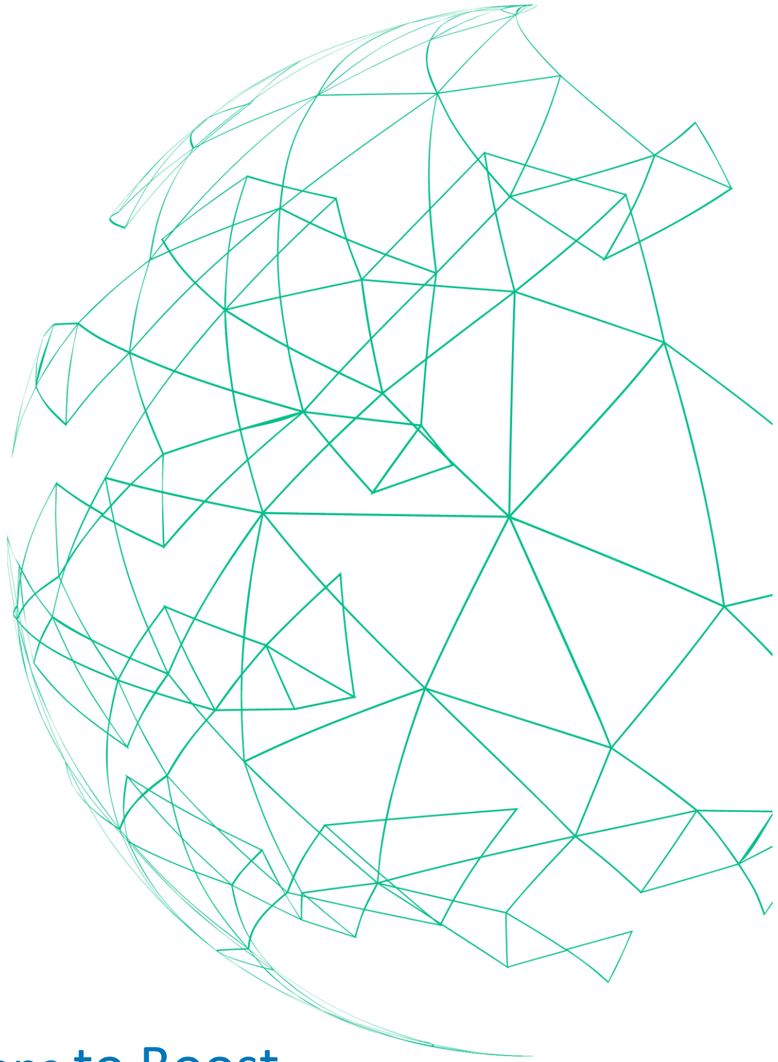


200-mm GaN-On-Silicon Intelligent Power Solutions to Boost Performance of a New Generation of Power Converters.

Eric Moreau

Exagan

Spin off SOITEC & CEA-LETI

Created in 2014 - employees

2 sites in France – 1 in Taiwan

3 Industrial partnerships (MFG, Sales, Quality)

Focus on GaN 650..1200 V Power Switch Solutions

Unique 200 mm GaN/Si technology

Fab-light industrial model, in-house epitaxy

Global go-to-market strategy coupled with regional sales deployment

FAB FUTURE ELECTRONICS

Joint Dev. Collaboration

Grenoble

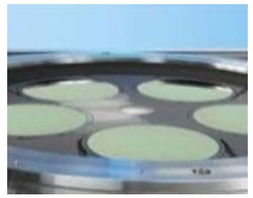
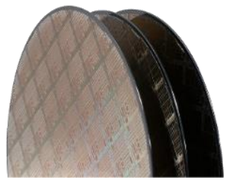
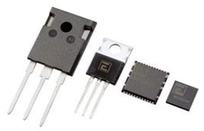
Toulouse

Taipei

Exagan's Fab-light Model with Established 200 mm Supply Chain

- **Robust & cost competitive manufacturing, for high volume production with limited CAPEX on materials using standard CMOS manufacturing**

Exagan Manufacturing

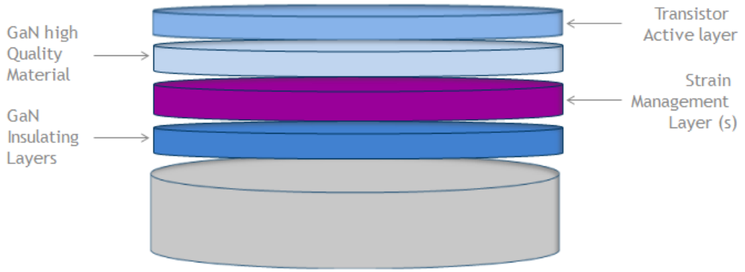
Exagan direct manufacturing & volume shipment	Process transfer to partner (exclusive)	Test transfer to partner (exclusive)
 STEP 1 Material	 STEP 2 Process	 STEP 3 Packaging/Test
▰ MFG fab in France ▰ Standard & automated ▰ Equipment ▰ Process = 1 equipment	▰ Fabs in Germany and France ▰ Standard CMOS 200mm ▰ No specific CAPEX ▰ High capacity available	▰ Standard packaging lines ▰ Very high-volume production ▰ Automated testing ▰ Turnkey service: direct shipment to customers
		

Customers

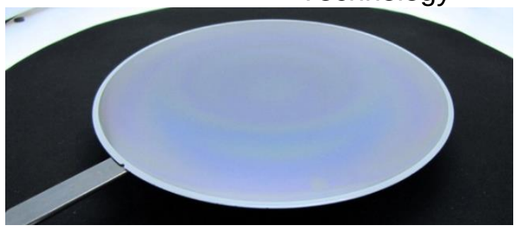
Fab light
- Volume scalability
- Cost competitiveness
- Full technology control

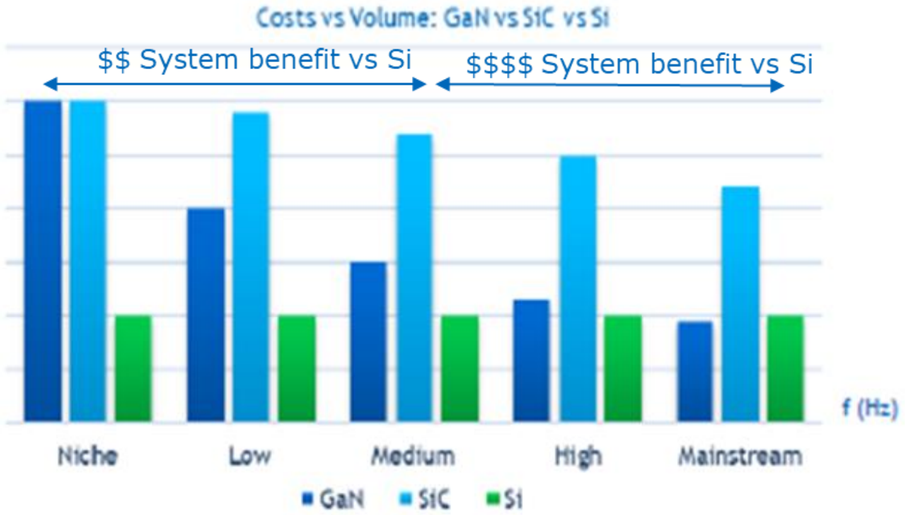
200-mm GaN-Si: Silicon Scability, High Quality and Competitive Cost

