

Power protection in the digital age

eFuse and hot-swap strategies for modern data center design

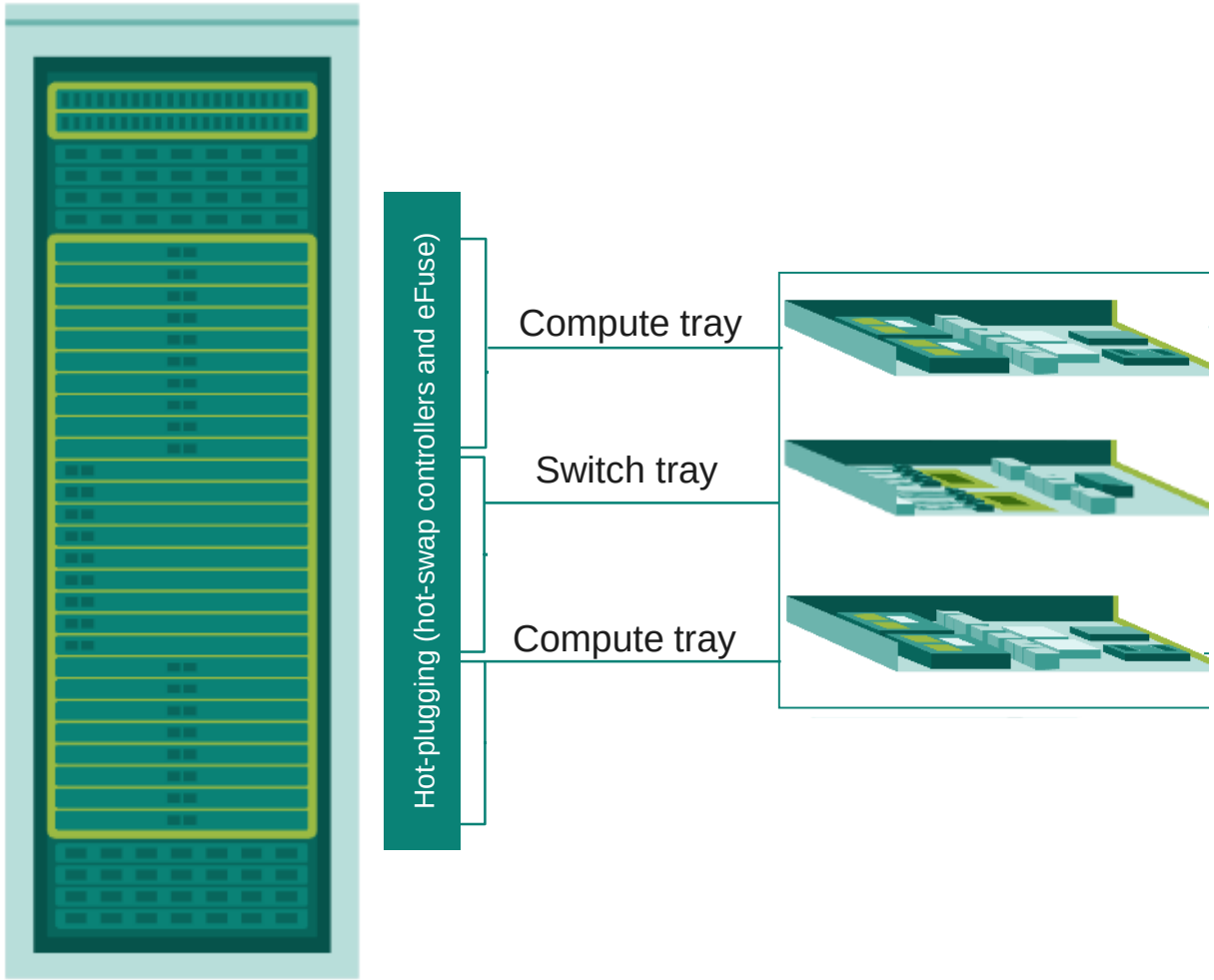
March 2026

public

Purpose of the protection ICs

We power AI from grid to core

High density AI server with **compute trays** for accelerated compute



Simplified visualization

Power System Reliability Modeling

Protection
(Hot-swaps, eFuses)

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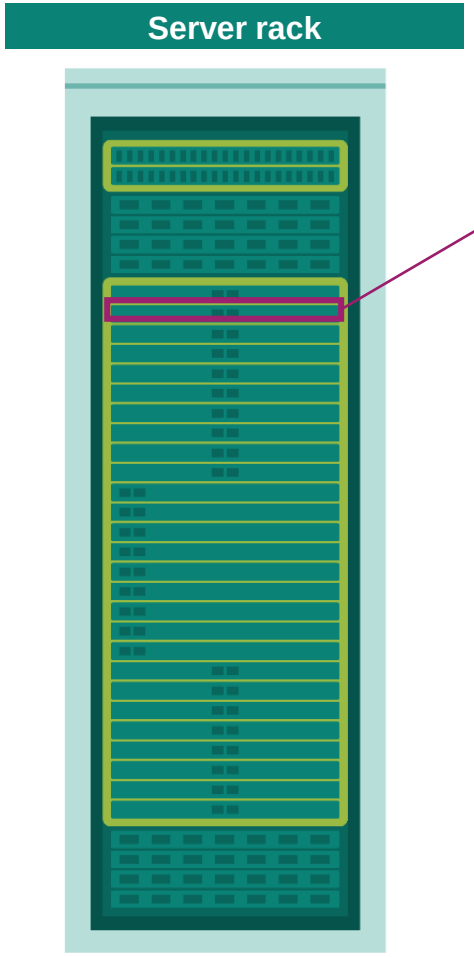
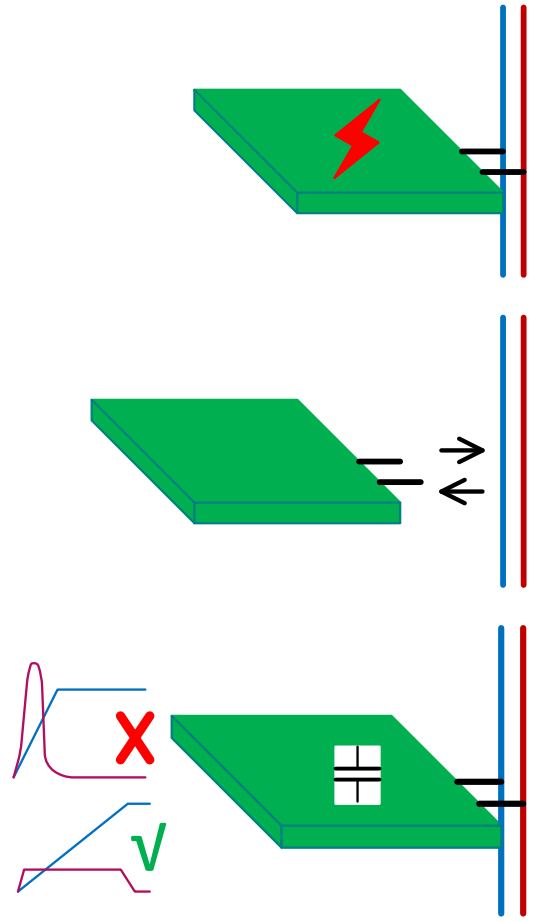
What is hot-swapping?



Device being replaced
(i.e., faulty server blade removed from backplane, and replaced with a new healthy one)

- Multiple AI **server blades** are **operated in parallel**, plugged into a **48 V live backplane** and powered by the same source as the processors
- If one blade fails, the load is shared by the others to keep the system running
- The **faulty blades** are **replaced** by plugging new healthy blades into the live backplane without taking the entire system offline
- This process is called “hot-plugging” or “hot-swapping”



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Why hot-swapping?

Benefits of hot-plugging

– Zero-downtime maintenance

– Reduced Total Cost of Ownership (TCO)

– Enhanced system flexibility

Main feature of hot-swap

– Control the inrush current

– Monitor and protect against faults to protect server blade as well as server rack



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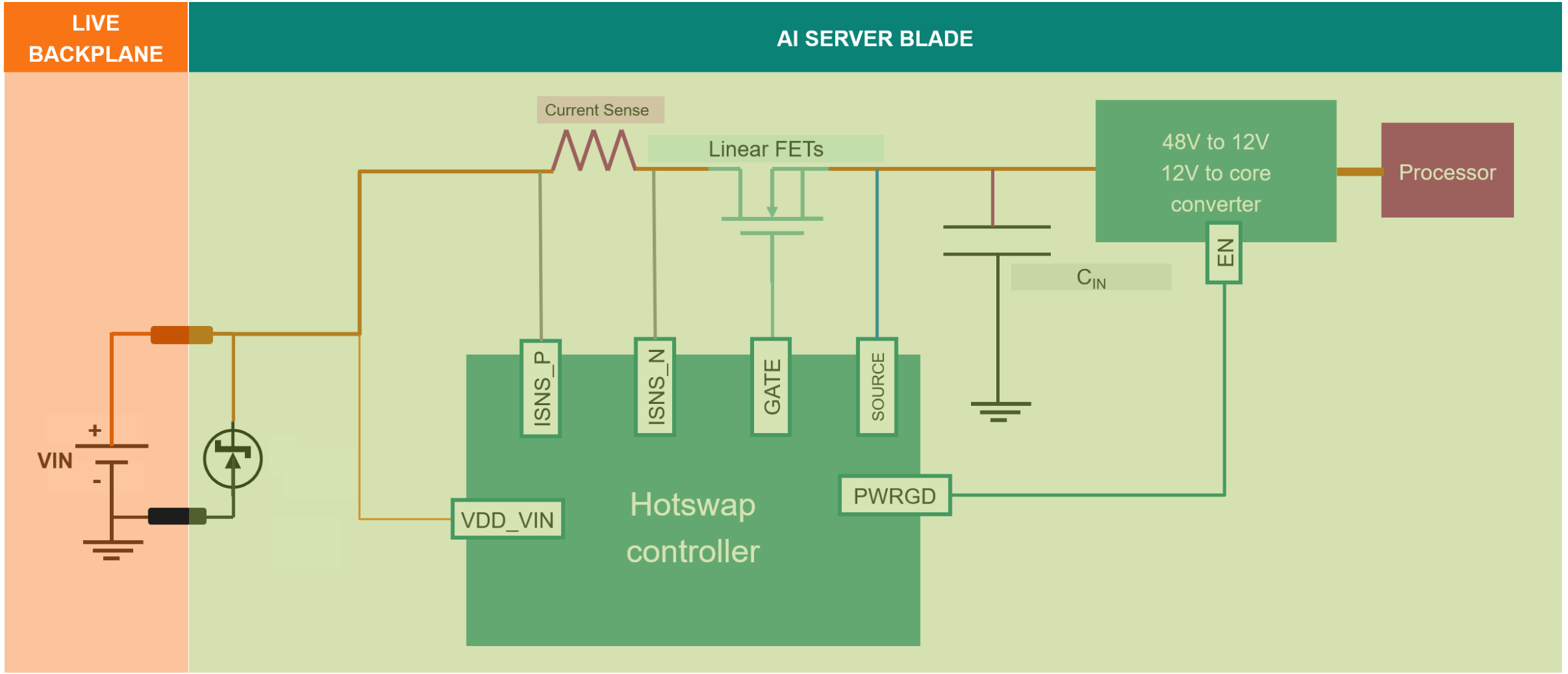
Server blade block diagram with hot-swap in focus



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XDP™ Protection IC portfolio

