



Techday

Taiwan | 2023

OUR TECHNOLOGY STARTS WITH YOU

**Sub-track I –
Smart Mobility Presentation**



life.augmented

ST smart gate driver solutions

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STMicroelectronics





STGAP for EV applications

Multiple options to address a variety of applications in Industrial and Automotive markets

EV Traction Inverter



EV Inverter applications
must be **extreme robust**

Power management



Power conversion
OBC, DC-DC applications
must be **more and more efficient**



GATE DRIVERS portfolio overview

Driving MOS / IGBT / SiC / GaN

Low Side drivers MOS

- PM8851 , PM8841
- PM8834

Single driver for IGBT

- TD3501, TD351, TD352

<100 V 3-Phase drivers MOS

- STDRIVE101
- STDRIVE102x dev

600V Half bridge drivers for IGBT, MOS

- A6387, L638x, L639x
- L649x

600V Half bridge drivers for GaN

- STDRIVEG600
- STDRIVEG610, STDRIVEG611

600 V 3-Phase drivers

- STDRIVE601

Galvanic isolated drivers

- STGAP1
- STGAP2S, STGAP2D
- STGAP2HS, STGAP2HD
- STGAP2SICSN
- STGAP2SiCS, STGAP2SiCD
- STGAP2GS, STGAP2GSN
- STGAP2SICSAN, STGAP2SICSA
- STGAP3x dev
- STGAP4

AEC-Q100 qualified

....enhancing the product family in all segments



STGAP isolated drivers for electrification

Full automotive-grade isolated driver solution for electrification



STGAP4S offers the optimal solution for a scalable platform reaching best-in-class system efficiency along with optimized thermal management

STGAP2SiCS offers the optimal solution to achieve high system efficiency while optimizing the footprint of the final application





STGAP key performances

STGAP1

- Driving SiC, IGBT
- SPI Programmable with full protections & diagnostic
- Single channel
- 5A sink/source current
- 4kV magnetic isolation
- AECQ100

- Traction Inverter
- Industrial applications
- ESS, Pumps, DC-DC

STGAP2

- Compact solutions for SiC, IGBT, GaN
- Single & Dual- channel
- 4A sink/source current
- 6kV magnetic isolation
- Industrial + AECQ100

- OBC, DC-DC Automotive
- Inverters & drives
- Power & Energy
- Automation

STGAP3

- Robust solutions for SiC, IGBT
- DESAT protection
- Single channel
- 3A, 6A, 10A sink/source current
- 9.6kV reinforced capacitive isol.
- Industrial

- EV charging stations
- Server Power
- Inverters & drives

STGAP4

- Driving SiC & IGBT
- Flexible & scalable
- Suitable for all currents >15A
- On-chip flyback and ADC
- Self diagnostic
- 6.4kV capacitive isolation
- AECQ100







- Traction Inverter
- Industrial applications
- ESS, Pumps, DC-DC

- Addressing all Applications Industrial & Automotive
- Robust solutions and wide driving current capability offer from 3A to > 15A
- Galvanic Isolation embedded from Magnetic to Reinforced capacitive



Automotive Grade
AEC-Q100

Galvanic isolated gate driver portfolio

		IGBT / MOSFET	SiC		GaN	
Single Channel	SO8N - Narrow body Isolation 6 kV V _{PEAK} 4.8 kV		STGAP2S SINGLE isolated gate driver 4.8 kV, 1700 V HV rail	STGAP2SiCSN SINGLE isolated SiC driver 4.8 kV (higher UVLO) 1700 V HV rail	STGAP2SiCSAN SINGLE Isolated SiC Driver 4.8kV (higher UVLO) 1700V HV rail	STGAP2GSN SINGLE Isolated GaN Driver 4.8kV (lower UVLO) 1700V HV rail
	SO8W - Wide body Isolation 6 kV V _{PEAK} 6 kV		STGAP2HS SINGLE isolated gate driver 6 kV, 1200 V HV rail	STGAP2SiCS SINGLE isolated SiC driver 6 kV (higher UVLO) 1200 V HV rail	STGAP2SiCSA SINGLE Isolated SiC Driver 6kV (higher UVLO) 1200V HV rail	STGAP2GS SINGLE Isolated GaN Driver 6kV (lower UVLO) 1200V HV rail
	SO24W - Wide body Isolation 4 kV V _{PEAK} 4 kV		<div>Qual Q1-2024</div> STGAP3x platform SINGLE isolated SiC driver 6 kV 1200 V HV rail SO16W, SO28W - DESAT		STGAP1BS SINGLE isolated SiC driver 4 kV, 1500 HV rail	
	SO36W - Wide body Isolation 6.4 kV V _{PEAK} 6.4 kV				STGAP4S SINGLE isolated SiC driver 6.4 kV, 1200 HV rail	
Dual Channels	SO16N - Narrow body Isolation 6 kV V _{PEAK} 4.8 kV		STGAP2D DUAL isolated gate driver 4.8 kV, 1700 HV rail			
	SO36W - Wide body Isolation 6 kV V _{PEAK} 6 kV		STGAP2HD DUAL isolated gate driver 6 kV, 1200 HV rail	STGAP2SiCD DUAL isolated SiC driver 6 kV (higher UVLO) 1200 HV rail		



Galvanic drivers for Silicon Carbide FETs

Optimized UVLO (under voltage lock out) for safe SiC FETs driving

STGAP2SiCS
STGAP2SiCS AUTO
6.0kV SO8W package
SiC FETs



Compact and flexible
solution enabling **system**
safety

STGAP2SiCSN
STGAP2SiCSN AUTO
4.8kV SO8N package
SiC FETs



Squeezed solution with
functional isolation
enhancing **system**
robustness

STGAP2G
6.0kV SO8W package
GaNHEMT



GaNHEMT isolation to
enlarge **new generation**
system.

Key applications

- OBC, EV Charger
- Switch-mode power supplies
- Factory automation
- Industrial drives and fans
- DC-DC converters
- Motion Control



STGAP2SICSA, STGAP2SICS & STGAP2HS

Galvanic isolated, single-channel gate drivers for SiC MOSFETs and IGBTs in SO-8W package

- STGAP2SICS in Production
- STGAP2HS in Production
- STGAP2SICSA in Production

Compactness

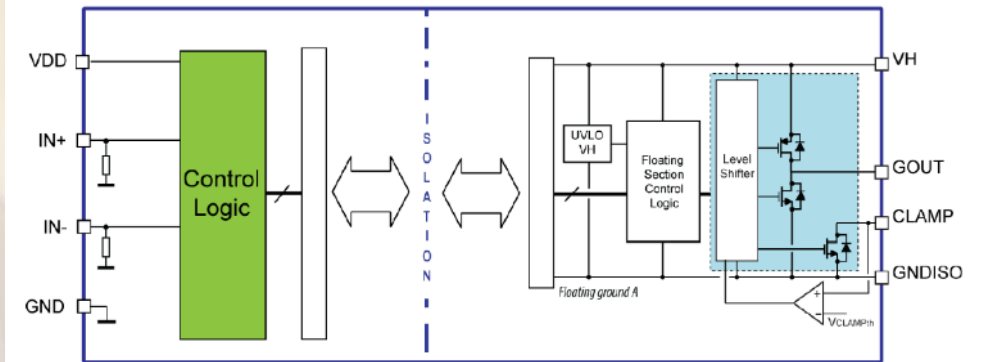
- On-chip galvanic isolation
- Robust SO-8W package

Robustness

- Optimized UVLO for SiC
- Watchdog
- Transient immunity ± 100 V/ns in all temperature range
- Isolation V_{PEAK} 6 kV
- STGAP2SICSA Automotive Grade qualification

Performance

- High voltage rail up to 1200 (SO-8W)
- Up to 26 V supply voltage
- 4A sink / source driver current capability
- **Miller Clamp and separate output options**
- Propagation delay 75 ns (45ns in STGAP2SICSA)
- Stand-by function
- Interlocking function



Key applications

- On-board chargers
- Motor control
- Switch-mode power supplies
- Factory automation
- Industrial drives and fans
- DC-DC converters
- EV chargers



STGAP2SICSAN, STGAP2SICSN & STGAP2S

Galvanic isolated, single-channel gate drivers for SiC MOSFETs and IGBTs in SO-8N compact package

- STGAP2SICSN in Production
- STGAP2S in Production
- STGAP2SICSAN in Production

Compactness

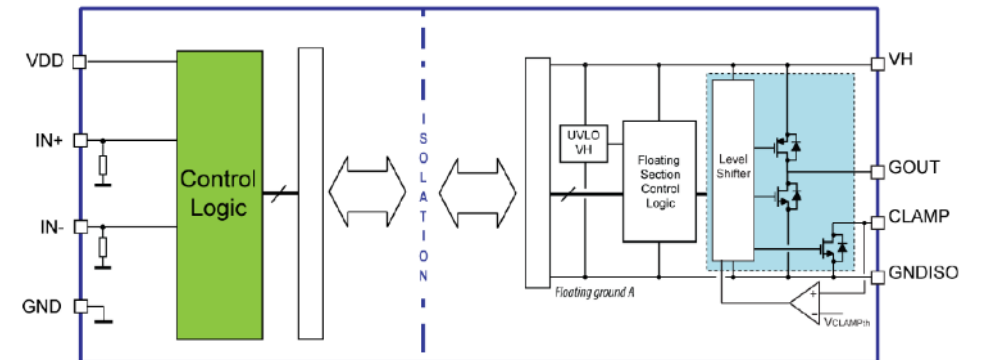
- On-chip galvanic isolation
- **Compact SO-8N package**

