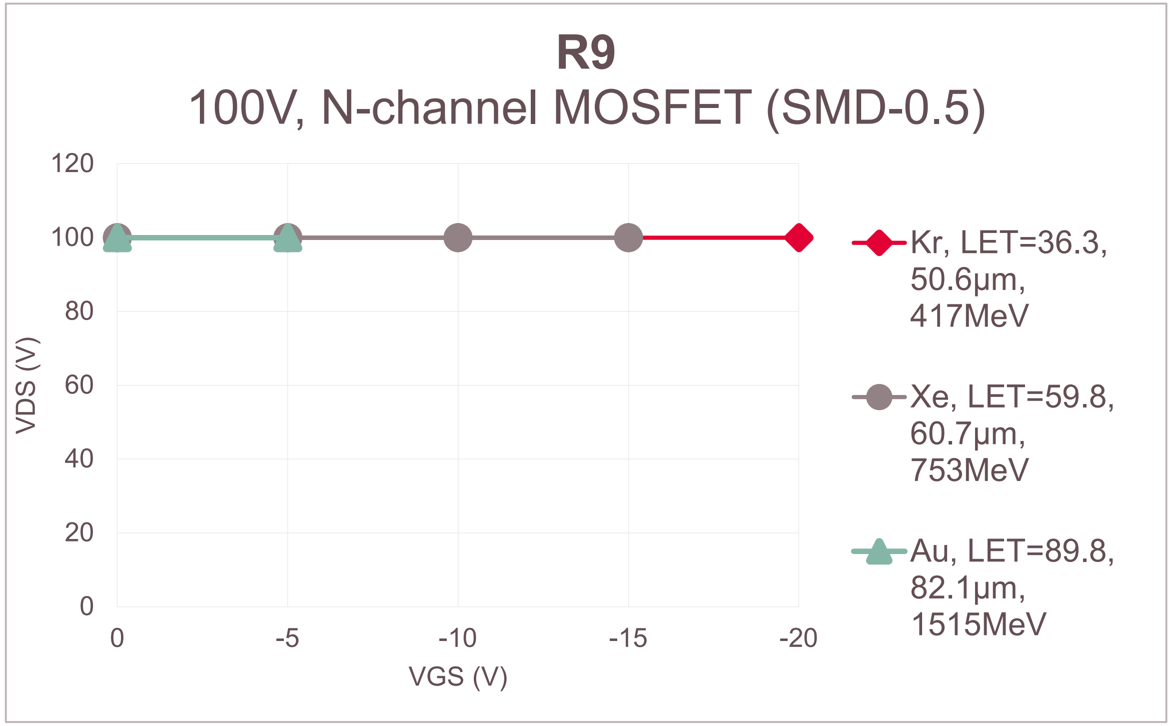




Superjunction: more robust destructive SEE performance

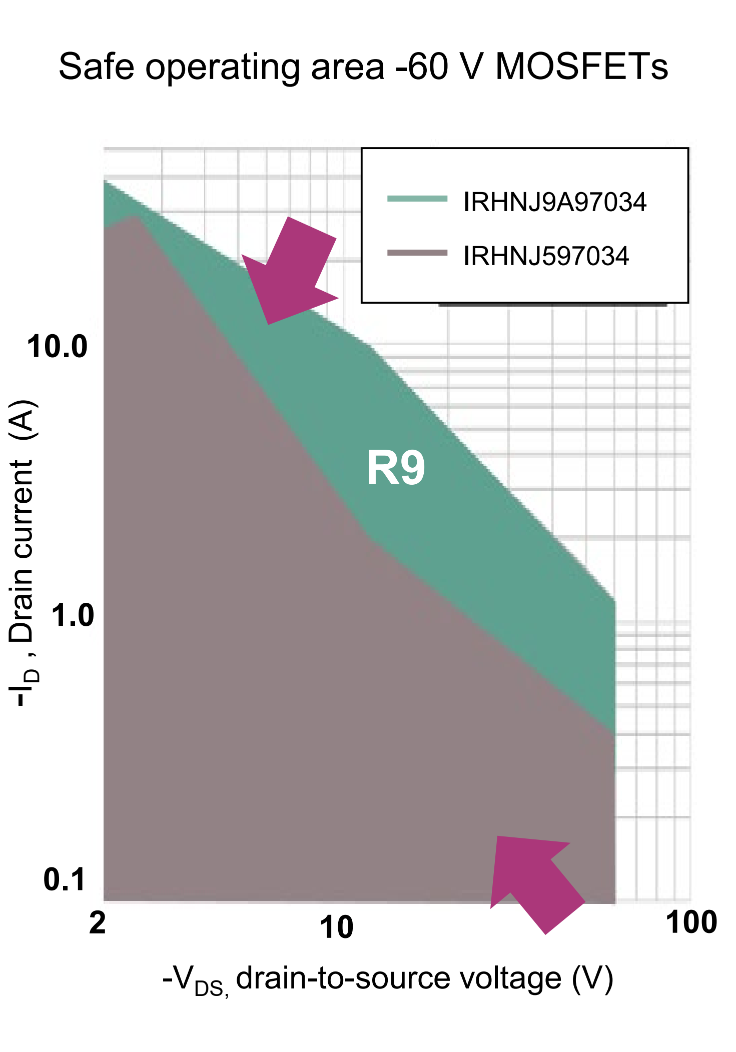