Differentiation of product family variants

Available upon request with reference design

	Hot-swap Controller					eFuse			Monitoring IC
Feature	XDP700	XDP710	XDP711	XDP712*	XDP701*	XDP730*	XDP720*	XDP721/XDP722*	XDM700*
Input voltage	-9.5 V to -80 V	+5.5 V to +80 V	+7 V to +80 V	+7 V to +80 V	+6.5 V to +24 V	+7 V to +80 V	+7 V to +80 V	+7 V to +80 V	+5 V to +80 V
Telemetry accuracy	V≤0.5%, I≤1.3%, P≤1.8%, E≤5.0%	V≤0.4%, I≤0.75%, P≤1.15%, E≤2.7%	V≤0.4%, I≤0.75%, P≤1.15%, E≤2.7%	V≤0.4%, I≤0.75%, P≤1.15%, E≤2.7%	V≤0.4%, I≤0.75%, P≤1.15%, E≤2.7%	V≤0.5%, I≤1.0%, P≤2.0%, E≤3.0%	V≤0.5%, I≤1.0%, P≤2.0%, E≤3.0%	x	V≤0.4%, I≤0.75%, P≤1.15%, E≤2.7%
Integrated FET driver/ controller	✓	✓	✓	✓	✓	✓	✓	✓	x
Integrated FET	x	x	x	x	x	✓	✓	✓	x
Modes of operation	AADM, FDM	AADM, FDM	AADM, FDM, Hybrid	AADM, FDM, Hybrid	FDM	FDM	FDM	Analog	X
Energy readings	24-bit	24-bit	40-bit	40-bit	40-bit	40-bit	40-bit	x	40-bit
Power averaging	13 ms (128 samples)	13 ms (128 samples)	3 s (32,768 samples)	3 s (32,768 samples)	3 s (32,768 samples)	3 s (32,768 samples)	3 s (32,768 samples)	x	3 s (32,768 samples)
Analog reporting	✖	✖	✓ Current, Power	✓ Current, Power	✓ Current, Power	✓ Current	✓ Current	✓ Current	✓ Current, Power
Faults	✓	✓	✓	✓	✓	✓	✓	✓	X
Warnings	✓	✓	✓	✓	✓	✓	✓	x	✓
Telemetry	✓	✓	✓	✓	✓	✓	✓	x	✓
OTP	✓	✓	✓	✓	✓	✓	✓	x	X
Analog programmability	✓	✓	✓	✓	x	✓	✓	✓	✓
Supported rails	Negative	Positive	Positive	Positive	Positive / Negative	Positive	Positive	Positive	Positive
HV Package	✓	✓	✓	✓	x ***	✓	✓	✓	x **
Package	VQFN-29 6x6	VQFN-29 6x6	VQFN-29 6x6	TSSOP-28 9.7x6.4	VQFN-24 4x4	LIQFN-42 7x7	LIQFN-23 6x5	LIQFN-23 6x5	VQFN-24 4x4

** Coming soon*
*** HV compliant if polymer coating is used during PCB assembly*
**** Maximum voltage seen by the IC XDP701 is 20 V max. so it can use 4x4 mm package*

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Infineon's hot-swap controller portfolio and key features

Value proposition to the customer provided by Infineon's XDP™ Hot-swap controller

Active SOA control

- SOA of FET programmed inside the controller
- SOA of FET is respected all the time

1

XDP™ Hot-swap controller



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Active SOA control vs dVdt control

- **SOA control limits the current that flows through the FET** based on the measured V_{DS} voltage, while the dVdt control relies on the inrush control to be defined by the slew rate of the Vout
- A potential **drawback of slew rate control** is that during startup, particularly in short-circuit or heavily loaded conditions, the controller may continue to increase the gate charge in an attempt to meet the required slew rate. This can cause a surge in input current, which is only limited by the power limit line, potentially leading to device damage

With SOA control, different current levels at different VDS levels can be programmed which allows for the controlled turn on time and controlled load current supplied at different VOUT levels. If the load current higher than programmed current, the controller will limit the current to the programmed current limit, preventing excessive stress on the FET. The maximum regulation time is also governed by the watchdog time, which ensures that the FET does not stay in linear region for too long, reducing the risk of overheating or damage

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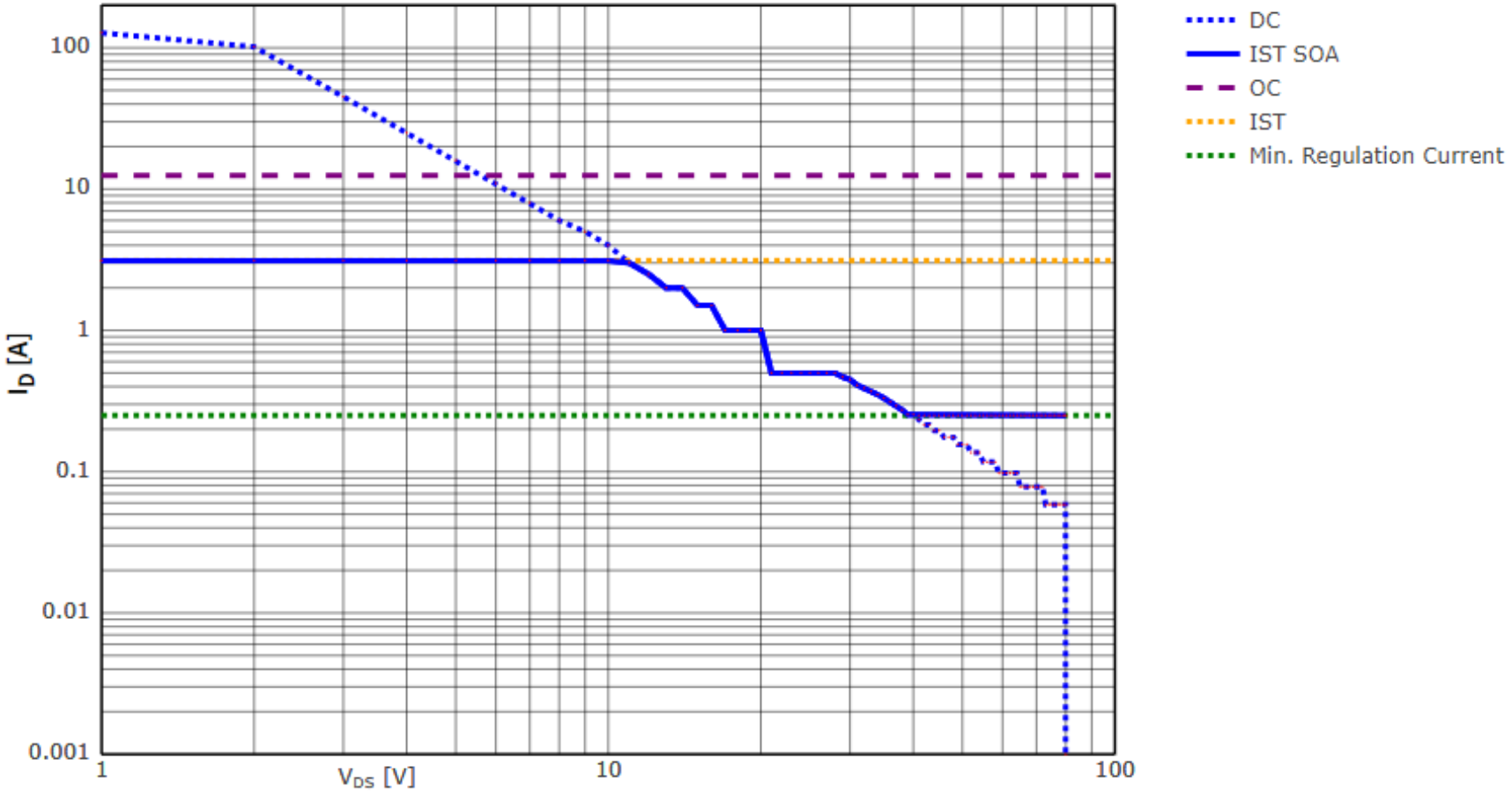
SOA based startup waveform



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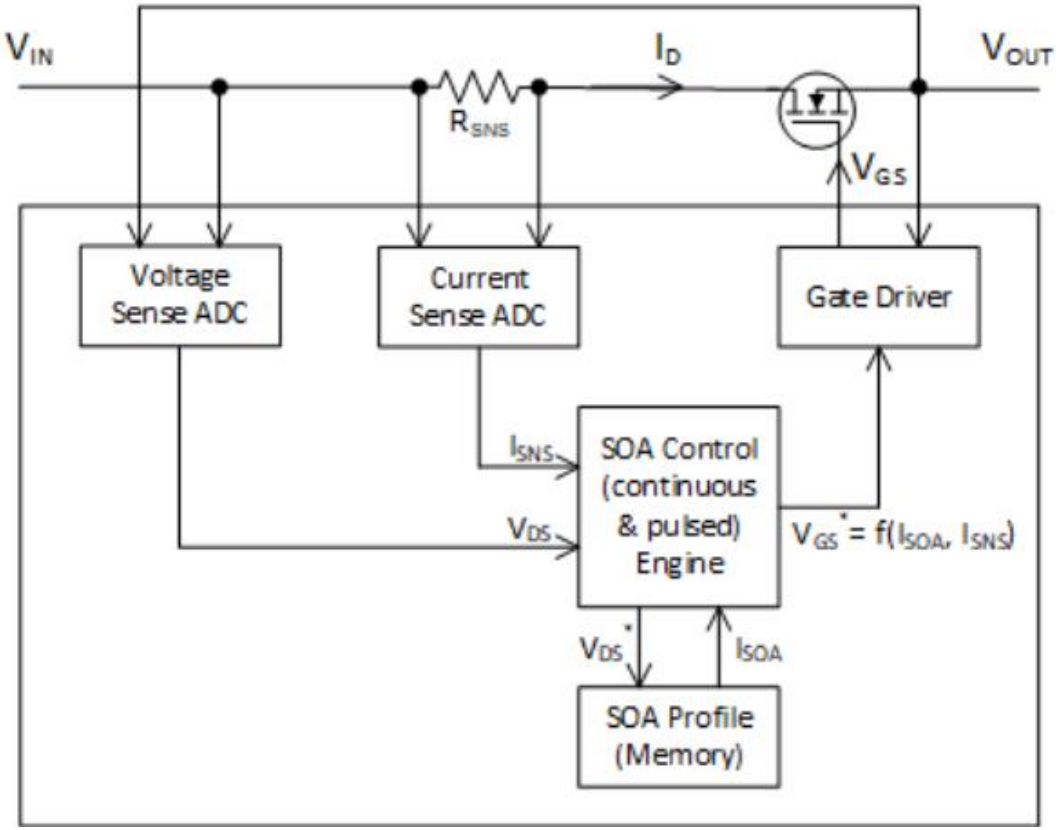

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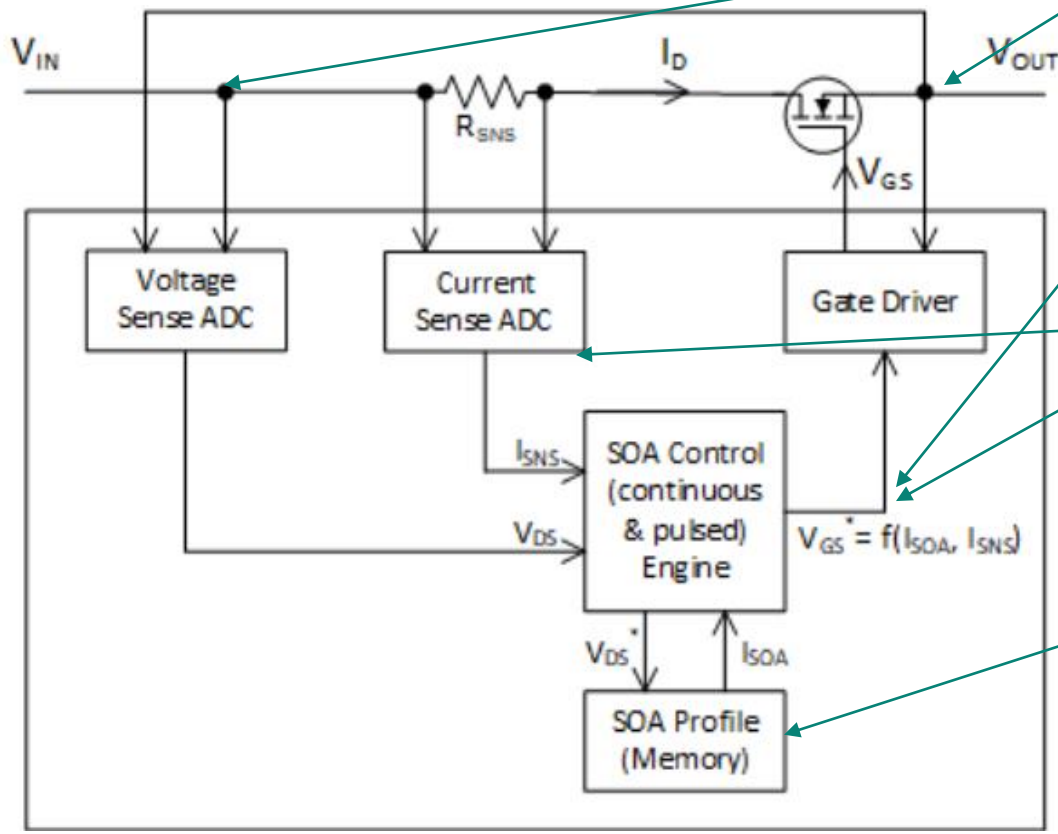
SOA based startup waveform



