GaN-On-Silicon
Intelligent Power Switch Solutions

Technology & Perspectives for Easy Design-in

Eric Moreau - Global NPI & Applications

IS04 – Paper ID 1152

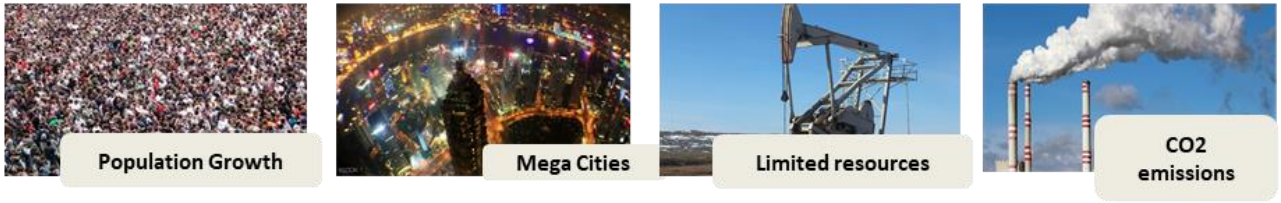
Exagan: Accelerating GaN technology adoption

- Sites : France (Grenoble, Toulouse) & Taiwan (Taipei)
- Launched in 2014 – 35 people
- Spin off SOITEC – CEA, 10y+ of GaN-on-Si R&D
- Focus on GaN 650 V/1200 V Power Switch Solutions
- Unique 200 mm GaN-Si technology
- Fab-light industrial model, in-house epitaxy
- G-FET™ & G-Drive™ Products Porfolio

Macro Factors Driving Wide Band Gap Usage

1 Fulfilling consumer new needs and aspirations

2 Societal challenges on the rise



3 (Self) Enforced Energy efficiency regulations

Wide Band Gap Materials

Semiconductor Materials		
Material	Chemical Symbol	Bandgap Energy (eV)
Germanium	Ge	0.7
Silicon	Si	1.1
Gallium Arsenide	GaAs	1.4
Silicon Carbide	SiC	3.3
Zinc Oxide	ZnO	3.4
Gallium Nitride	GaN	3.4
Diamond	C	5.5

Benefits

- Higher voltage operation
- Higher frequencies operation
- High Temperature operation
- Reduced energy loss
- Improve power quality

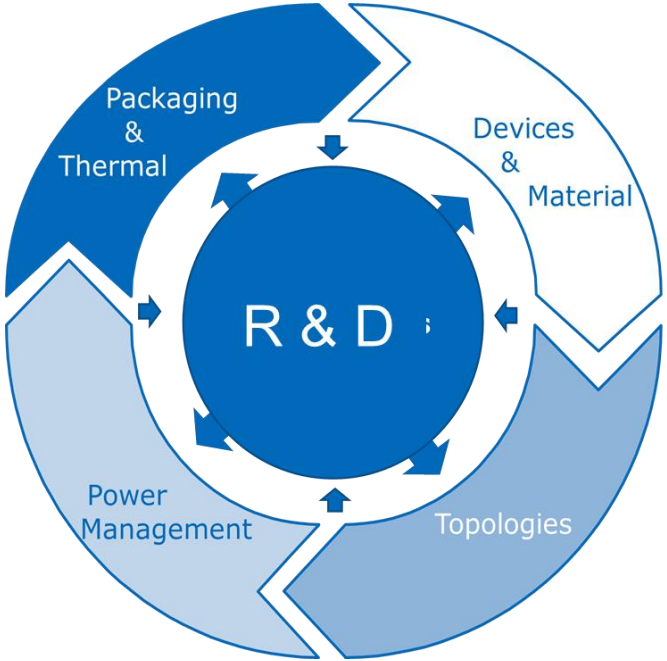
Challenges

- Wafer size & cost
- Device design & cost
- System integration
- Proven In Use /(FIT prediction)
- Robust Supply chain

➔ **Efficient, Small and Competitive Power Converters**

➔ **Bringing min. 3% energy saving on global electricity usage**

Power Electronic Converter Trends



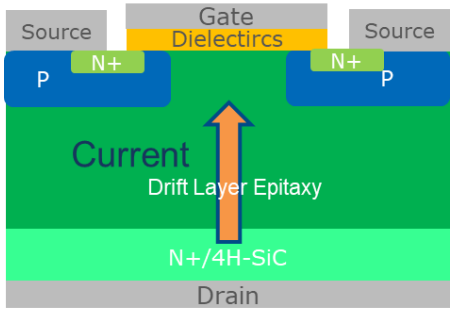
BOM R&D Life Cycle

- **WBG Power semiconductors**
  - . Switching cell
- **Use of Efficient Topologies**
  - Resonant switching
  - Interleave technics
  - Safe
- **New materials**
  - Magnetics, Dielectrics
- **System approach**
  - Device(s) Integration

GaN and SiC FET simplified device structure

❑ High Power

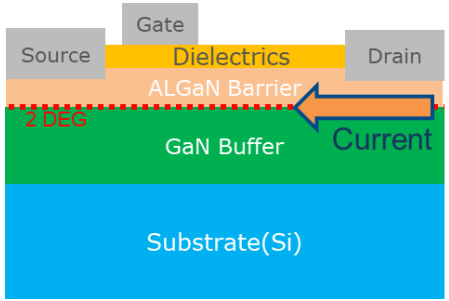
SiC MOSFET



- Vertical unipolar device
- Intrinsic body diode
- Voltage blocking capability
  - Drift layer epi thickness
  - Avalanche
- Low inversion layer channel mobility