G-Stack™ : Enabling Ultimate balance between GaN thickness, quality & flatness on Si 200 mm



Patented Technology



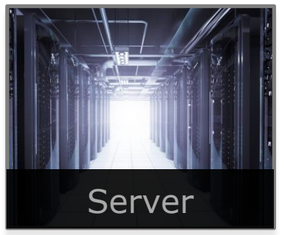


Designing Products for Outstanding Standards

From JEDEC JC70-1 to AECQ100/101

eV/pHeV
on board and fast charging

Integrated
power supply USB-PD



Compact & energy
efficient server

Solar inverter
& micro-inverter

UPS
motor drive

Aircraft
electrification

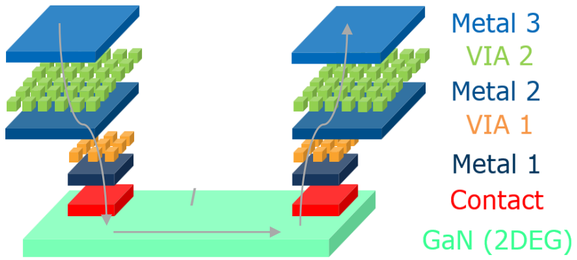
Integrated
supply

Design for the most demanding application in terms of quality and reliability

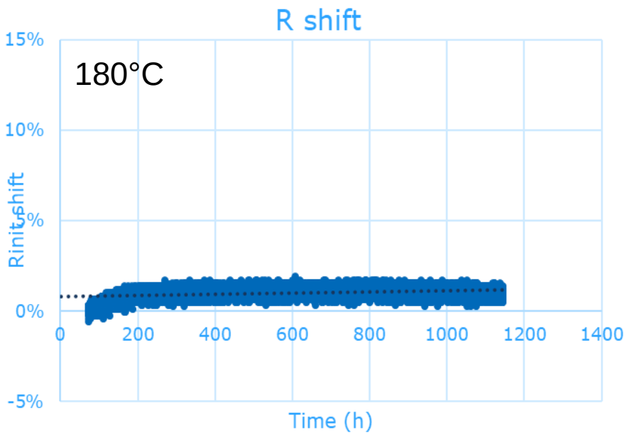
Material & Device Based Reliability Testing

2DEG & contact reliability

Elementary test structure

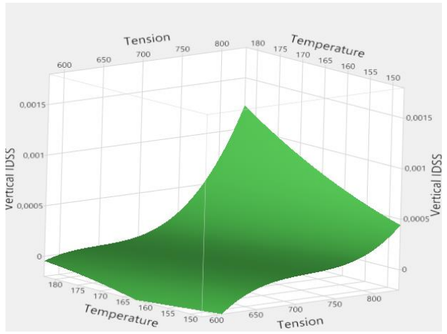


Continuous resistance monitoring

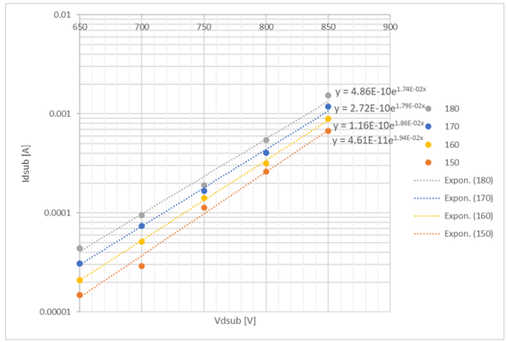


GaN-On-Si EPI Lifetime

DC EPI leakage measurements

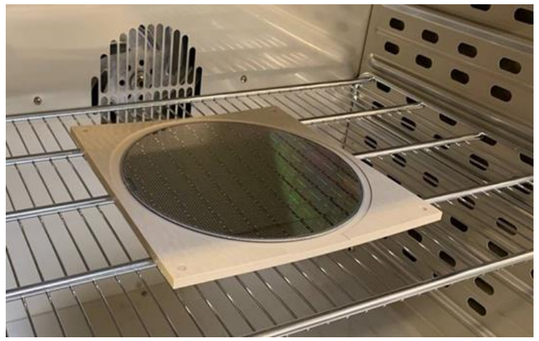


DC EPI leakage model

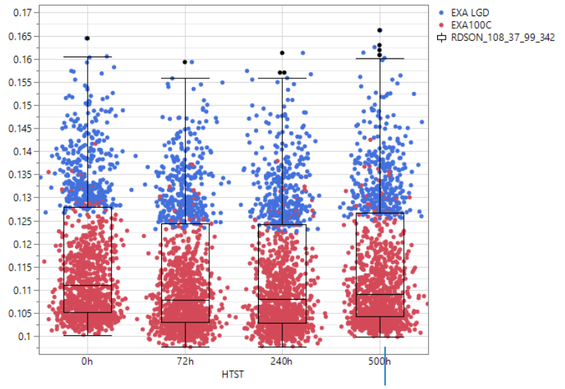


Thermionic emission $I_{sub} = T^2 * e^{\frac{-2.9*10^{-10}}{kT}} * e^{\left(\frac{1.8*10^{-22}}{kT} - 1.1*10^{-2}\right)V_{sub}}$