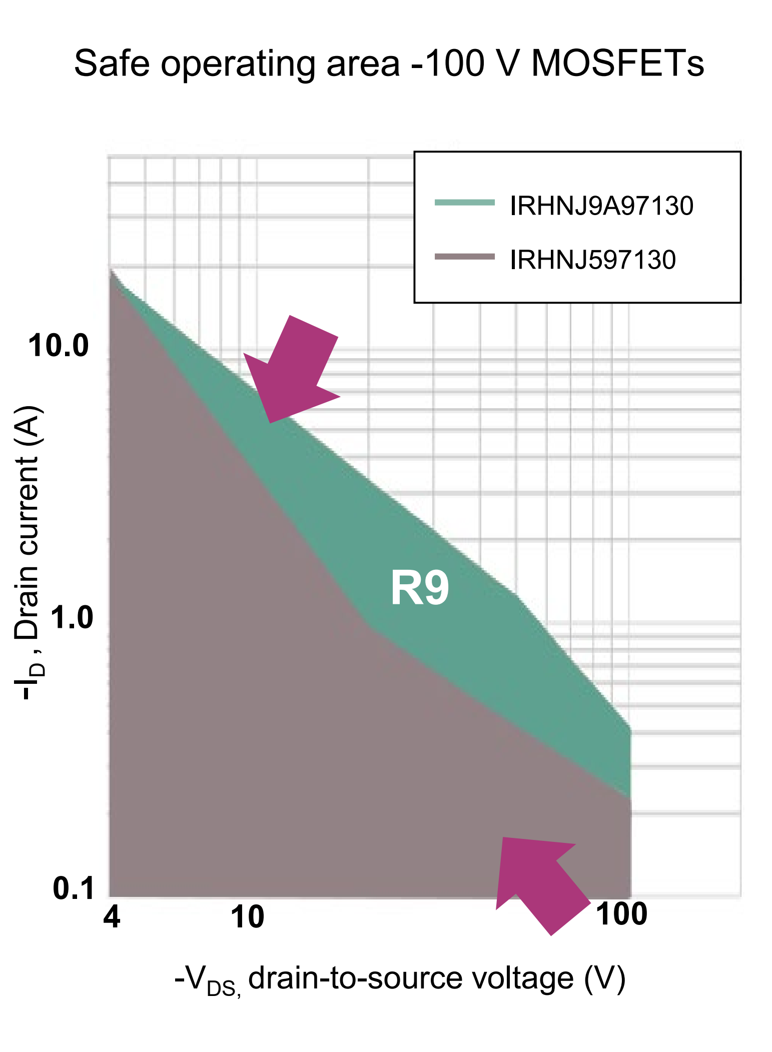
Single-Event-Effects – Worst Case Beam Conditions
Typical Response – IRHxx671x0