V_{DS} voltage is sensed via V_{IN} and V_{OUT}

Gate charge is supplied to allow the current I_D to flow through the MOSFET

Current is sensed and the gate charge is adjusted to regulate the current at programmed level

For the measured V_{DS} voltage the corresponding programmed current is looked up from SOA lookup table and set as target current

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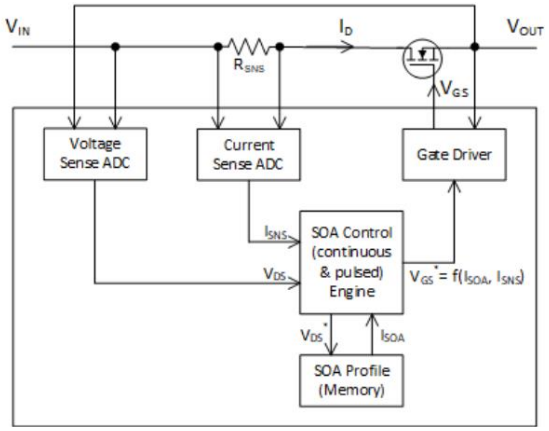
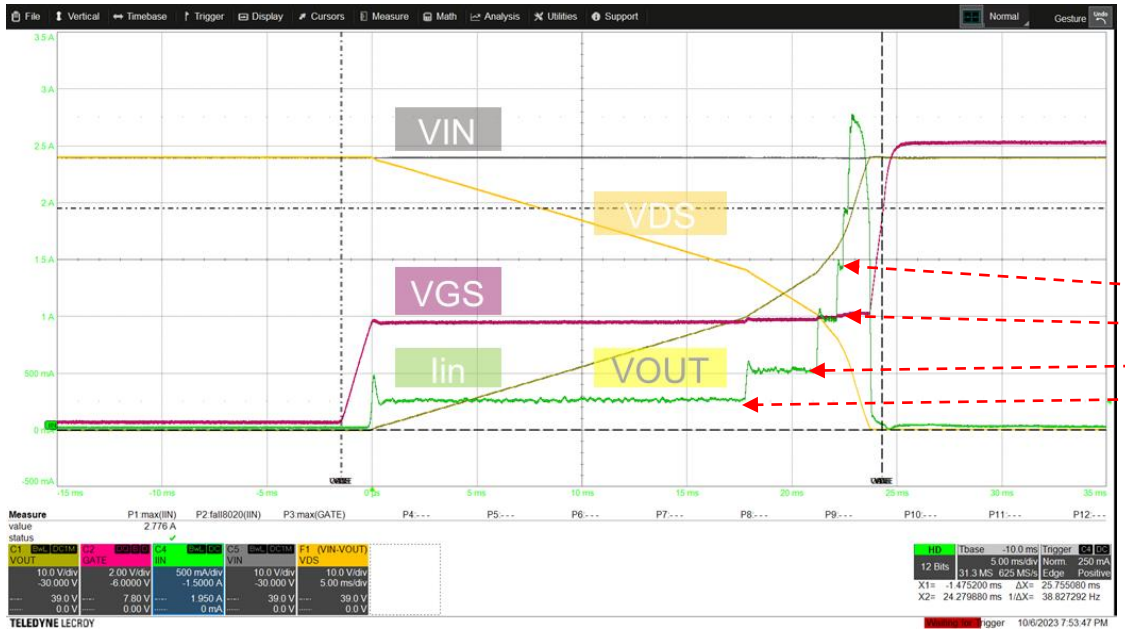
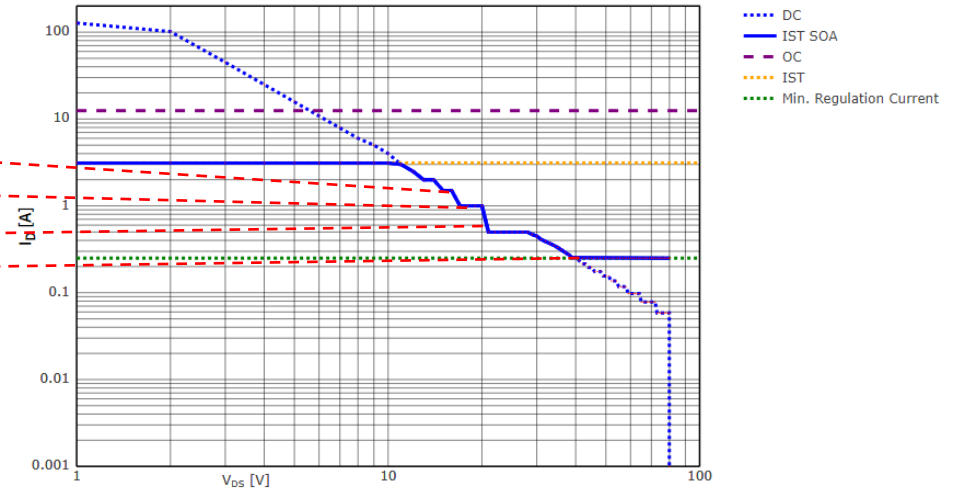
SOA based startup waveform







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Value proposition to the customer provided by Infineon's XDP™ Hot-swap controller

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- SOA of FET is respected all the time

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Pulsed SOA current control

- "Boost mode" operates (low SOA) FETs in a pulsed manner
- Allows for FET cooldown for high capacitive loads

2

XDP™ Hot-swap controller



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Pulsed SOA control (boost mode) for high capacitive loads

- When the output capacitance increases, so does the charging time, which extends the duration for which the FET is operated in linear region
- This puts on a lot of stress on the MOSFET and can results in overheating the FET
- To overcome this issue, the boost mode can be used where the output capacitor is charged from the pulsed current pulses instead of continuous current
- Pulsed SOA control allows the FET to be operated at 100 µs or 1 ms SOA lines at the startup. This allows the FET to be not operated continuously but in a **pulsed manner to allow for some cooldown time**
- This allows for the FETs with weak SOA to be used and helps with **more options of second sourcing**
- SOA control allows the **reliable charging of high capacitive load** especially liquid cooling pumps and robotics

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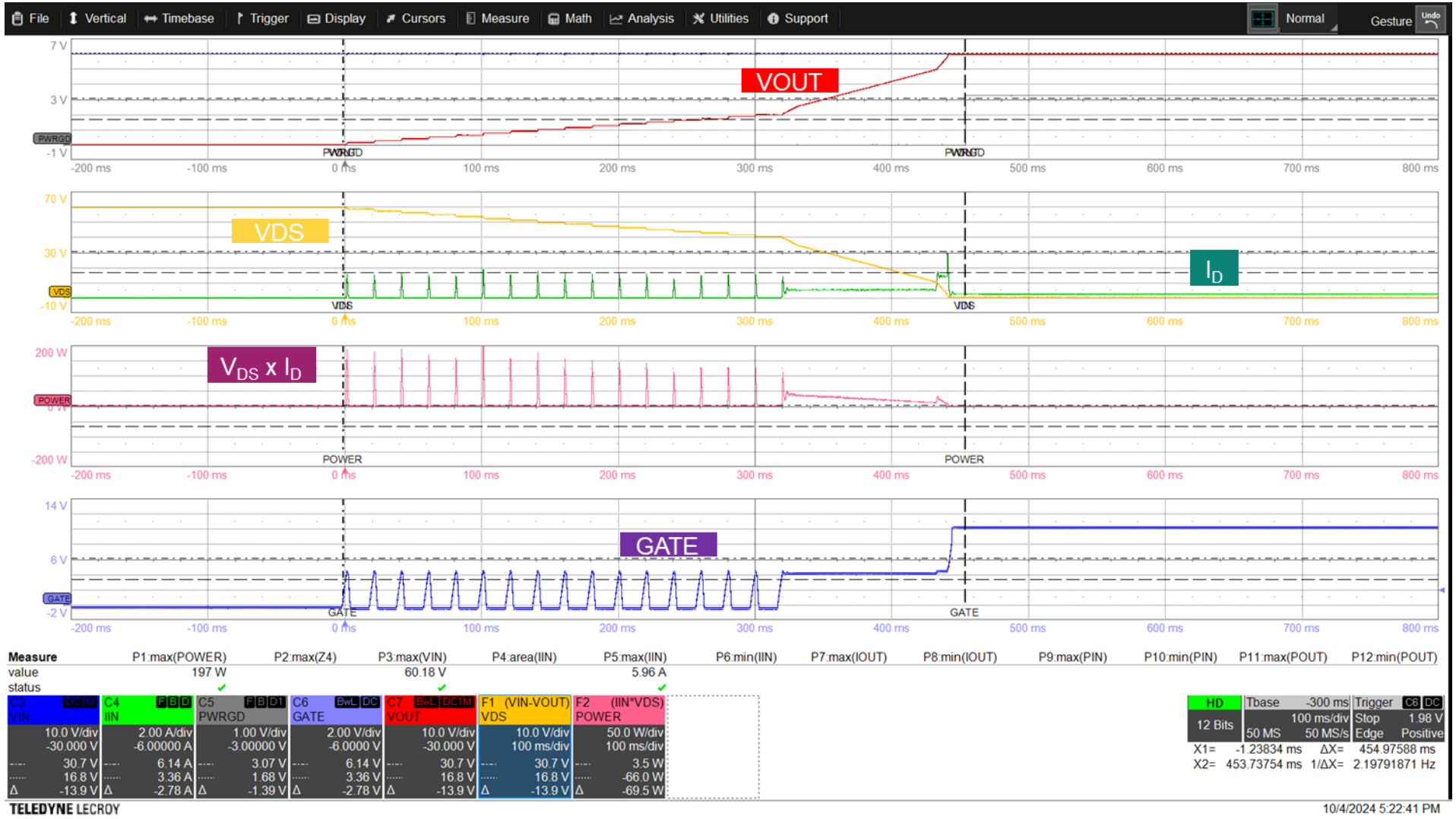
Boost mode implementation