Critical parameters drifts on wafer level



Ex: Rdson

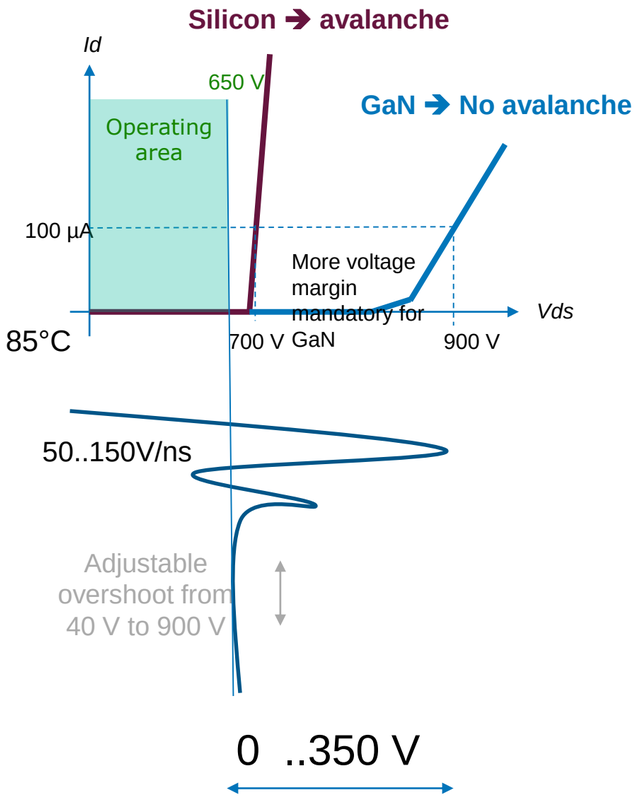


210°C / 1000 Hrs

Today : 45 Years less than 1 ppm 400 V/ 85°C

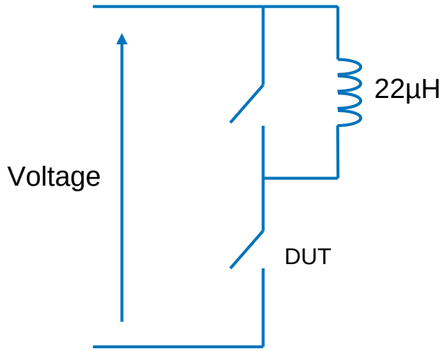
Product Use Case(s) Reliability Testing

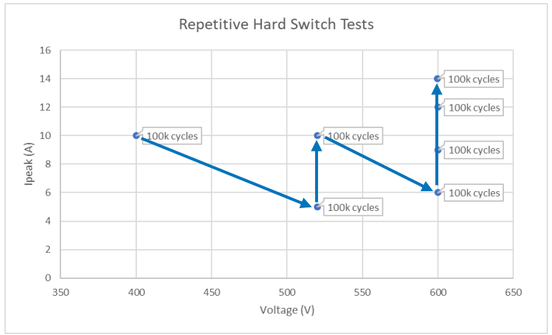
Repetitive HV Spikes



Leakage monitoring (Cp/Cpk) >> 10M spikes

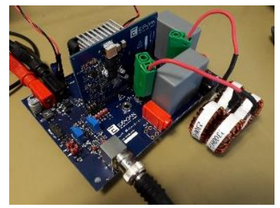
Repetitive hard switching

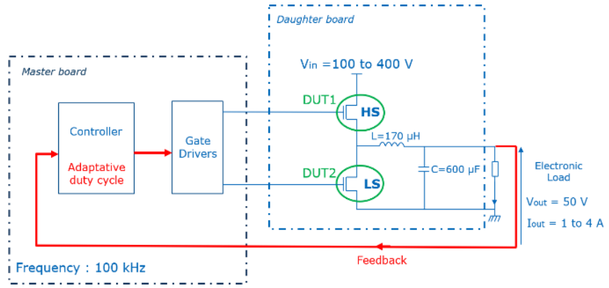




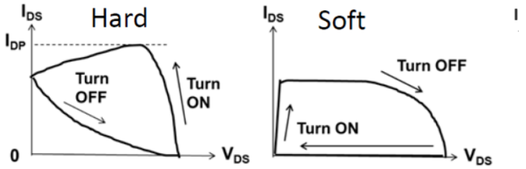
- 400 to 650 V
- 1…to Max DC Amp.
- 25°C & 150 °C

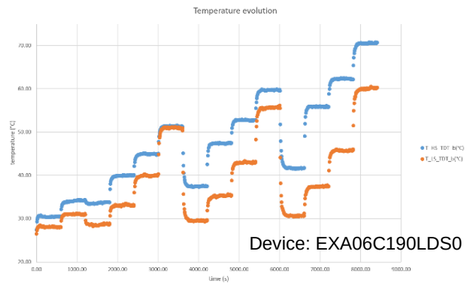
Buck/Boost Converter





Switching/Locus modes





Different magnetizing energies

&

Monitoring Tcase switches/Efficiencies

Exagan's Product Portfolio,

Easy to Use

G-FET™

650V Transistor

Safe and Powerful Switching

G-DRIVE™

650 V Transistor + Driver

Intelligent and Fast Switching

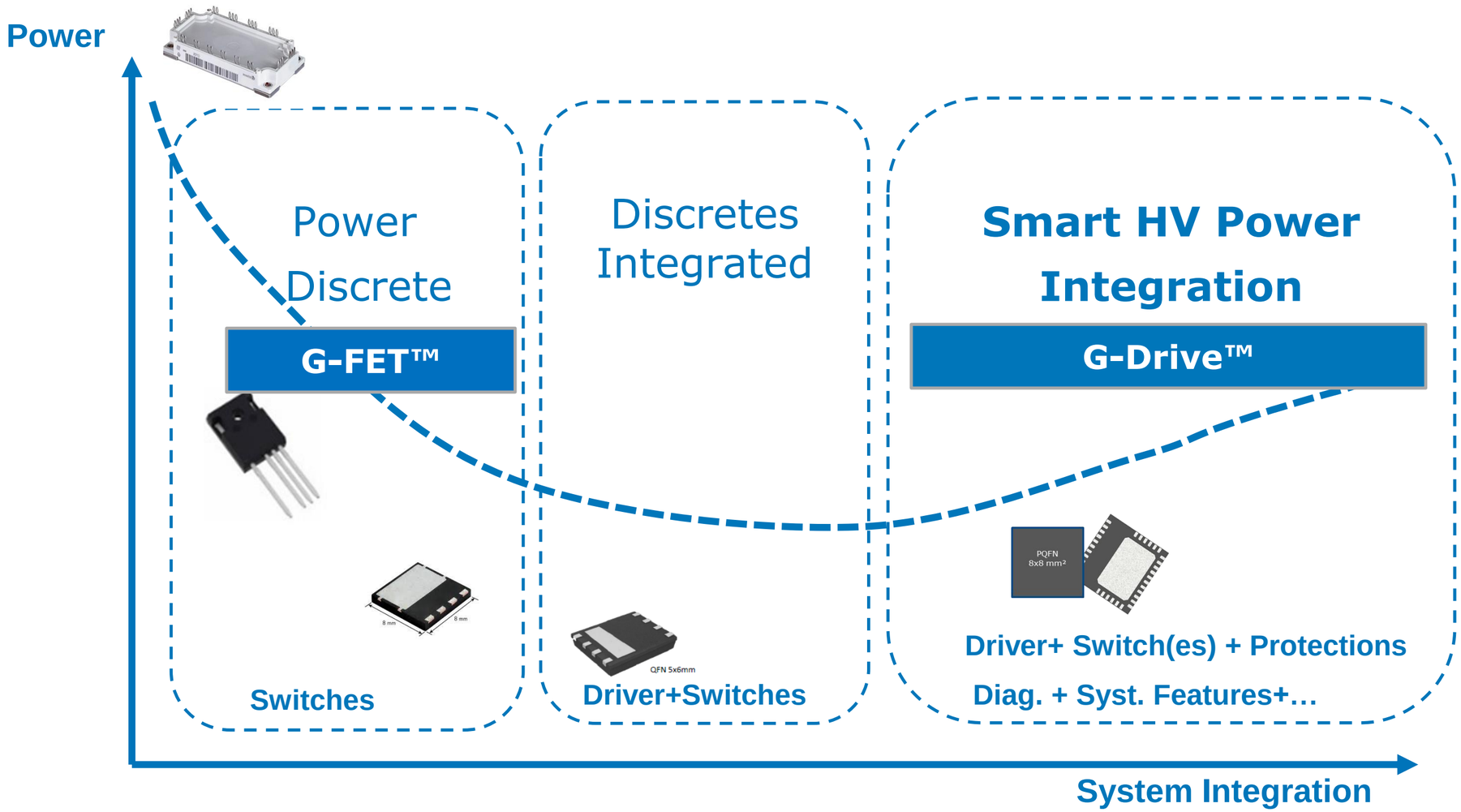
Integration

	TRANSISTOR	+ DRIVER
Technology	▰ GaN MIS Transistor ▰ Standard analog gate control	▰ Based on G-FET with embedded intelligent driver ▰ Digital Control (MCU)
Features	▰ < 500 kHz switching ▰ <10 up to 75 A capability ▰ Standard Silicon driver (external) ▰ Implementation in existing and new designs	▰ Up to 3 MHz switching ▰ Integrated protection & diagnostic ▰ High speed current monitoring capability
Applications	▰ Consumer power supply (Cost competitiveness, < 100 W) ▰ Automotive Charger (On/Off board) (High Reliability, 3-20 KW)	▰ High end consumer power supply (> 100 W) ▰ Datacenter power supply (KW) ▰ Industrial motor control ▰ Automotive DC/DC (1.5 KW)

