Radiation tolerant n- and p-channel power MOSFETs for space applications

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26.03.2025

Table of contents

Table of contents

Infineon is a global leader in power systems and IoT

Global leader

in automotive, power management,
energy efficient technologies and IoT

~58,060

employees[1]

Market position

Automotive	Power	Microcontroller
#1	**#1**	**#1**
TechInsights, April 2024	Omdia, October 2024	Omdia, March 2025

[1] As of 30 September 2024

Infineon leading in power systems – mastering all three key materials

- Reliable multi sourcing of raw materials
- World-scale fabs

Controller → **Driver IC** → **Power switch** (Si/SiC/GaN)

Software + Algorithms

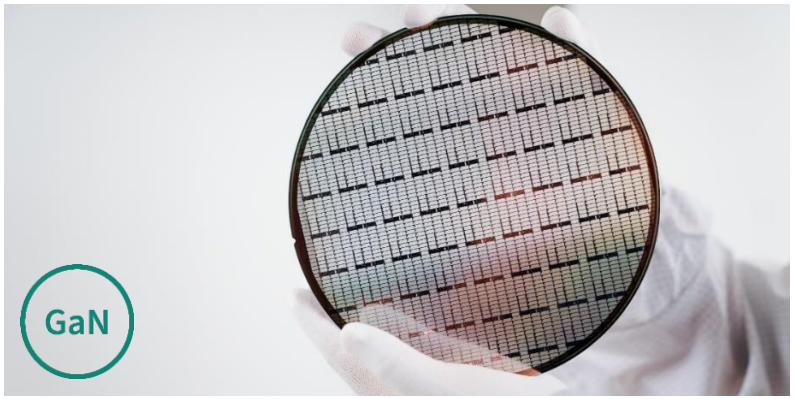
- Application understanding
- Packaging know-how and hybridization competence

Leadership in Power Systems across all materials and technologies

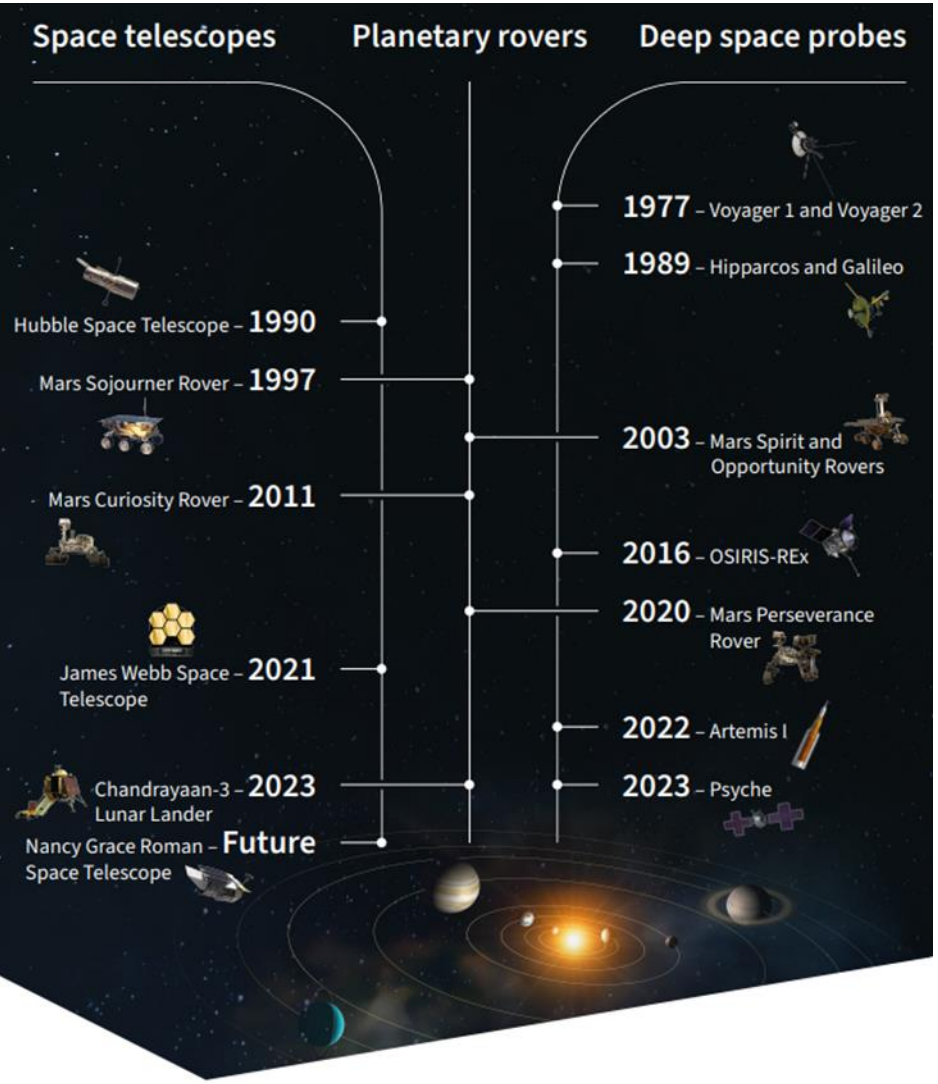
Silicon
Diode – MOSFET – IGBT – Driver – Controller

