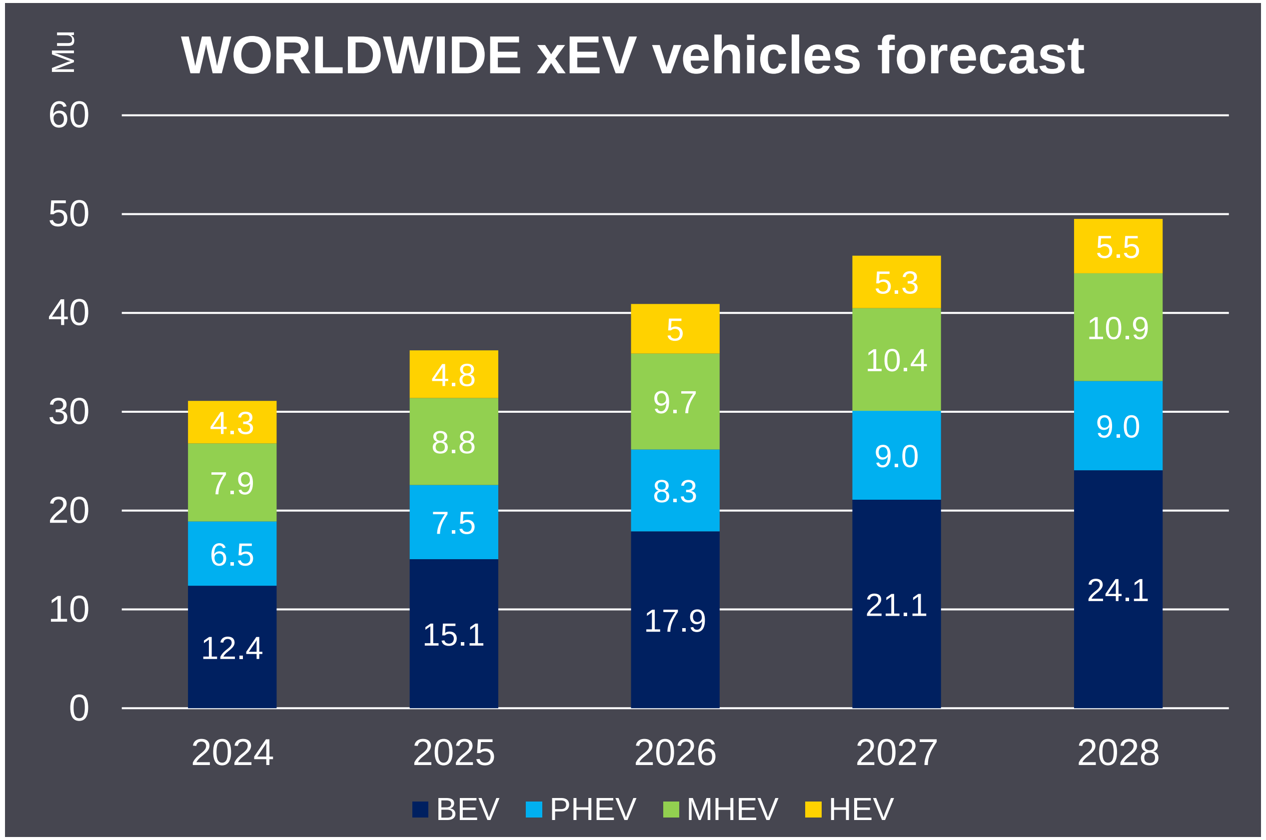
Automotive Intelligent and Integrated GaN STi^{2}GaN

GaN revolution in Automotive

STi²GaN overview

48 V / 12 V DC-DC solutions

Automotive trends and GaN domains



Forecast 800V system production in light duty BEV						
11%	**14%**	**16%**	**18%**	**21%**	**25%**	**27%**
2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**

Application trends	Requirements
Smaller/lighter systems	High frequency operation
Higher driving range	Higher system efficiency
Greater ADAS level	Systems/sensor redundancy