Product roadmap

2019	2020	2021
Generic product portfolio	Application specific standardized products	Automotive qualified products

GaN Discrete to Smart Power Integration Solution



G-FET™ Series

G-FET™

Safe and Powerful

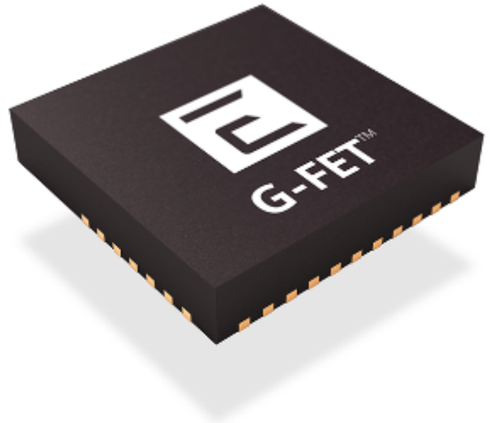
- Broad power range
- Easy system implementation
- Rugged gate

Product features

System design	Analog power
Driving	+/- 20V analog

Benefits for power-conversion designers include:

- Compatibility with standard silicon drivers
  - 10-volt analog signal to control the gate
  - Robust gate with a maximum rating of ± 20 V
  - No gate leakage
  - No negative voltage to force in off-state
- Gate return pin to reduce the switching inductance loop



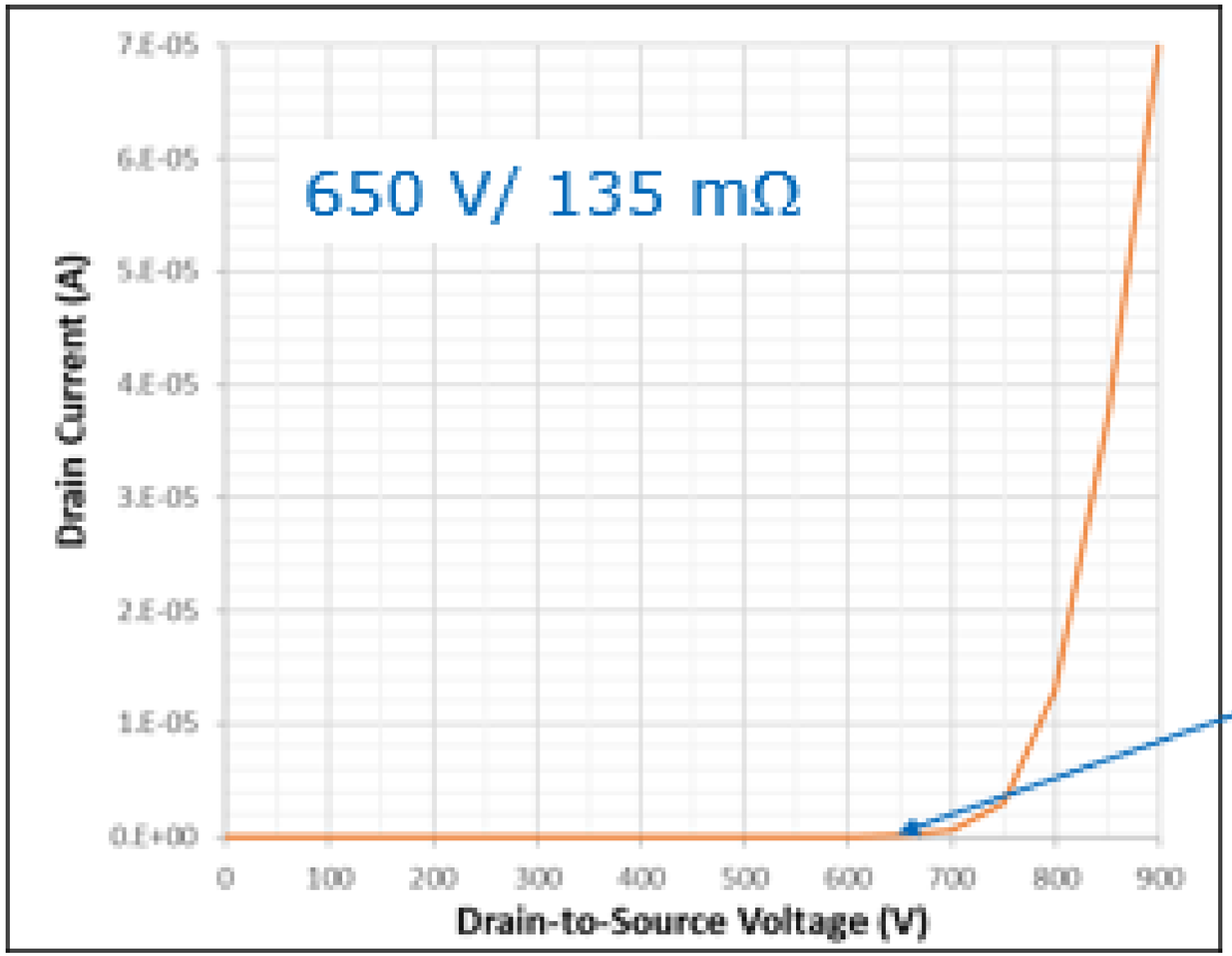
650 V products portfolio

	Part number	$R_{DS\,(on)}$ (mΩ)[3]	I_{D25} (A)[3]	I_{DM} (A)[3]	C_{OSS} (pF)[3]	Package	
G-FET™	EXA06C190LDS0	190	10	30	45	PQFN8x8	
	EXA06C135LDS0	135	25	75	65	PQFN8x8	
	EXA06C075LDS0	75	30	90	110	PQFN8x8	
	EXA06C050XDS0	50	40	120	145	TO247-4L	
	EXA06C030HSS0	30	75	225	240	PQFN15x15	