Silicon carbide
Diode – MOSFET

Gallium nitride
HEMT – Driver



Infineon has more than 50 years of space heritage



RF and power devices from Infineon are part of many missions

- First order for RH RF component received in 1977

- Some more examples in alphabetical order
  - Alphasat (Joint ESA/Inmarsat communications satellite)
  - Artemis (Advanced Relay And Technology Mission, ESA)
  - JUICE (Jupiter Icy Moons Explore, ESA, 2023)
  - Intelsat (Communication, commercial)
  - IRNSS (India Regional Navigational Satellite System, ISRO)
  - Galileo NG (Satellite navigation system, ESA, 2014-2024)
  - GPSII (Global Positioning System, NASA)
  - Mars Rover (Exploration, NASA)
  - Meteosat SG (Weather monitoring & forecasting, ESA/EUMETSAT)
  - Sentinel (Earth observation, ESA)

Table of contents

Key features of new family of radition tolerant (RT) products

- **Package**
  - Plastic with matte Tin lead finish
- **Radiation ratings** provided
  - **SEE** (Single Event Effect): **46 LET MeVcm²/mg**
  - **TID** (Total Ionization Dose): **30krad**
- **Qualified / tested according**
  - AEC-Q101
  - MIL-STD-750/883
  - ASTM E595 (outgassing)
  - MIL-STD-883 method 1009.9 (salt atmosphere)
- **Fixed production** locations
  - Chip: Infineon power factories (**Dresden, Kulim**)
  - Package: Infineon qualified assembly lines, **Asia**

Comparision with automotive grade and full space qualified party

Parameter	Automotive Grade	RT MOSFET	ESA	JANS
Package type	Plastic Encapsulated	Plastic Encapsulated	Ceramic	Ceramic
Lead finish	Pure/Matte Sn	Matte Sn *)	Au	Solder Sn/Pb or Au
Operating temperature range	-40°C to 125°C	-40°C to 125°C	-55°C to 150°C	-55°C to 150°C
Qualification	According AEC Q101	According AEC Q101	According to ESCC5000	According to MIL-PRF-19500
Electrical Testing	Automotive standard testing	Automotive standard testing	According to ESCC5000	According to MIL-PRF-19500
Screening (BI, TC, Hermeticity…)	No additional screening	No additional screening	According to ESCC5000	According to MIL-PRF-19500
Fixed Process Flow	None	Yes	Yes	Yes
SEE Testing	None	One time for technology 46 LET	One time for technology >80 LET	One time for technology >80 LET
TID Testing	None	Specified TID 30kRad	RHA by diffusion lot TID>100kRad	Wafer by wafer RHA TID > 100krad(Si)
DOC	No	On request	Yes	Yes
Traceability	No	No serialization SLDC on request	Serialization	Serialization

*) lead finish is qualified to meet class 2 of JESD 201A

Overview on qualification and radiation tests

Product qualification

- Qualification according to AEC-Q101 Rev. E
- Family qualification for PG-TO263 and PG-TO247
- Standard stress tests are applied:
  - UHAST, TC, HTGS, HTRB, ...
- ESD HBM & CDM are assured
  - HBM 1kV to <2kV
  - CDM >1kV