Robustness

- **Specific part with optimized UVLO for SiC**
- **Watchdog**
- **Transient immunity ± 100 V/ns in all temperature range**
- **Isolation V_{PEAK} 4.8 kV**
- **STGAP2SICSAN Automotive Grade qualification**

Performance

- High voltage rail up to 1700V (SO-8N)
- Up to 26 V supply voltage
- 4A sink / source driver current capability
- **Miller Clamp and separate output options**
- Propagation delay 75 ns (45ns in STGAP2SICSAN)
- Stand-by function
- Interlocking function



Key applications

- On-board chargers
- Motor control
- Switch-mode power supplies
- Factory automation
- Industrial drives and fans
- DC-DC converters
- EV chargers



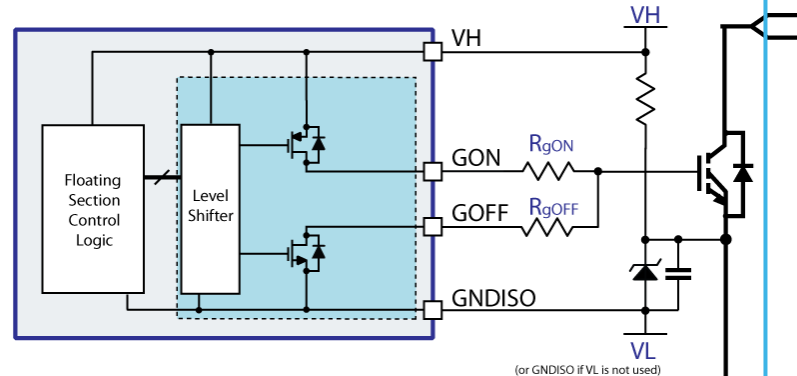
STGAP2 single-channel drivers for maximum robustness

Maximum flexibility for the power stage driving

SEPARATED OUTPUTS

for easy gate driving tuning

STGAP2SM
STGAP2HSM
STGAP2SiCS
STGAP2SiCSN

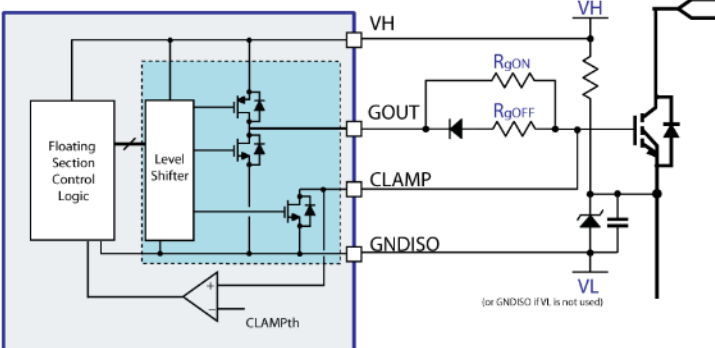


- “**SEPARATE OUTPUTS**” allow to differentiate easily the turn-on / turn-off paths to tune dV/dt and to avoid induced turn-on
- Induced turn-on can be avoided
 - with integrated MILLER CLAMP
 - driving the gate with negative voltage
- Power devices with low threshold voltage such as SiC and GaN MOSFETs are more exposed to induced turn-on
- “**MILLER CLAMP**” solution sets a low impedance path bypassing the turn-off gate resistor and avoiding induced turn-on

MILLER CLAMP

to avoid induced turn-on

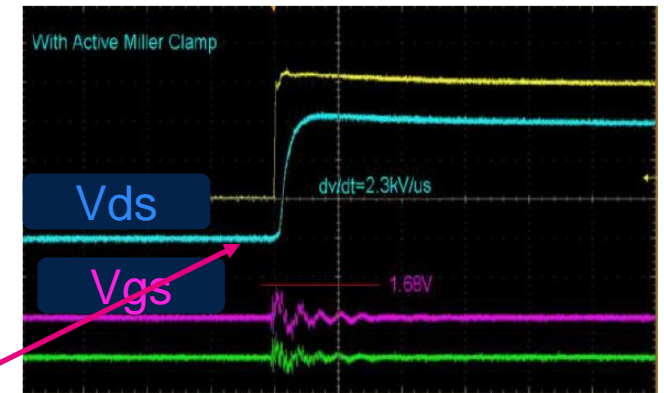
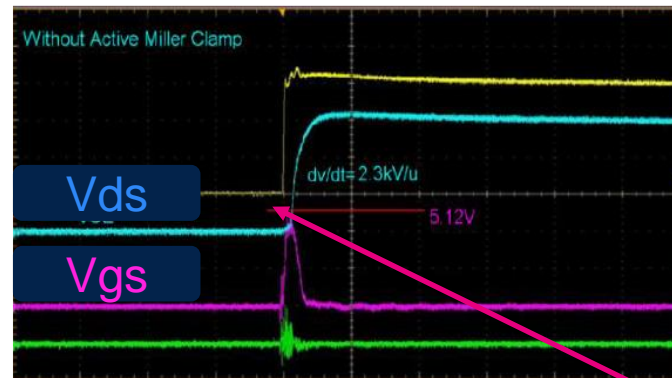
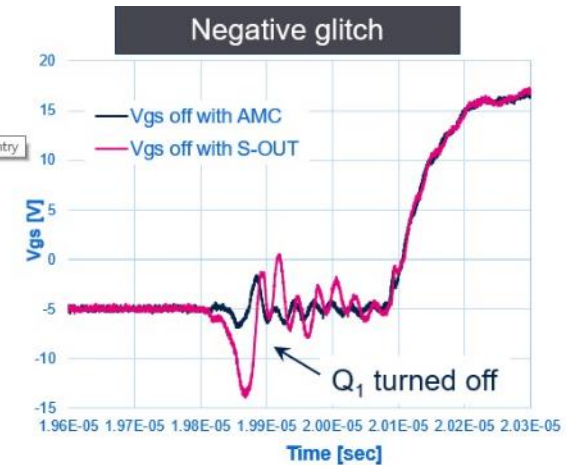
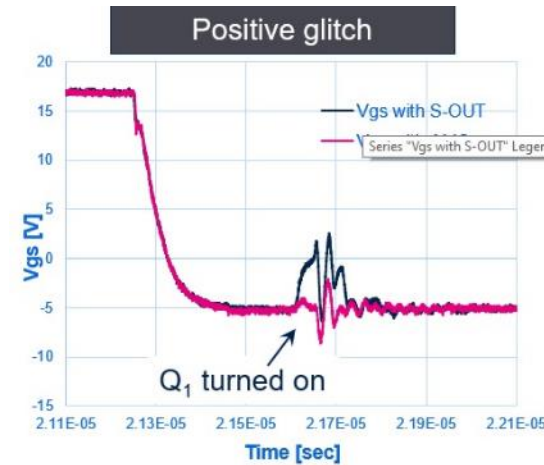
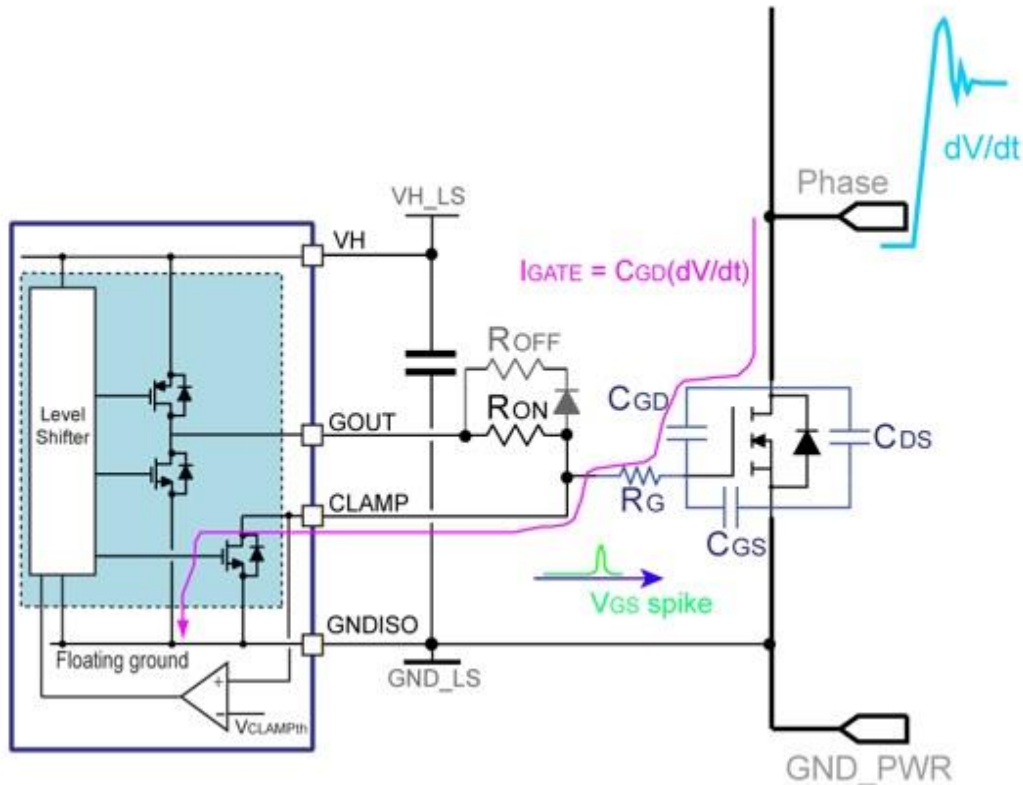
STGAP2SCM
STGAP2HSCM
STGAP2SiCSC
STGAP2SiCSAC
STGAP2SiCSNC
STGAP2SiCSANC





