



# ST smart gate driver solutions

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# 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 extremely 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 key benefits

## STGAP1

- Driving SiC, IGBT
- SPI Programmable with full protections & diagnostic
- Single channel
- 5A sink/source current
- 4kV magnetic isolation
- AEC-Q100

- 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 + AEC-Q100

- 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 diagnostics
- 6.4kV capacitive isolation
- AEC-Q100

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

- **Addressing all industrial & automotive applications**
- **Robust solutions and wide driving current capability offer from 3 to > 15 A**
- **Galvanic isolation embedded from magnetic to reinforced capacitive**



# 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**





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

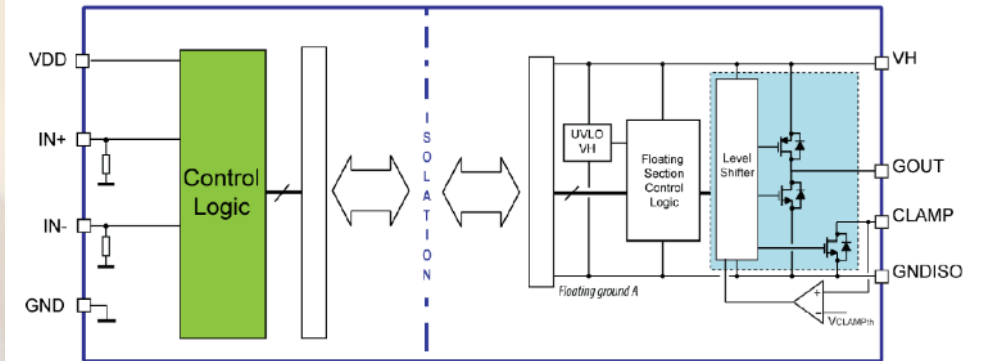
- On-chip galvanic isolation
- Robust SO-8W package

## Robustness

- Optimized UVLO for SiC
- Watchdog
- Transient immunity  $\pm 100$  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

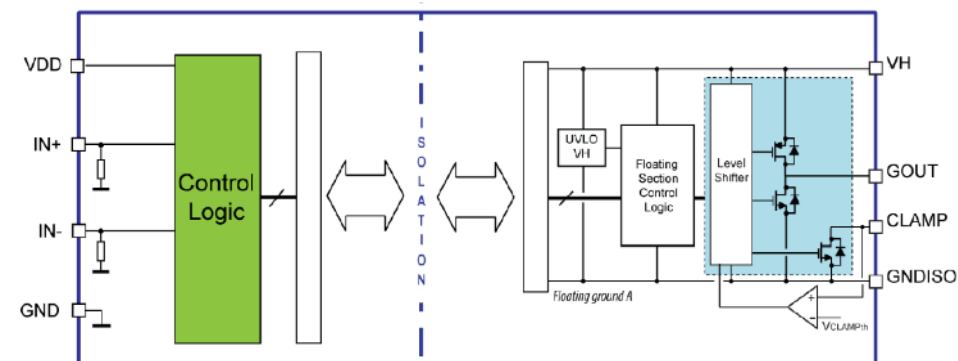
- On-chip galvanic isolation
- Compact SO-8N package

## Robustness

- Specific part with optimized UVLO for SiC
- Watchdog
- Transient immunity  $\pm 100$  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

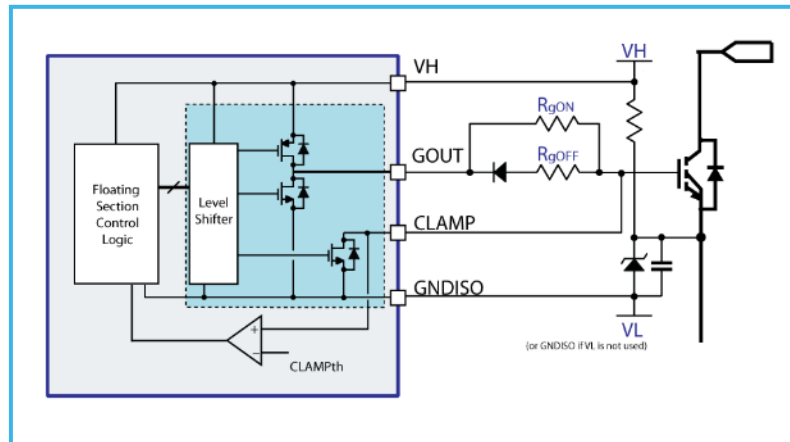
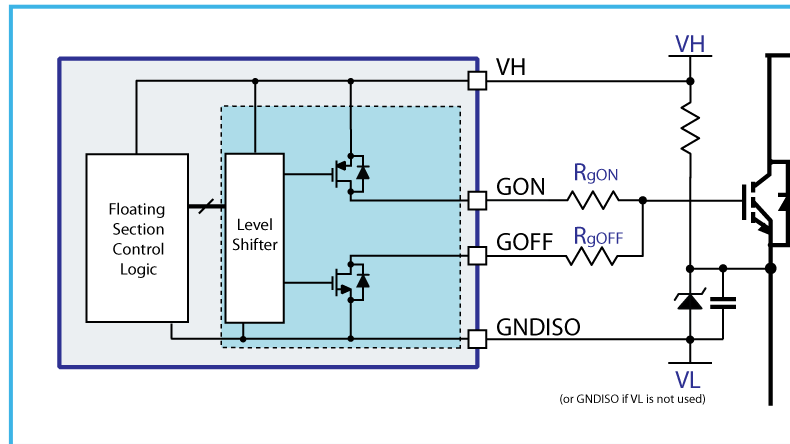
for easy gate driving tuning