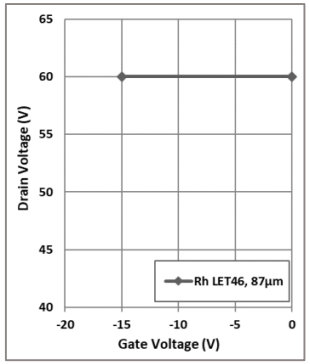
TID testing

- Irradiation according to ESCC22900 standard
- Radiation tolerance is part of the product specification
- Test conditions:

	V_{DS} [V]	V_{GS} [V]
C1	0	+12
C3	80% of VDS (48V, 120V, 200V)	0

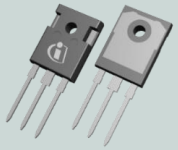
SEE testing

- Irradiation according to ESCC25100 and MIL-STD-750 test method 1080
- SEE performance published as SOA diagram in the latest datasheet



Product portfolio for power MOSFETs

– **Product overview**

Product	Package	Type	U_{DS}(max)	R_{DSon}(max) @25°C	I_{Dmax} @25°C	TID	SEE	Package
BUP06CN015E-01		N	60V	15mΩ	52A	30krad	46LET	PG-TO247-3
BUP15CN027E-01		N	150V	27mΩ	98A			
BUP06CN035L-01		N	60V	35mΩ	36A			PG-TO263-3
BUP15CN060L-01		N	150V	60mΩ	106A			
BUP06CP038F-01		P	60V	38mΩ	-35A			PG-TO252-3

– Sample available for all types
– **Product status** “active and preferred”

Target applications

– Typical use cases: DC-DC Converter, Power distribution unit, load switch, PoL, Motor drive

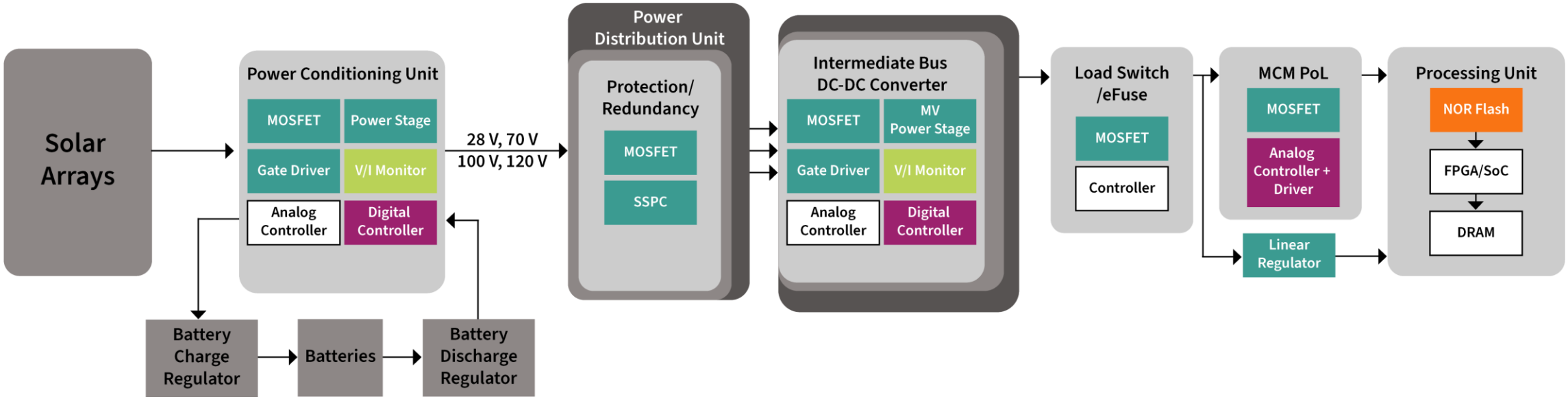


Table of contents

Additional environmental tests for plastic package used in space

Salt Atmosphere Test

- This test evaluates the corrosion resistance of materials when exposed to a salt fog or spray, e.g. during transport.
- For electronics, especially those used in harsh environments this test is critical. It ensures that the product's packaging and materials can withstand corrosive environments, preventing premature failures.
- RT products passed test according MIL-STD-883 method 1009.9