Applications augmented by GaN technology

100 V domain

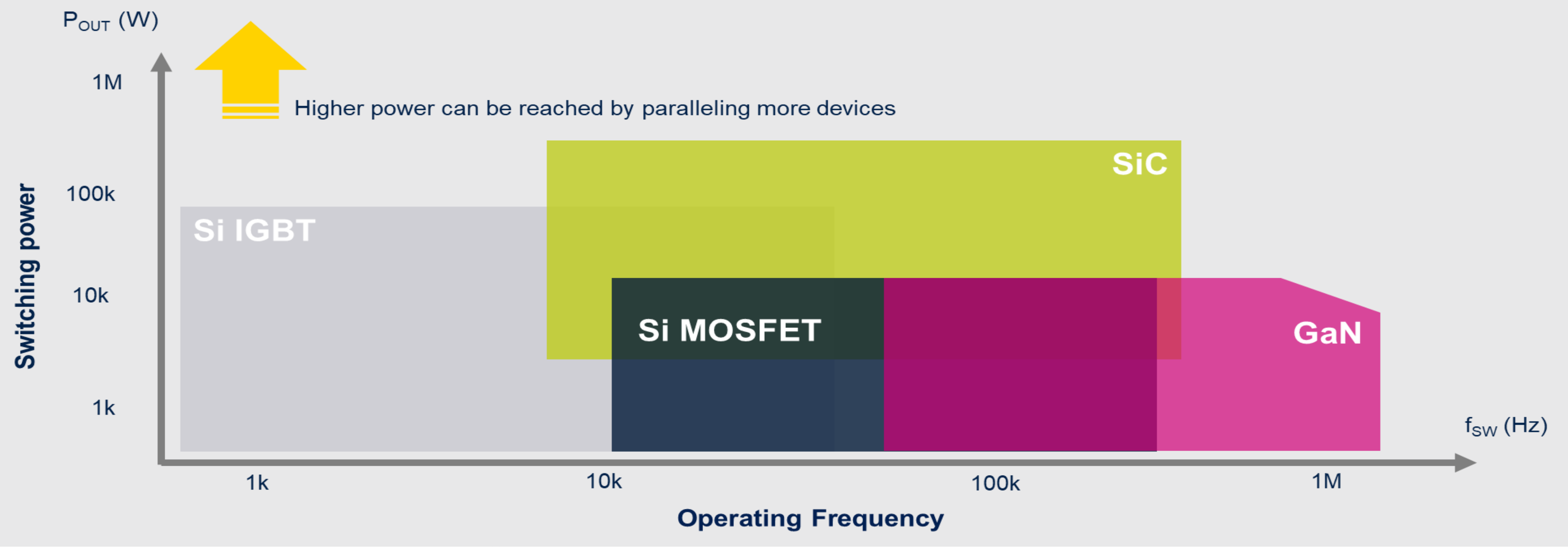
- Centralized DC-DC & POL
- Class-D audio amplifier
- Lidar & motor control

650 V domain

- On-board charger
- HV to LV DC-DC converter
- Emergency power supply

Source: Yole & ST workshop Sep 23
Power & Compound Semiconductor – Vehicle electrification

Gallium nitride (GaN) technology



GaN features

- Higher critical electrical field
- Higher electron mobility
- >x10 smaller Qg vs. Si (with same BVDSS and R_{ON})
- No body diode, no Qrr.
- Lateral tech. allows bridge configuration integration

GaN benefits

- Lower switching losses
- Higher operating frequency
- Enabling system miniaturization
- Higher power density

STi^{2}GaN smarter power electronics

STi^{2}GaN solutions range from monolithic power stage plus driver to full control logic integration

Easily integrate full GaN performance in innovative, robust, and reliable bond-wire free packages

STi^{2}GaN SiP

Monolithic multiswitch GaN power stage + Si driver and controller

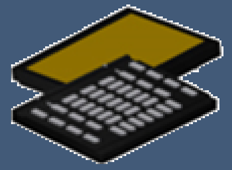
STi^{2}GaN full GaN solution

Power & driver in GaN

- GaN power stage
- GaN driver & protection

BCD logic control

QFN-DCI package



- Bond-wire free
- Low and controllable parasitic elements
- Double-sided cooling

Easy | Compact | Performance

(*) GaN HEMT (High-electron-mobility transistors)

STi²GaN lowers stray inductances

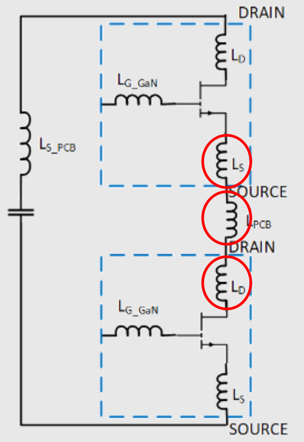
Discrete GaN solution

Stray inductance:

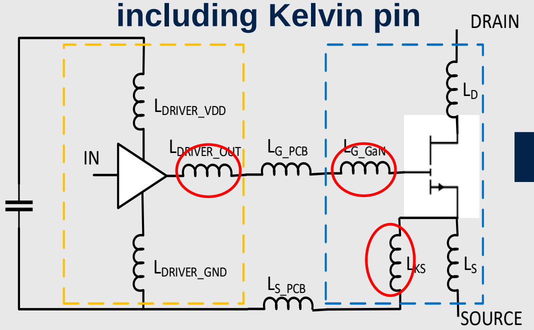
- **In power loop c**auses higher voltage spikes and limits switching speed
- In **gate drive loop** causes gate ringing, increases false turn-ons and gate stress (SOA violation of the gate)

Higher development effort:
Require a gate dumping resistor and a multilayer PCB with optimized layout to reduce the effects of stray inductance

Power loop inductance in half-bridge configuration

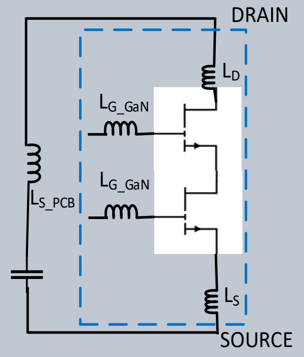


Gate drive loop inductance including Kelvin pin

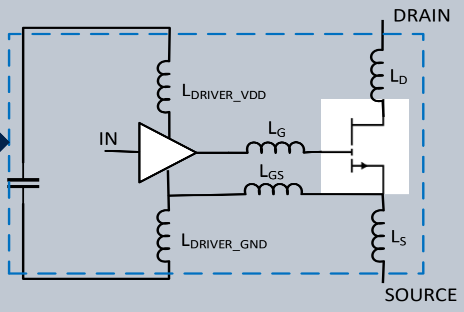


Integrated GaN solution

Power loop inductance in half-bridge configuration



Gate drive loop inductance



Lower stray inductance in the power loop drastically reduces V_{DS} spikes:

- Lower switching losses
- Lower EMI
- Lower V_{DS} voltage stress

Very low gate drive loop stray inductance vastly reduces V_{GS} ringing:

- Improved reliability thanks to lower stress on gate structure
- Improved switching and efficiency thanks to lower dumping resistance on driver output

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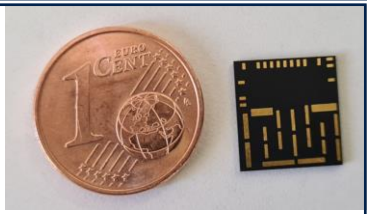
100 V IG1BC01A – Bidirectional DC/DC converter

SiP with GaN power stage + BCD driver & controller for 48V to 3 ÷ 44V power conversion



Power stage in GaN technology:

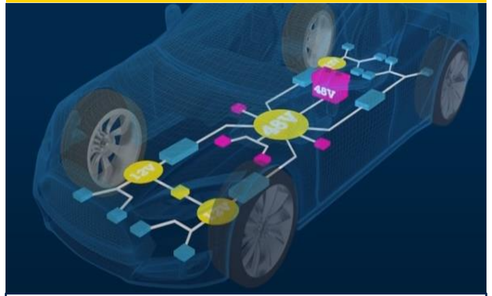
- ➢ Half bridge, H-side (~2.5 mΩ) & L-side (~1.4 mΩ)
- ➢ Buck mode output current capability $75\ A_{RMS}$
  - ➢ **1 kW** @ V_{OUT}= 13.5V - **375 W** @ V_{OUT}= 5V

Gate driver & controller in Si BCD technology:

- ➢ Wide Buck-mode output voltage range: **3V to 44V**
- ➢ Ultra fast Half-Bridge driver tailored to GaN
- ➢ Advanced protection and safety features (**ISO26262 ASIL B ready)**
- ➢ **Fully compliant with ISO21780** (48V road vehicles)
- ➢ SPI interface to set control parameter & diagnostics
- ➢ Switching frequency range: 200kHz ~ **1MHz**
- ➢ **Current and voltage control loops**

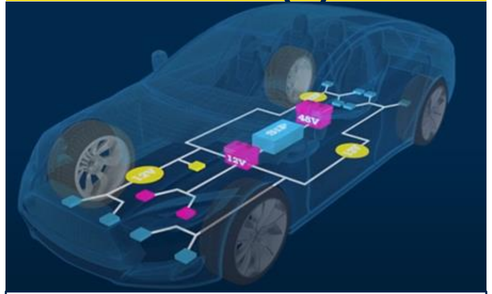
Potential applications

BEVs with 48V rail (*)