STGAP2SM  
STGAP2HSM  
STGAP2SiCS  
STGAP2SiCSN

### MILLER CLAMP

to avoid induced turn-on

STGAP2SCM  
STGAP2HSCM  
STGAP2SiCSC  
STGAP2SiCSAC  
STGAP2SiCSNC  
STGAP2SiCSANC



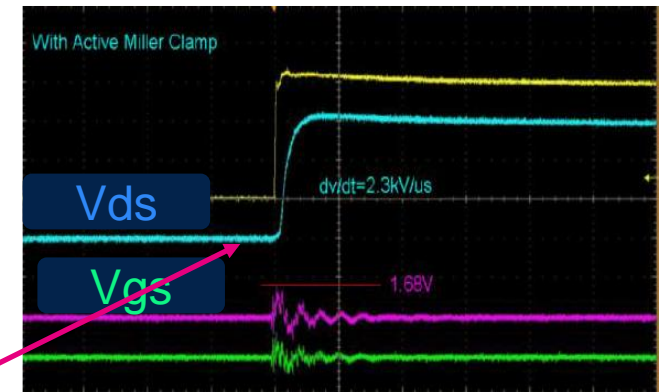
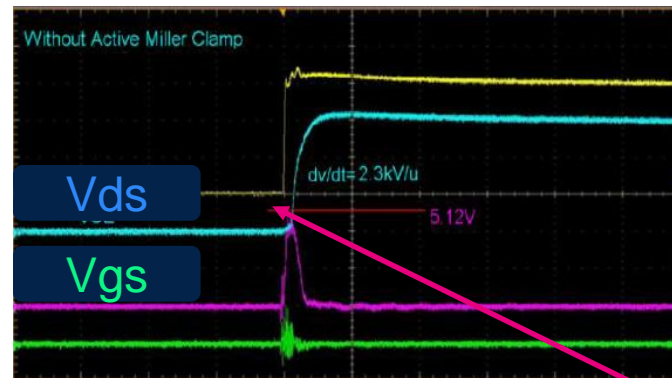
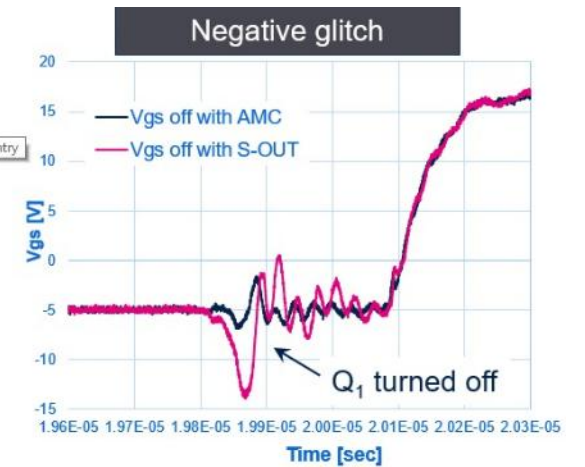
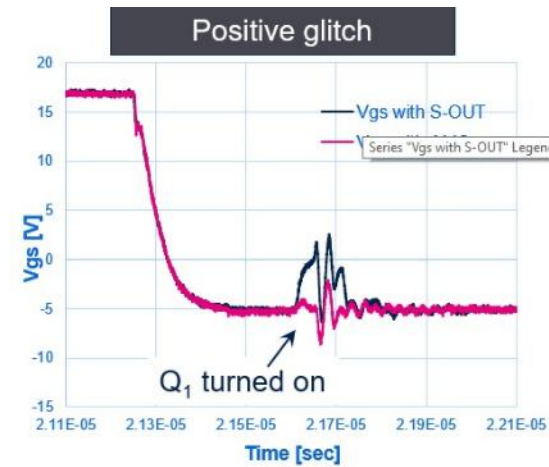
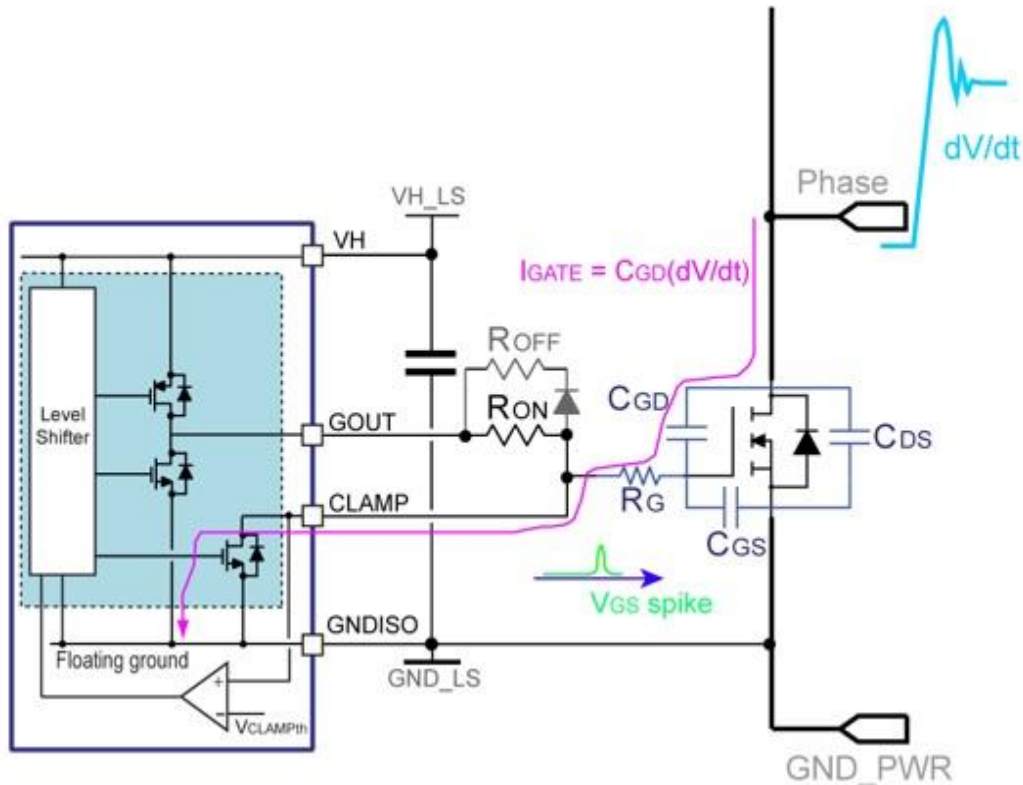
- “**SEPARATE OUTPUTS**” allow to differentiate easily the turn-on / turn-off paths to tune  $dV/dt$  and to avoid induced turn-on
- Induced turn-on can be avoided
  - with integrated MILLER CLAMP
  - driving the gate with negative voltage
- Power devices with low threshold voltage such as SiC and GaN 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