Outgassing Test

- This test measures the amount of volatile compounds that a material releases in a vacuum.
- In space applications, outgassing is a major concern because released volatiles can contaminate sensitive optical surfaces or other components.
- Understanding outgassing properties is essential for ensuring the reliability of electronics in vacuum environments, such as those found in Space
- RT product passed test according ASTM E595

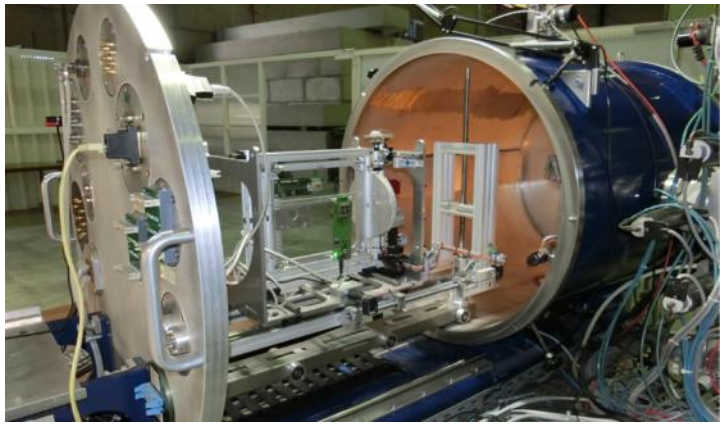
SEE test set-up for RT power MOSFETS

- Test location for SEE test: Cyclotron Resource Centre (CRC) in Louvain-la-Neuve, Belgium
- Test set-up: DUT was mounted on a test PCB in line with the beam at normal incidence and irradiated while the Keithley SMUs measured device voltages and currents

- Irradiation specification: ESCC Basic Specification No. 25100 Iss. 2, Oct 2014

- SEE test criteria are shown below:
  - Ion Species: $^{103}Rh^{31+}$
  - LET: 46.1 $Mev*cm^2/\ mg$
  - Flux: 3e3 $ions/$cm²/ s^{-1}
  - Fluence: 3e5 $ions$ / cm²

Source: CRC - Cyclotron Resource Centre, UCLouvain



Source: CRC - Cyclotron Resource Centre, UCLouvain

Infineon RT power MOSFET products are SEB and SEGR free

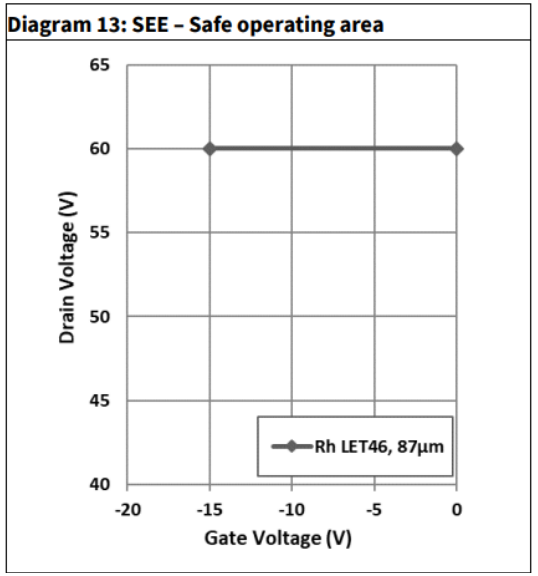
SEE performance

- SEE performance: The test results show that both devices are immune to single event burnout and gate rupture up to their maximum rated drain-source voltages for LET=46.1 $Mev*cm^2 / mg$