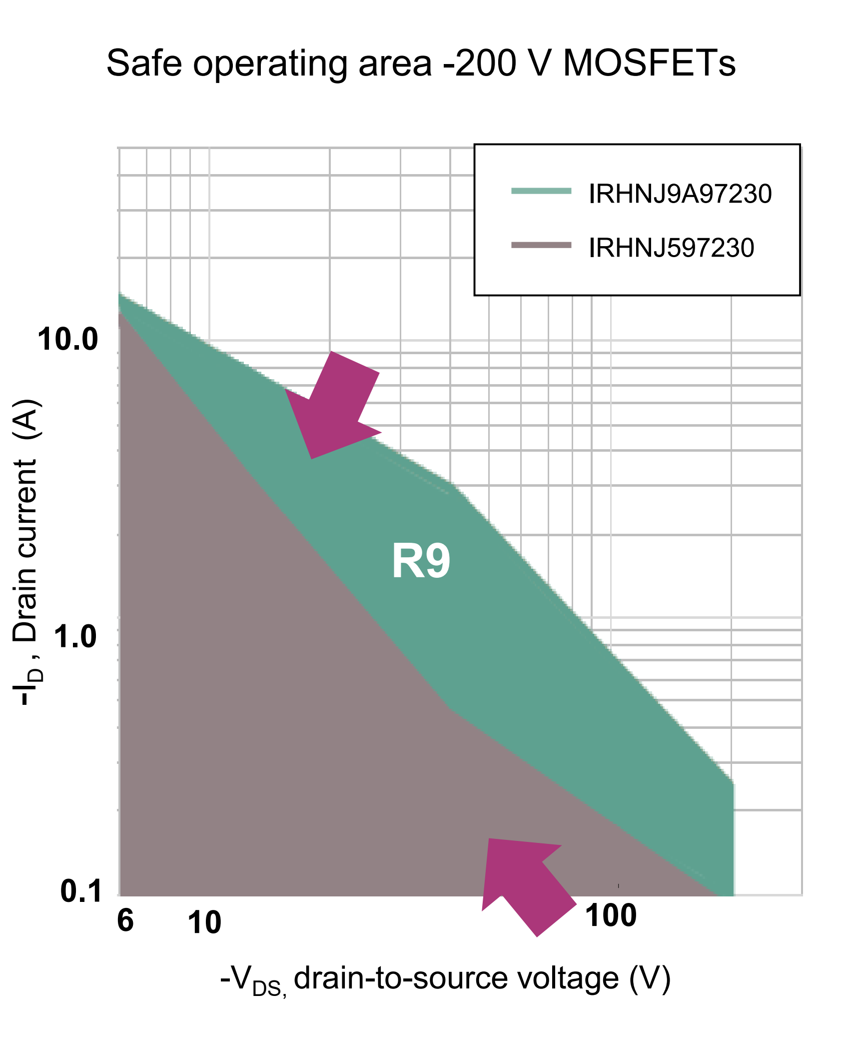


Single-Event-Effects – Worst Case Beam Conditions
Typical Response – IRHxx9A7130

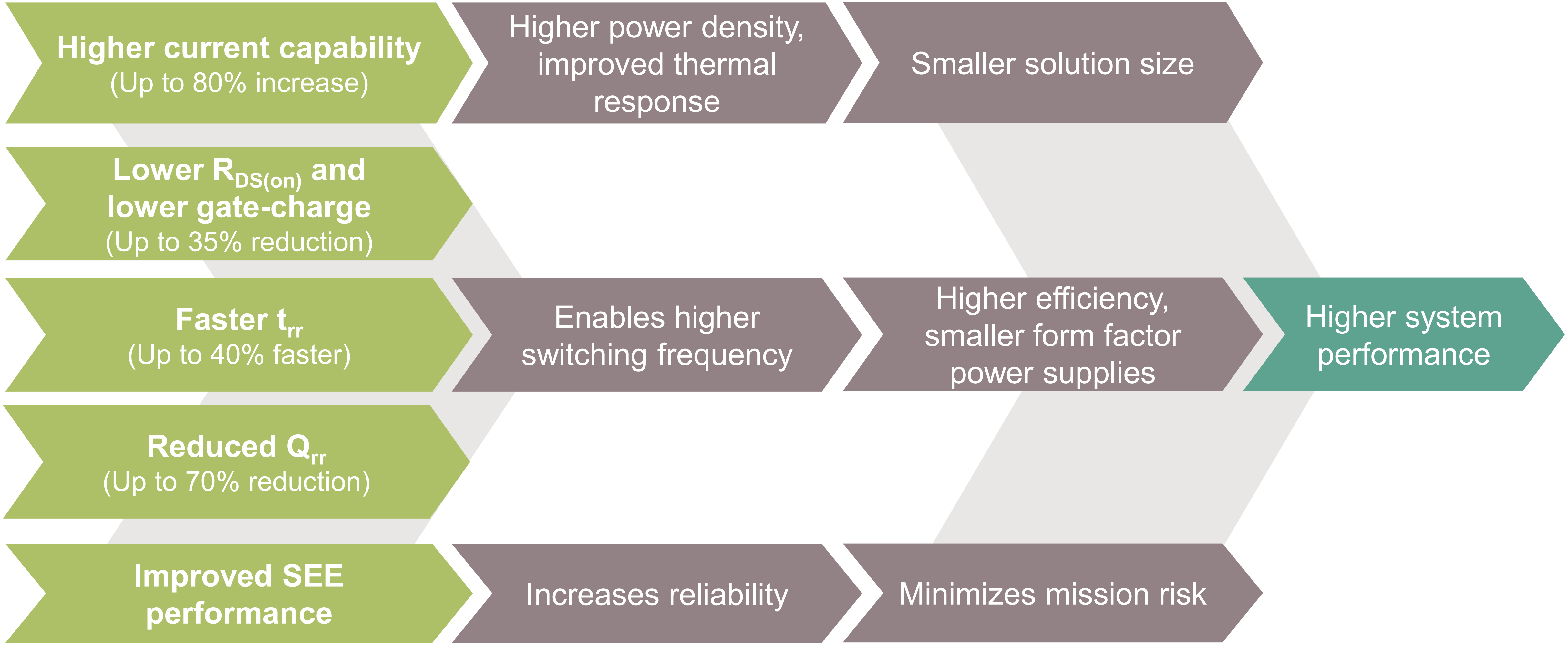
Superjunction expands the envelope for DC safe operating area