# 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.



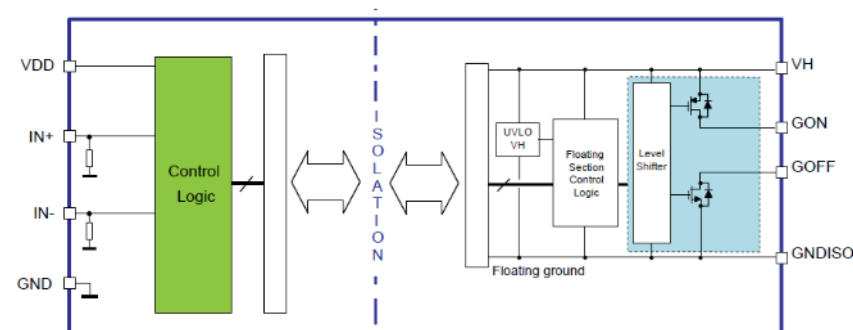




# STGAP2G galvanic driver for GaN

## 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 @ 25C, 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

- 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

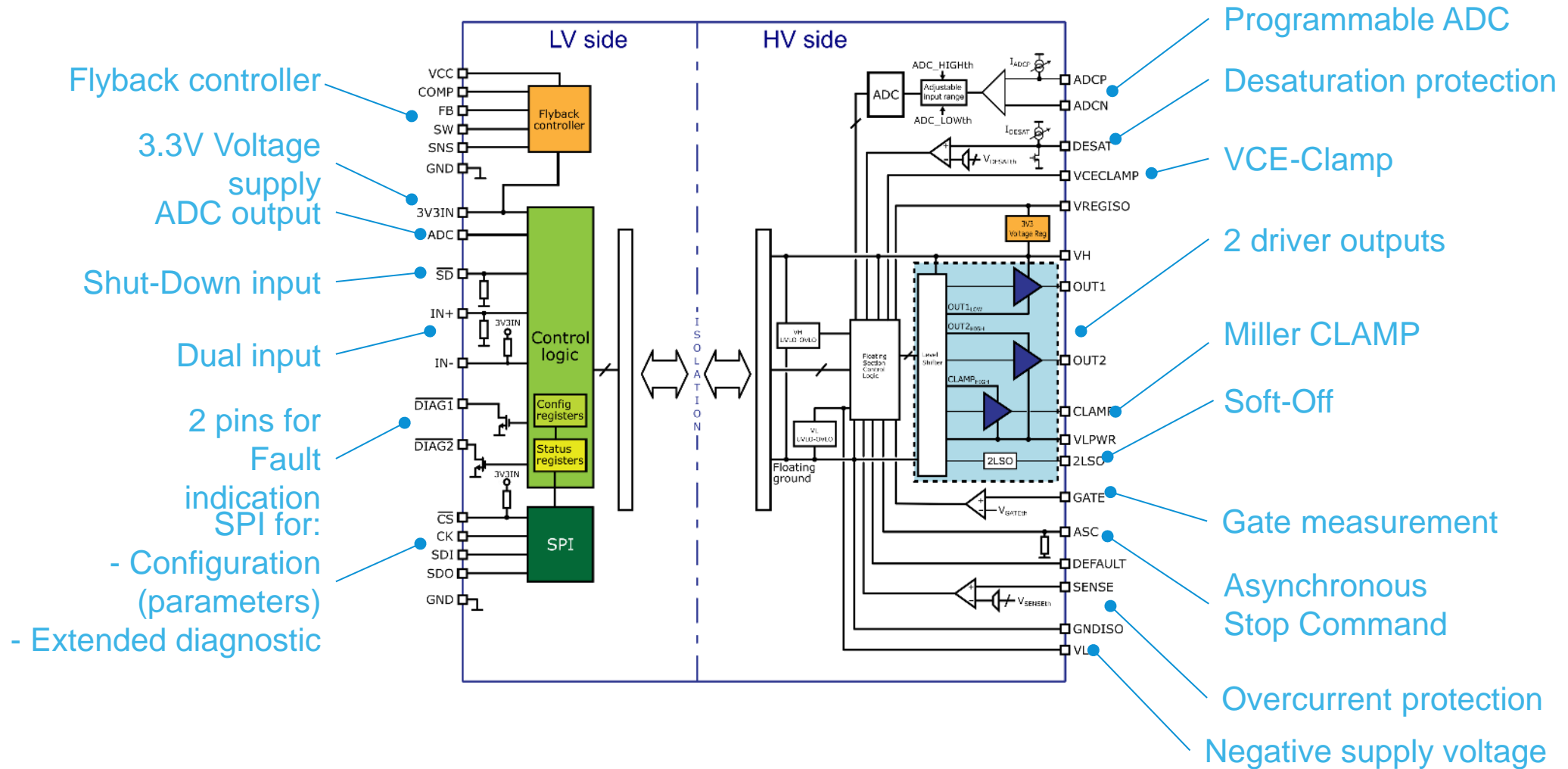


SO-36W



# STGAP4S – Block Diagram

Best in class integration and performance

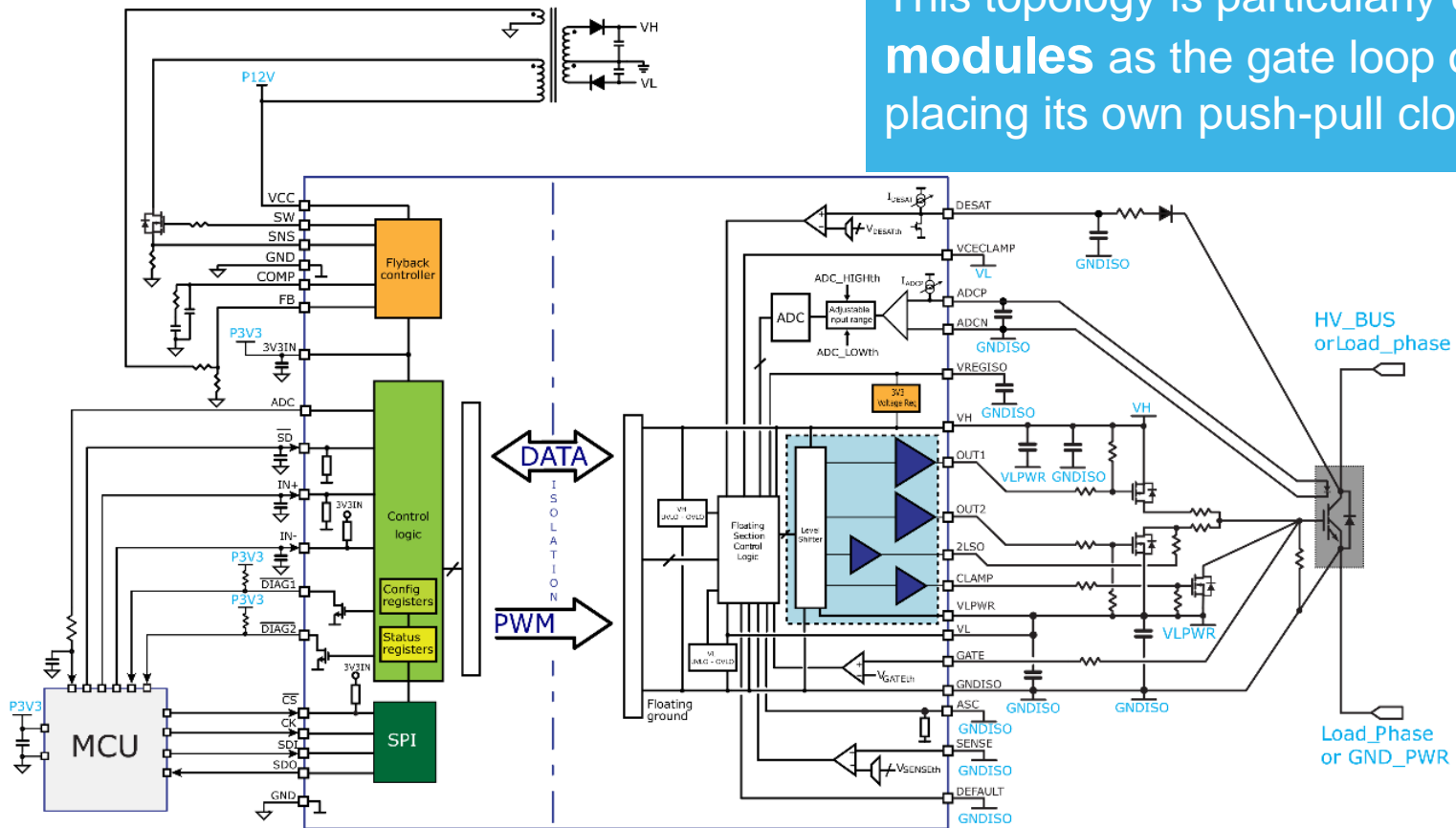