Exagan GaN technology

650 V Optimized soft breakdown

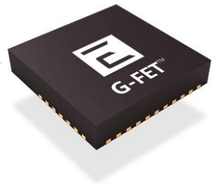
< 100 µA @ 900 V



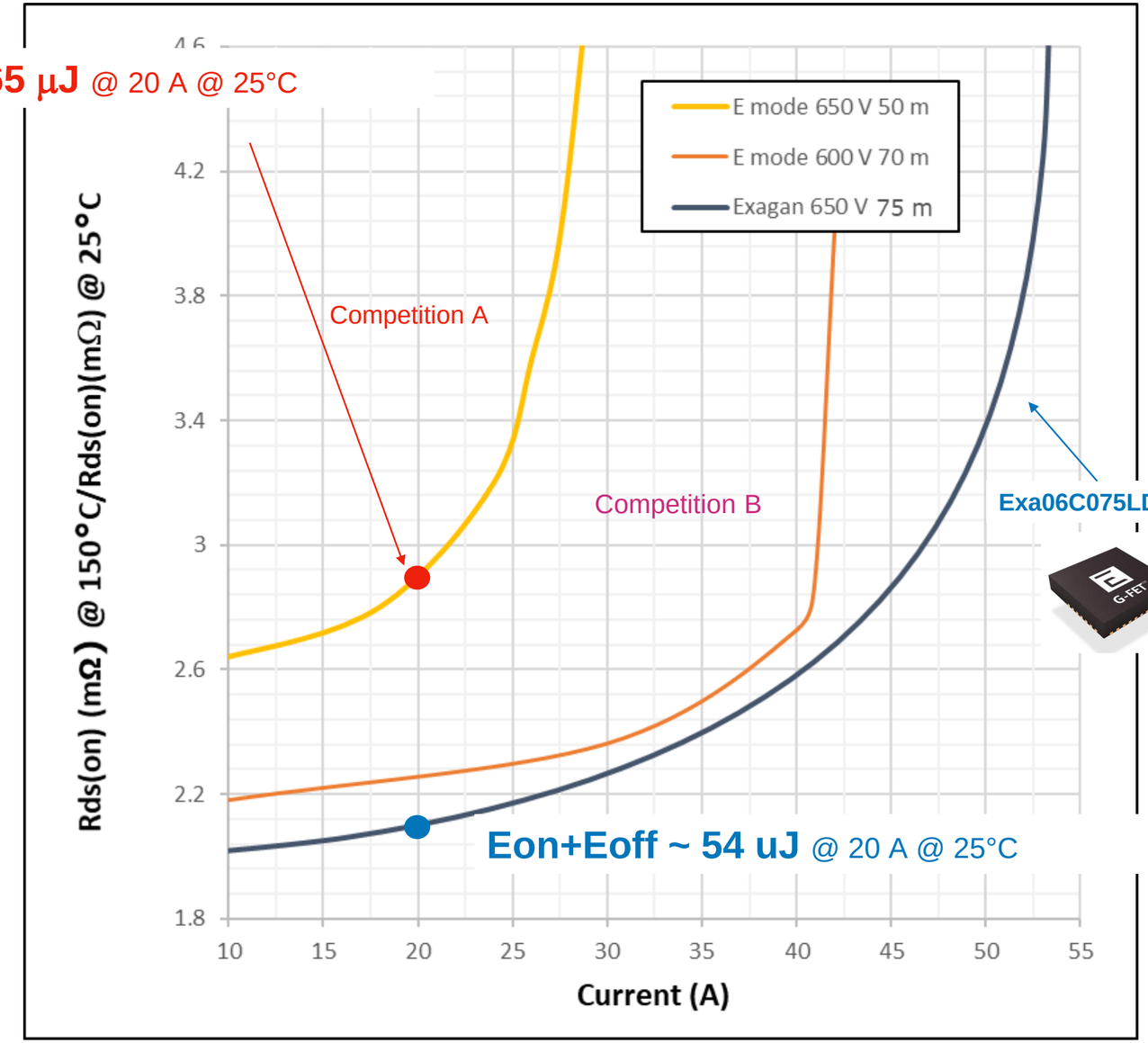
100 nA @ 650 V

EXA06C135LDS0 Device

G-FET™ 650 V / 75 mOhm



Eon+Eoff ~ 65 µJ @ 20 A @ 25°C



G-DRIVE™ Series

G-DRIVE™

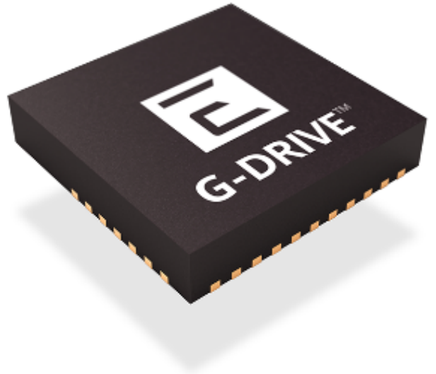
Intelligent and fast

- Embedded GaN gate driver
- Fast switching capapility (MHz)
- Integrated protection and diagnostic
- Slew rate control capability
- Peak current monitoring

Product features

System design	Digital power
Driving	3.3V to 5V CMOS
Diagnostics	UVLO, OCP, TSD[2]
Self protected	State machine
Current sensing	Adjustable, SFB[2]
EMI	Slew rate control

2. UnderVoltage LockOut, Over Current Protection, Thermal Shut Down, Sense FeedBack



Benefits for power-conversion designers include:

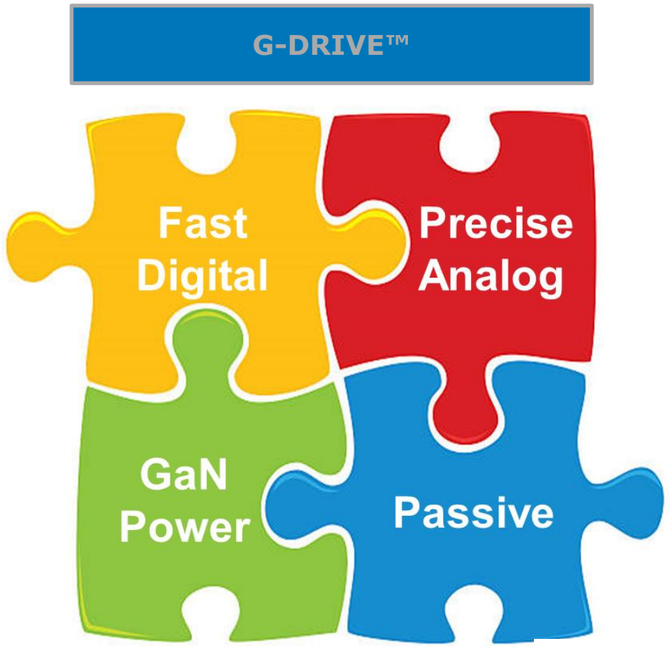
- Control of the load current without complex software
  - CMOS digital control and diagnostics
  - Current loop regulation using Sense Feedback (SFB)
  - Embedded state machine for protection
- Self-protection thanks to an embedded state machine
- EMI optimization using slew rate adjustment