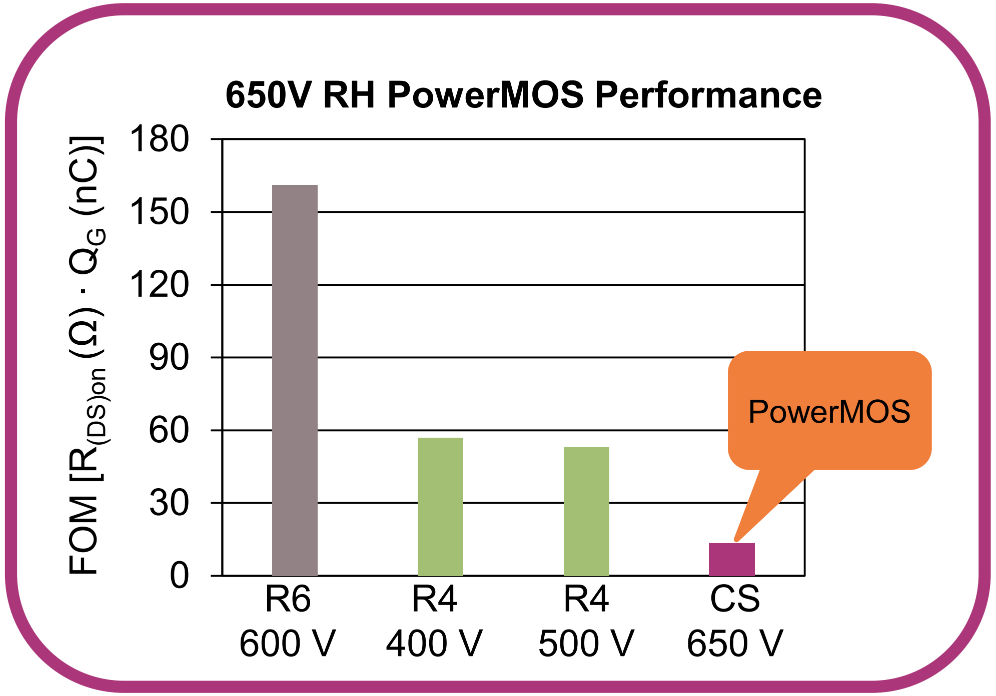


Superjunction MOSFETs boost your system performance

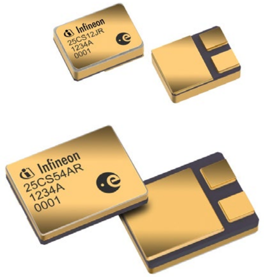


Rad hard high voltage (>400 V) N-channel comparison

- Key features of 650 V rad hard PowerMOS family
  - Benchmark products for high voltage rad hard MOSFETS
  - Best in class $R_{(DS)on}$ and figure of merit ($R_{(DS)on}$ *Q_G); >10x lower than 600 V R6 devices
  - Internal coating to meet vacuum requirements
- Radiation hardness
  - Total Ionization Dose TID 100krad
  - Single Event Effect (SEE)