# STGAP4 architecture

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

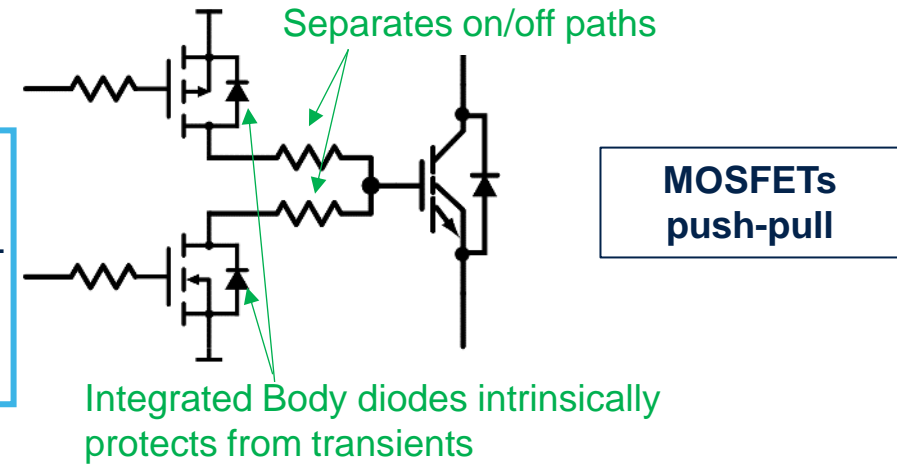




# STGAP4S - External MOSFET push-pull

## 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

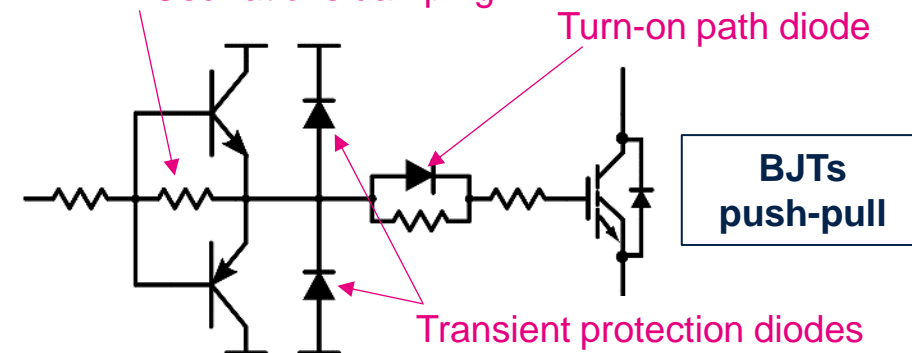


The two topologies have comparable performance, but **looking to the market offer:**

- 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

Resistor for:

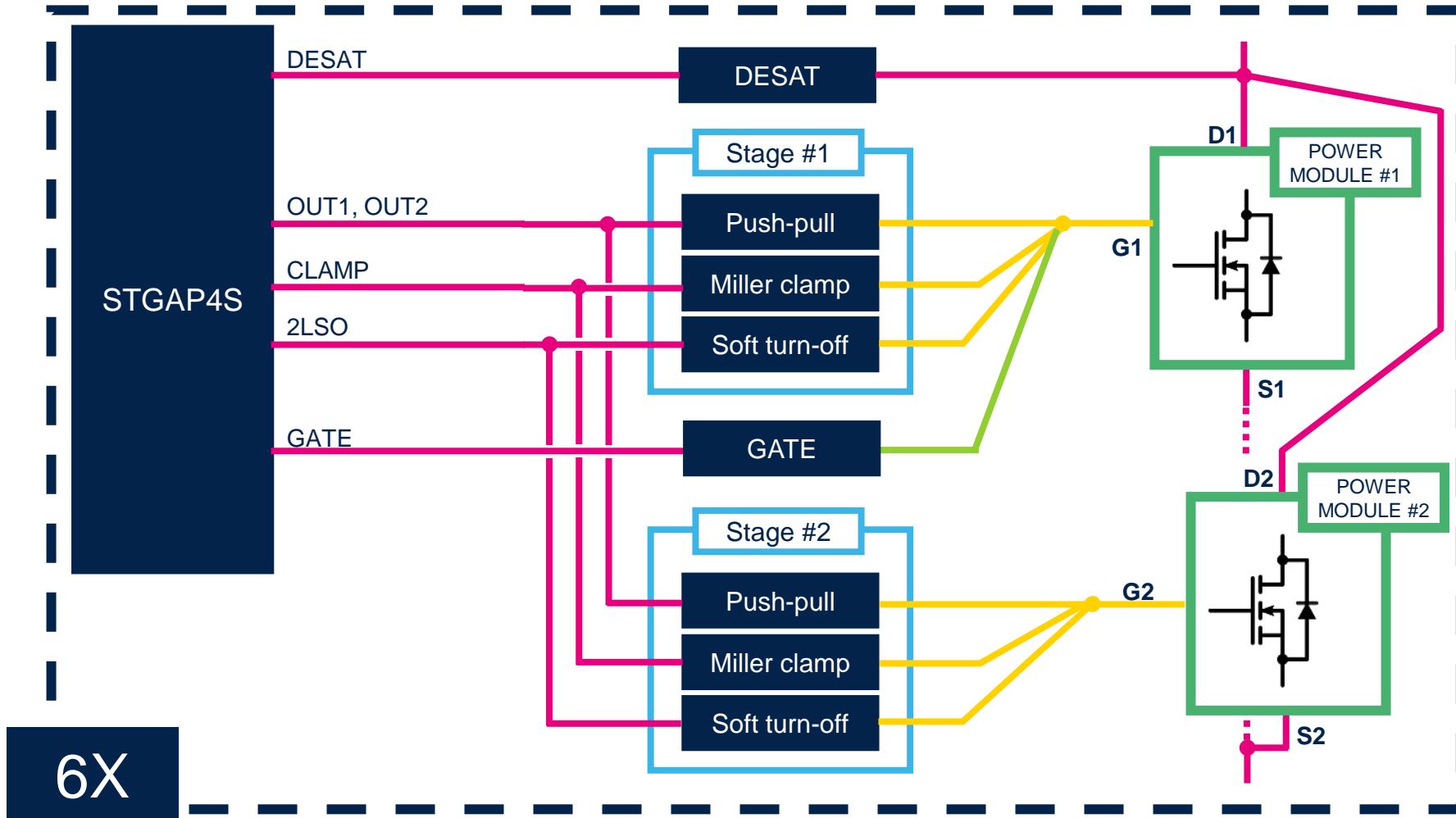
- Rail to rail in steady state
- Oscillations damping





