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Power Surfing

MasterGaN rides the new wave of GaN Power

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Agenda

- 1 Energy management trends -> GaN vs. Silicon based transistors
- 2 Smart GaN: integrating GaN with driver->The MasterGaN* platform
- 3 Application usage of MasterGaN and Design Tips
- 4 The MasterGaN Ecosystems
- 5 Takeaways

Energy management trends

GaN vs. Silicon based transistors



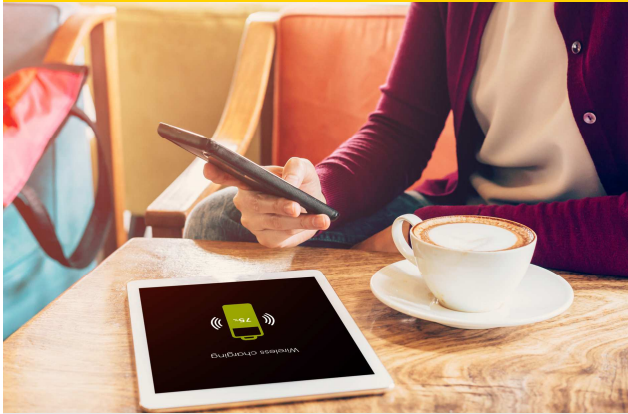
The future of energy

Efficiency & power density



High power – Mini size

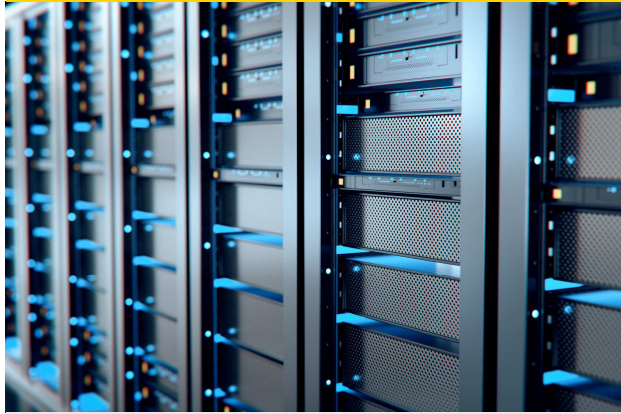
AC-DC adapter & Smartphone fast charger



4x smaller

3x lighter

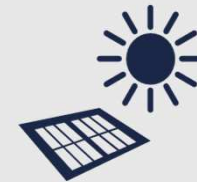
Server power supply



50%
higher power density

20% lower P_{LOSS}

Solar ESS (Energy Storage System)