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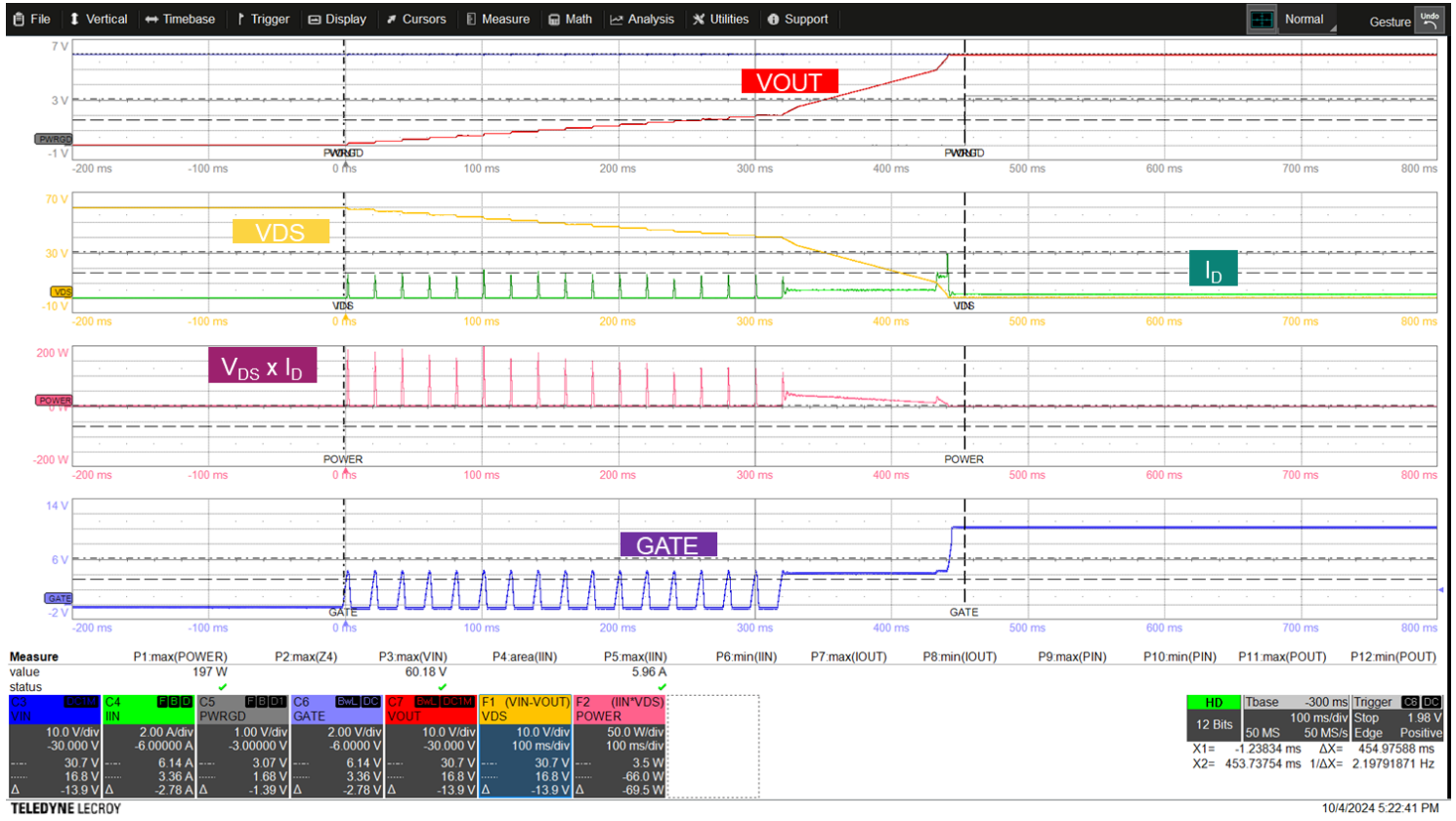
Boost mode implementation



Regulation for 1 ms



Total period: 20 ms



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Startup waveform with 6x IPM018N10NM5LF2 and 9800 uF load capacitance with 166 A OCP level



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Active SOA control

1

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Pulsed SOA current control

2

- "Boost Mode" operates (low SOA) FETs in a pulsed manner
- Allows for FET cooldown for high capacitive loads

Surge immunity protection

3

- Differentiation between surge and short-circuit event
- Increased system availability
- Smooth operation

XDP™ Hot-swap controller



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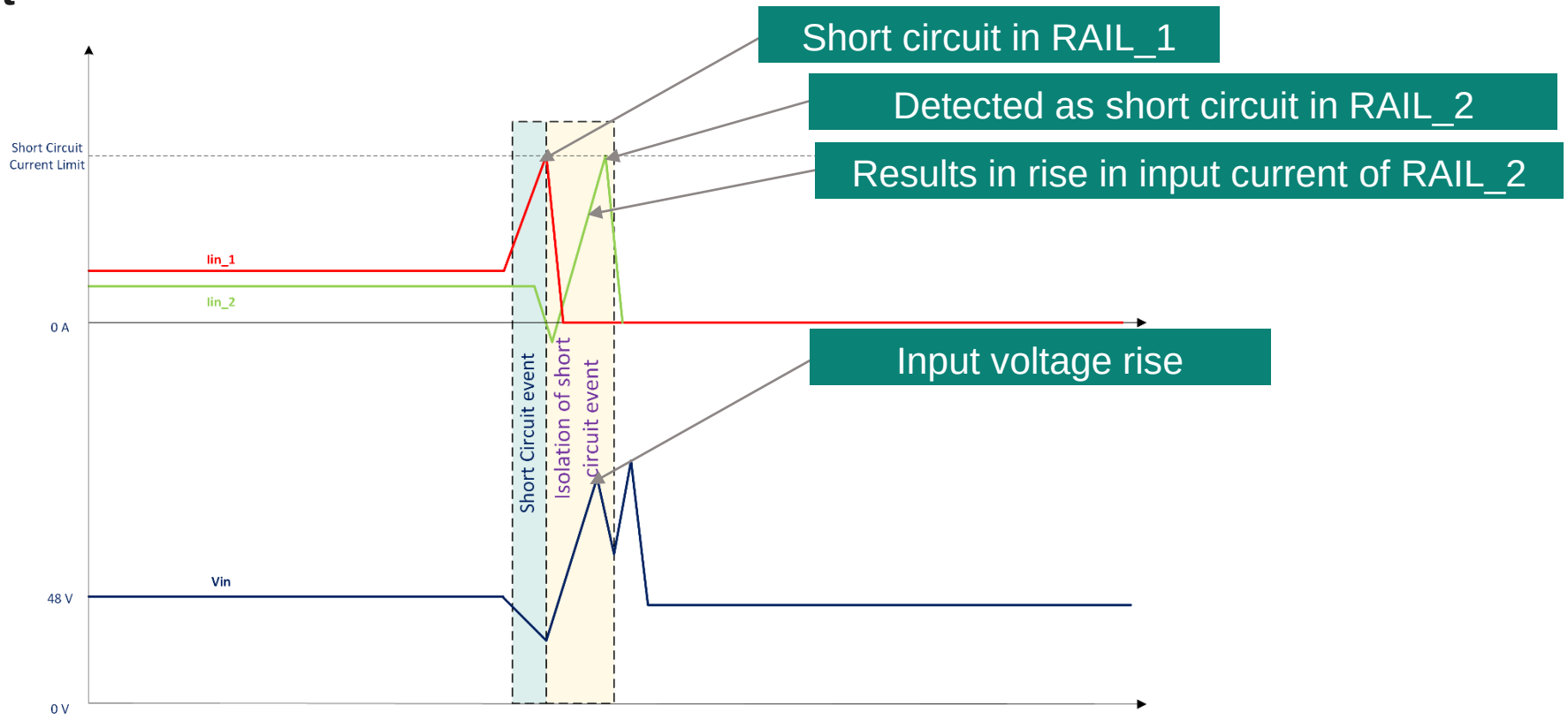
Surge immunity

- If an input voltage surge event occurs due to a short circuit in an adjacent tray or due to high load transient, then it will be detected as a short circuit and trigger a short circuit fault protection and latch off
- Surge immunity increases the **availability of the system** by **differentiating** between an **input voltage surge** and a **short circuit event**



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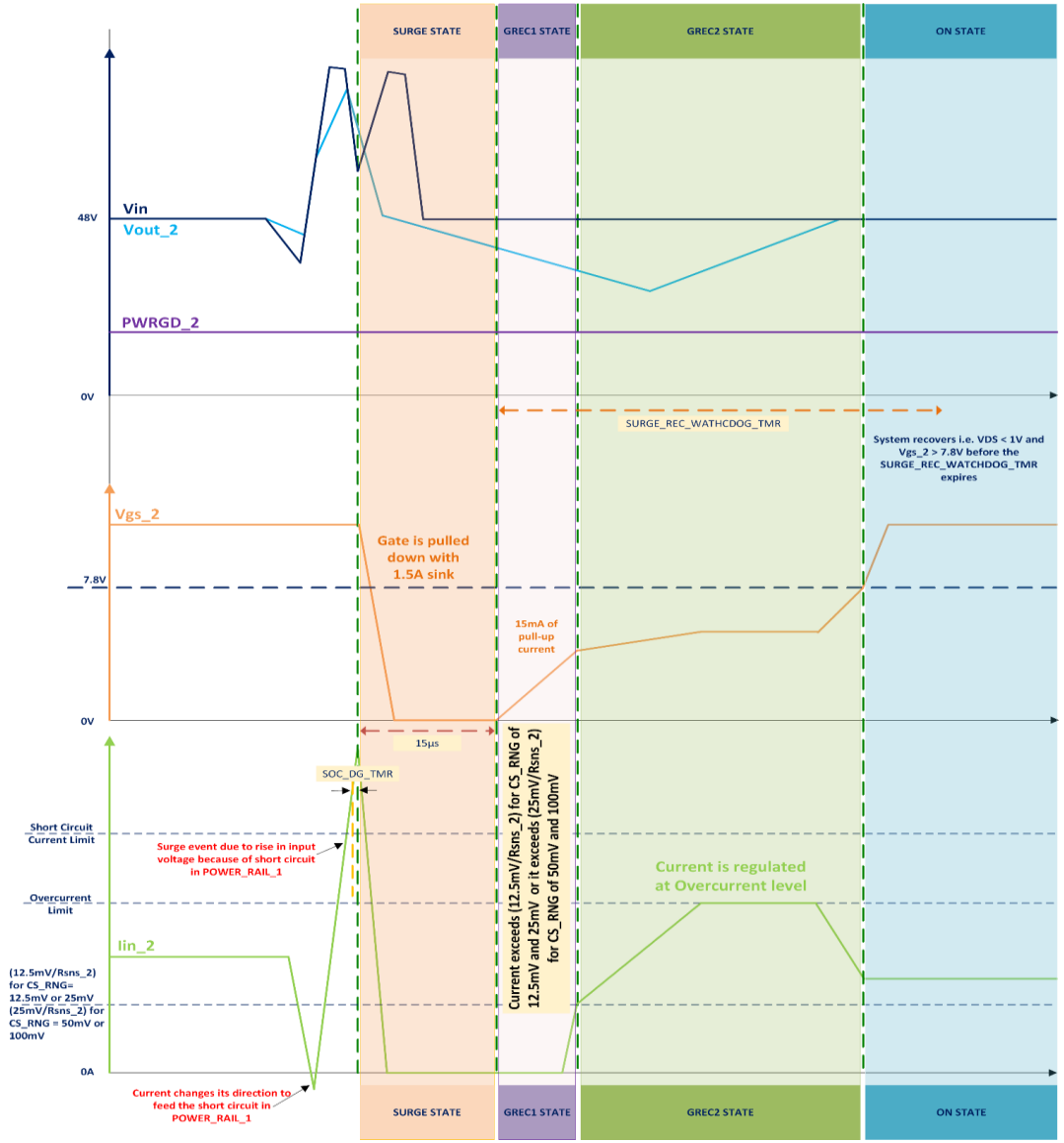
Surge immunity algorithm