LET	Range	V_{GS}	BV_{DSS}
90	122 µm (Pb)	-10 V	650 V
62	73 µm (Xe)	-15 V	650 V



Type	ESCC ref.	$R_{(DS)on}$ max; 25°C	I_D	V_{DSS}	Package	ESA QPL
BUY65CS08J-01	5205/032/01	450 mΩ	8 A	650 V	SMD-0.5	Yes
BUY65CS28A-01	5205/032/02	150 mΩ	28 A	650 V	SMD-2	Yes

*Devices also available as qualified bare die (chip)

ESA qualified Device!

R9 rad hard MOSFET technology platform

Benefits

- Increase power density
- Higher efficiency
- Drop-in replacement for existing MOSFET
- Improved SEE performance
- Smaller footprint with innovative packaging

Features

- Increased I_D capability
- Lower $R_{DS(on)}$
- TID levels – 100 krad and 300 krad
- SEE tolerant to LET 90 MeV·cm^2/mg
- Best Figure of Merit (FoM = $R_{DS(on)}$* Q_G)

N-channel platform

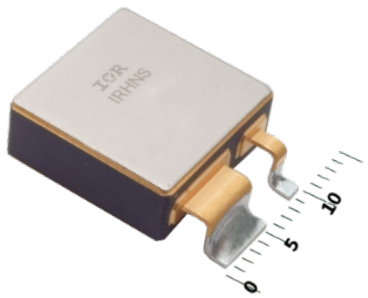
Size \ Volt	60V	100V	250V
6	released	released	planned
3	released	released	released
1.7	released	released	planned
1	planned	planned	development

P-channel platform

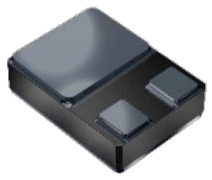
Size \ Volt	60V	100V	200V
6	planned	planned	planned
3	released	development	development

✓ released ✓ development ● planned

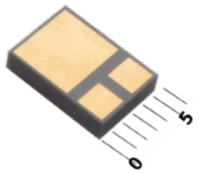
Direct-to-PCB packaging solutions



SupIR-SMD™
Size 6 die



SMD-0.5e
Size 3 die



SMD-0.2e
Size 2 die

R9 offers more choices for designers to optimize

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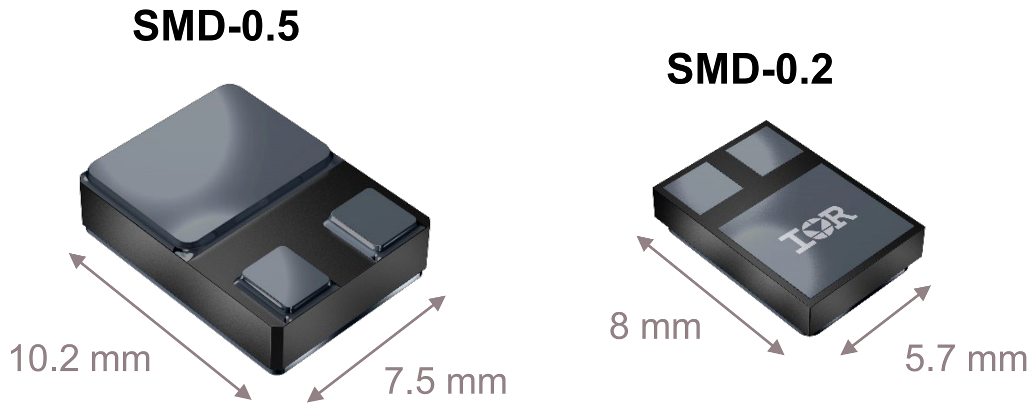
1 Smaller size with better performance

- Better performance in smaller package

Gen	Type	VDS	FoM	R_{DSon} (mΩ)	Qg (nC)	Id (A)	Package
R9	**N**	**60**	**0.93**	**30**	**31**	**25**	**SMD-0.2**
R5	N	60	1.35	30	45	22	SMD-0.5