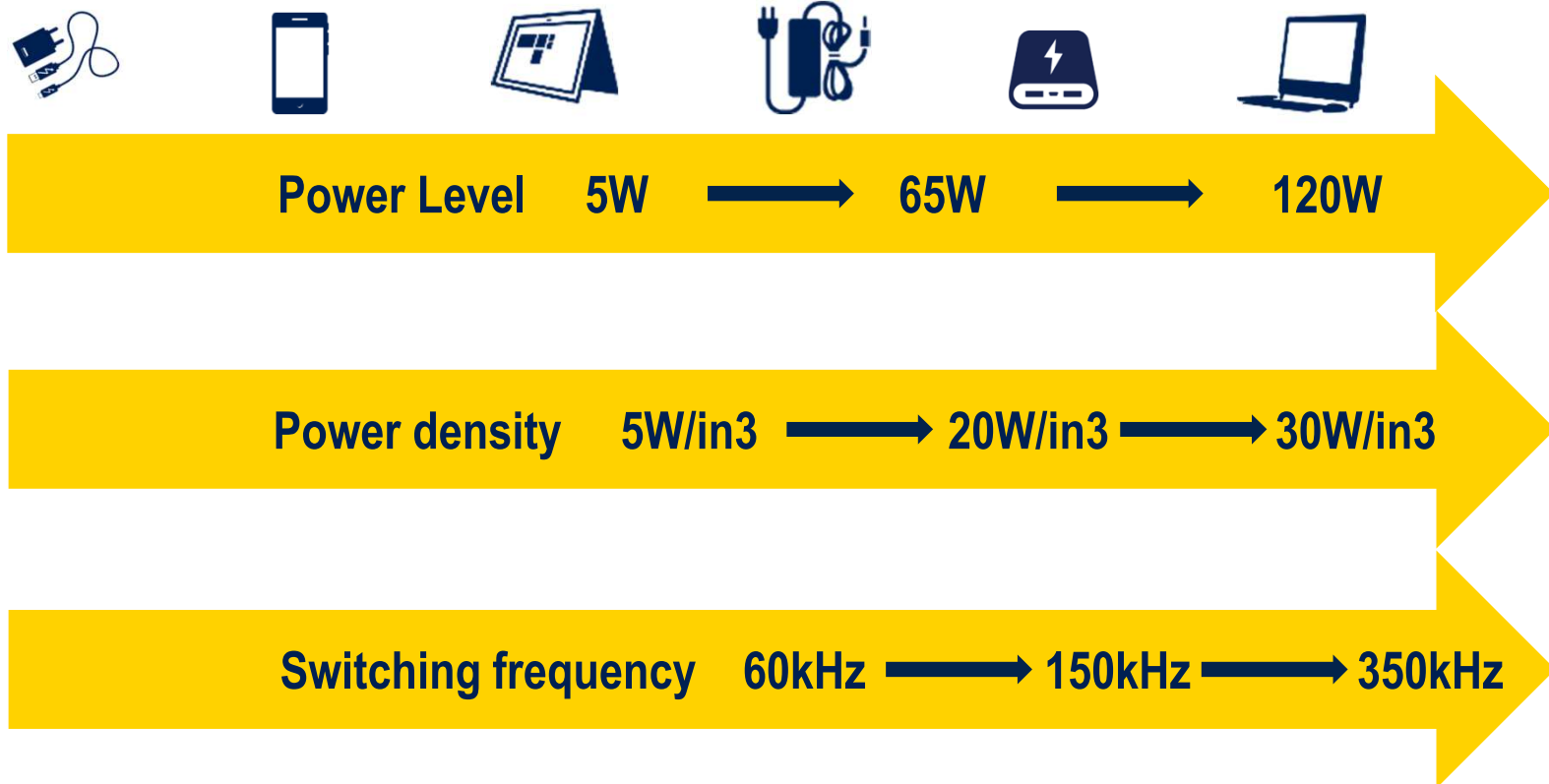


2x smaller

3x lighter

Fan-less

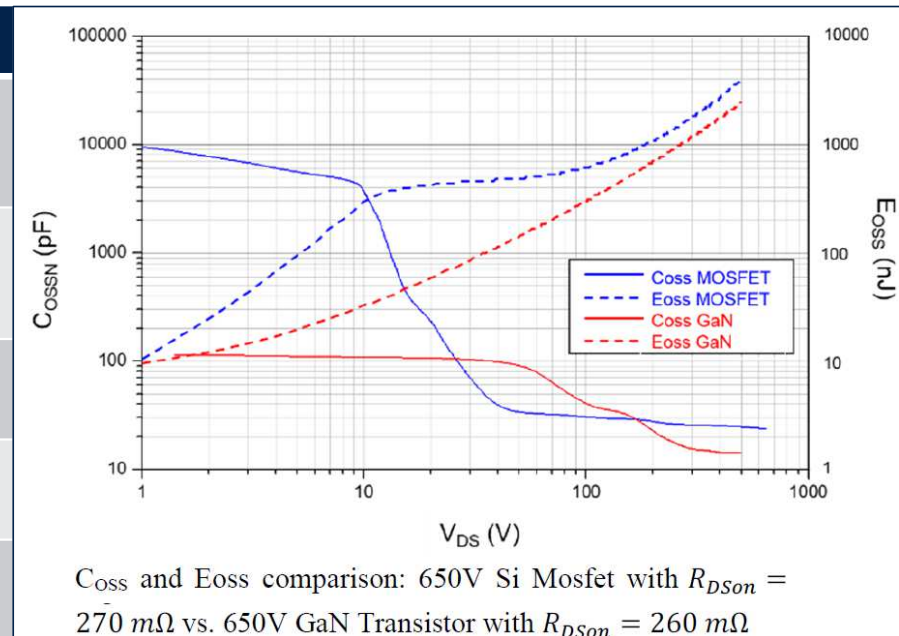
Travel adapter development



GaN vs. Silicon based transistors

GaN transistors allow higher frequencies, better efficiency and higher power density than silicon-based transistors.