# STGAP4S - HV push-pull split principle

## Driving 2 power modules with split push-pull



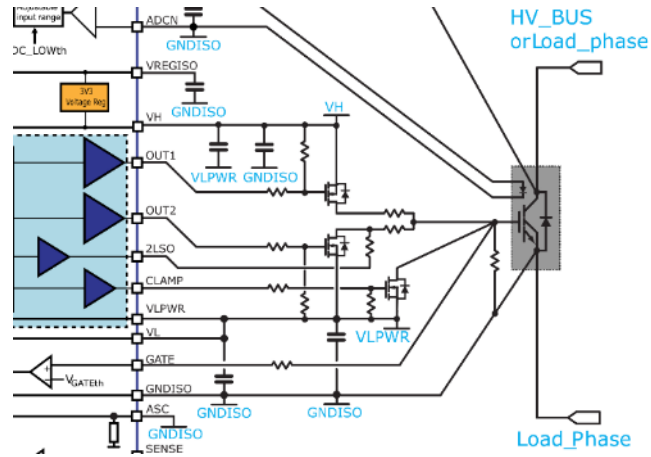
6X



# STGAP4S Innovative driving architecture

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

## STGAP4S PRE- DRIVER ARCHITECTURE



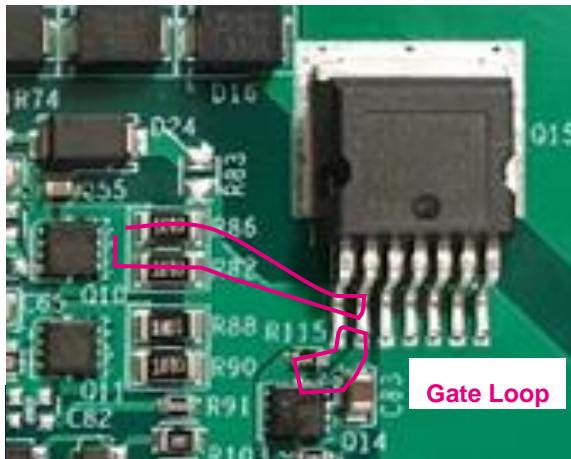
- Enable short gate-loop Gate-to-Source
  - Smaller gate-loop inductance
  - Reduced ringing and overshoot
  - Optimizes switching performance: better efficiency and EMC
- MOS vs. BJT in external push-pull
  - Differentiated ON and OFF R<sub>gate</sub> without using diodes
  - Faster than BJT and Rail-to-rail 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



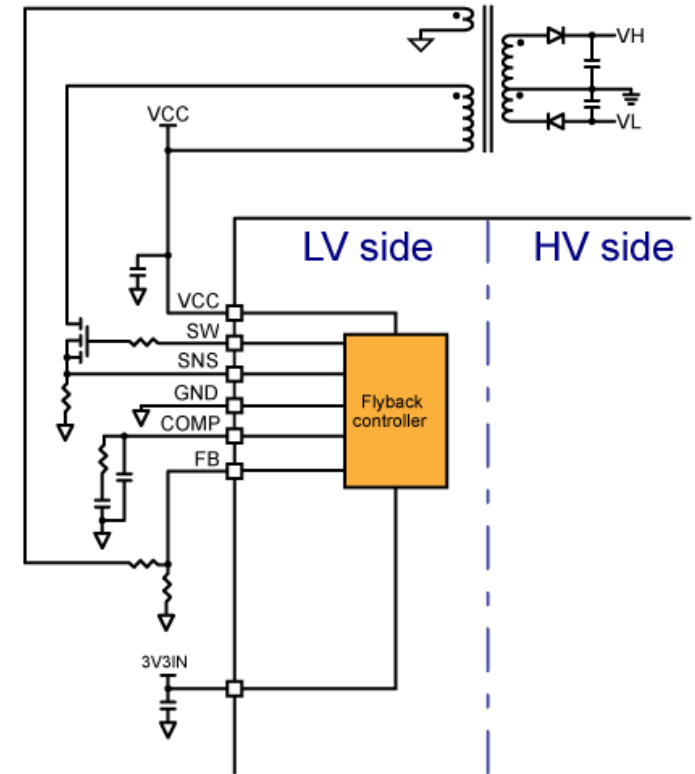
60V, 144 Apk current in 3.3x3.3 mm package



# 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

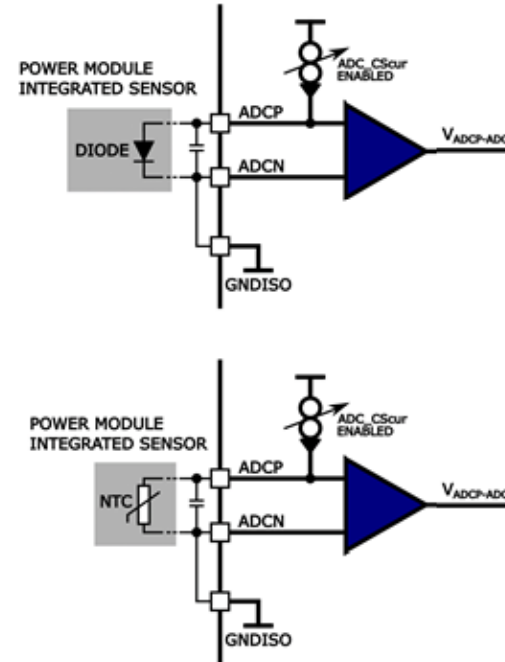




# STGAP4S – A/D converter

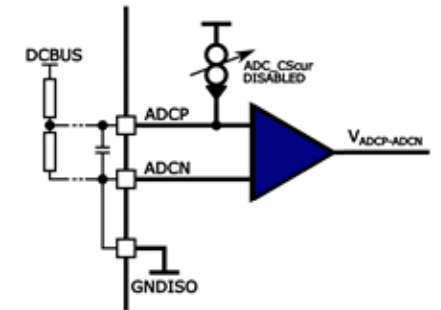
## Fully configurable 8bit Analog to Digital converter, high flexibility

- 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.