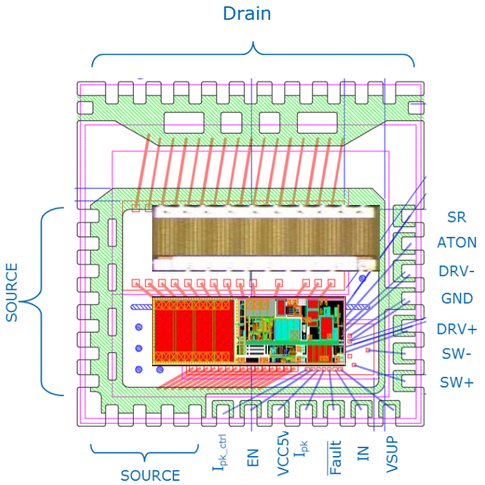
650 V product portfolio

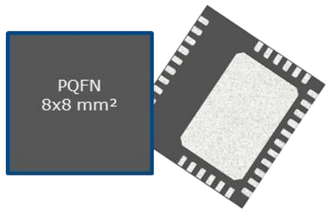
Part number	$R_{DS(on)}$ (mΩ)[3]	I_{D25} (A)[3]	I_{DM} (A)[3]	C_{OSS} (pF)[3]	Package
EXA06D190MSS0	190	10	30	30	PQFN8x8
EXA06D115MSS0	115	25	75	35	PQFN8x8
EXA06D065MSS0	65	35	100	80	PQFN8x8

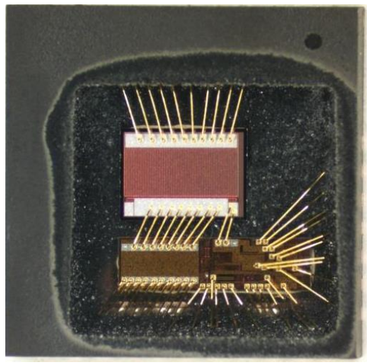
3. 25°C typical values

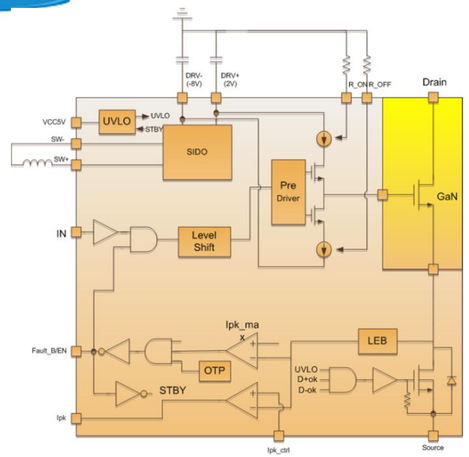
G-DRIVE™ GaN Solutions





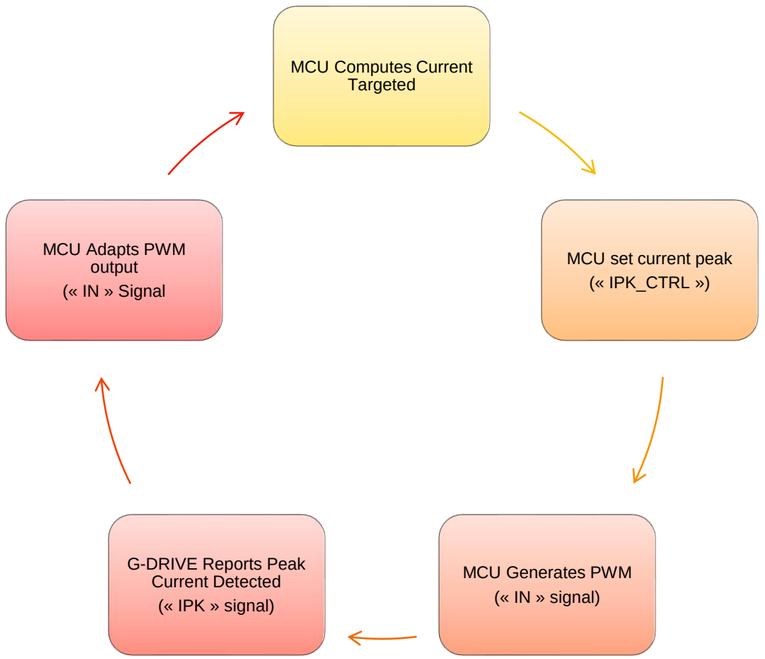




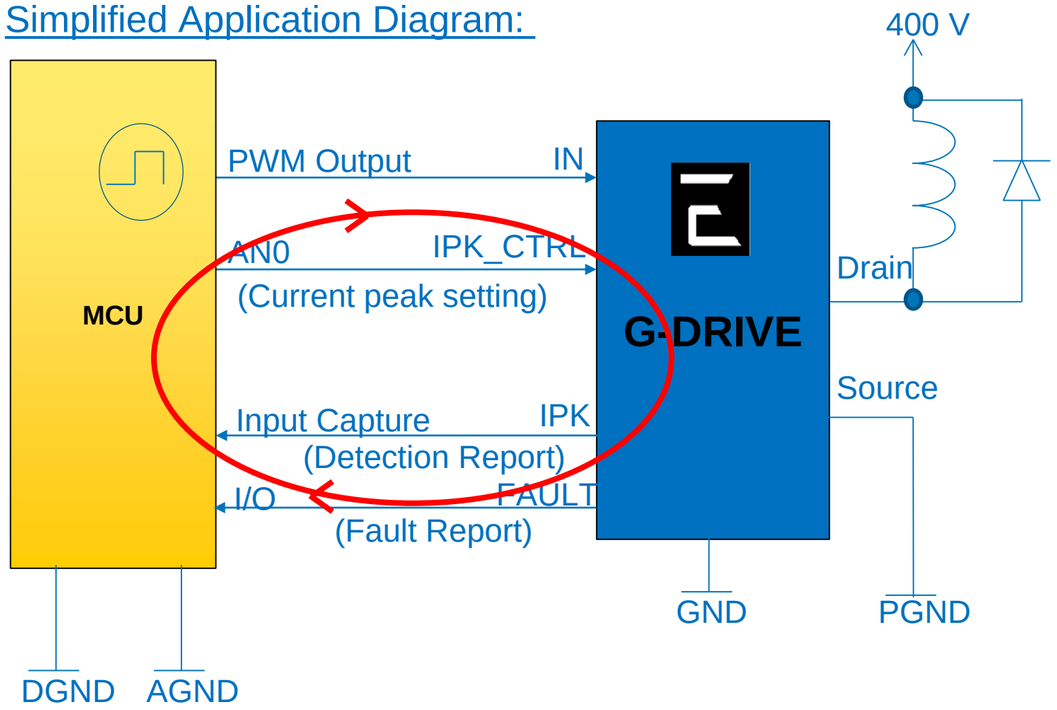


- GaN-Si Power
- Dedicated Driver
- Built-In Protected (Current, Temp.,..)
- Current sensing (Loss less)
- Very fast resp. time (SC < 40 ns)
- Very fast switching time (< 5ns)

G-DRIVE™ Implementation



Simplified Application Diagram:



Current Regulation Loop

Cycle by Cycle

G-DRIVE™ EXA06D190LDS0

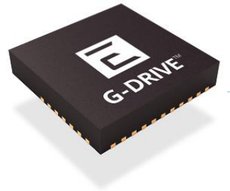
400 Volts

Fall < 7ns

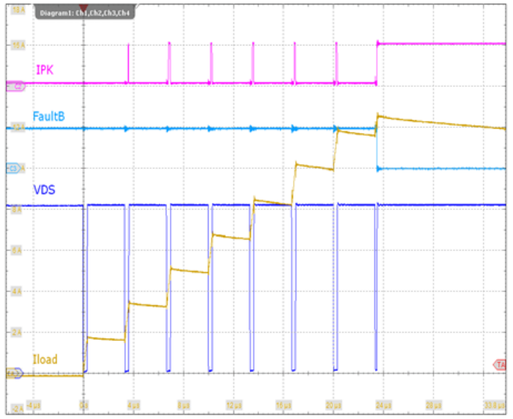
~ 25V ripple

~ 3 Amps

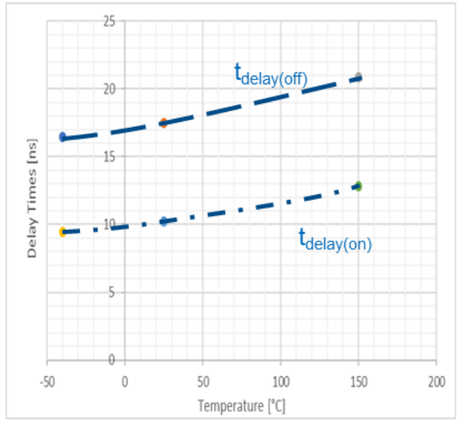
G-DRIVE™ at a Glance



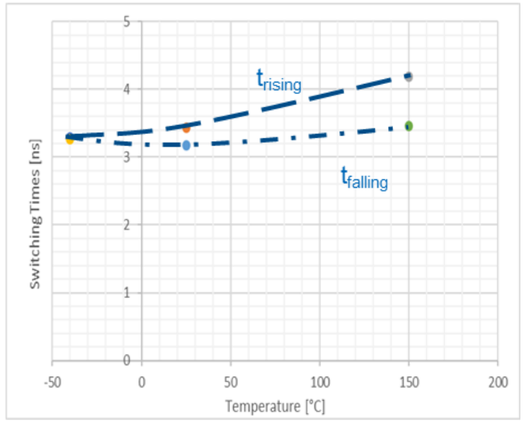
Up to 3 Mhz



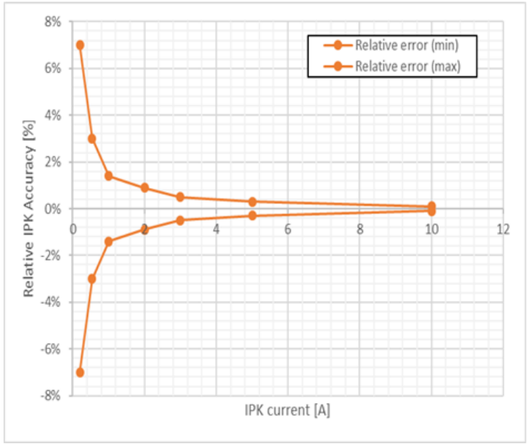
PropagationTime (10 to 20 ns)

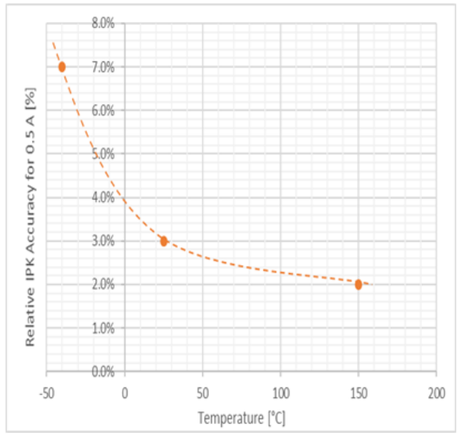


Switching Time (< 5 ns)

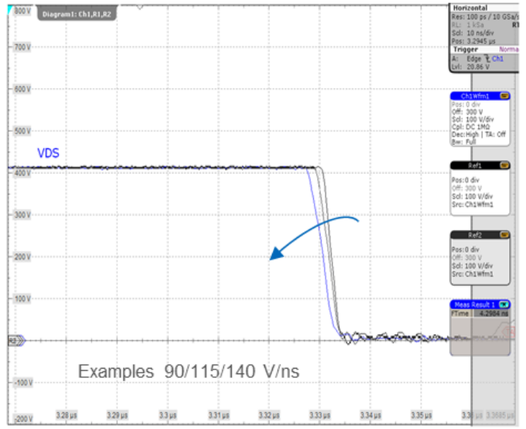


Peak Current Accuracy < 5% @ 250 mA (0 to 150°C)