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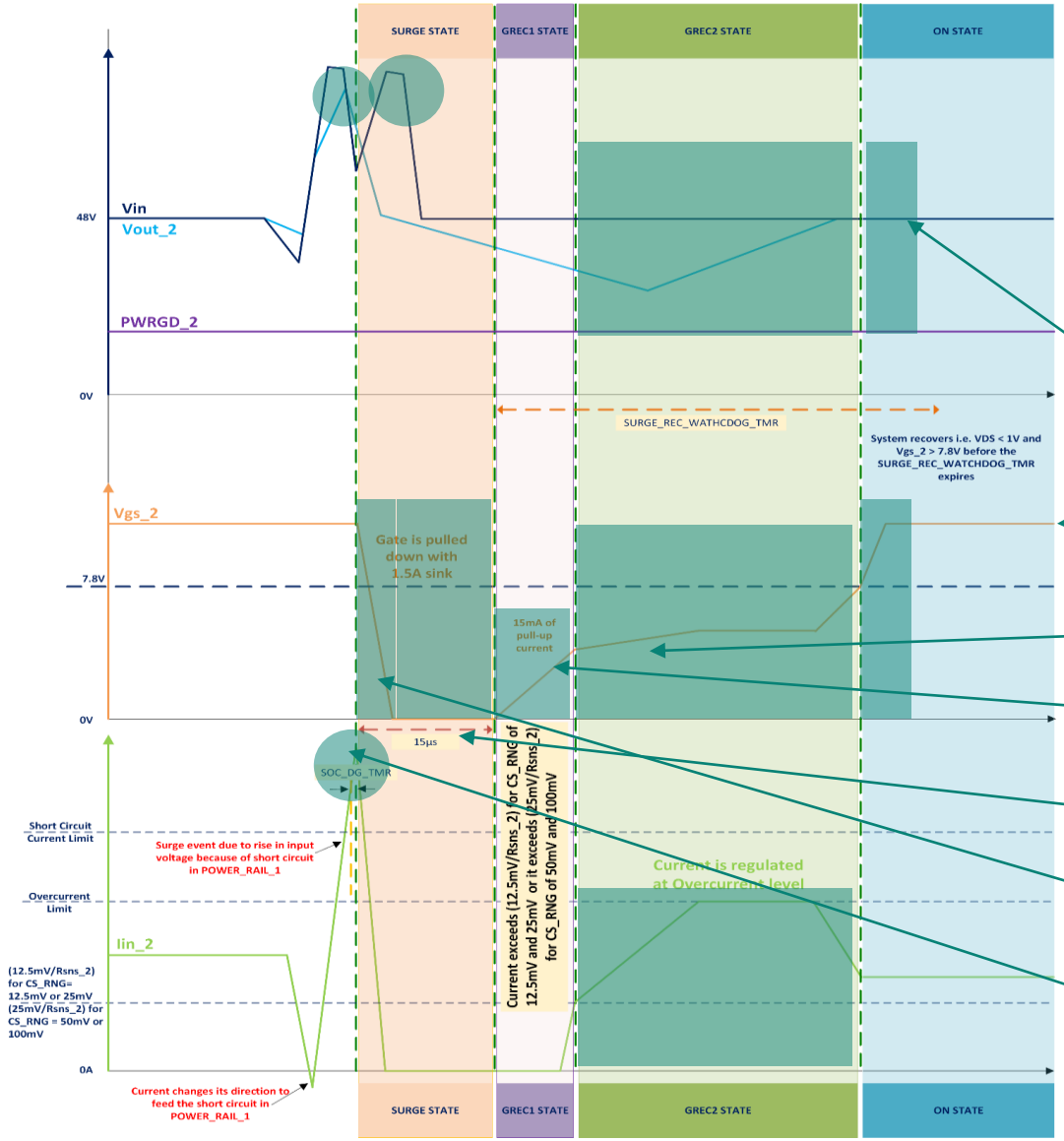
Surge immunity algorithm



System recovered within watchdog time

Current is kept below OC level

Gate is pulled up with 15 mA gate current

Stay off for 15 µs

Gate is pulled low with 1.5 A strength

Surge event is detected

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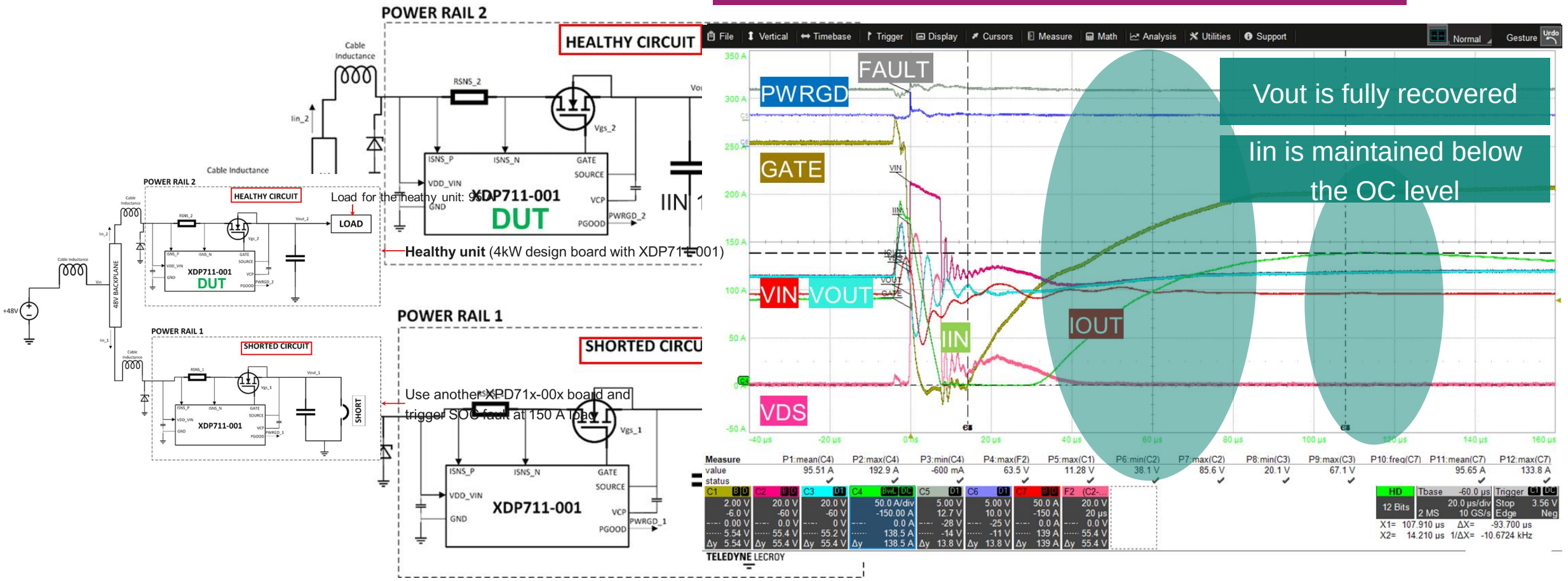
Surge immunity example



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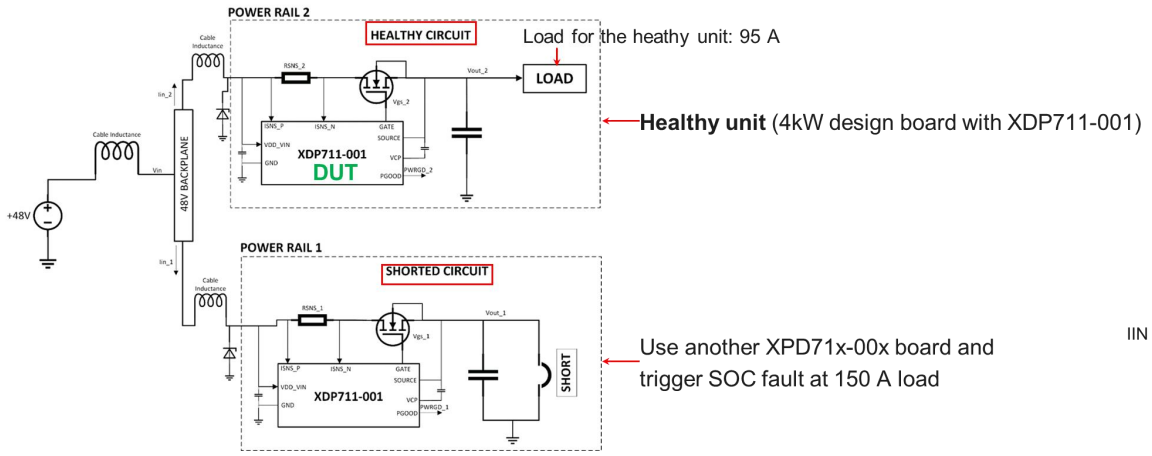
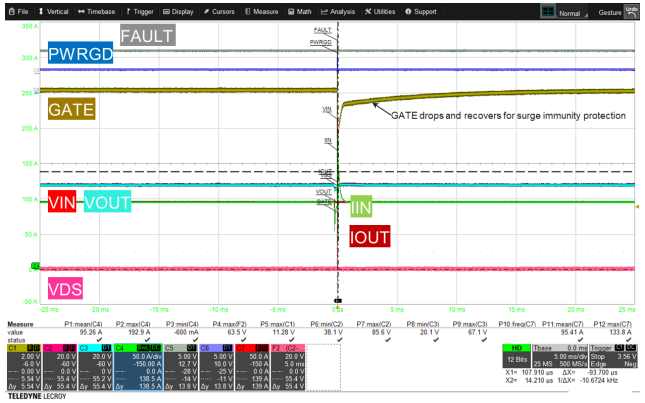
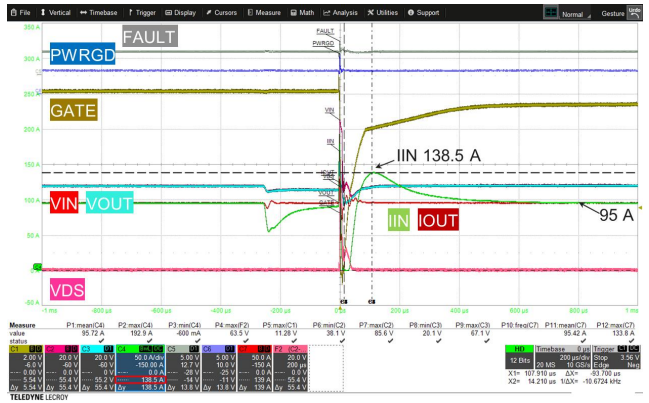
Surge immunity example

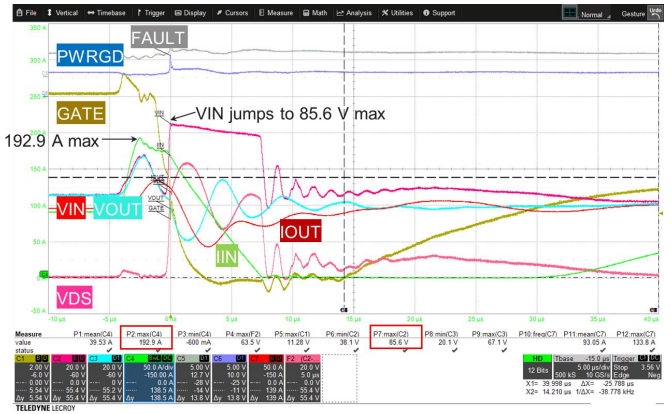


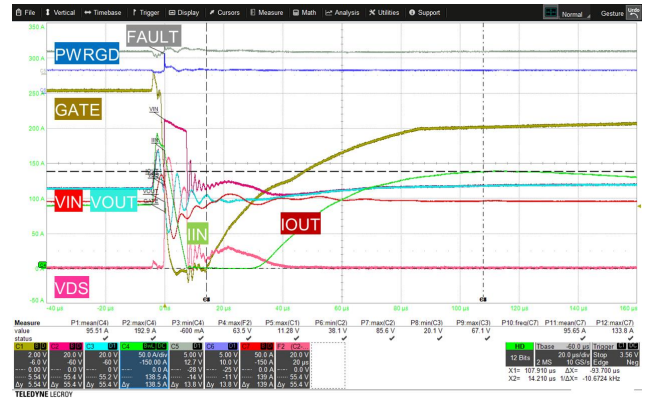
Healthy unit (4kW design board with XDP711-001)

Use another XPD71x-00x board and trigger SOC fault at 150 A load









If surge immunity feature is not to be used, then the digital deglitch shall be added on the short circuit detection to blank the surge current but this adds stress on the MOSFET

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Value proposition to the customer provided by Infineon's XDP™ Hot-swap controller

XDP™ Hot-swap controller



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- Increased system availability
- Smooth operation

4 Programmable blanking timers

- UV and OV deglitch timers to override input voltage sag and transients
- OC deglitch timer to override load transients
- SOC deglitch to override voltage surge

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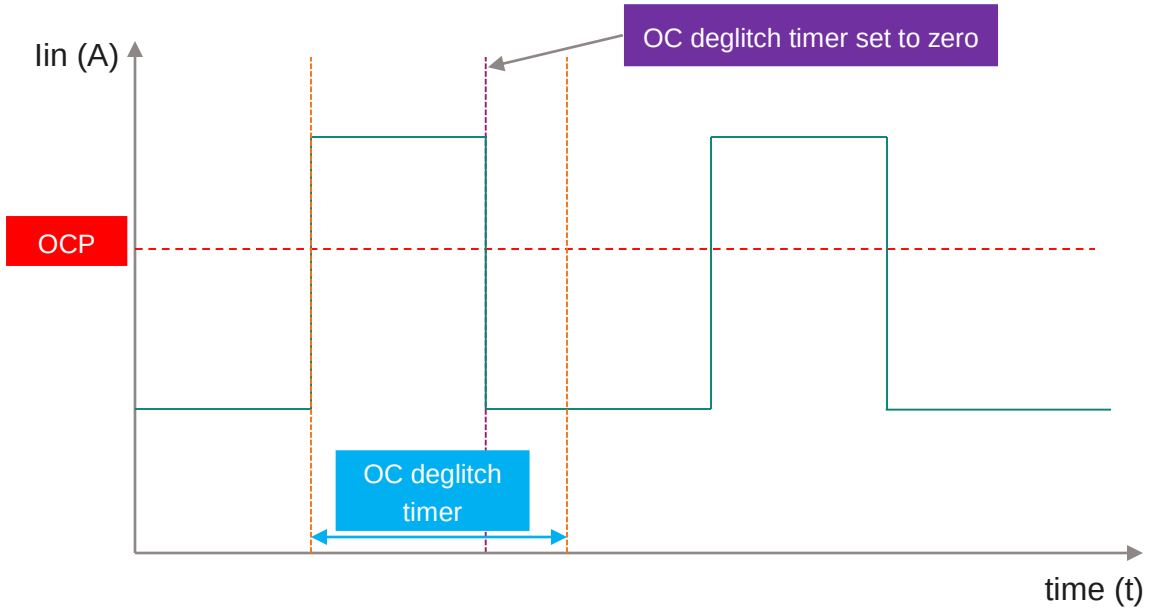
Overcurrent de-glitch timer