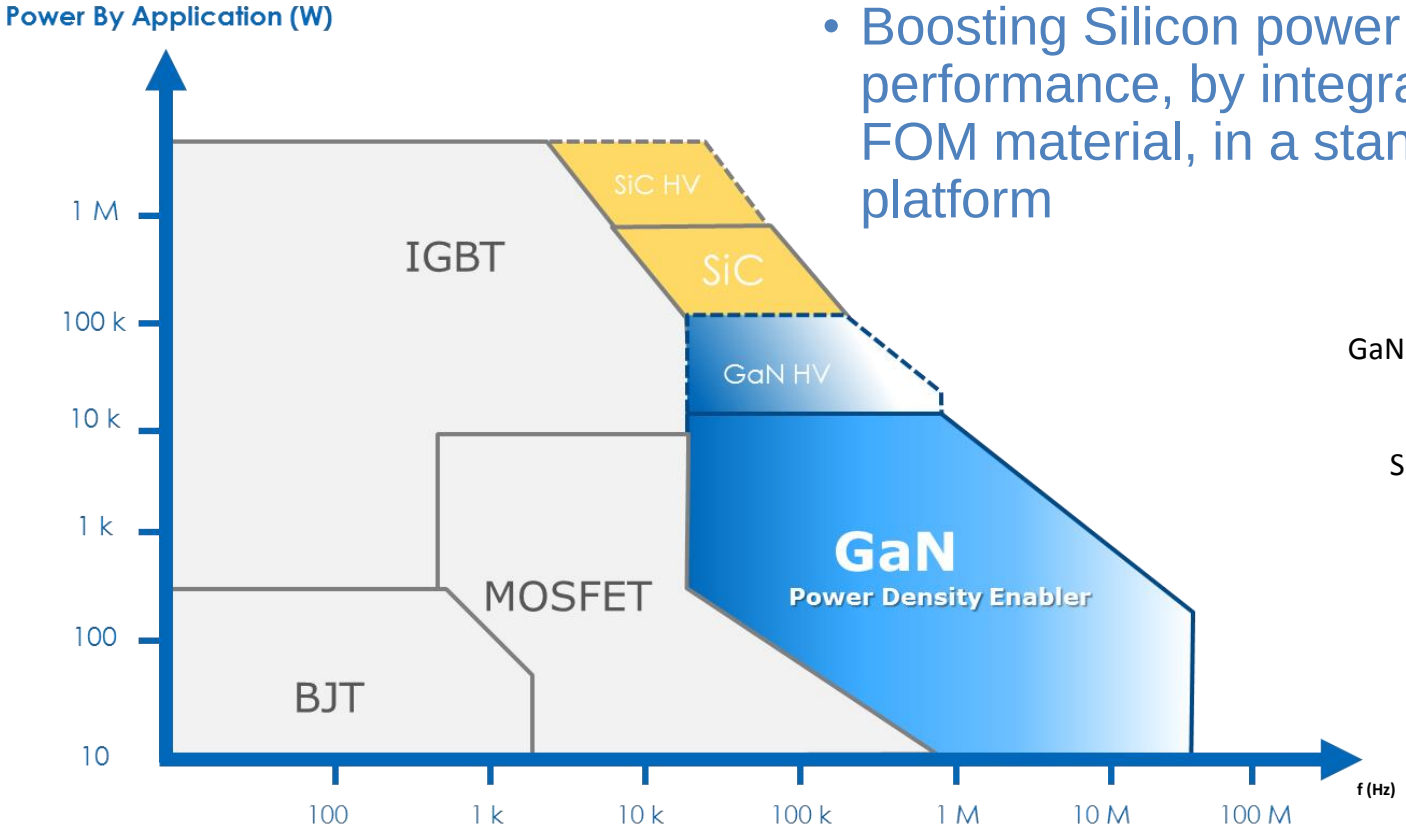
❑ Med. Power

GaN HEMT

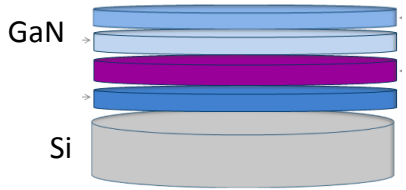


- Lateral unipolar device
- No body diode
- Voltage blocking capability
  - LGD spacing and buffer (epi thickness)
  - No avalanche
- 2 dimension electron gas (2DEG)

GaN: Disruptive Technology to Accelerate Roadmap



- Boosting Silicon power device performance, by integrating 10x better FOM material, in a standard silicon platform



GaN: All Benefits of WBGs on a Silicon Plateform

	Si IGBT	Si FET (MOSFet, SJFet,..)	GaN HEMT (GaN/Si)	SiC
Voltage & Current	High	Medium	**Medium to High**	**High**
Switching speed	Low	Moderate	**High**	**High**
CMOS compatibility	High	**High**	**High**	Low
IC Integration roadmap	Low	**High**	**High**	Low

Fast devices - Plateform for HV integration

GaN Leveraging on the 200-mm CMOS Silicon Infra.

X-FAB Dresden

May 10, 2017

X-FAB and Exagan Successfully Produce First GaN-on-Silicon Devices on 200-mm Wafers

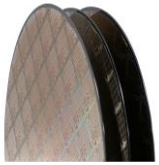
Silicon Foundry and GaN Start-Up Achieve Major Milestone in Establishing a 200-mm, Fully CMOS-Compatible Process While GaN Power Products Gain Market Traction

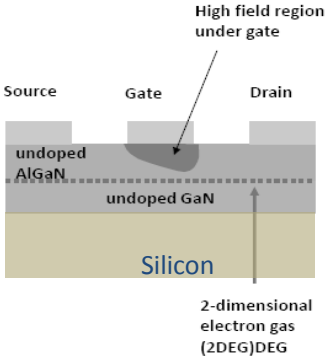
Erfurt, Germany and Grenoble, France – May 10, 2017 – X-FAB Silicon Foundries and Exagan, a start-up innovator of gallium-nitride (GaN) semiconductor technology enabling smaller and more efficient electrical converters, have demonstrated mass-production capability to manufacture highly efficient high-voltage power devices on 200-mm GaN-on-silicon wafers using X-FAB's standard CMOS production facility in Dresden, Germany. This accomplishment is the result of a joint development agreement launched in 2015, enabling cost/performance advantages that could not be achieved with smaller wafers.