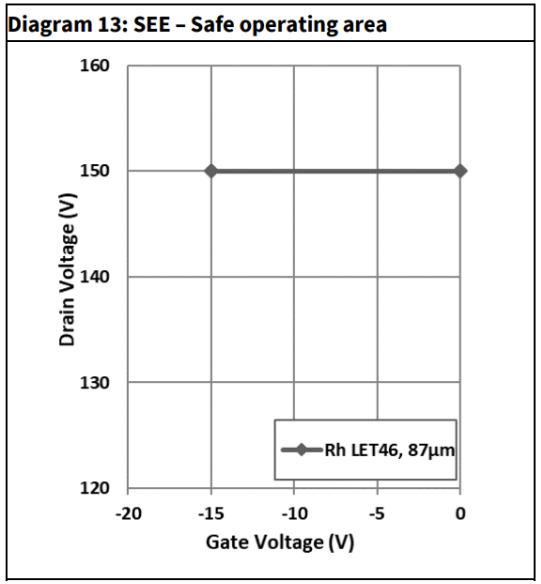
- FAIL criteria:
  - IDS>2μA or IGS>100nA
- PIGS FAIL criteria:
  - IDS or IGS > 100nA
- Required PASS samples: 3

Safe operating area curves

60V n-channel SEE SOA



150V n-channel SEE SOA



TID test set-up for RT power MOSFETS

- For TID testing, devices were irradiated by a Co-60 source at the JS-9000 facility in Germany and electrical measurements were taken under the following conditions:
  - Prior and post irradiation
  - Posterior to room-temp anneal of 24 hours
  - Posterior to 168 hours of anneal at 100°C

- Irradiation specification: ESCC Basic Specification No. 22900 Iss. 5, June 2016

- Electrical bias conditions:

Electrical Bias Condition	Bias Condition	Supply voltages		
		Gate	Drain	Source
C1	Fig. 1	+12V	0V	0V
C3	Fig. 1	0	80% $V_{DS(max)}$	0V

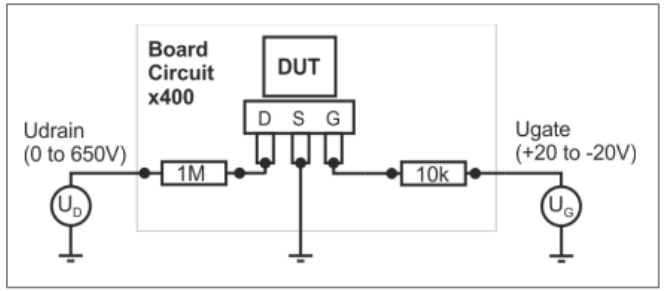


Fig. 1 Bias circuit for TID test

Infineon RT products are radiation robust up to 30krad (Si)

TID performance

- No failures occurred during TID testing, which indicates that both devices are radiation tolerant up to 30 krad (Si)
- The pass/fail criteria are the electrical test parameters as defined in the specification data sheet
- An example of this is shown on the right
  - black = no irradiation
  - red = gate bias (C1)
  - blue = drain bias (C3)
- The plot's y limits are the threshold for pass/fail in this case