Parameter	GaN	Silicon	Comments
Qg-Gate charge	Lower	Higher	GaN has lower driver loss for higher frequency & efficiency
Coss-Output capacitance	Lower	Higher	GaN has lower switching loss for higher frequency & efficiency
Qrr-Reverse recovery charge	Lower	Higher	GaN suitable for higher frequency & efficiency
Vgs- gate voltage	Difficult	Easy	GaN needs better gate drive circuit and PCB layout
Vsd-body diode conduction	Higher	Lower	GaN needs better control of deadtime



Smart GaN: integrating GaN with driver

The MasterGaN* platform





Smart GaN: Integrating GaN with driver



Higher efficiency



Reduced power losses, reduced power consumption, exceeding the most stringent energy requirements

Higher power density



Higher switching speed to reduce systems size and cost

Faster go-to-market



Packaged solution simplifies the design, with a higher level of performance



MasterGaN – Riding the new wave of GaN Power

The world first solution combining 600 V half-bridge driver with GaN HEMT



One driver – Many scalable power size, pin to pin compatible for half bridge configuration



Compact

High power density

4x smaller vs Si solution
High efficiency

Robust

Offline driver optimized for GaN HEMT for fast, effective and safe driving and layout simplification

Easy Design

Smart solution in GQFN 9 x 9 mm² package
Scalable power, pin to pin compatible



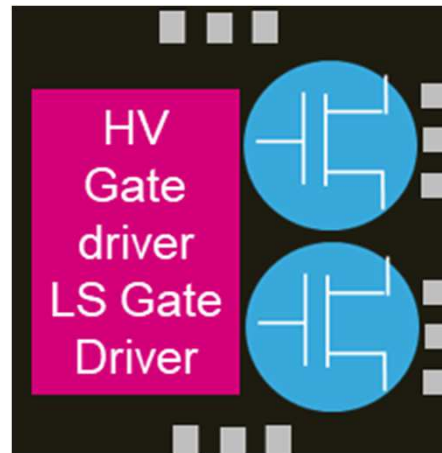
MasterGaN applications and benefits

Applications

	Telecom/Server Power
	Power Supply for 5G Communication Infrastructure
	HV/HEV Charging Stations
	Energy Storage Systems (UPS)
	Solar DC-AC Converters
	PC Power, OLED TV
	High-Density AC-DC Adapters, Fast Charging, USB-PD

Key benefits

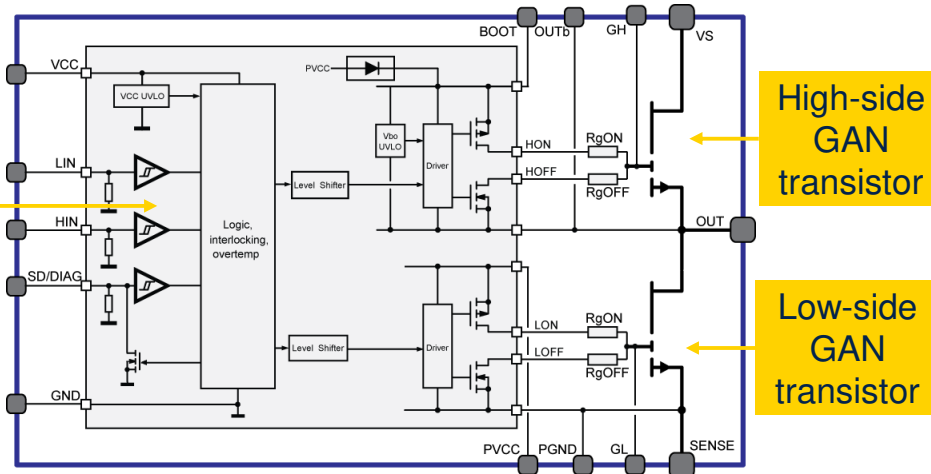
- Compact system solution and simplified layout
- BOM reduction: SiP with offline driver optimized for GaN
- Robust solution: driver and GaN power transistors integration
- Package GQFN 9x9
- Flexible, easy and fast design
- Scalable p2p solution for power range 30-400 W





MasterGaN key features

High power density half-bridge 650V GaN with embedded driver



QFN 9x9 mm²,
pin-to-pin scalable

Features

- Power system-in-package integrating half-bridge gate driver and high-voltage GaN transistors:
 - $BVDSS = 650\text{ V}$
 - $RDS(ON) = 150\text{ m}\Omega$
 - $IDS(MAX) = 10\text{ A}$
- Reverse current capability
- Zero reverse recovery loss
- UVLO protection on low-side and high-side
- Internal bootstrap diode
- Interlocking function
- Dedicated pin for shutdown functionality
- Accurate internal timing match
- 3.3 V to 15 V compatible inputs with hysteresis and pull-down
- Overtemperature protection
- Bill of material reduction
- Very compact and simplified layout
- Flexible, easy and fast design



MasterGaN* platform

The world first solution combining 600 V half-bridge driver with GaN HEMT: compact, robust & easy to design