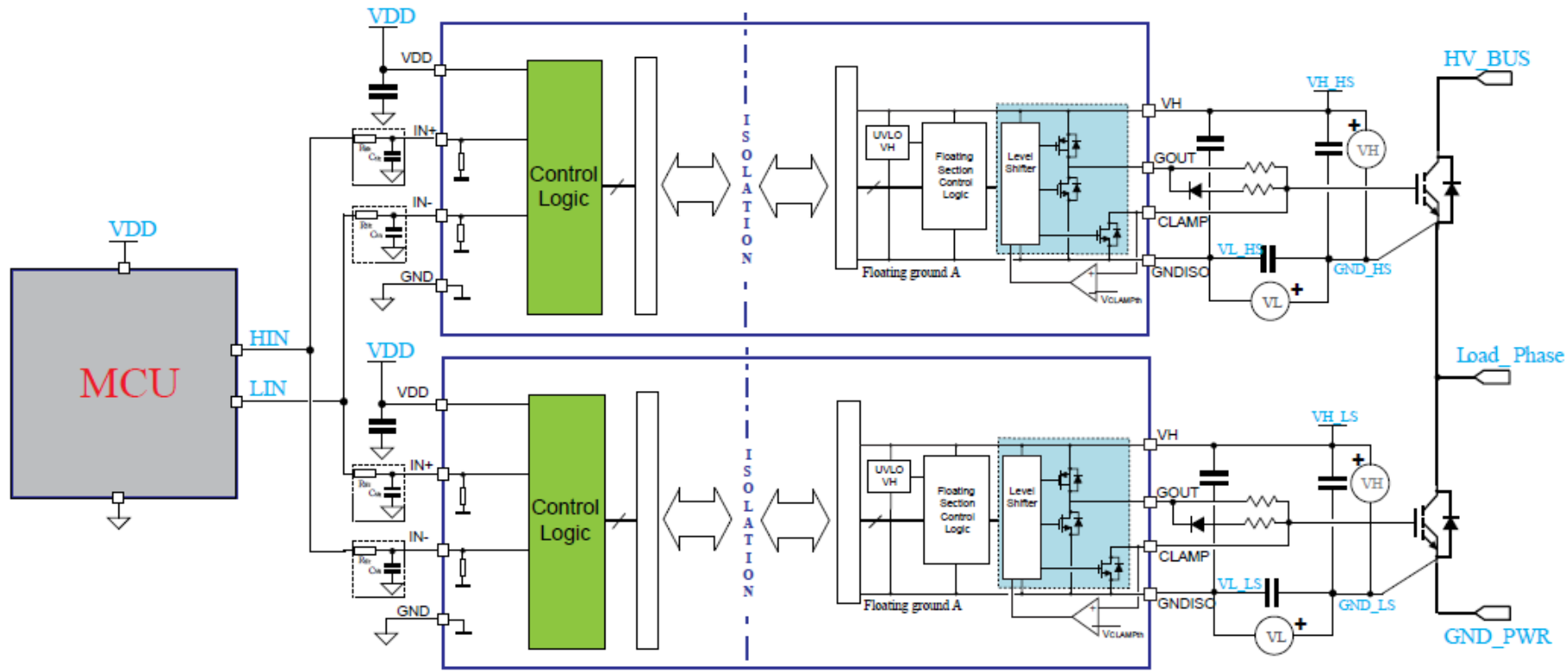
Active Miller Clamp to avoid induced turn-on

Advantages of Active Miller Clamp



Comparing the waveforms, the active miller clamp function brings **more reliabilities** for SiC applications.

Miller Clamp and negative gate driving example

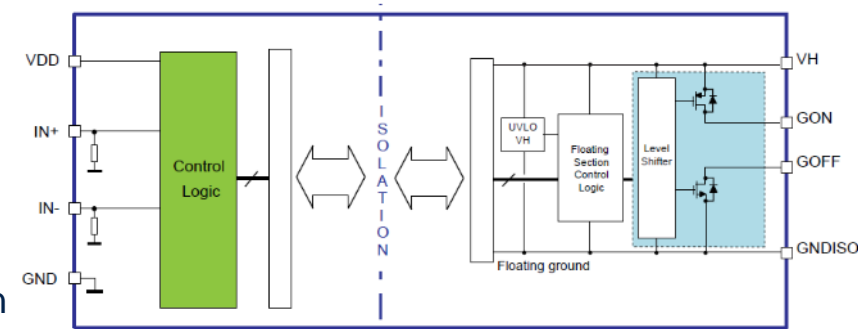




STGAP2G galvanic driver for GaN

Galvanic isolated, single-channel gate driver for GaN in SO-8W and in SO-8N

- High voltage rail up to 1200 V (SO8W), 1700 V (SO8N)
- Galvanic isolation 6 kVpk (SO8W), 4.8 kVpk (SO8N)
- Current capability: 2 A / 3 A source/sink @25 °C, $V_H = 6\text{ V}$
- Separate sink and source option for easy gate driving configuration
- Propagation delay: 45 ns @ 25°C, VDD 5V
- UVLO function optimized for GaN
- Gate driving voltage up to 15 V
- dV/dt transient immunity $\pm 100\text{ V/ns}$ in full temperature range
- Temperature shut down protection
- 3.3 V, 5 V TTL/CMOS inputs with hysteresis
- Stand-by function
- SO8 Wide body STGAP2GS
- SO8 Narrow body STGAP2GSN



Key applications

- SMPS
- Server power, UPS
- PFC & DC-DC converters
- Charging stations
- Industrial Automation
- Motor drivers & drivers