Exagan and X-FAB have successfully resolved many of the challenges related to material stress, defectivity and process integration while using standard fabrication equipment and process recipes. Combined with the use of 200-mm wafers, this will significantly lower the cost of mass producing GaN-on-silicon devices. By enabling greater power integration than silicon ICs, GaN devices can improve the efficiency and reduce the cost of electrical converters, which will accelerate their adoption in applications including electrical vehicle charging stations, servers, automobiles and industrial systems.

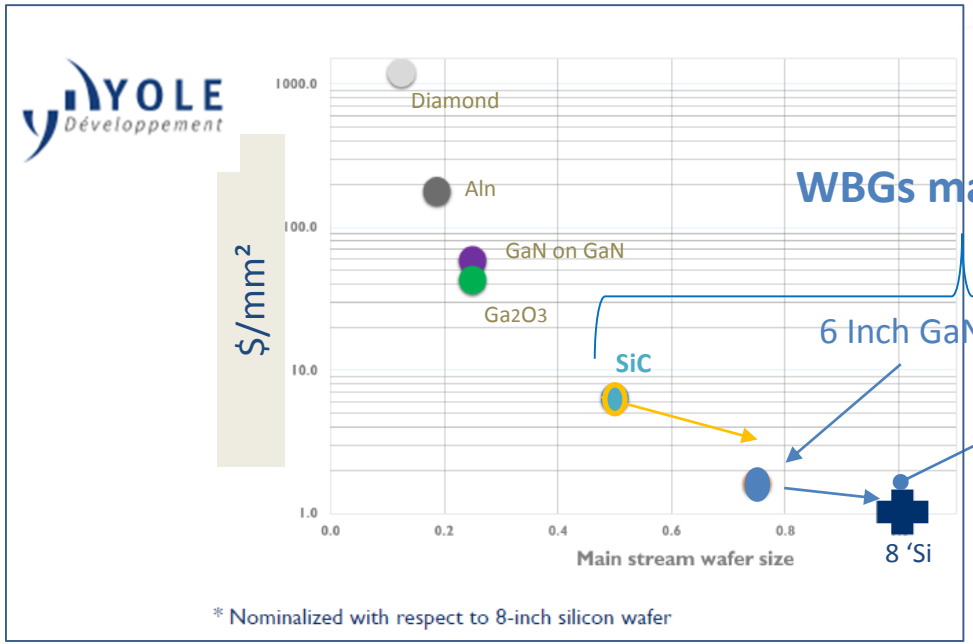
The new GaN-on-silicon devices have been built using substrates fabricated at Exagan's 200-mm epi-manufacturing facility in Grenoble, France. These epi wafers meet the physical and electrical specifications to produce Exagan's 650-volt G-FET™ devices as well as the tight requirements for compatibility with CMOS manufacturing lines.

- Well Established Supply Chain
- Diversity of Supply Ready
- Competitive for High Volume





GaN: Challenging High Voltage Current Solutions



WBGs main stream

6 Inch GaN

8 Inch GaN
(200-mm Wafers)

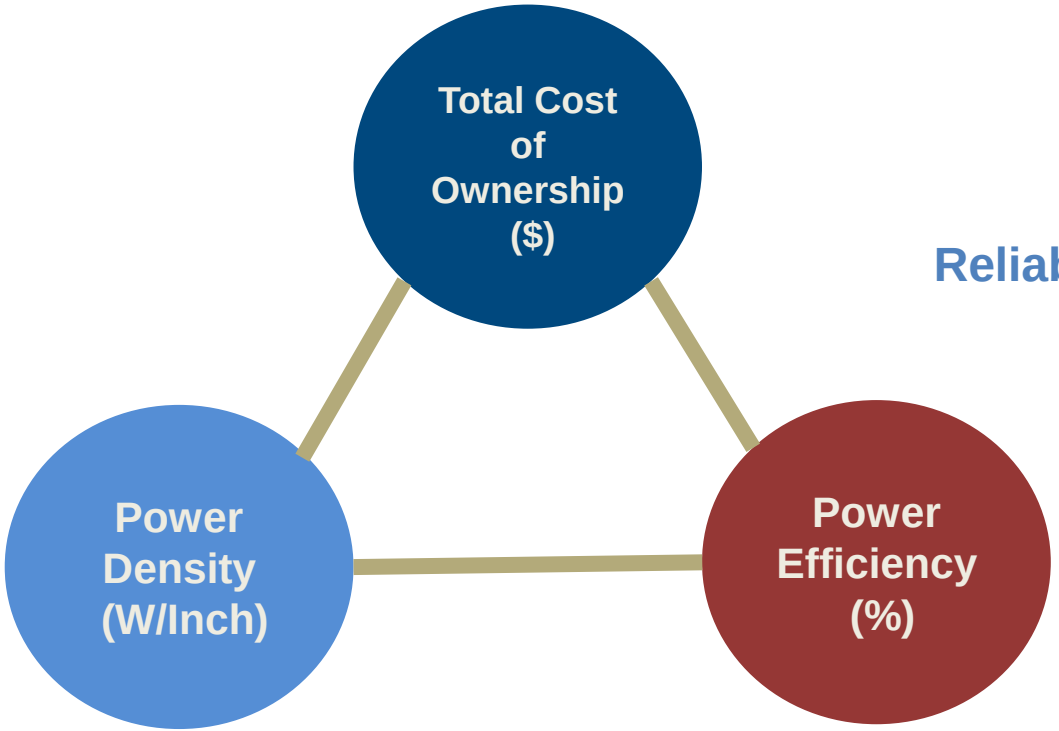
Ref: 8 Inch Silicon

SYSTEMPlus CONSULTING

	Transistor	Voltage breakdown	Current at 25°C	Die area	Current density	Rdson	Qg	FOM
Si	IPD65R225C7	650 V	11 A	6.6 mm²	1.7 A/mm²	0.22 ohm	20 nC	4.4 ohm*nC
GaN	GS66504B	600 V	15 A	6.5 mm²	2.33 A/mm²	0.11 ohm	3 nC	0.3 ohm*nC
SiC	C3M0280090D	900 V	11.5 A	2.1 mm²	5.4 A/mm²	0.28 ohm	9.5 nC	2.7 ohm*nC