When computing highly complex mathematical problems, the GPU in the AI server enters a high performance mode, increasing the power consumption for a short period of time. When these transient currents occur in the system, they shall not cause the system to shutdown abruptly. **De-glitch timers are essential** to override these transient conditions



XDP71x makes use of a **digital de-glitch timer** which starts counting once current goes above OCP level and then clears back to zero once current goes 10% below the OCP level. This enables lower system OCP, which in turns improves the reliability of the system

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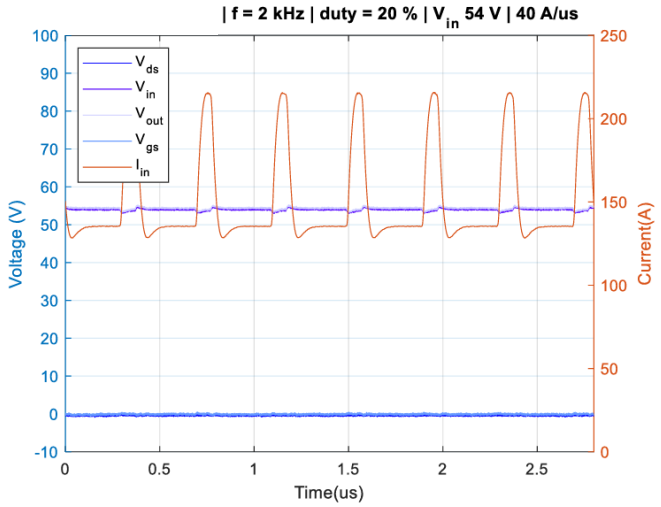
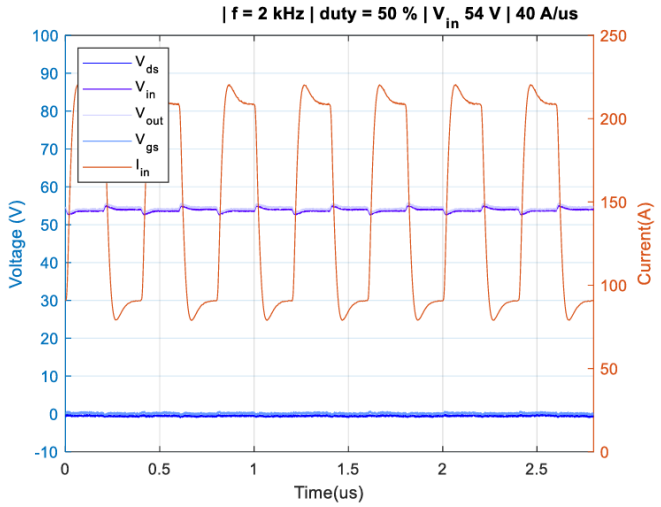
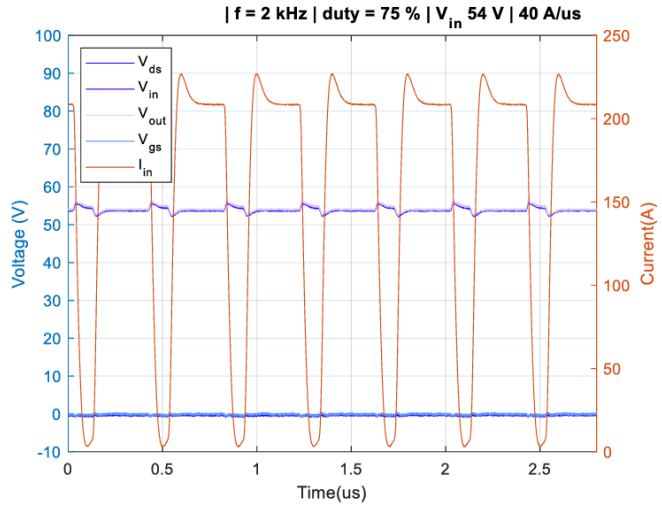
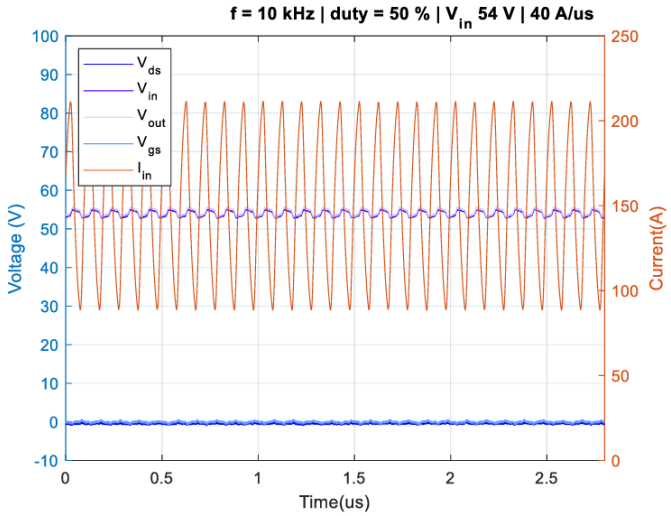
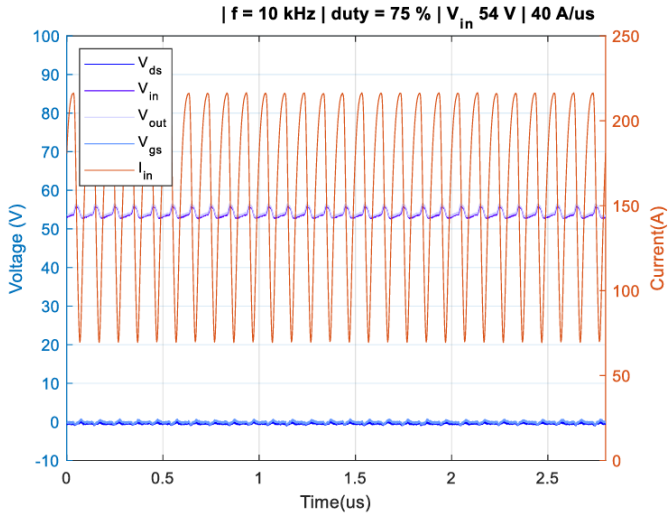
Design example with OCP = 200 A and deglitch of 500 µs

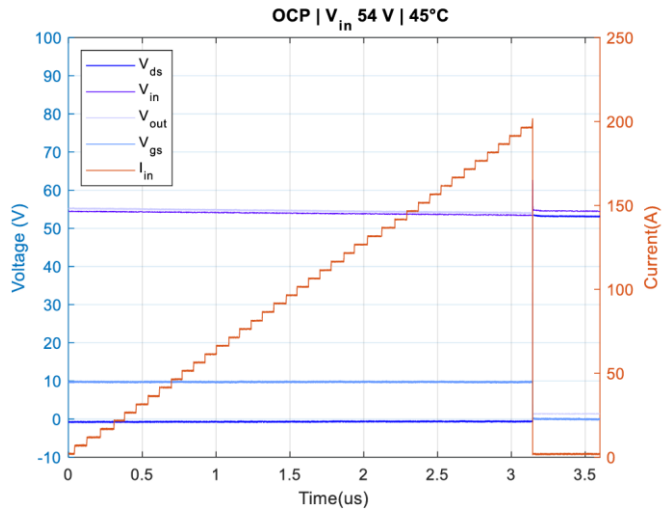












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5 Protection features

- Fast system shutdown to prevent catastrophic failures
- For a robust design along with debugging

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Fast system shutdown

- The power consumptions of the GPUs are increasing exponentially which increase the hot-swap power design levels. High power hot-swap designs require higher short circuit current levels and higher number of total MOSFETs
- For designs with this high short circuit current levels and high number of MOSFETs, the controller needs to have a strong pulldown strength to able to isolate these high level of short circuit currents without damaging the MOSFETs.
- XDP71x offers **fast short circuit detection** (<200 ns) and up to **1.5 A of pull-down current on gate** which allows the short circuit current to be isolated without exceeding the SOA of the MOSFETs.

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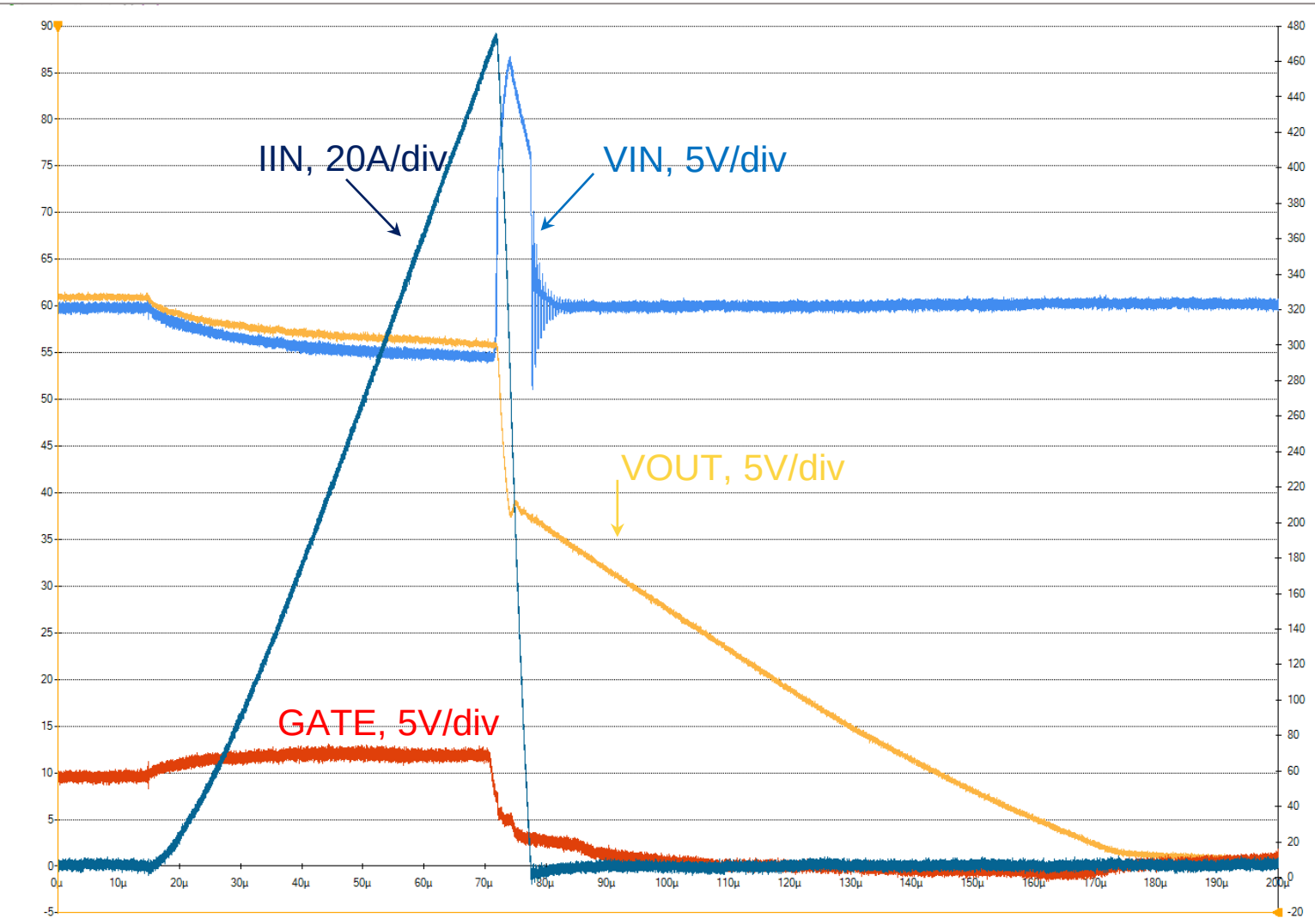
Isolation of SOC fault of 475 A powered by 6x FETs