2 Same size with better performance

- Better efficiency
- Higher power density

Gen	Type	VDS	FoM	R_{DSon} (mΩ)	Qg (nC)	Id (A)	Package
R9	**N**	**60**	**0.81**	**18**	**45**	**40**	**SMD-0.5**
R5	N	60	1.35	30	45	22	SMD-0.5

3 Reduce BoM

- Use a higher voltage rating, reducing number of unique part numbers on BoM

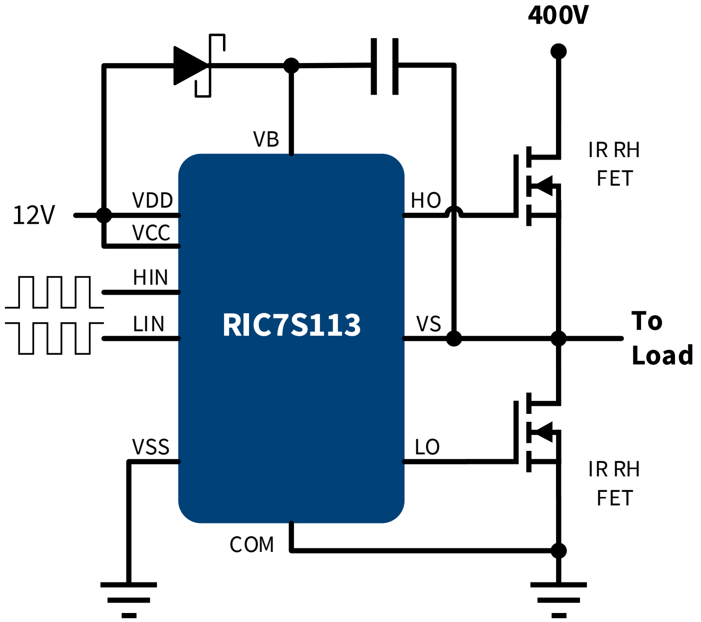
Gen	Type	VDS	FoM	R_{DSon} (mΩ)	Qg (nC)	Id (A)	Package
R9	**N**	**100**	**1.63**	**34**	**48**	**35**	**SMD-0.5**
R5	N	60	1.35	30	45	22	SMD-0.5

Comparing performance across MOSFET technologies

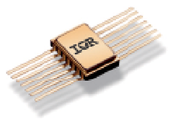
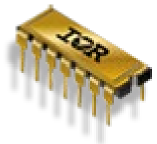
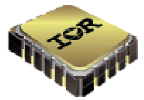
RIC7S113 | 400 V high & low side MOSFET gate driver

- Key features
  - 400 V bus voltage
  - VDD logic supply = 5 V to 20 V
  - VCC gate drive = 10 V to 20 V
  - Low propagation delays
    - t_{ON} = 120 ns | t_{OFF} = 100 ns
    - t_{MATCH} = 5 ns
- Radiation hardness
  - TID = 100 krad(Si)
  - SEE characterized to 50.4 MeV·cm^2/mg
- Benefits
  - Reduce size by eliminating bulky magnetics
  - Increase reliability over opto-coupler based designs
  - Compatible with all rad hard PWM controllers
  - 50 V/ns transient immunity for robust high-speed switching