Ron*Qg

GaN: Outstanding End-equip. Application TradeOffs

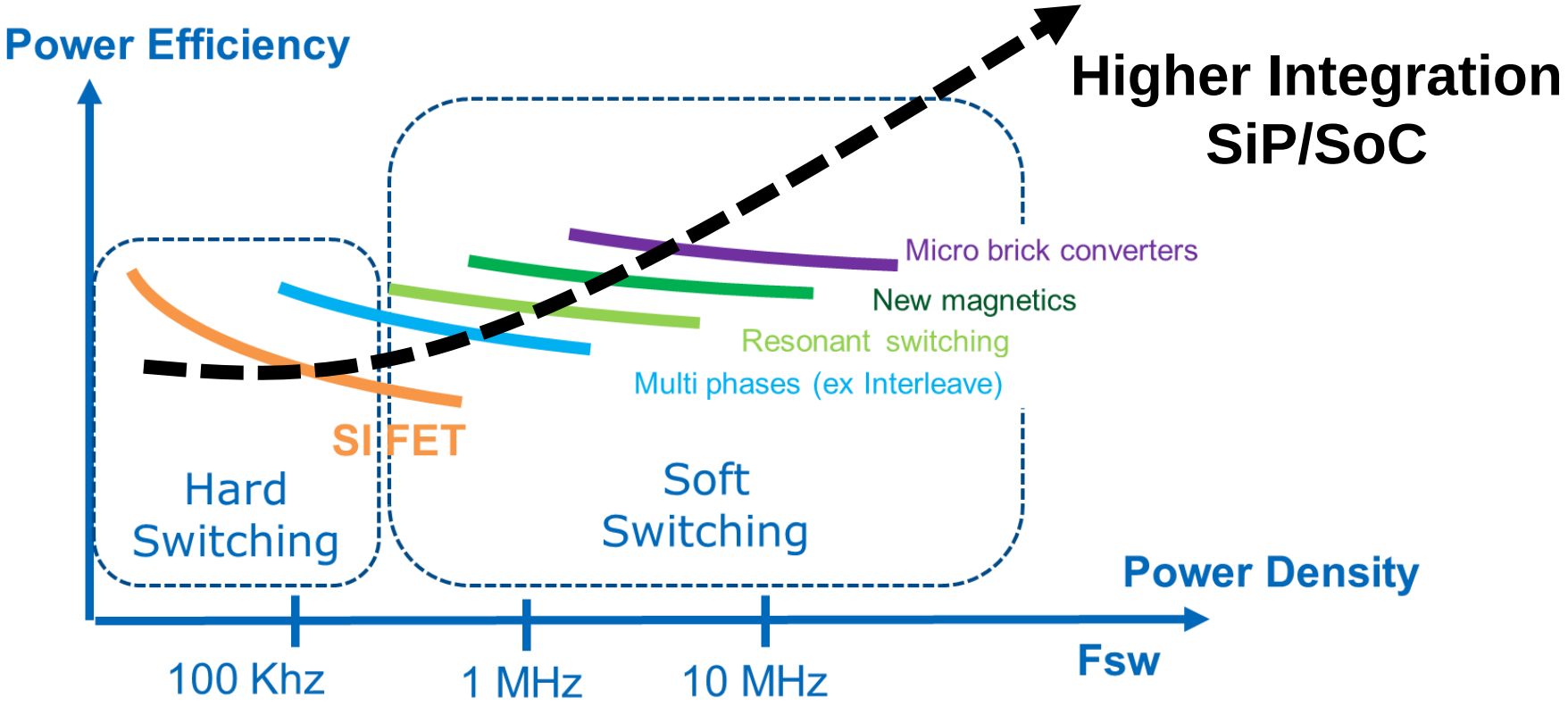


Reliability ..a must do ..