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6 High-speed communication

- PMBus® v1.3 interface for high accuracy (<1%)
- Better understanding of energy and power usage
- IMON/PMON for load management

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High speed communication and accurate telemetry

- Supports PMBus® communication up to 1 MHz, i.e. telemetry register can be read within 50 us
- Superior **voltage** (≤0.4%), **current** (≤0.75%), **power** (1.15%) and **energy** (2.7%) **reporting accuracy**
- **12-bit** ADC with telemetry data available every **102.4 µs**
- **IMON** provides the analog current monitoring of the input current with a bandwidth up to 1 MHz

- The high telemetry accuracy and high speed of communications allows the user to **monitor the health of system reliably in real-time**
- High speed communication enables the device to function **as a digital oscilloscope** to see the voltage and current behavior
- The highly accurate energy telemetry allows customers to confidently monitor energy usage of the server using this data, without relying on costly and bulky external energy meters

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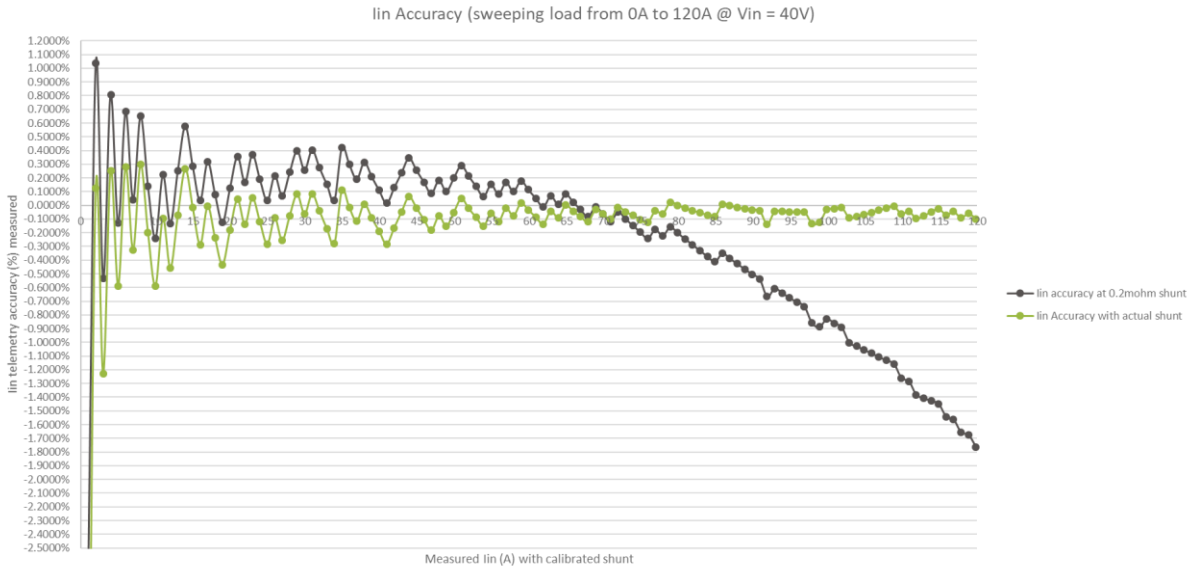
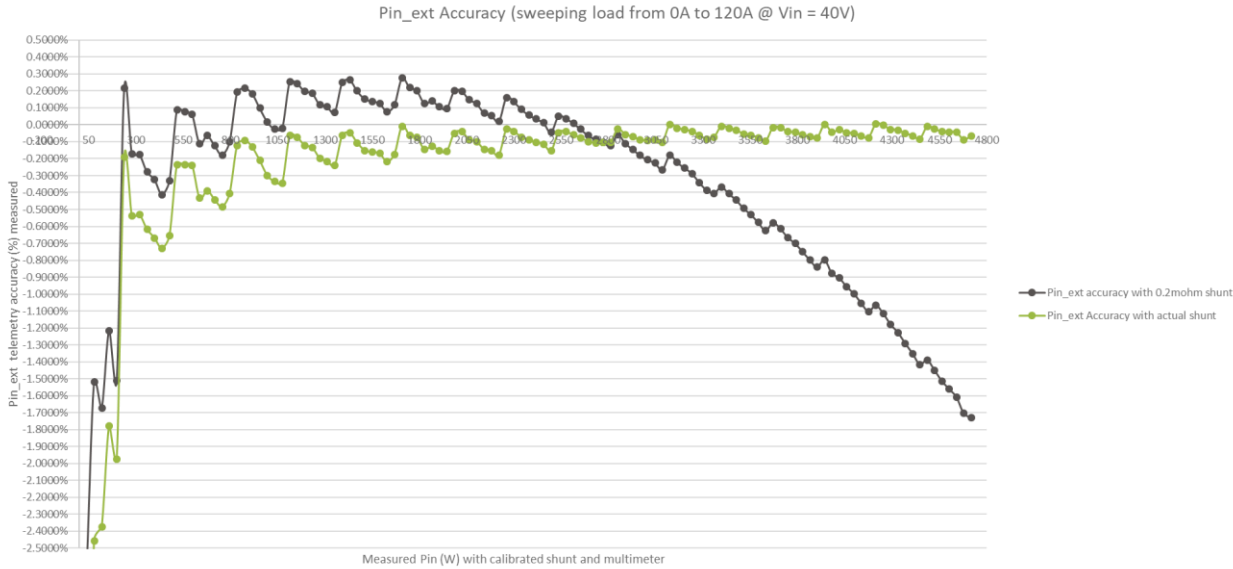
Accuracy test results for input current and power





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Infineon’s eFuse portfolio and key features

Introduction to Infineon's smart eFuses

XDP730 and XDP72x eFuses incorporate an **XDP71x hot-swap controller** + **power MOSFET** + **current sense,** extending the Protection ICs portfolio



Digital hot-swap controller + **NEW** eFuse features

+



Power MOSFET

+



Current sense



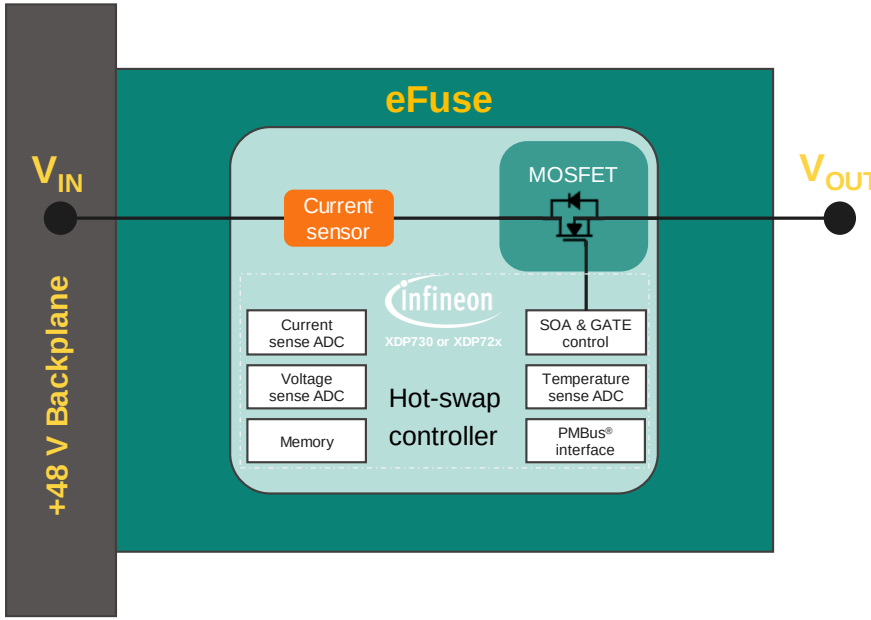
XDP730 for AI server cards, 30 A



XDP720 for base boards, 20 A



XDP721/722 w/o PMBus® for fan control and secondary eFuse for base boards, 20 A



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In addition to available hot-swap controllers, XDP730 and XDP72x eFuses complement the XDP™ Protection IC portfolio



XDP730 eFuse for AI server cards

Key features
- Integrated hot-swap controller, current sensor and low $R_{DS(on)}$ (**1.5 mΩ**) OptiMOS™ FET **30 A**
- PMBus® Interface: **1 MHz**
- Active SOA and surge immunity protection
- 42-lead (7 mm x 7 mm) LIQFN package

Key applications
- 48 V/54 V servers and data centers
- 24 V/48 V industrial systems
- Power distribution systems
- Network routers and switches

Footprint compatibility

Yes, 7 mm x 7 mm QFN-42
eFuses compatible



XDP720 eFuse for base boards

Key features
- Integrated hot-swap controller, current sensor and low $R_{DS(on)}$ (**3.2 mΩ**) OptiMOS™ FET **20 A**
- PMBus® Interface: **1 MHz**
- Active SOA and surge immunity protection
- 23-lead (6 mm x 5 mm) LIQFN package

Key applications
- Fan control applications
- 48 V/54 V servers and datacenters
- 24 V/48 V industrial systems
- Power distribution systems
- Network routers and switches

Footprint compatibility

Yes, 6 mm x 5 mm QFN-23
eFuses compatible



XDP721/722 eFuse for fan control

Key features
- Integrated hot-swap controller, current sensor and low $R_{DS(on)}$ (**3.2 mΩ**) OptiMOS™ FET **20 A**
- Fault response: auto-retry (XDP722) or latch-off (XDP721)
- 23-lead (6 mm x 5 mm) LIQFN package

Key applications
- Fan tray/control applications
- 48 V/54 V servers and data centers
- Power distribution systems
- Power supplies
- Test equipment

Footprint compatibility

Yes, 6 mm x 5 mm QFN-23
eFuses compatible



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Value proposition to the customer provided by Infineon's XDP™ eFuses

Active SOA control

1

- Programmable current limits
- Faster turn-off of the FET within safe SOA limits

XDP™ eFuses



Surge immunity protection

3

- Differentiation between surge and short-circuit event
- Increased system reliability
- Smooth operation

High-speed communication

6

- Highly accurate telemetry
- Better understanding of energy and power usage
- IMON for load management

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Value proposition to the customer provided by Infineon's XDP™ eFuses

Active SOA control

1

- Programmable current limits
- Faster turn-off of the FET within safe SOA limits

Small integrated solution

2

- Smaller application footprint
- Common footprint, easier co-layout
- Reduction in system BOM
- Minimum external components

New

XDP™ eFuses



Surge immunity protection

3

- Differentiation between surge and short-circuit event
- Increased system reliability
- Smooth operation

High-speed communication

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Small integrated solution
Cost effective, low BOM and easy to design

- **Hot-swap controller**, power **MOSFET**, and **current sensor** have been integrated into **one single device / package**
- Most of the configuration of the part is done **digitally,** leading to an even **less BOM usage** and the following advantages:
  - Configuration can be modified without altering the components → **reduced design time**
  - Low BOM usage **reduces supply chain issues, second sourcing** and **inventory**

- Small and **compatible** footprints of 7 x 7 mm and 6 x 5 mm enable a **compact, high-power density design**
- This allows for **easily co-layout** with our competitors' eFuses on the same board

Customer value

See next slide for PCB area savings of eFuse compared to 1.2 kW hot-swap solutions