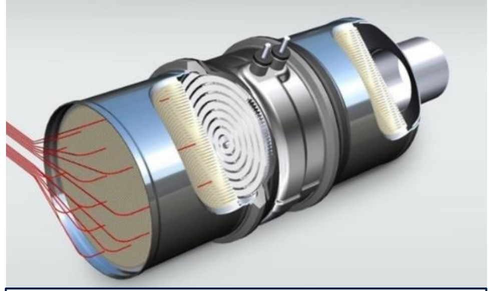
- No 12V battery
- Local DC/DC 48V→12V/5V/3.3V loads

Multiphase DC/DC in MHEV (**)

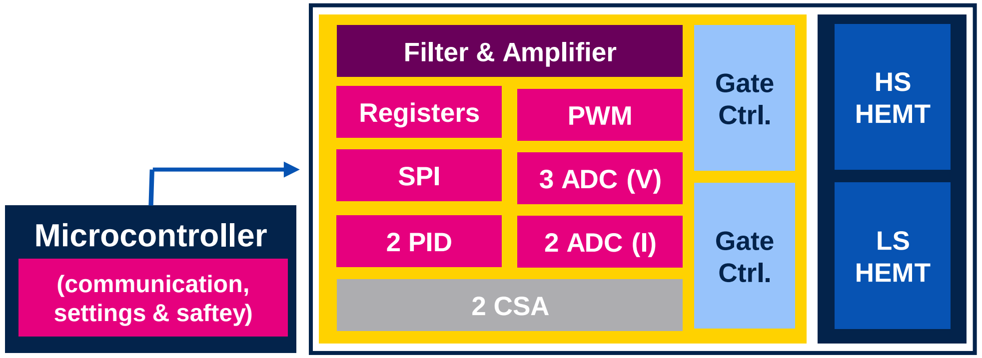


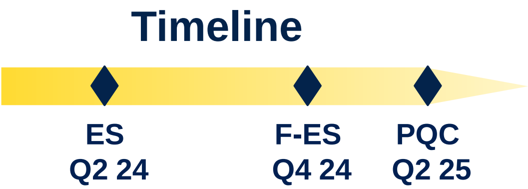
- Bidirectional 48V & 12V batteries energy flow
- Up to 6 phas interleaved

Catalyst eHeater



- 48V or 24V pre-heater for catalytic converters
- Multiphase configuration

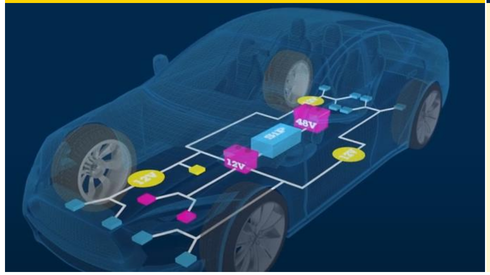




(*) Single phase voltage or current regulator
(**) Buck or Boost current regulator with up to 6 interleaved phases

IG1BC01A – Application architecture

48V Centralized architecture	Current regulator, with up to 6 interleaved phases:

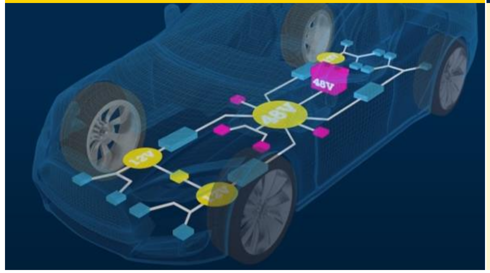


External CPU should supply the PWM Clock signal and set up the following operating parameters:

- **Current Setpoint** – same for all ICs for a better system performance
- **VHIGH or VLOW desired threshold limit**
- **Positional number of each specific phase IC (Ni)** within the interleaving sequence.
- **Number of active phases (N)** → All phases with Ni > N are disabled