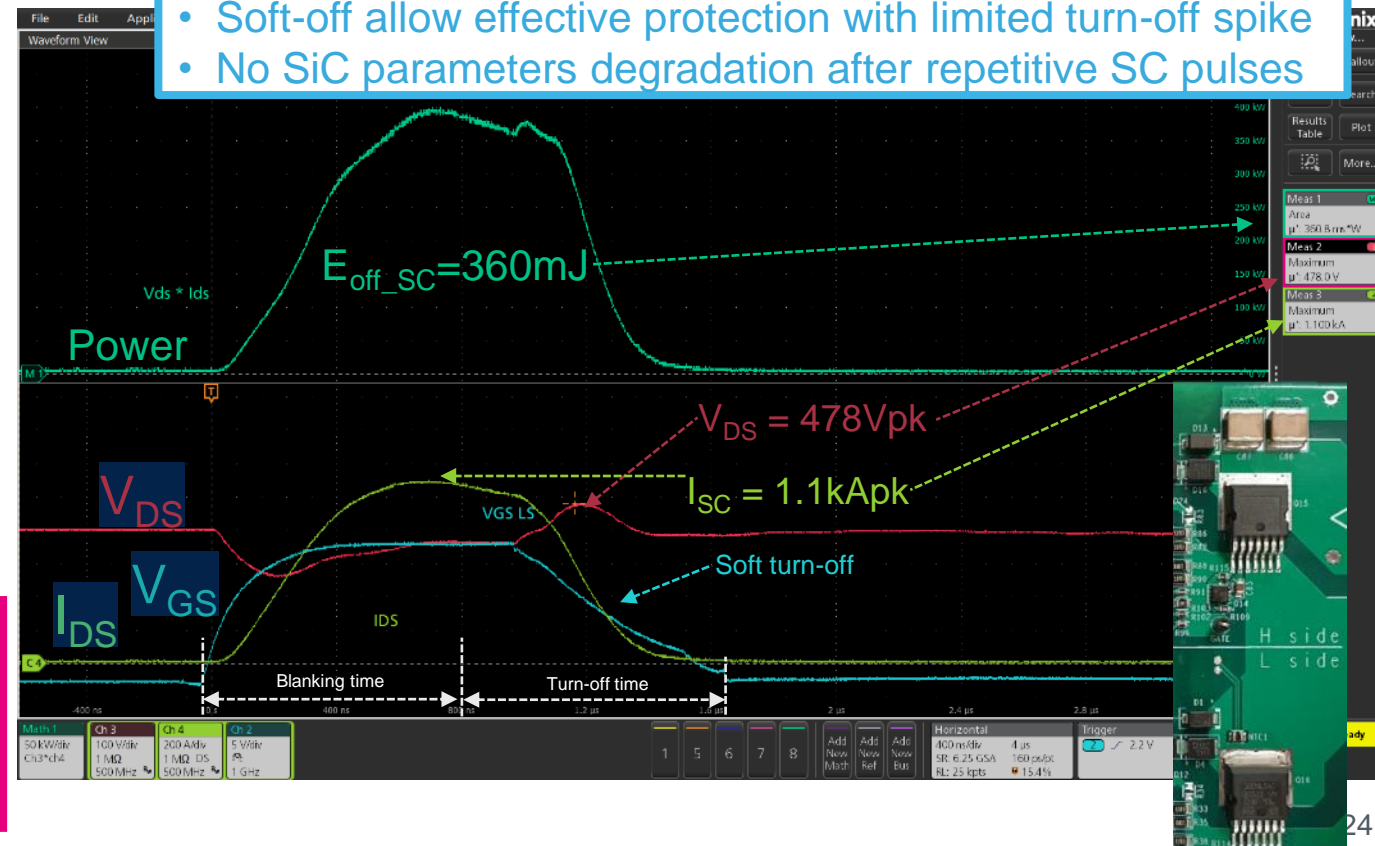
The short-circuit turn-off speed can be easily tuned without compromising the performance during normal operation

### Best in class short-circuit protection performance

- Despite test board high collector inductance, drain overshoot is just 78V @ 1100 A<sub>pk</sub> 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