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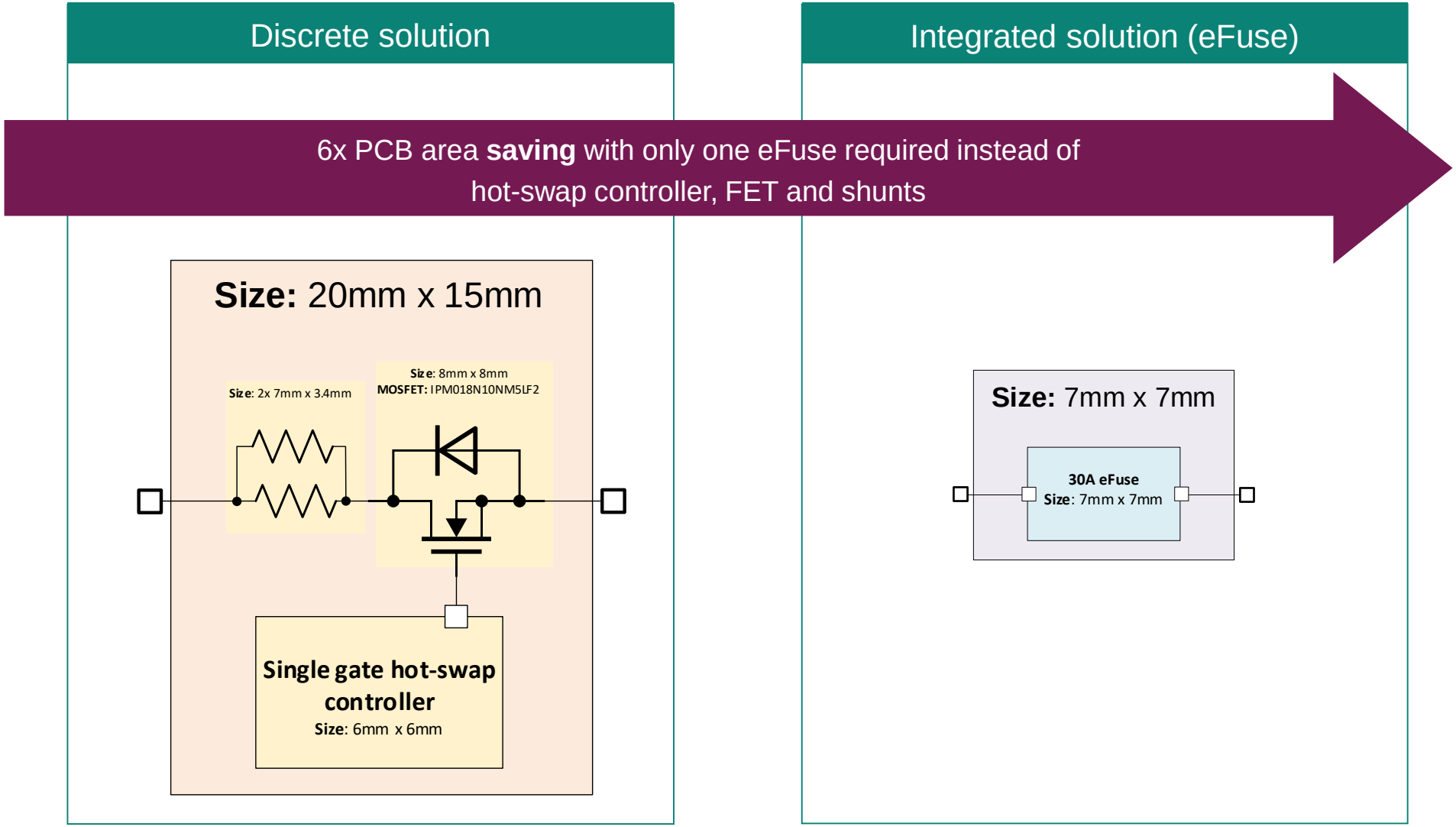
1.2 kW hot-swap solution vs eFuse

eFuse integrated solution allows for 6x PCB area saving



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Value proposition to the customer provided by Infineon's XDP™ eFuses

Active SOA control

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New

Surge immunity protection

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- Smooth operation

XDP™ eFuses



Stackable solution

New

4

- Integrated gate driver
  - Capability for current sharing at startup
  - Fast switch-off
- Achieving higher output current

High-speed communication

6

- Highly accurate telemetry
- Better understanding of energy and power usage
- IMON for load management

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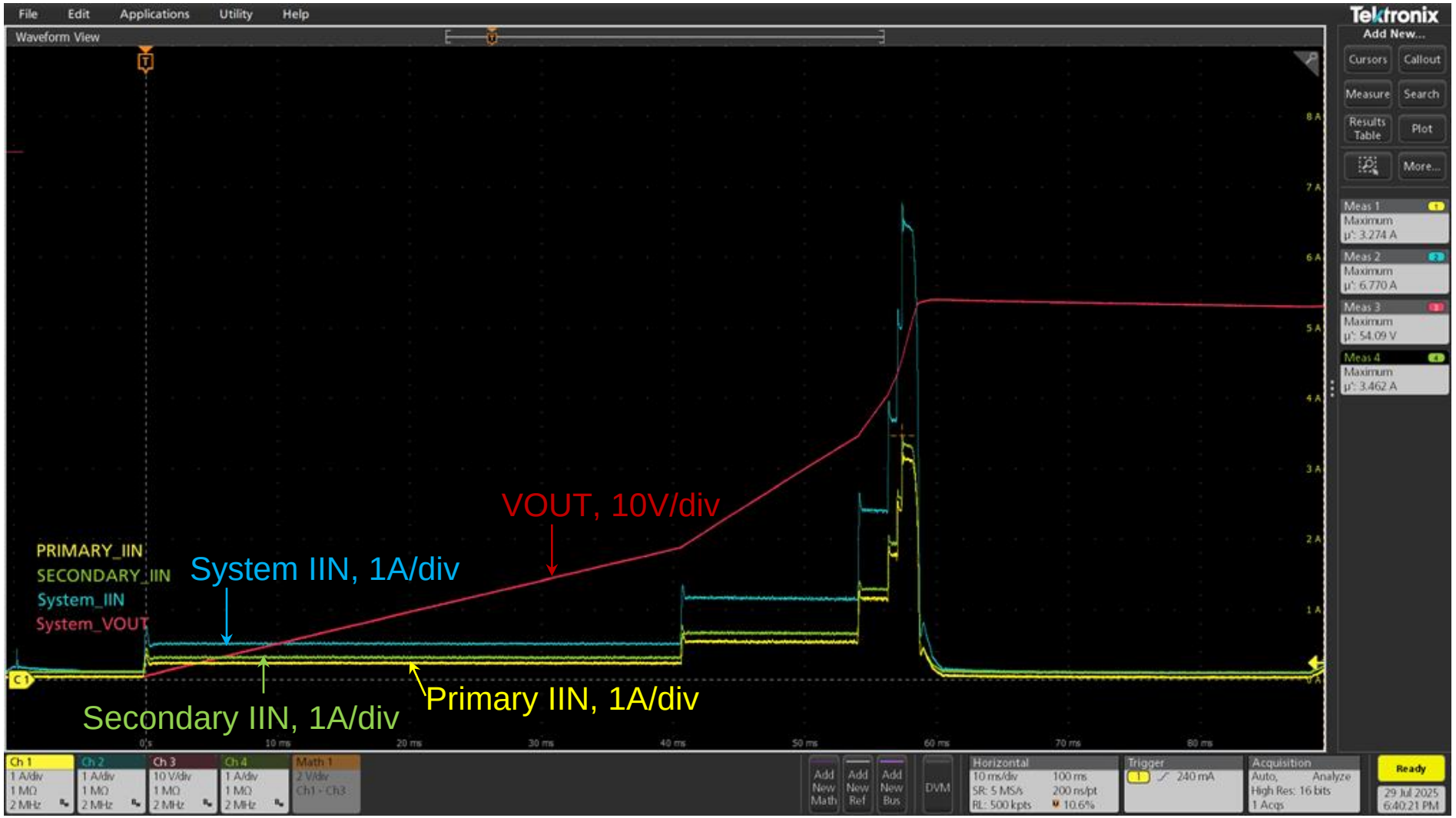
XDP730-001 parallel operation: turn-on

- VIN = 54 V
- Cout = 1 mF
- EN pulled to 3.3 V



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Value proposition to the customer provided by Infineon's XDP™ eFuses

1 Active SOA control
- Programmable current limits
- Faster turn-off of the FET within safe SOA limits

2 Small integrated solution
- Smaller application footprint
- Common footprint, easier co-layout
- Reduction in system BOM
- Minimum external components

New

3 Surge immunity protection
- Differentiation between surge and short-circuit event
- Increased system reliability
- Smooth operation

XDP™ eFuses



4 Stackable solution
New
- Integrated gate driver
  - Capability for current sharing at startup
  - Fast switch-off
- Achieving higher output current

5 Protection features
- Robust design with debugging
- 3-level of OCP (system OC, local OC, and SOC)

New
- Adjustable restart wait time (0.58 s to 74.2 s)
- Primary/secondary FS and SYNC

6 High-speed communication
- Highly accurate telemetry
- Better understanding of energy and power usage
- IMON for load management

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EVAL boards overview
XDP™ eFuses

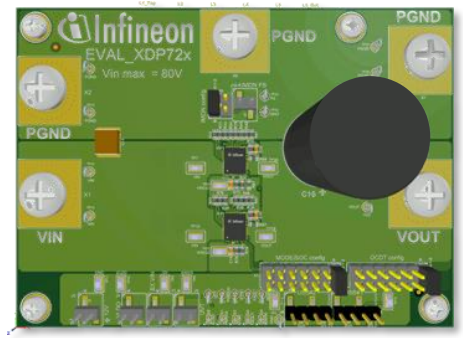
EVAL_XDP730-001

- Features **XDP730 eFuse** with integrated digital controller, current sensor and a low $R_{DS(on)}$ (**1.5 mΩ**) OptiMOS™ FET with up to 30 A continuous current carrying capability
- Current sharing to achieve higher output current
- To evaluate XDP730 with **three or two eFuses** in parallel, **or single** eFuse
- Port for XDP™ Designer dongle
- Configurable 3.3 V/5 V bias
- On board I^2C pull-ups



EVAL_XDP72X-001

- Features **XDP720** (with PMBus®) and/or **XDP721/722** (w/o PMBus®) eFuse with integr. digital controller, current sensor and a low $R_{DS(on)}$ (**3.2 mΩ**) OptiMOS™ FET with up to 20 A continuous current carrying capability
- Current sharing to achieve higher output current
- One single EVAL board to evaluate **XDP720/721/722 or combinations**
- Port for XDP™ Designer dongle
- Configurable 3.3 V/5 V bias
- On board I2C pull-ups



Evaluation board

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Collaterals and support

Collaterals and support - hot-swap controllers and eFuses

** Coming soon*

Product Materials	• Webpages • Product Brief • Data Sheet • Selection Guide • Product Presentation • Eval Boards	– Protection & Monitoring ICs | XDP730* | XDP720* | XDP721* | XDP722* | XDP711 | XDP710 | XDP700 – Product Brief XDP730/72x* | XDP711 | XDP710 | XDP700 – Datasheet Prelim. XDP730* | Prelim. XDP720 | Prelim. XDP72x | XDP711 | XDP710 | XDP700 – Product Selection Guide (PSSG26/26) – Product Presentation eFuses XDP7xx* | Hot-swap controller XDP7xx – EVAL_XDP730-001* | EVAL_XDP72x-001* | EVAL_XDP711-001 | EVAL_XDP710_V2 | EVAL_XDP700 |
Technical Materials	• App Notes • XDP™ GUI • PMBus® Document • XDP7xx User Manual • Qualification • Migration Guide	– External fast switch-off circuit XDP710 App Note – GUI download https://softwaretools.infineon.com/tools/com.ifx.tb.tool.xdpdesigner – PMBus® Commands documents XDP711 | XDP710 | XDP700 – XDP7xx Gang Programmer User Manual – Product Qualification Report XDP711 | XDP710 | XDP700 – Migration XDP711
Other	• Whitepaper • Podcast4Engineers • Technical Article	– AI server hot-plugging Whitepaper | Why integrated eFuse matter for AI-era PSUs Whitepaper – “Powering the future of AI” Whitepaper | DR-HSC IBC topology solution Whitepaper – Podcast episode “Protection ICs in AI data centers” www.infineon.com/wepoweraipodcast – Bodo’s Power Systems®: AI server hot-plugging with robust hot-swap controllers (Jan 2025) – PSD (Power Systems Design) North America: Infineon eFuses for AI server power applications (Dec 2025)

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