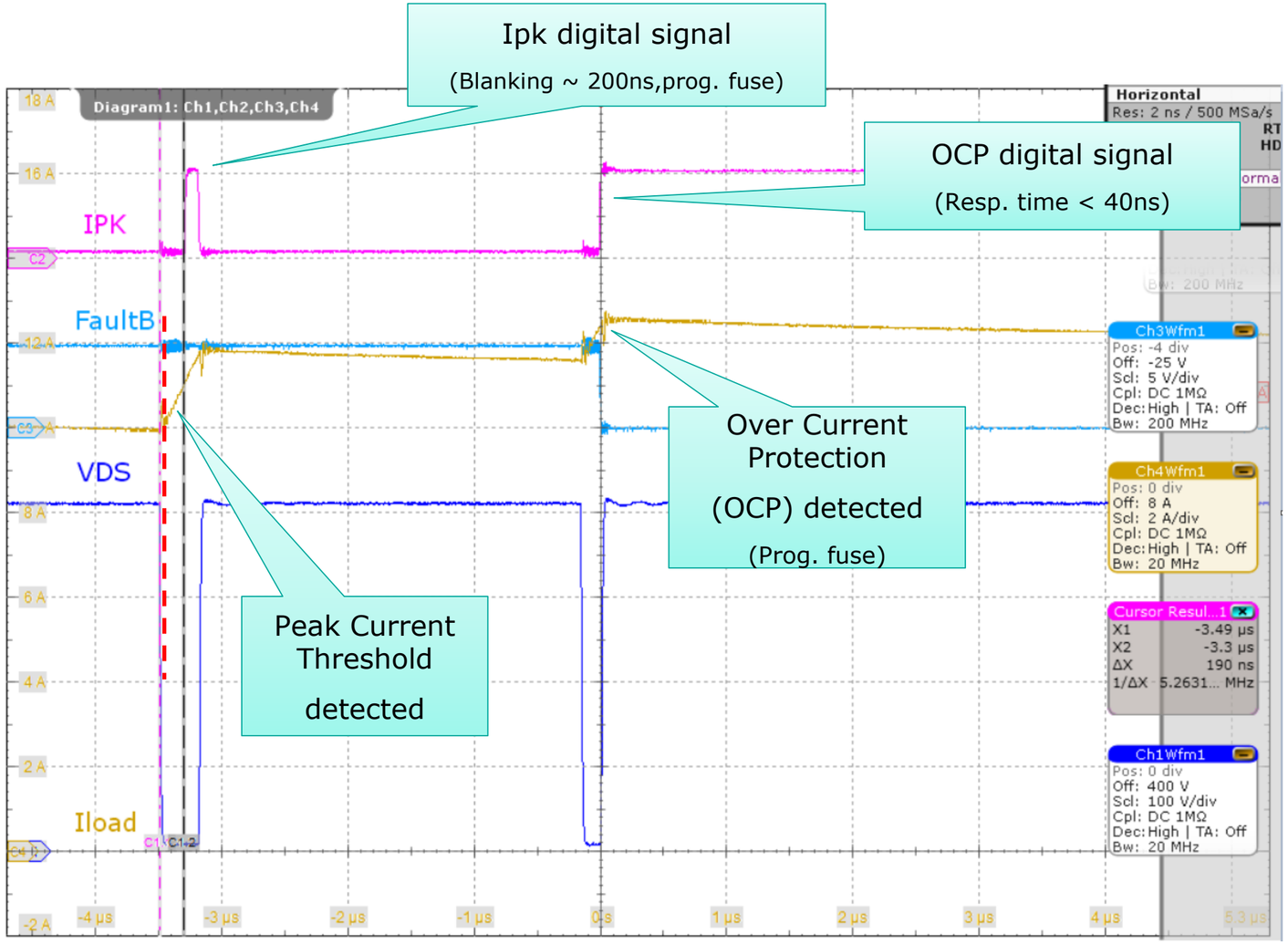
Slew Rate Control



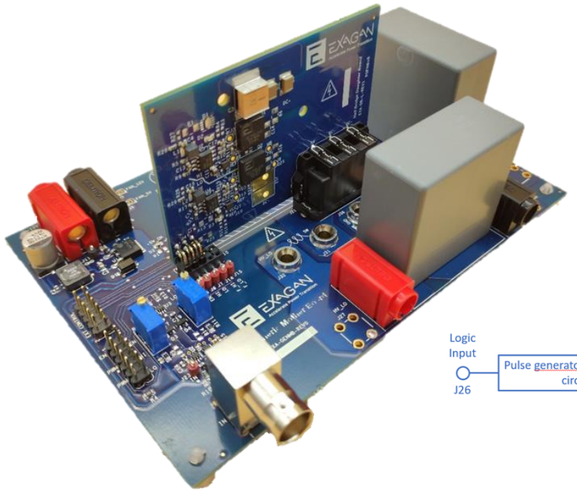
Current Peak & Over Current Detections (EXA06D190MSS0)

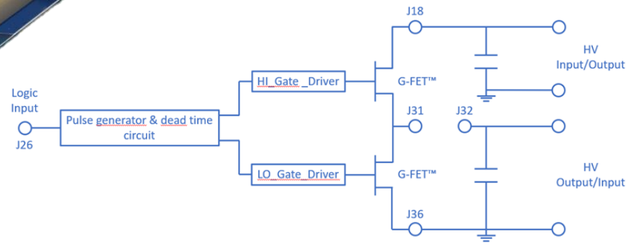
example

- Current Threshold set @ 10 A
- Over Current Protection set @ 12 A

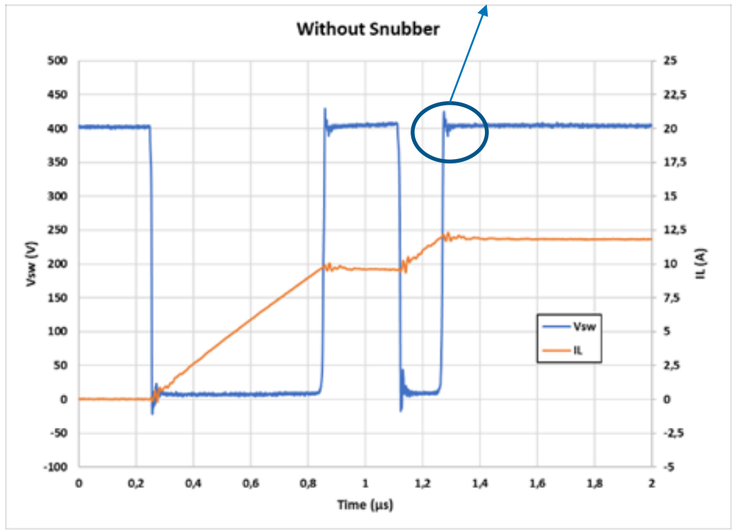


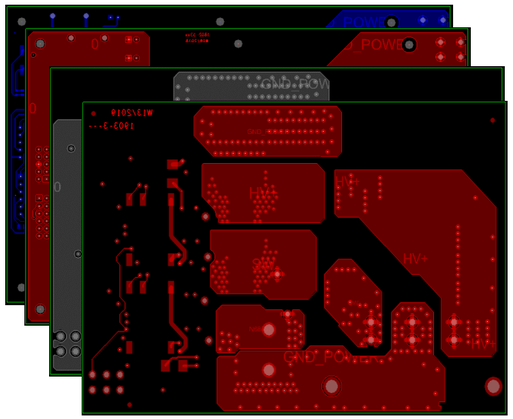
G-FET™ & G-DRIVE™ Evaluation Modules

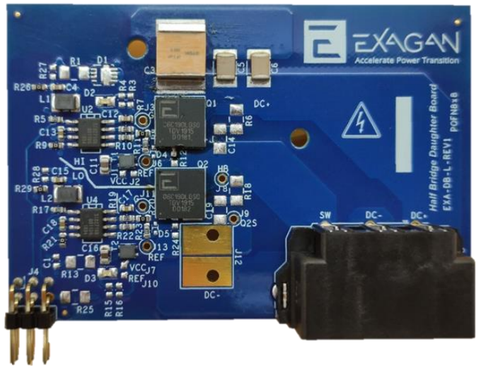


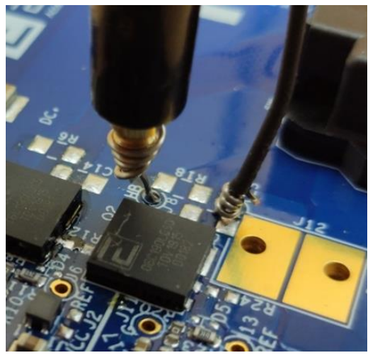


HS 400 V / 12 A ➔ 25 V Ripple









4 layers PCBs

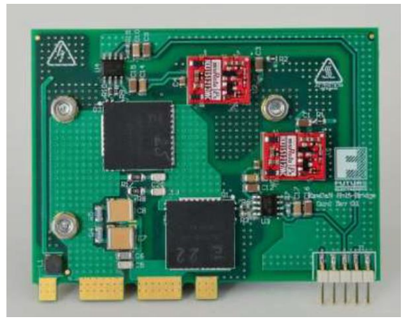
Switching node capacitance & Power loop Inductance optimized

G_FET™ Solutions for PFC Totem Pole

GaNDalf

- Specifications:-
  - 85Vac to 265Vac input
  - 400Vdc out
  - <10% THD, >0.98 PF
  - 99% efficiency target

650 V/ 30m



PQFN 15*15

650 V/ 190m

PQFN 8*8

650 V/ 50m

TO247-4L

Thank you