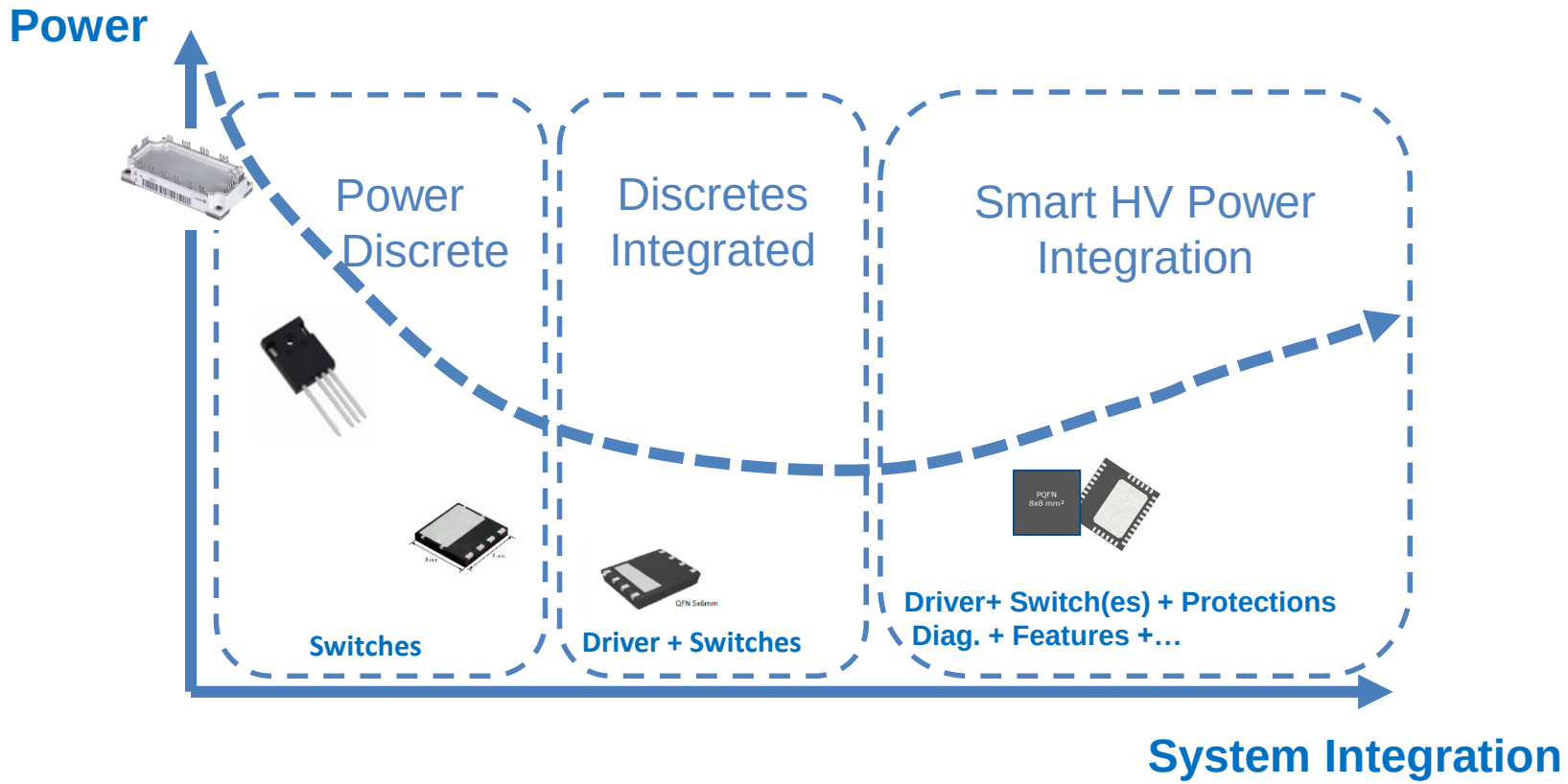
System Size/ Volume & Weight

Power Loss & Thermal Management

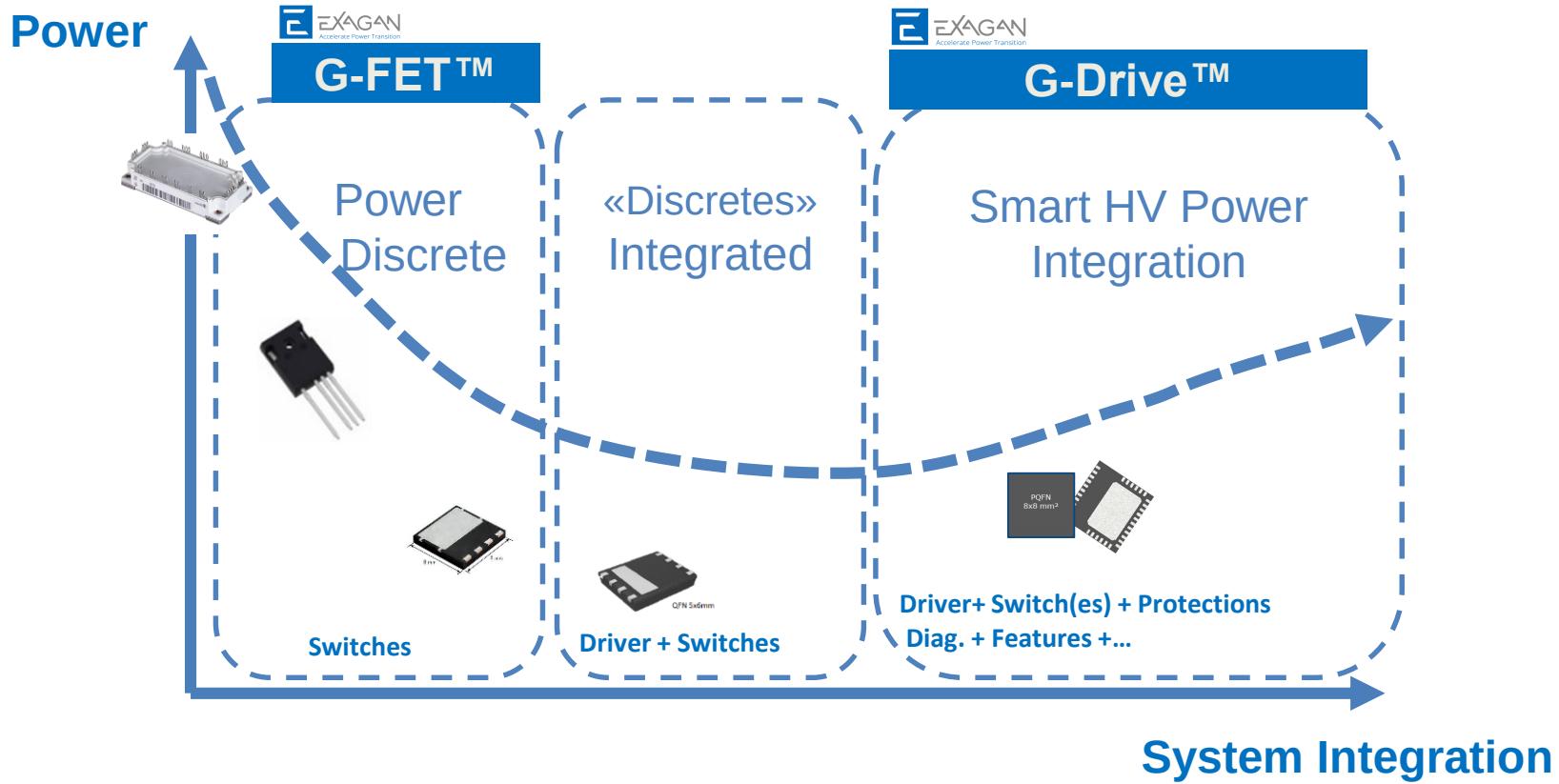
GaN Enables Freq. Scalling for Ultimate TradeOffs