STGAP4S

**advanced isolated gate
driver for IGBTs and SiC
MOSFETs**



STGAP4

new advanced gate driver

The new high-end driver generation feature for high power and high current > 10A

Best performance & programmability

Advanced protections & diagnostic features

Maximum safety & robustness

Extreme flexibility for current capability

BOM optimization & space saving

AEC-Q100 qualified- & in MASS PRODUCTION



STGAP4

AEC-Q100 qualified

Advanced galvanic isolated gate driver for SiC FETs



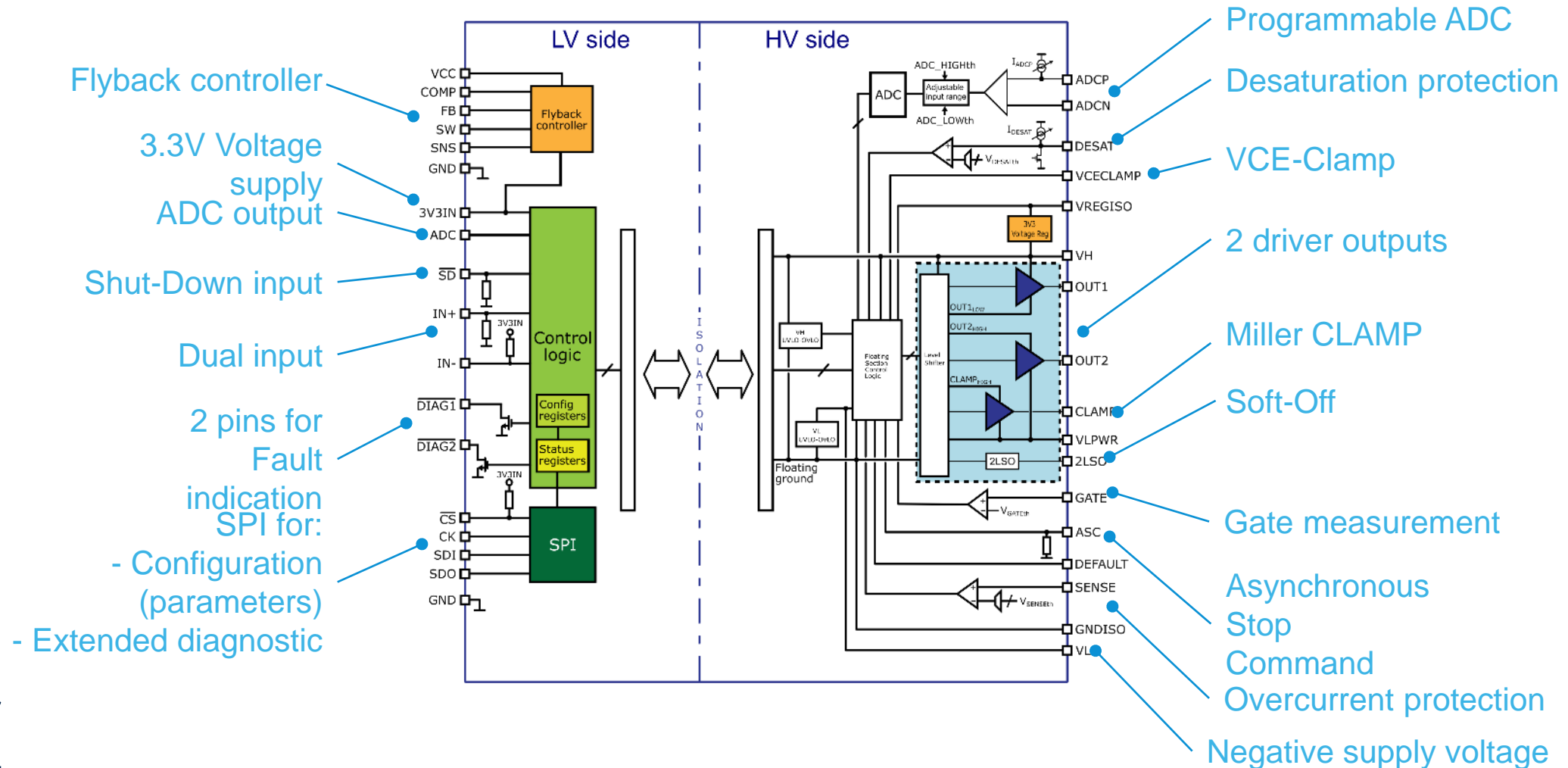
SO-36W

- High voltage rail up to 1200 V
- 6.4 kVpk galvanic isolation
- >100 V/ns CMTI
- Fully protected Integrated **isolated flyback** controller
- VH supply rail between 10 and 32 V
- **Negative gate drive ability**, VL supply rail between 0 V and -10 V
- **Programmable input deglitch filter**
- Programmable **deadtime**, with violation error
- Two **Diagnostic** status outputs
- **SPI** interface for parameters programming and extended diagnostic
- Gate level monitoring
- Embedded functions & **Self Diagnostic routines** support ASIL-D system certification
- SO-36W fine-pitch package
- **Programmable UVLO and OVLO** functions on VH and VL
- VCC flyback supply and 3.3V supply UVLO
- Active Miller clamp driver
- **Programmable Desaturation** detection
- **Programmable SENSE** overcurrent detection
- **Adjustable** Soft-TurnOff for **effective** and **optimized** short-circuit protection
- **VCE-Clamp**
- Asynchronous stop command (ASC)
- **Optimized ADC for temperature monitoring.**
- **Synchronized ADC sampling-time (Sample in noiseless period).** with current source for Power Module T_j measurement
- Temperature warning and shutdown protection



STGAP4S – Block Diagram

Best in class integration and performance

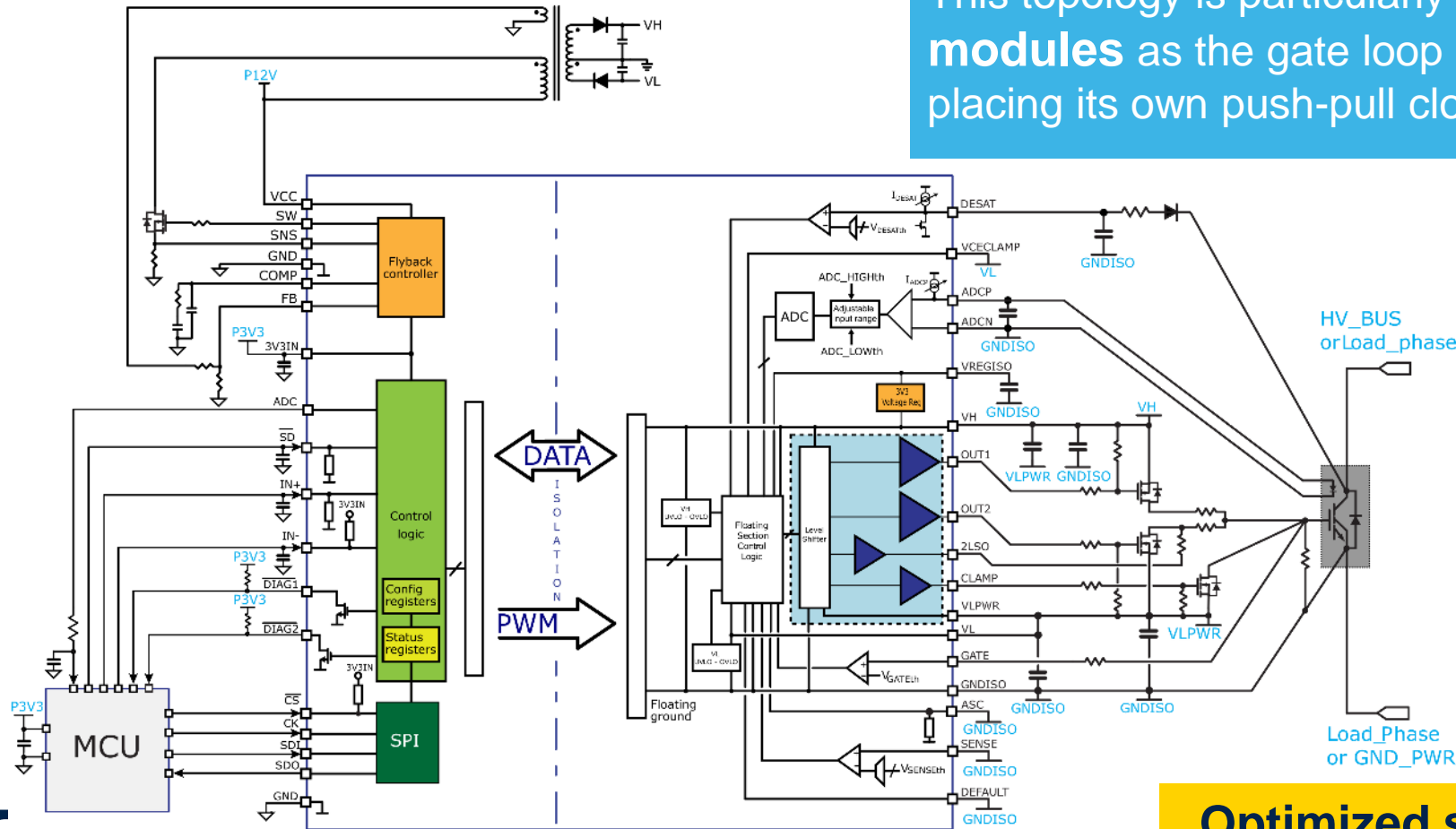




STGAP4 architecture

Innovative concept for system design and performance optimization

This topology is particularly effective with **paralleled power modules** as the gate loop of each module can be optimized placing its own push-pull close to the gate-source pins



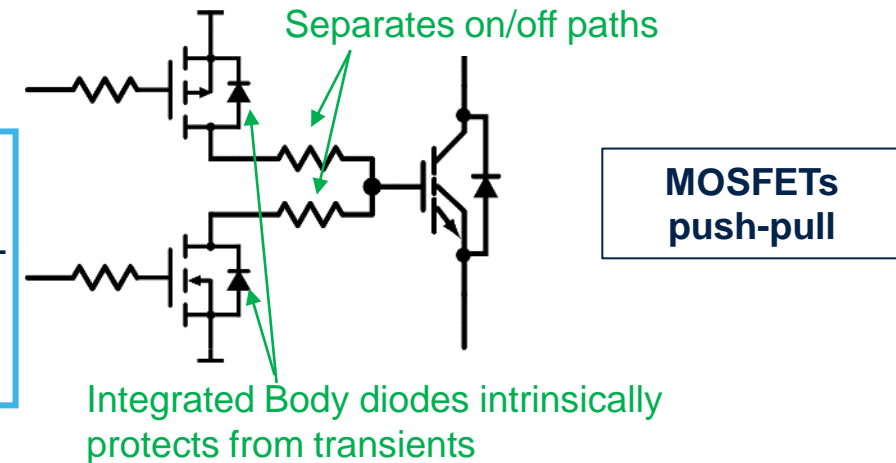
Optimized solution for high power driving topology