Half bridge configuration diagram



RIC7S113 package options

14-lead flatpack	MO-036AB	LCC-18
		

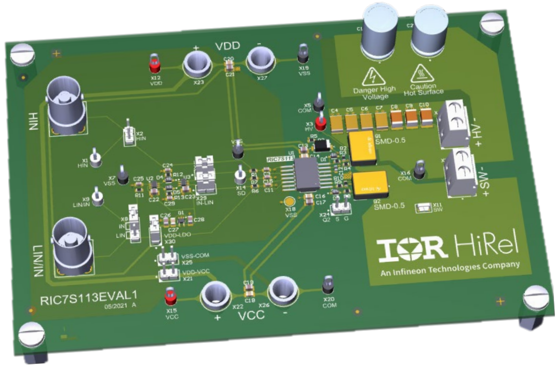
R9 vs. previous generation

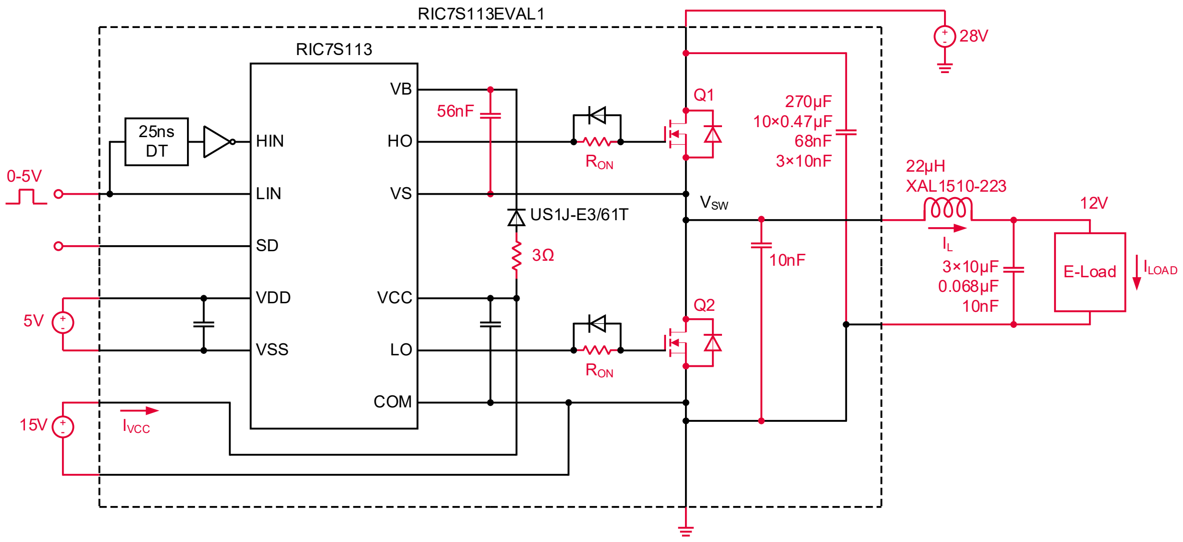
Measured efficiency between R9, R6 and R5

- Open loop half bridge power stage with modified RIC7S113EVAL1 PCB
- Fixed frequency operation, duty cycle adjusted to maintain 12 V output
- Power stage identical, only change FET Q1, Q2
- Snubber added and R_{ON} adjusted between FET to maintain peak V_{SW} overshoot around 50 V

Generation

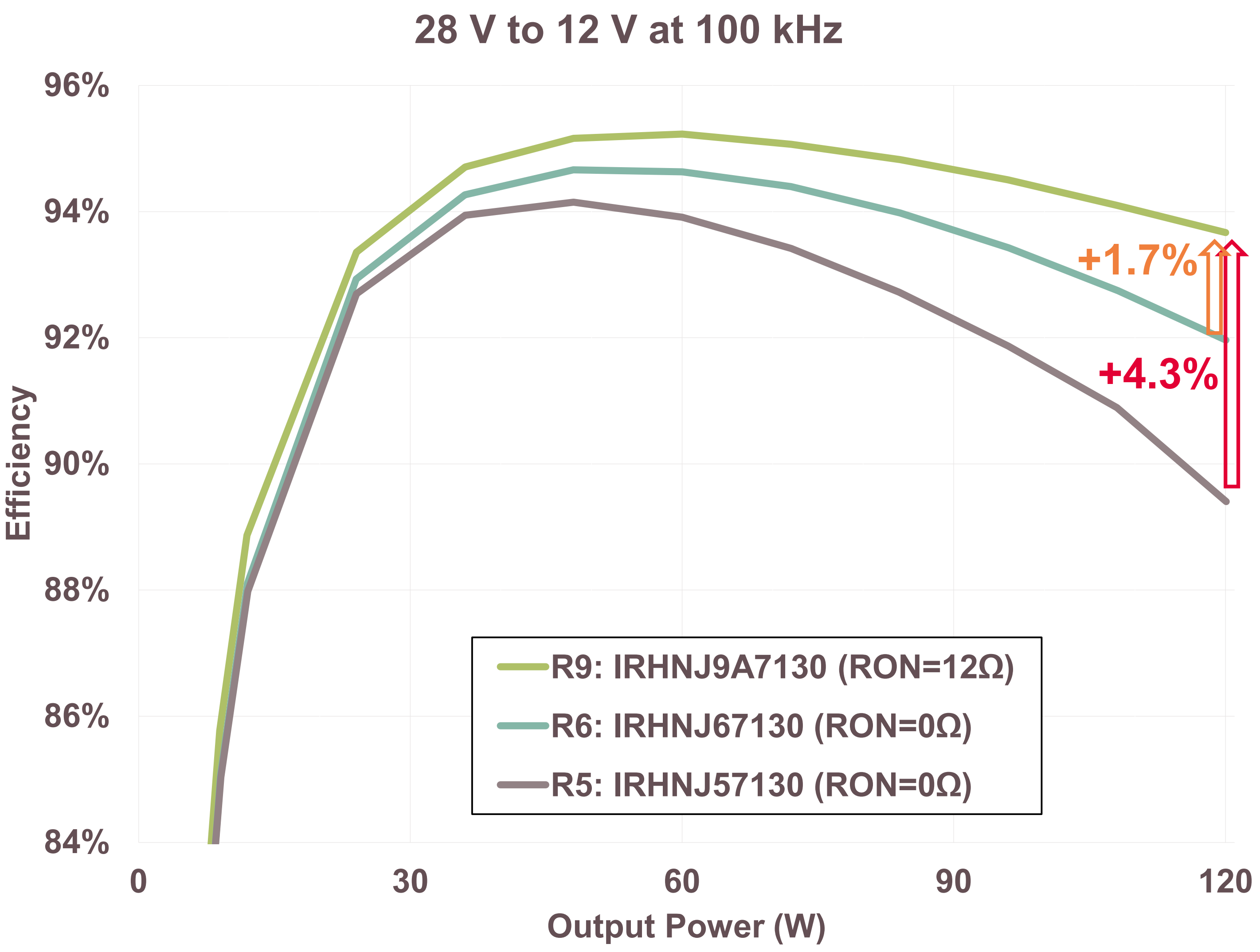
Gen	Part #	BV_{DSS} (V)	I_D (A)	$R_{DS(on)}$ (mΩ)
R9	**IRHNJ9A7130**	**100**	**35**	**34**
R6	IRHNJ67130	100	22	42
R5	IRHNJ57130	100	22	60