GaN Discretes to Smart Power Integration Solutions



GaN Discretes to Smart Power Integration Solutions

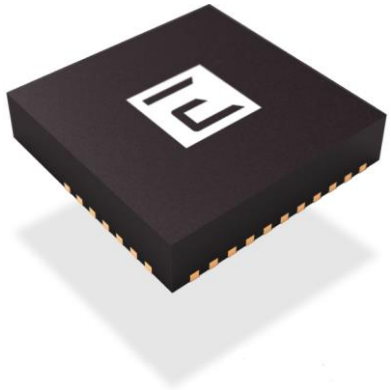


First Product Launch at PCIM 2018 (Nuremberg June 5-7th)

G-FET™

Safe and Powerful

- Broad power range
- Easy system implementation
- Rugged gate



G-DRIVE™

Intelligent and fast

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

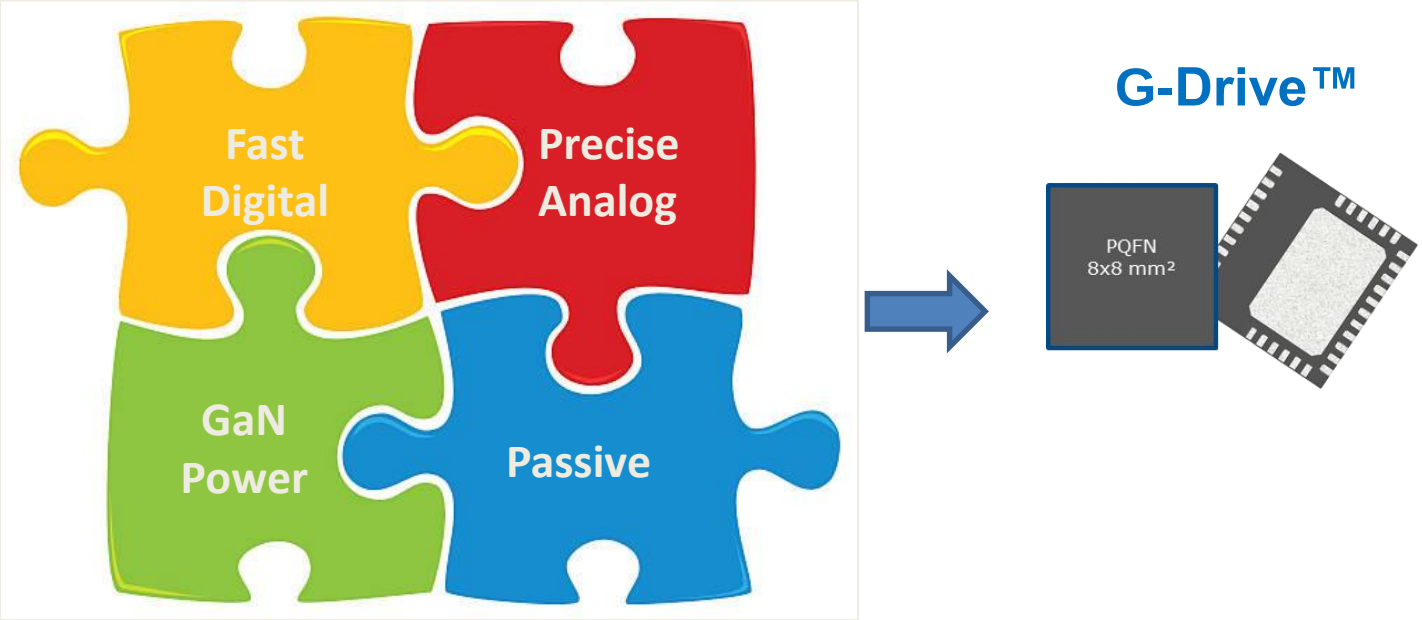
650 V products portfolio

	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
	EXA06C115LDS0	115	25	75	65	PQFN8x8
	EXA06C050XDS0	50	40	120	145	TO247-4L
	EXA06C030HDS0	30	75	150	240	PQFN15x15

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-DRIVE™	EXA06D190MSS0	190	10	30	30	PQFN8x8
	EXA06D115MSS0	115	25	75	35	PQFN8x8
	EXA06D065MSS0	65	35	100	80	PQFN8x8

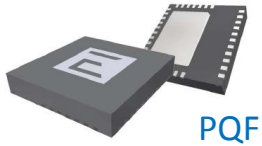
Reshaping Device Solutions for Power Converters



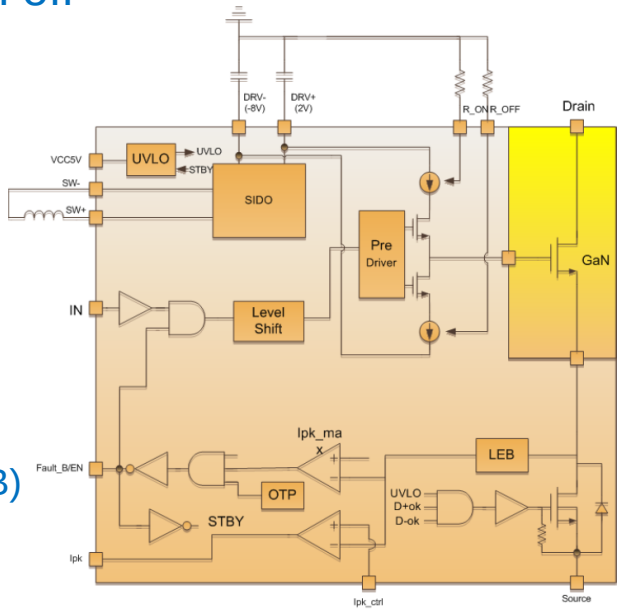
Providing outstanding SiP solutions and,……. **much faster and lossless.**