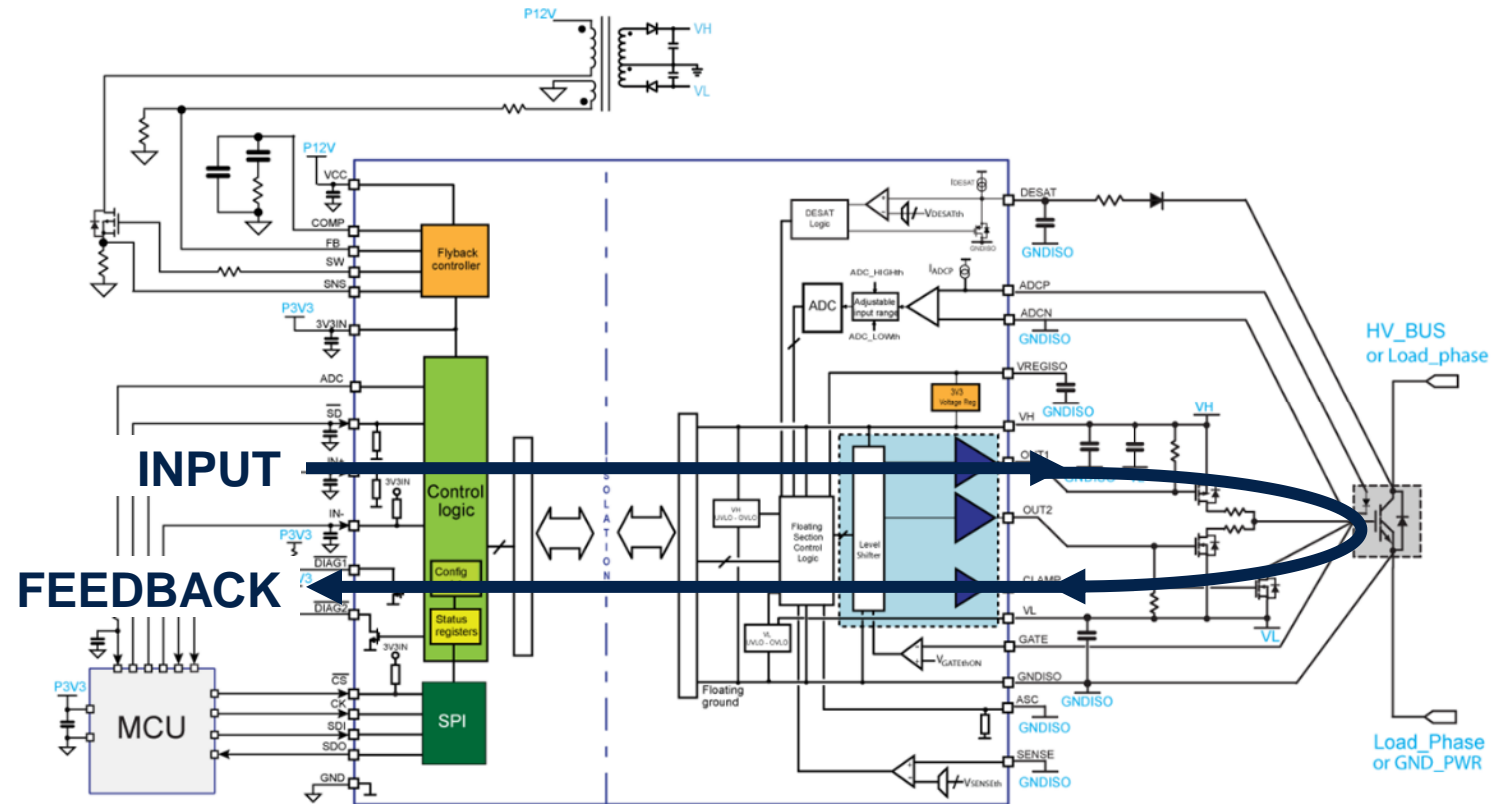


# STGAP4S – safety functions

## Built-in self-diagnostic routines

Check modes to verify the integrity of several features:

- 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





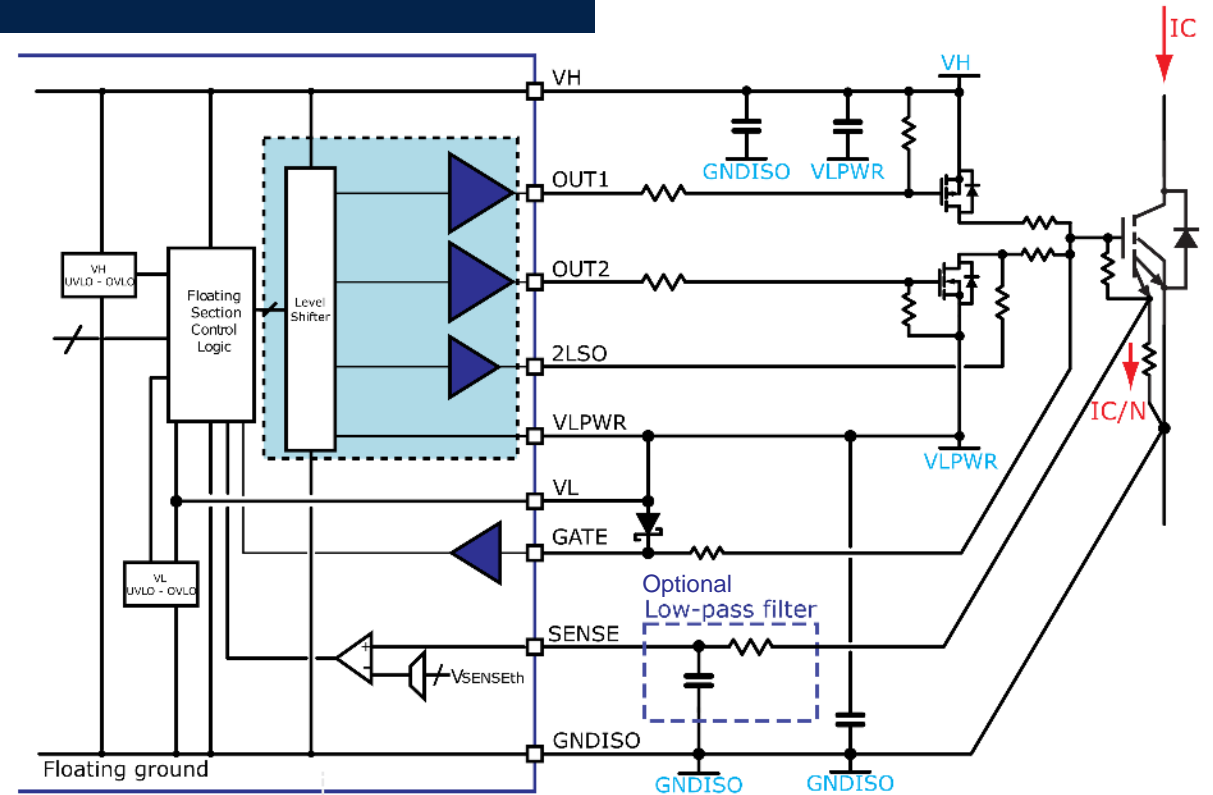
# STGAP4S – SENSE protection

## 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.

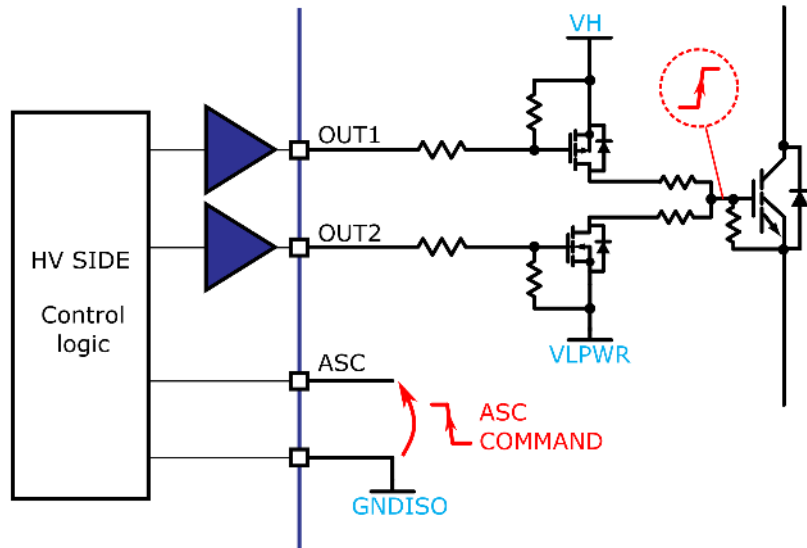
**The short-circuit turn-off speed can be easily tuned without compromising the performance during normal operation**