Vth TID response

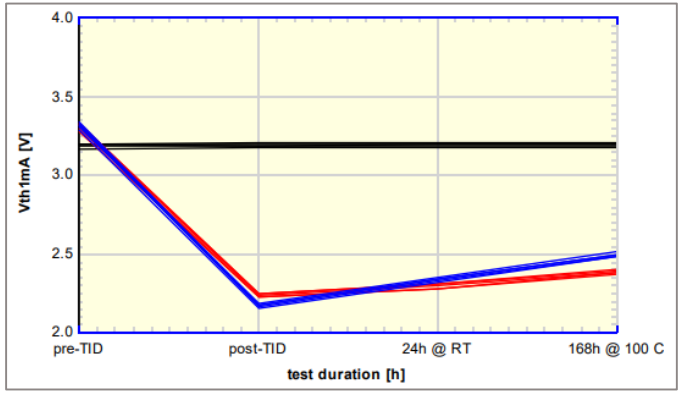


Fig. 2: 60V n-channel Vth TID response

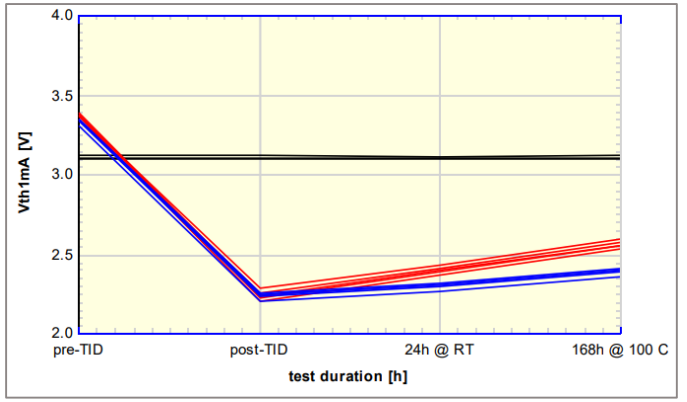
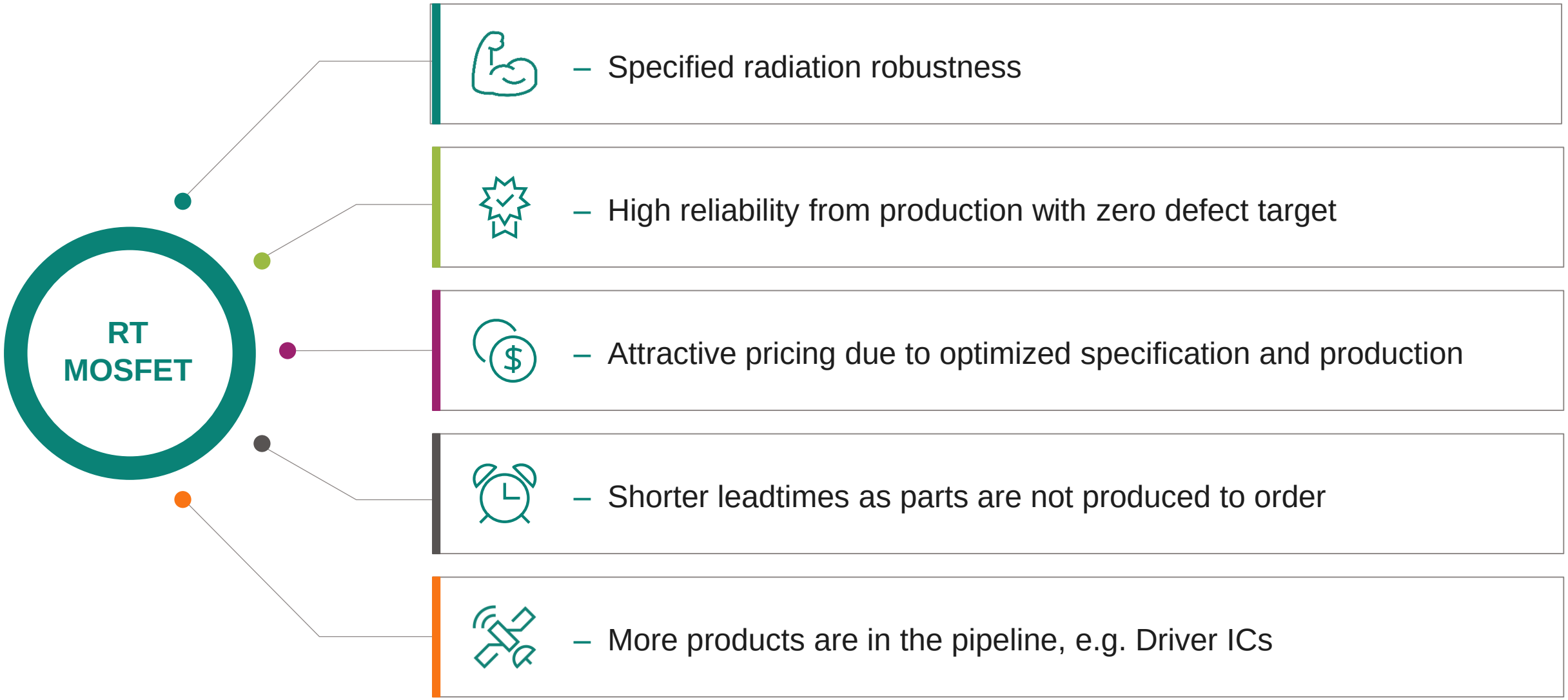


Fig. 3: 150V n-channel Vth TID response

Table of contents

Summary & Outlook



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