STGAP4S - External MOSFET push-pull

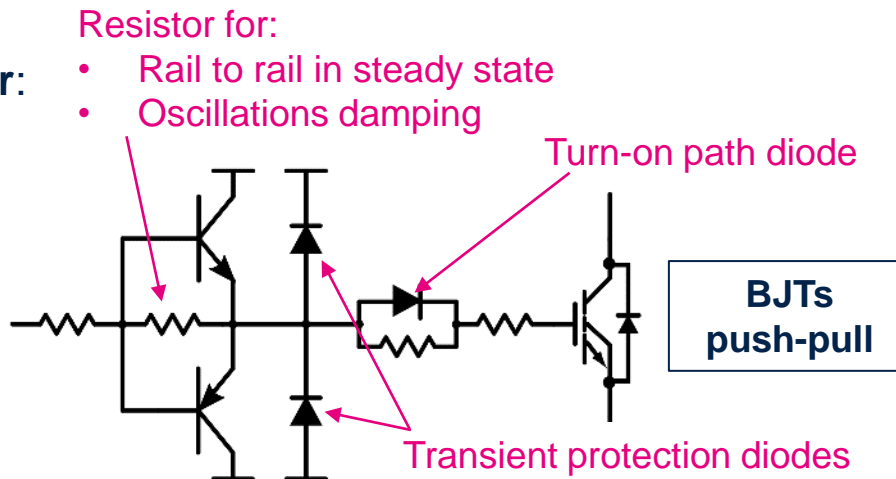
Easy MOSFET push-pull implementation

- Easy implementation of MOSFET push-pull topology
- Rail to rail output: the ON/OFF voltage depends only on the precision of V_H , V_L
- R_{OFF} and R_{ON} without external diode
- Integrated overvoltage protection thanks to intrinsic body diodes



The two topologies have comparable performance, but **looking to the market offer**:

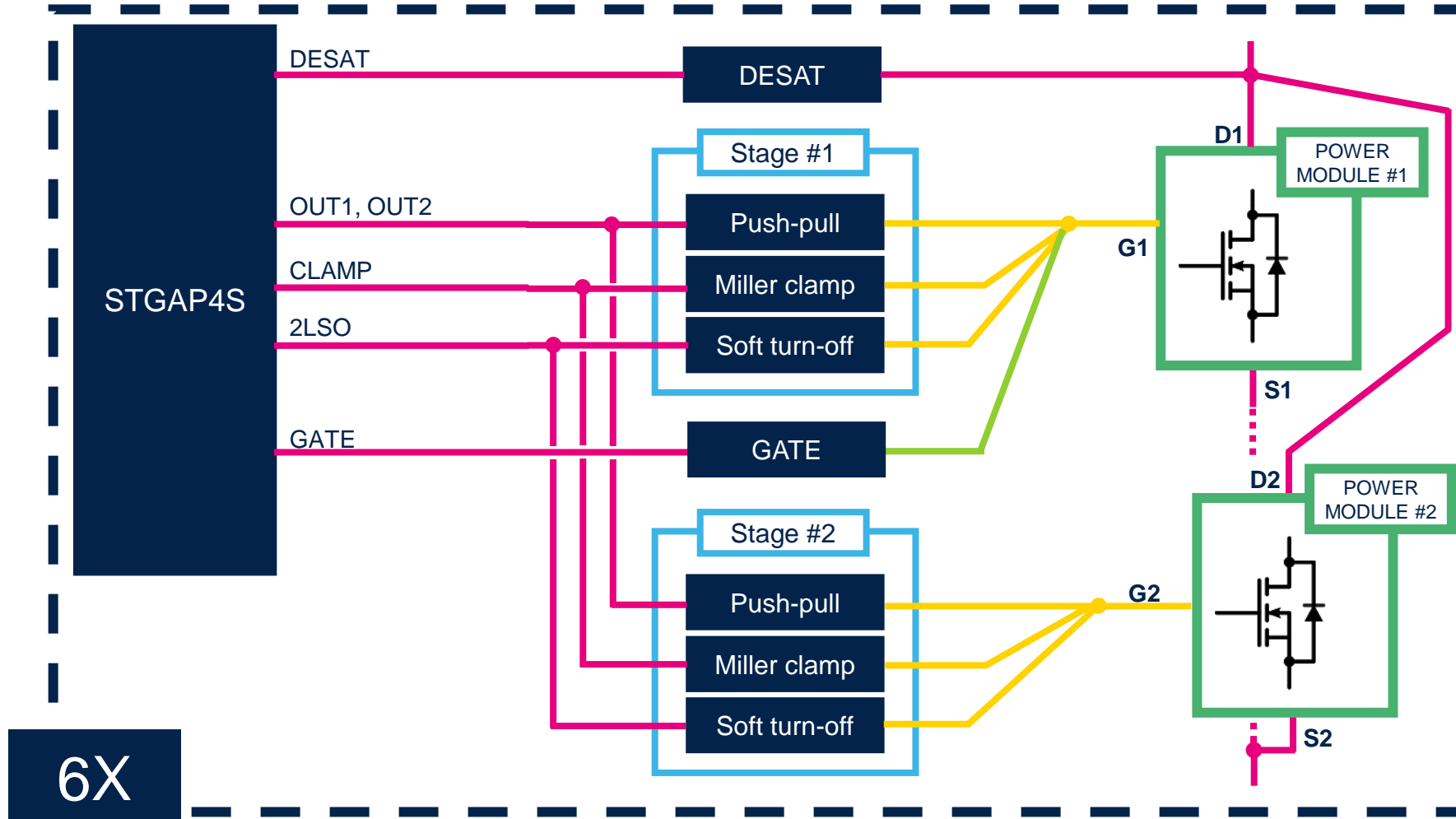
- availability of high-current BJT is far less compared to high-current MOSFETs
- MOSFETs market offers much wider package possibility with:
 - a higher miniaturization
 - a better thermal performance
- with MOSFETs higher power density can be reached





STGAP4S - HV push-pull split principle

Driving 2 power modules with split push-pull

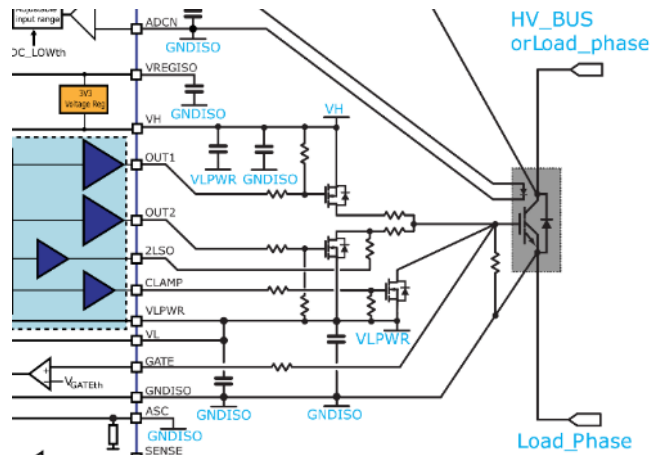




STGAP4S Innovative driving architecture

STGAP4: optimized external push-pull with small gate-loop inductance (key design parameter)

STGAP4S PRE- DRIVER ARCHITECTURE



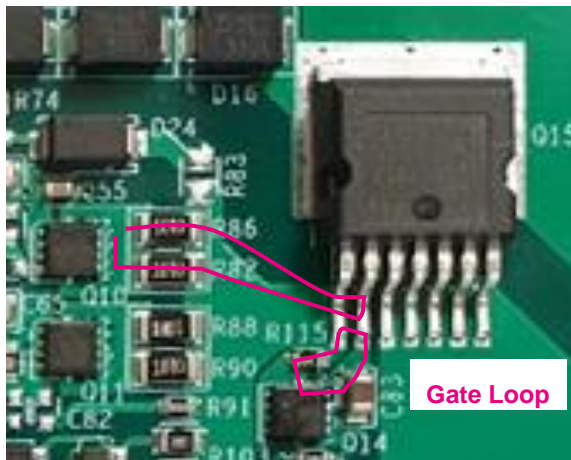
- Enable short gate-loop Gate-to-Source
 - Smaller gate-loop inductance
 - Reduced ringing and overshoot
 - Optimizes switching performance: better efficiency and EMC
- MOS vs. BJT in external push-pull
 - Differentiated ON and OFF Rgate without using diodes
 - Faster than BJT and Rail-to-rail driving
 - Much more scalable than BJT
- External MOS for Miller Clamp
 - Can be closer to the Power Transistor: reduced inductive spikes.
 - Also clamps negative Gate spikes
 - Zero drop compared to PNP BJT

STGAP4S ADVANTAGE

- ✓ Reduced power dissipation. Lower T_j
- ✓ Low ringing in high-power applications
- ✓ More efficiency and better EMC
- ✓ Optimized switching performance
- ✓ Improved Miller CLAMP effectiveness
- ✓ Tiny MOSFETs can easily dissipate gate power

STGAP4S can be tuned to any power rating

- Package for galvanic isolation have no exposed pad due to creepage requirements: limited power can be handled.
- Traction inverters have considerable gate power dissipation
- By moving gate power on external push-pull, the gate driver's operating T_j is reduced → improved mission profile and reliability performance
- Tiny external MOSFETs can easily dissipate gate power and quickly provide correct driving current for any inverter size