G-DRIVE™ Products Family

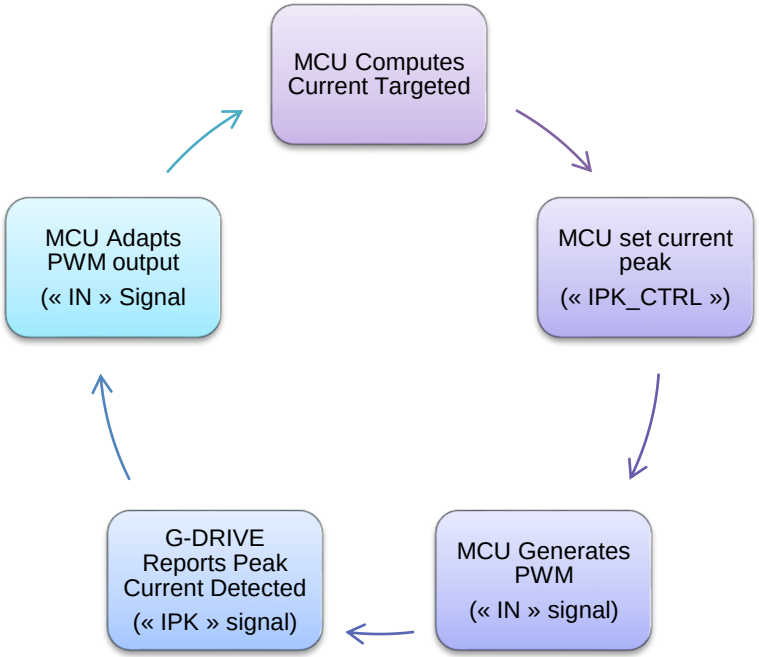
- High speed (> 3 MHz) GaN driver power stage for depleted GaN-HEMT switch
- 650 V GaN Low On-resistance from 65 to 190 mΩ
- Adjustable independent turn-on/ turn-off gate GaN drive strength
- Fast propagation time, 10-ns turn on and 15-ns turn off
- Fast rise and fall time (~ 5-ns)
- Enhanced protections with fault pin output
  - Under voltage lockout
  - Over current protection
  - Over temperature protection
  - Leading edge blanking time
- Adjustable Ipeak detection signal (Det. ~ 40 ns with LEB)
- Enable input for very low current standby



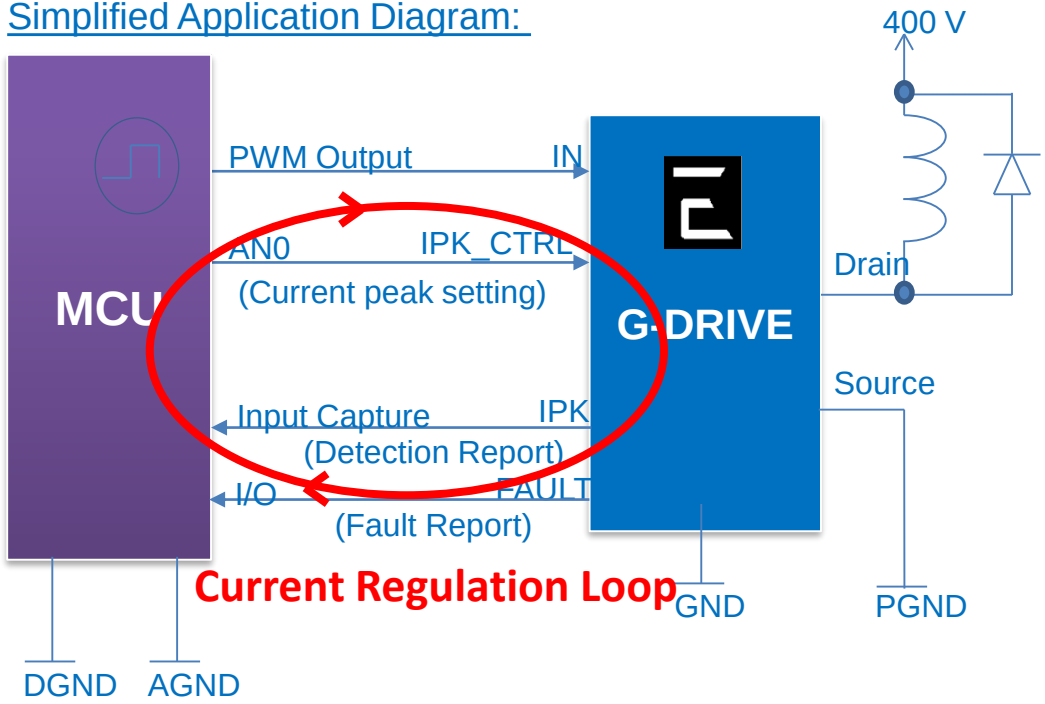
PQFN 8x8



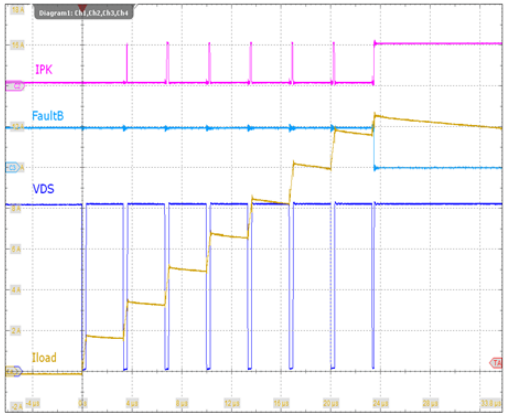
Easy Current Regulation Software Loop



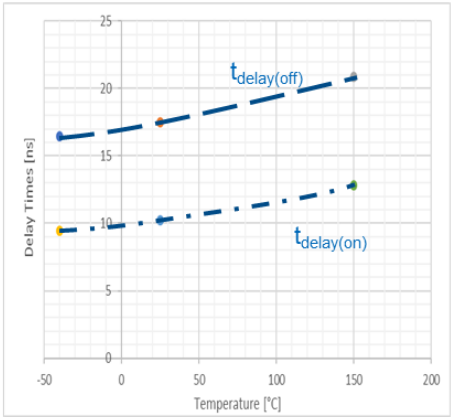
Simplified Application Diagram:



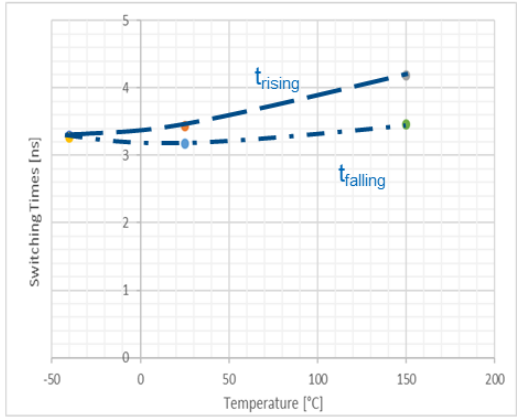
Up to 3 Mhz



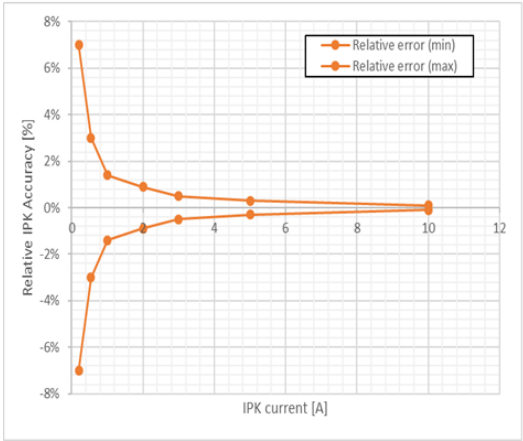
PropagationTime (10 to 20 ns)

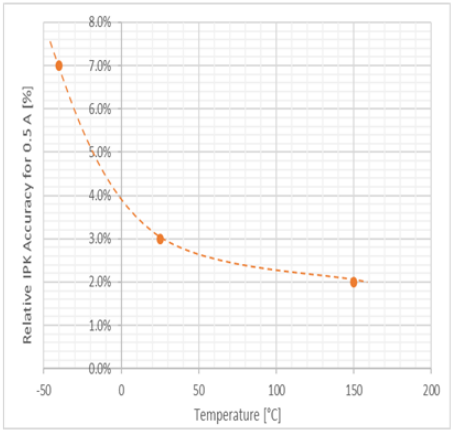


Switching Time (< 5 ns)

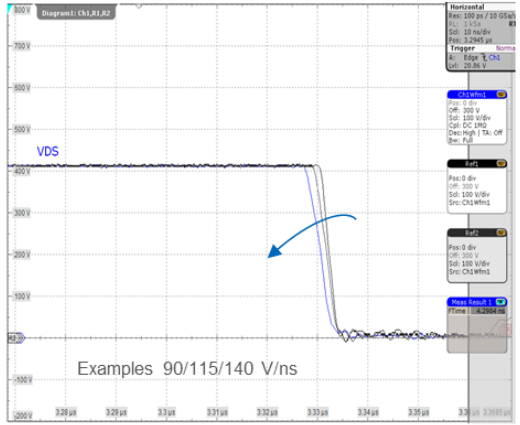


Peak Current Accuracy < 5% @ 250 mA (0 to 150°C)



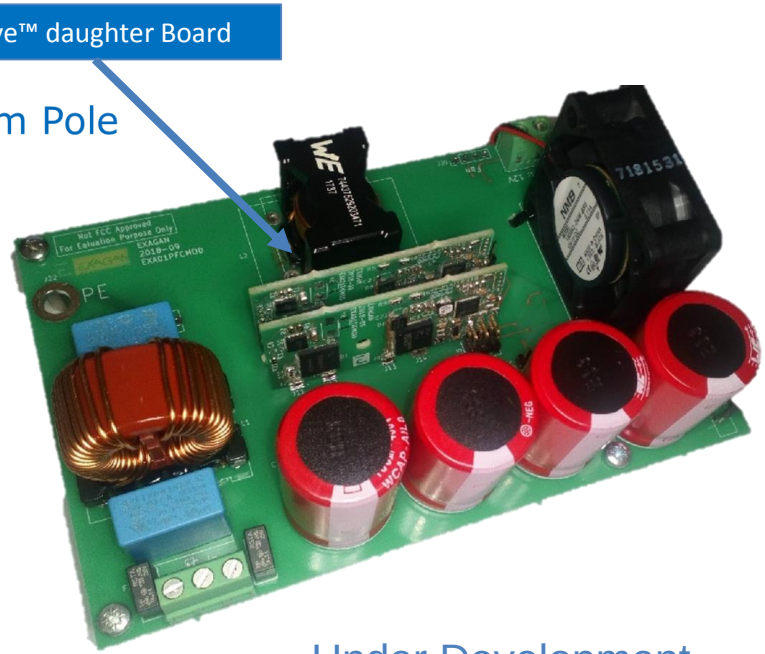


Slew Rate Control



Totem Pole PFC 1 kW G-Drive™ Based

- PFC : Power Factor Corrector (Front End ac-dc) in Totem Pole configuration
- Input Voltage 90-265 Vac
- Output Voltage 380 Vdc
- Efficiency 99+% Target
- G-DRIVE™ GaN 650 V 115 mΩ in PQFN8x8
- Switching Frequency 100-150 kHz
- Active Inrush Current Control



Under Development

THANK YOU

Q & A