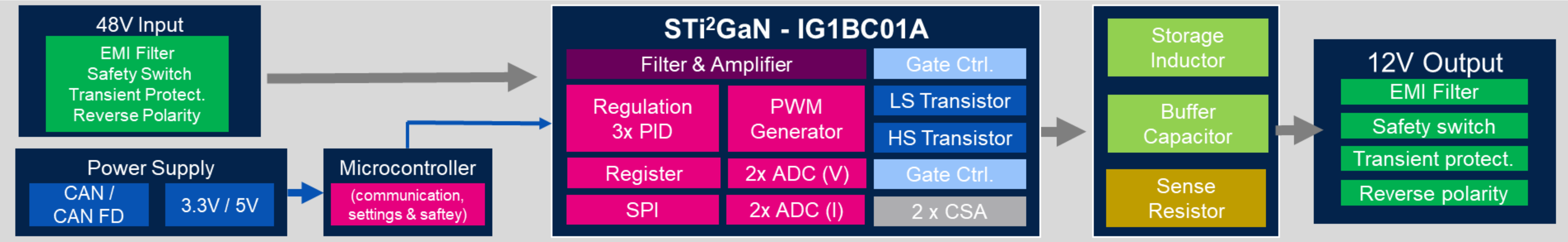
The device is able to work either as a Buck (Current setpoint> 0) or Boost (Current setpoint < 0) regulator, specifically working as a current regulator with a "Voltage Limit" operation.

48V Distributed architecture	Single phase voltage or current regulator:



- **V_{HIGH}, V_{LOW}, and current setpoint**
- **Number of active phases equal to '1' (N = 1)**
- **Positional number of the interleaving sequence equal to '1' (Ni = 1)**

For voltage regulation: the user should set V_{HIGH} or V_{LOW} setpoint, fixing the current setpoint at a value higher than the expected output current, thus acting as a safety current limitation. An additional security layer can be added by programming the overcurrent protection thresholds via SPI.
For current regulation: the user should set the required current setpoint, fixing the VHIGH or VLOW setpoint at a value higher than the expected output voltage, thus acting as a safety voltage limitation.



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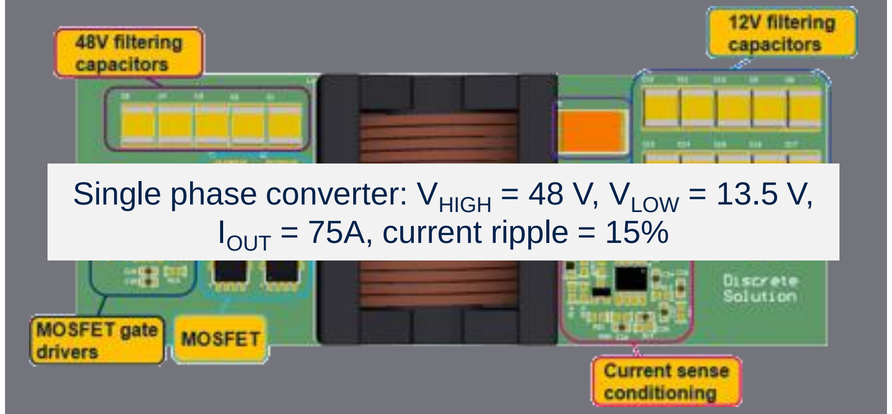
100 V IG1BC01A bidirectional DC-DC converter Application advantages

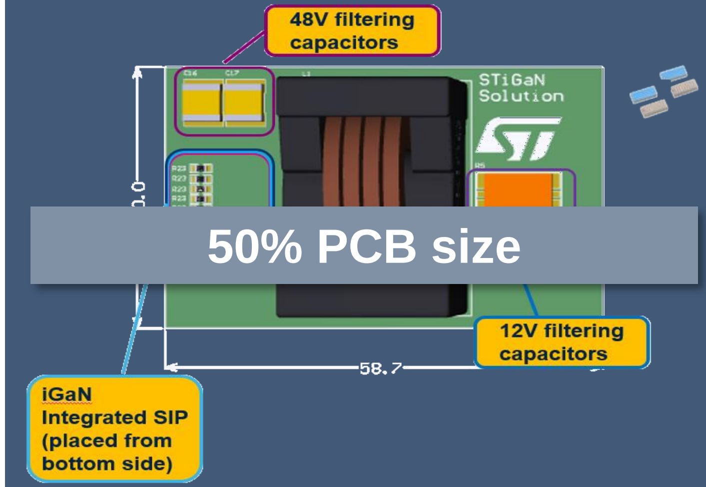
More compact and more efficient than discrete MOSFET solutions, and comparable in terms of cost

Discrete Si MOSFET @ 100kHz



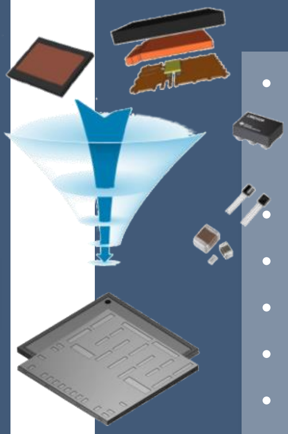
Single phase converter: V_{HIGH} = 48 V, V_{LOW} = 13.5 V, I_{OUT} = 75A, current ripple = 15%