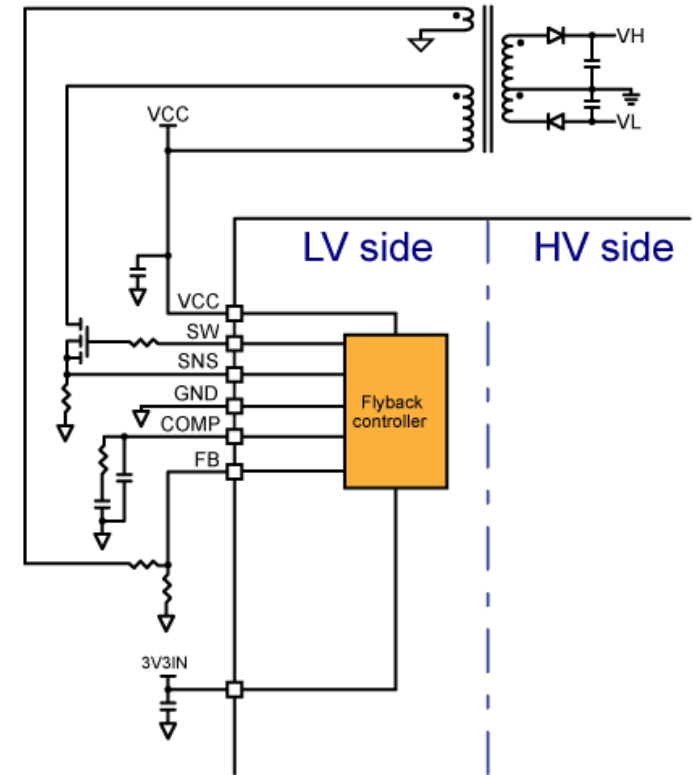
60V, 144 Apk current in 3.3x3.3 mm package



STGAP4S – integrated flyback controller

Fully protected generation of VH & VL supplies for gate driving stage

- Wide VCC input voltage (8 – 24 V), UVLO protected
- SW pin for MOSFET gate driving
- Soft start
- Programmable F_{SW} (200, 300, 400, 600 kHz)
- Voltage mode controller
- Full set of protection functions
 - Input undervoltage, OVP, UVP, anti-CCM operation, 2-levels OCP
- If the flyback is not used the pins must be simply left unconnected

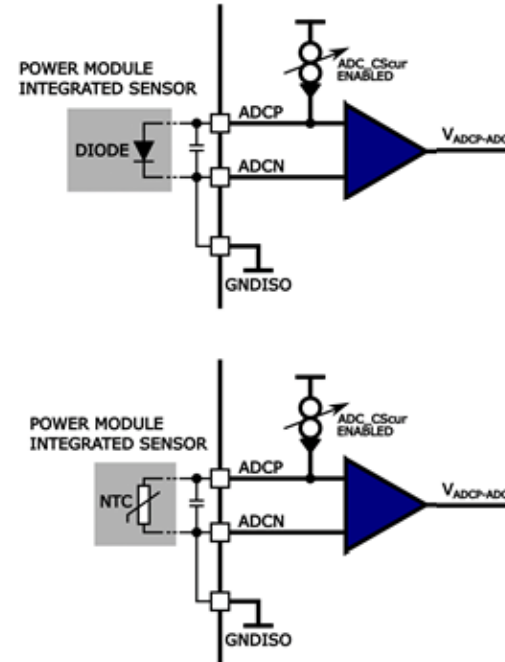




STGAP4S – A/D converter

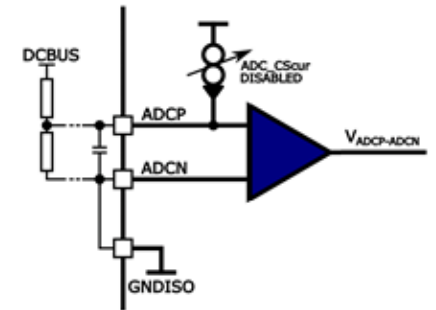
Fully configurable 8bit Analog to Digital converter, high flexibility

- Adjustable input voltage conversion range:
 - 8 high levels (1.5V to 3V)
 - 8 low levels (0V to 1.5V)
- Selectable input source:
 - External differential voltage between ADCP and ADCN pins
 - Internal temperature sensor
- Programmable current source
 - 3 programmable currents (300uA, 600uA, 1mA) + Disable
 - External sensors feeding without any additional external component
- Converted data available through SPI:
 - Data available in STATUS register
- “ADC” output pin for PWM encoded data:
 - 10% to 90% duty cycle, proportional to digital converted value
 - Self-diagnostic: PWM at 100% when the ADC conversion is missing
 - PWM fixed low when the encoding function is disabled



TEMPERATURE
SENSING

Connection examples



DC LINK
VOLTAGE MEASURE



STGAP4S – Desat protection

Ultrafast and rugged overload and short-circuit protection, easily tunable protection

- 8 programmable thresholds (3V to 10V, 1V step)
- Enhanced blanking time:
 - Fixed blanking time for high noise immunity
 - 4 programmable currents (250uA, 500uA, 750uA, 1mA) for flexible blanking time extension
- Very fast intervention time: 150ns typ, 220ns max
- Adjustable Soft turn-off feature
 - Optimal trade-off between normal switching and protection
 - Very simple protection fine-tuning to Power Switch characteristics, no granularity limitations.

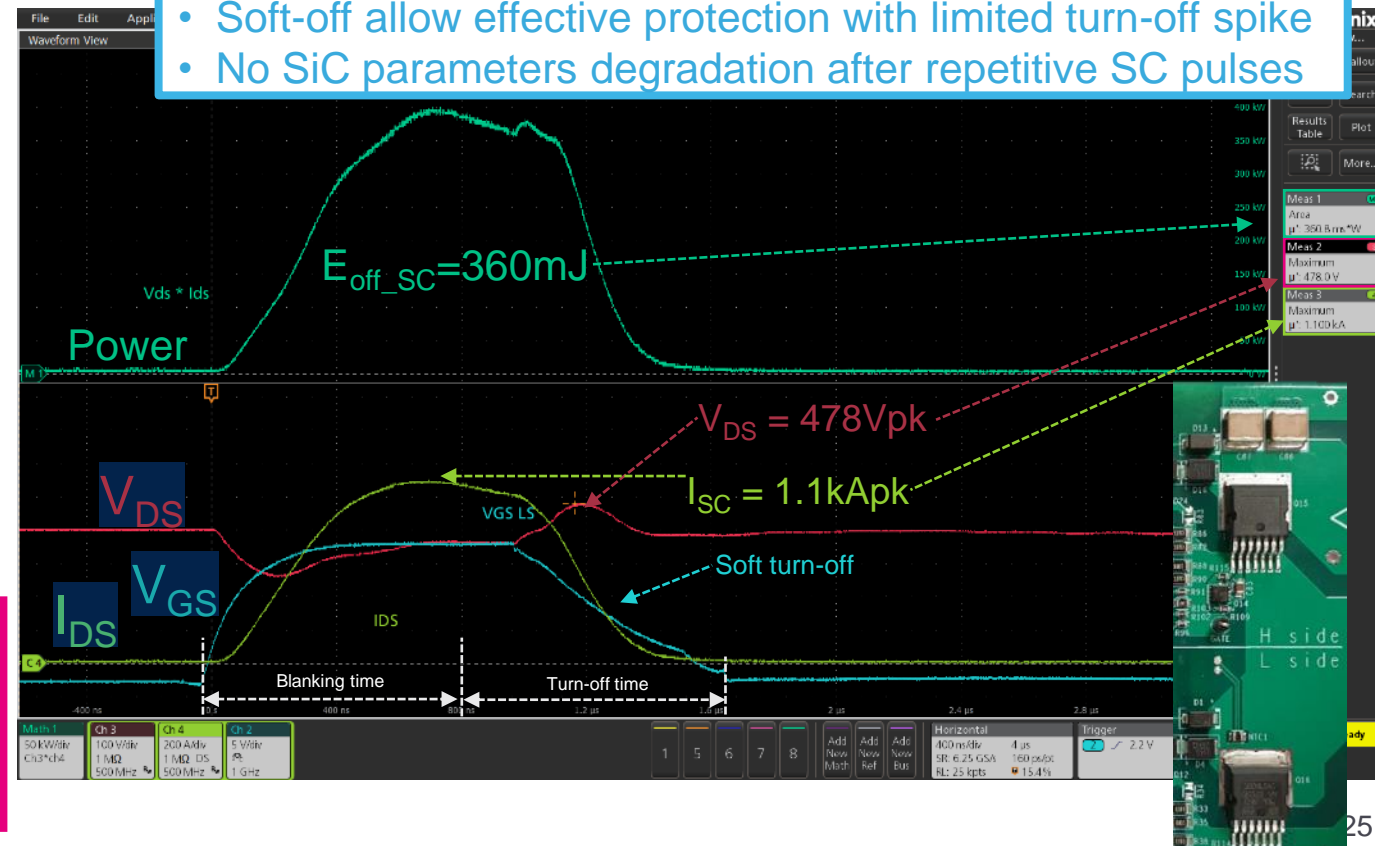
The short-circuit turn-off speed can be easily tuned without compromising the performance during normal operation