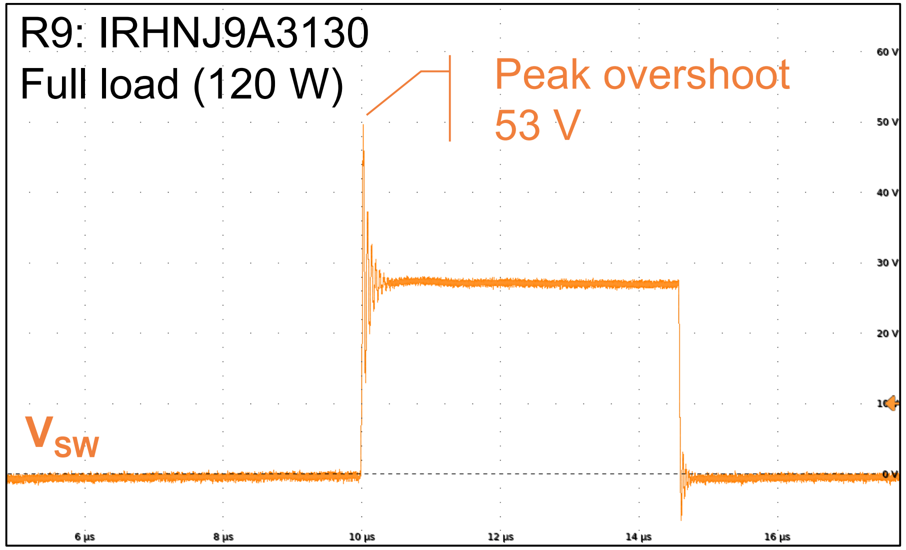


Modifications to RIC7S113EVAL1 shown in red

R9 shows significant efficiency improvement over prior generation



- R9 has 1.7% efficiency improvement over R6, 4.3% efficiency improvement over R5
- Efficiency includes power stage loss and gate drive
- Peak overshoot for all three device around 50 V



Latest gen rad hard power solutions improve PMAD system efficiency

- Next generation MOSFET die and packaging enable improvements with minimal design risk
  - Minimize IBC size and power dissipation
  - Improve efficiency for greater current output at PoL levels

- Superjunction MOSFET technology enables
  - Better electrical performance which leads to higher efficiency and power density
  - Increased radiation robustness to SEGR and SEB
  - Technology modularity enables rapid voltage scalability

www.infineon.com/r9

Questions?

Oscar Mansilla
oscar.mansilla@infineon.com
Product Marketing Director, Space Discretes & ICs

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