STi²GaN @ 500kHz



50% PCB size

STi²GaN vs discrete GaN



- Easier to use
- Fully integrated, fewer components
- ISO26262 ASILB safety ready
- Less PCB surface
- Compatible with std PCB
- Grounded top slug, easier to cool
- Less volume than discrete GaN at system level

100 V STi²GaN full GaN half bridge IG1HB5RA (5 mΩ) & IG1HB8RA (8 mΩ)

100 V e-GaN half bridge with drivers, level shifter, protections, and diagnostic

GaN Class-D demonstrator development ongoing

Applications

Class-D audio amplifier

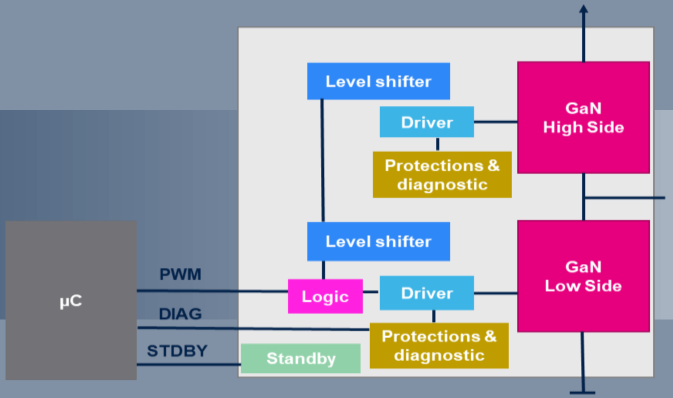
- Half- & full-bridge output stage
- > 400 VA with V_{CC} > 42 V

DC-DC converter

- Local Buck DC-DC
- 48 V→12/5/3.3 V loads (150 to 360 W)

Motor control

- 3-phase 48 V inverters (300 W → 1 kW)
- BLDC and PMSM

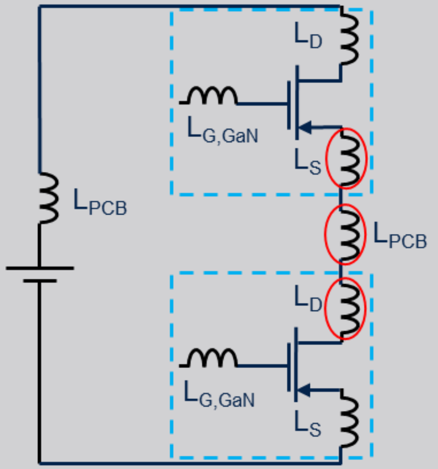


- HS & LS $R_{DS(on)}$ = **5mΩ** or **8mΩ** typ. @ 25°C
- Standby mode
- Logic level compatible inputs (3.3 & 5 V)
- Fast switching frequency capability up to 3 MHz
- Adjustable turn-on dV/dt
- High slew rate transient immunity
- Overtemperature protection & diagnostic
- Overcurrent protection & diagnostic
- ESD protections
- Cross-conduction protection
- Direct copper interconnected package

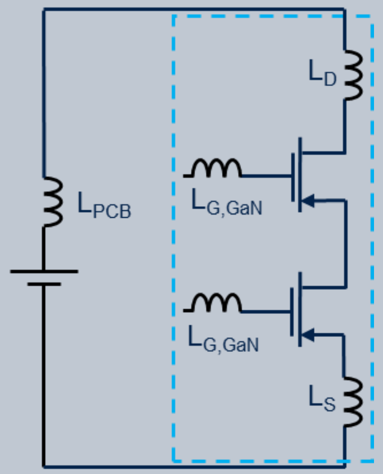
100 V GaN
Power stage
Driver
Protections

IG1HB01A monolithic half bridge 2.2 mΩ HS and 1.2 mΩ LS

Discrete approach



Monolithic approach



- HS $R_{DS(on)}$ = **2.2 mΩ** typ. at @ 25°C
- LS $R_{DS(on)}$ = **1.25 mΩ** typ. at @ 25°C
- High frequency operation above 1 MHz
- Extremely low $R_{DS(on)}$
- Low EMIs
- Zero reverse recovery charge
- Available in direct copper interconnected bond-wire free package for high-frequency and high-power operation
- Dual-side cooling
- Monolithic approach, supporting discrete implementation for DC-DC conversion: lower stray inductance in power loop