Best in class short-circuit protection performance

- Despite test board high collector inductance, drain overshoot is just 78V @ 1100 A_{pk} short-circuit current
- Very limited short-circuit duration

Short circuit test executed with the EVALSTGAP4S:

- SiC power MOSFET: SCTH100N65 (H7PAK)
- HV BUS = 400V
- Soft-off allow effective protection with limited turn-off spike
- No SiC parameters degradation after repetitive SC pulses

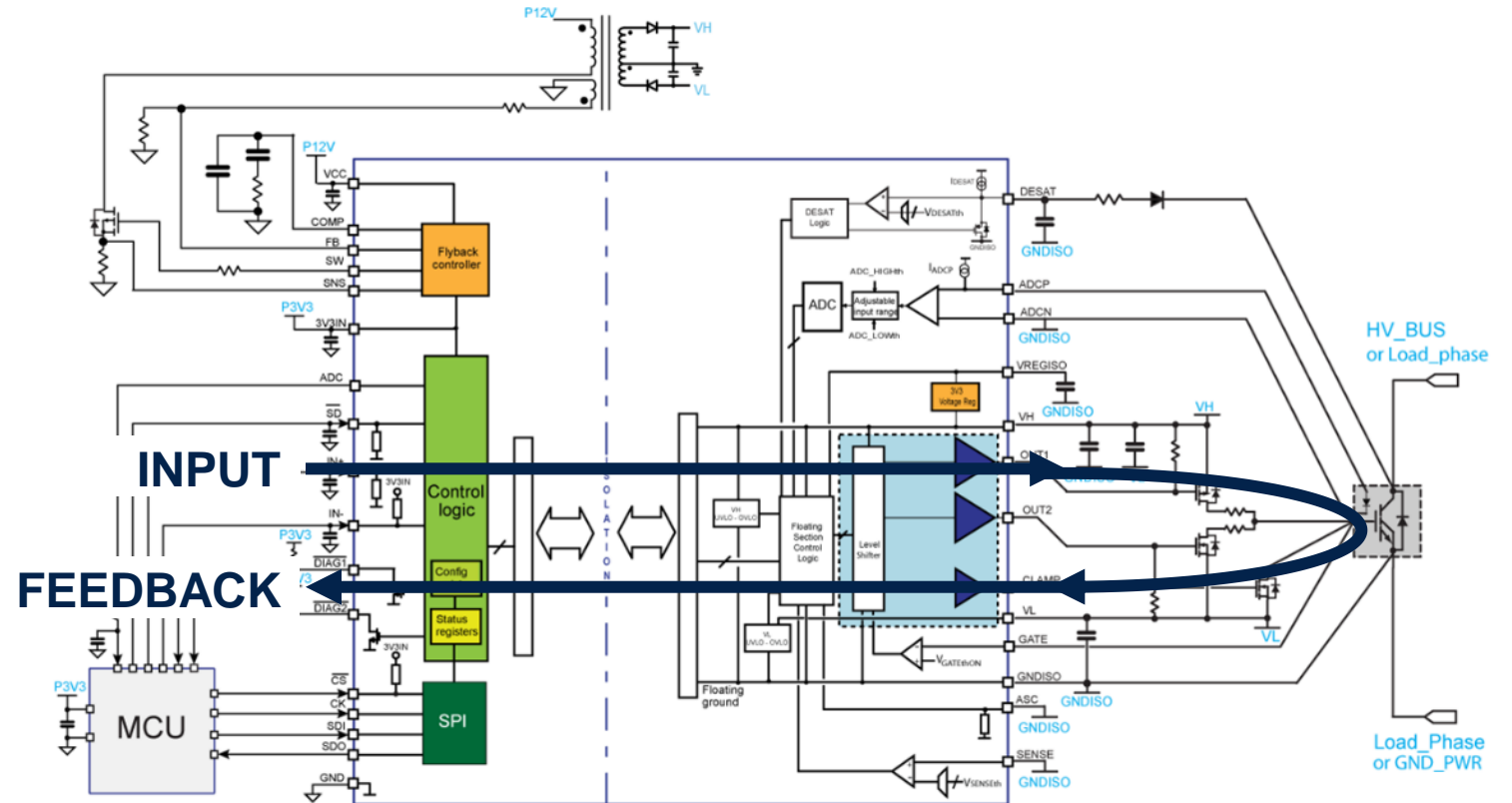




STGAP4S – safety functions

Built-in self-diagnostic routines

- Gate voltage monitoring and gate path integrity
- HV to LV gate status feedback
- DESAT protection
- SENSE protection
- External shunt resistor connection
- Miller clamp driver
- ADC





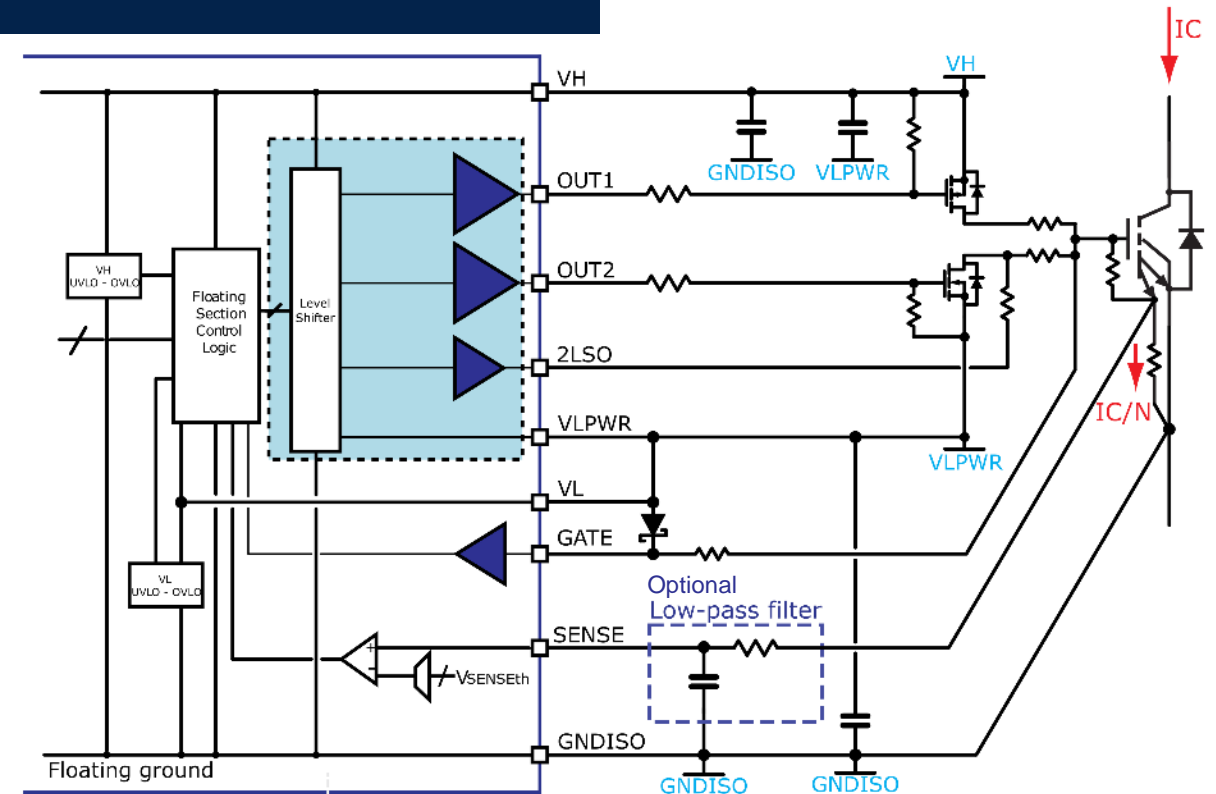
STGAP4S – SENSE protection

Ultrafast and rugged overcurrent protection, easily tunable

- Very fast intervention time: 95ns typ, 120ns max
- Adjustable Soft turn-off feature
 - Optimal trade-off between normal switching and protection
 - Very simple protection fine-tuning to Power Switch characteristics, no granularity limitations.