- 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



## 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

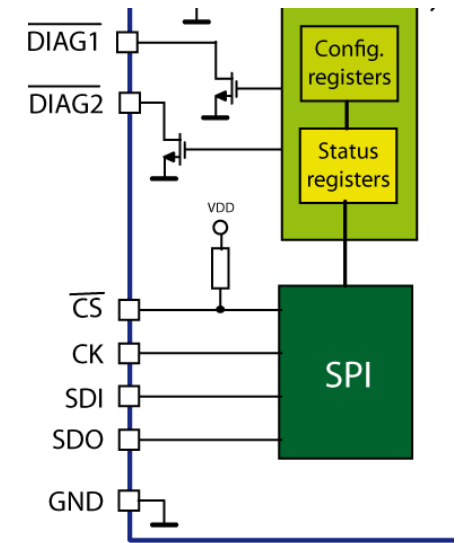
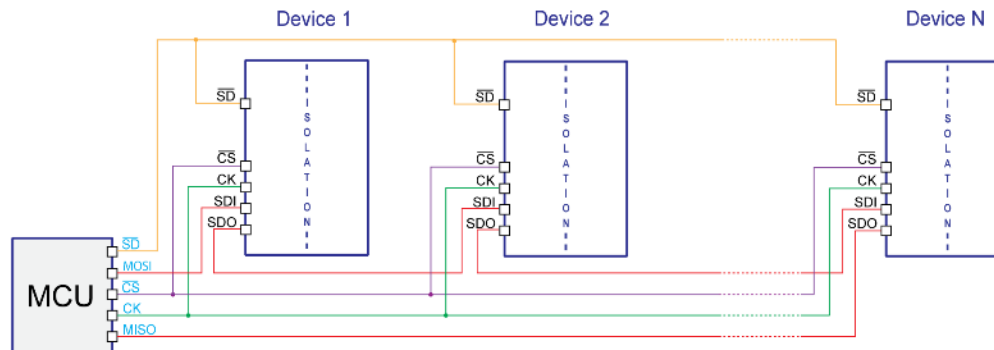




# STGAP4S – programmability and diagnostic

## 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

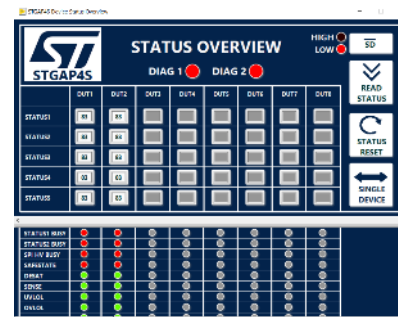
## Complete evaluation of the STGAP4S and its features

### 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

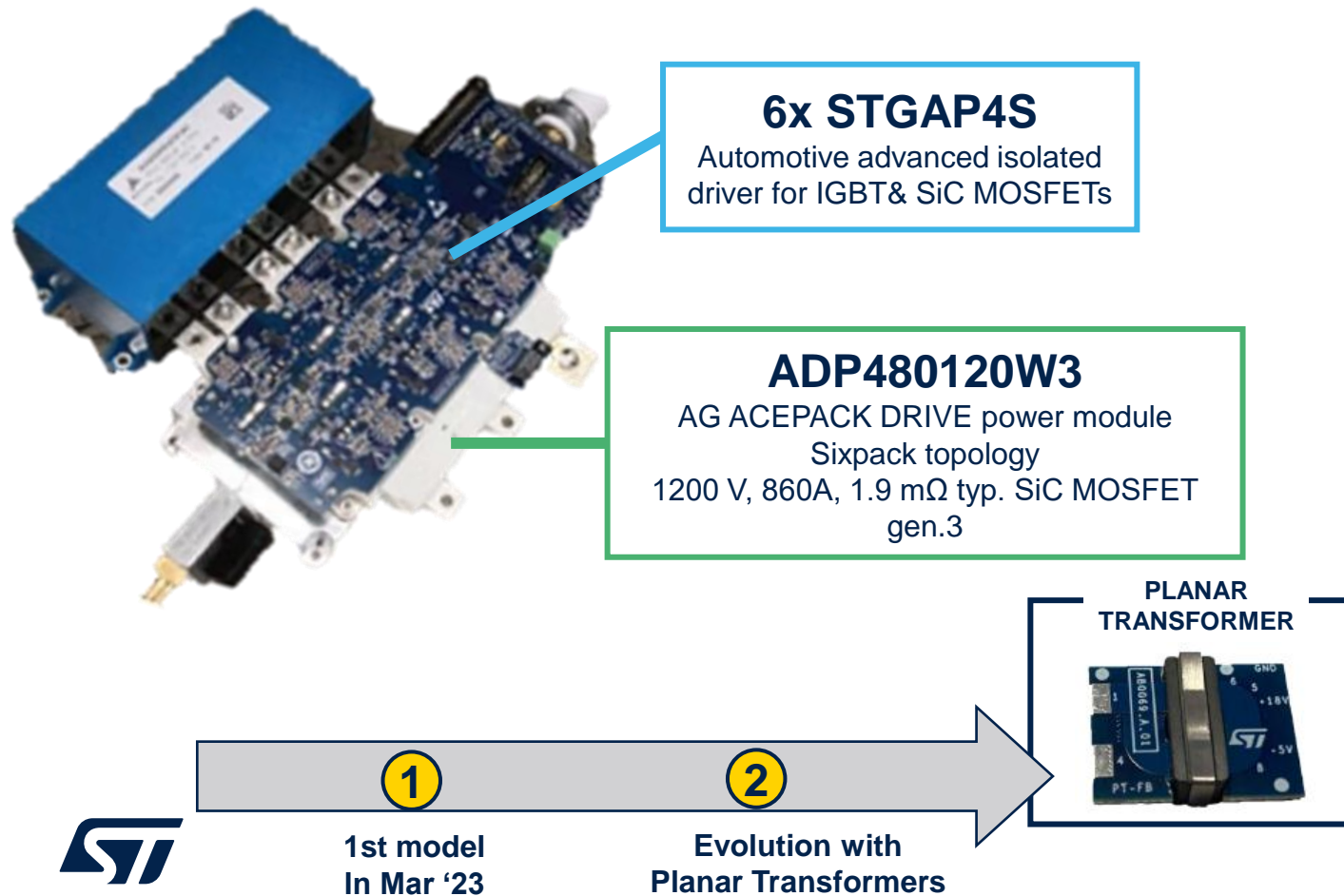




# STGAP4S reference design for traction inverter

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



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