The short-circuit turn-off speed can be easily tuned without compromising the performance during normal operation

- In some applications Over-Current Protection is better achieved with current sensing through a shunt resistors
- Typical examples include low-current applications or applications using Current-sensing IGBTs

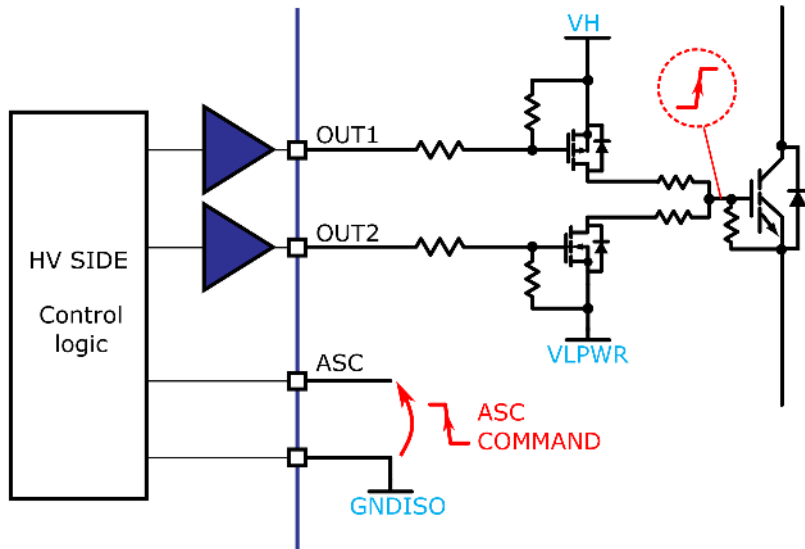




STGAP4S – ASC

Asynchronous Stop Command

- The ASC pin allows to turn-on the power switch acting directly on the isolated side driver logic, regardless of the status of the primary side
- The ASC function works even with primary side not supplied and the device in *SafeState*
- The DESAT, SENSE, Overtemperature functions are still available and the external power switch is turned-off in case of protection event
- One typical application is the motor braking in specific safety cases

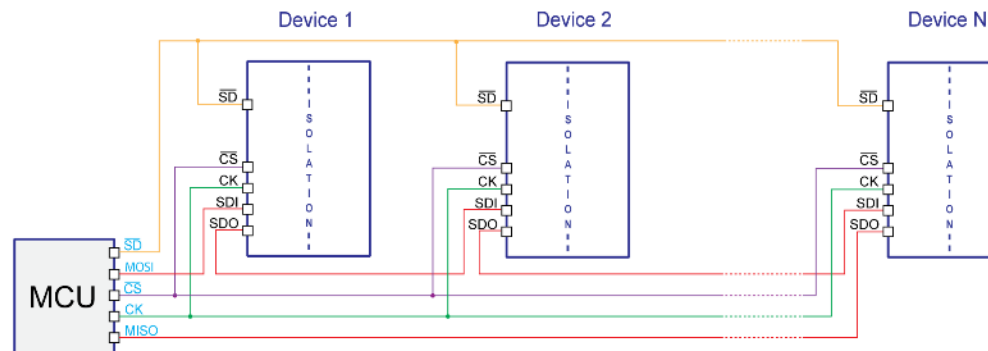
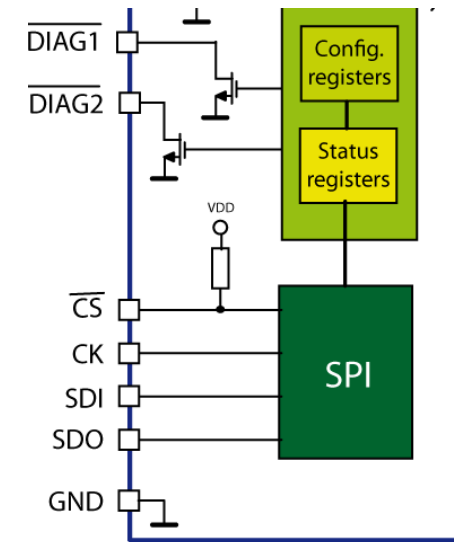




STGAP4S – programmability and diagnostic

SPI Interface for parameters setting and advanced diagnostic

- Communication with external MCU by means of 16-bit SPI, CRC Protected
- Parameters configured in dedicated Registers
- Customization for different Applications
- Diagnostic information stored in Status Registers accessible by MCU
- Status Registers data can trigger 2 configurable diagnostic pins to inform the MCU
- Daisy-chain configuration for multiple drivers management by 4 wires





STGAP4S evaluation board

Complete evaluation of the STGAP4S and its features

EVALSTGAP4S



- Allows STGAP4S features evaluation driving a power switch with a voltage rating up to 650V

- SiC MOSFETs in H2PAK-7 package connected in half-bridge configuration
- The 2 drivers connected in SPI daisy-chain
- Multiple boards can be connected and share the same supply voltage
- Configure or disable protections and control features through SPI interface
- Advanced diagnostic accessible through SPI
- Single supply: primary side 3.3V and secondary side positive and negative driving voltage on-board generated
- Configuration with STEVAL-PCC009V2 communication board
- 3-phase inverter can be implemented by connecting three boards through the daisy chain connection of the SPI bus
- Configuration GUI available, up to 8 devices daisy-chain management

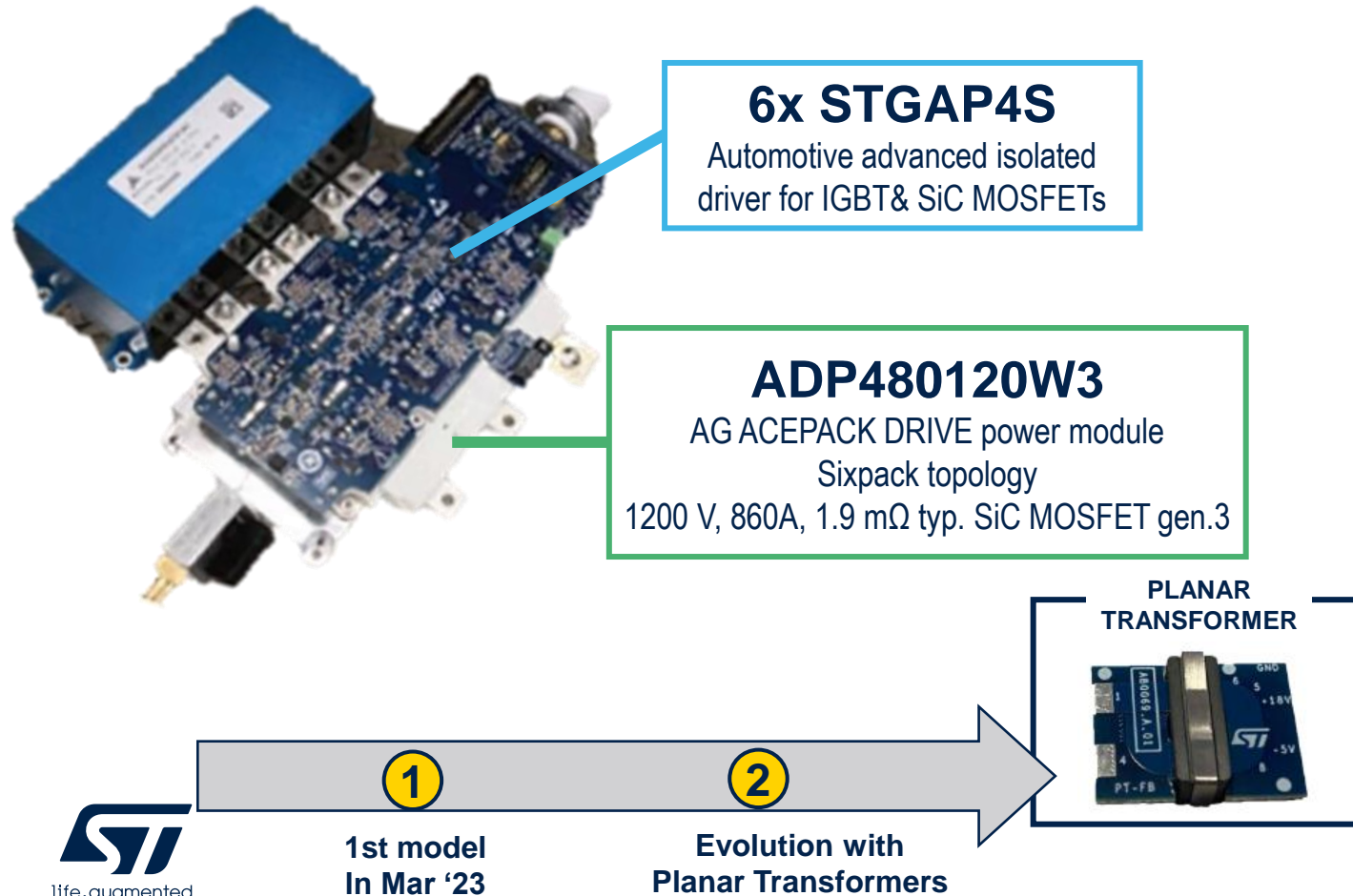




STGAP4S reference design for traction inverter

250 kW inverter featuring STGAP4S and SiC ACEPACK module

Key features



High gate driving current capability:

- 20A in the offered solution
- easy scalable/extendable selecting different push-pull

High level of integration with STGAP4S:

- flyback controller with full set of protections
- ADC for module temperature and HVBUS monitoring

Embedded protections:

- UnderVoltage, OverVoltage, OverTemperature
- Fast DESAT for SiC MOSFETs
- Active Miller clamp

Fully configurable through SPI:

- Flexible protection configuration
- Advanced diagnostic with configurable dedicated diagnostic

Security checks for self diagnostic routines

Our technology starts with You



Find out more at www.st.com

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