MasterGaN3



Up to 45 W

225m Ω + 450m Ω
Asymmetrical HB

MasterGaN2

Mass Production



Up to 65 W

150m Ω + 225m Ω
Asymmetrical HB

MasterGaN5



Up to 100 W

450m Ω + 450m Ω
Symmetrical HB

MasterGaN4

Mass Production



Up to 200 W

225m Ω + 225m Ω
Symmetrical HB

MasterGaN1

Mass Production



Up to 400W

150m Ω + 150m Ω
Symmetrical HB

Active Clamp Flyback mainly

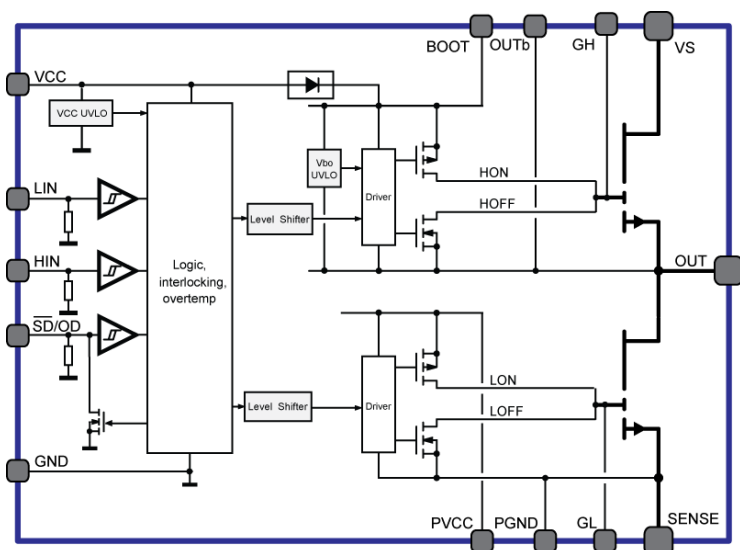
LLC Resonant and Active Clamp Flyback mainly



MasterGaN1

Advanced power solution integrating a gate driver and two enhancement mode GaN transistors in half-bridge configuration

Mass production



Compact

- Integrated power GaN
- Embedded gate driver easily supplied by the integrated bootstrap diode



VDS **600 V**
RDS_{ON} **150 mΩ (LS)**
+ 150 mΩ (HS)
IDS_{MAX} **10 A (@25°C)**

Robust

- UVLO protection on both the lower and upper driving sections, preventing the power switches from operating in low efficiency or dangerous conditions, and the interlocking function avoids cross-conduction conditions
- Over temperature protection

Easy Design

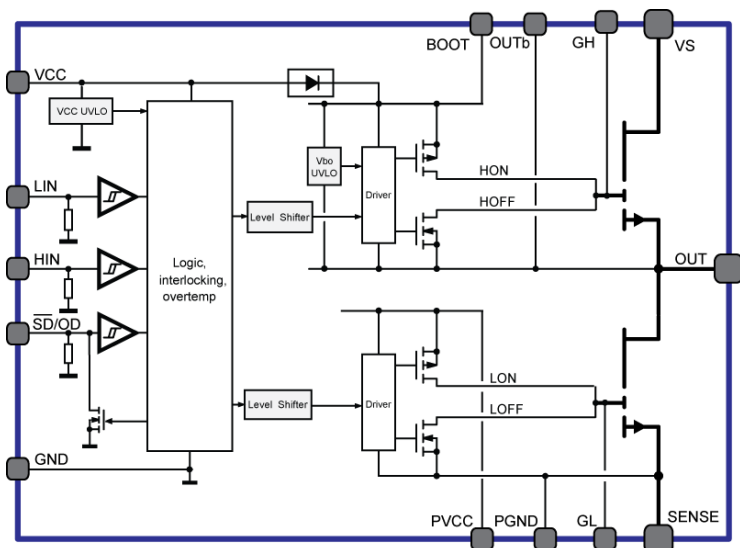
- Smart solution in GQFN 9x9 mm² package
- Input pins extended range -3.3 to 15 V with hysteresis and pull-down- allows easy interfacing with microcontrollers, DSP units or Hall effect sensors
- Dedicated pin for shutdown functionality
- Accurate internal timing match



MasterGaN2

Advanced power solution integrating a gate driver and two enhancement mode GaN transistors in half-bridge configuration

Mass production



Compact

- Integrated power GaN
- Embedded gate driver easily supplied by the integrated bootstrap diode



VDS **600 V**
RDS_{ON} **150 mΩ (LS)**
+ 225 mΩ (HS)
IDS_{MAX} **10 A (LS) + 6.5 A (HS) (@25°C)**

Robust

- UVLO protection on both the lower and upper driving sections, preventing the power switches from operating in low efficiency or dangerous conditions, and the interlocking function avoids cross-conduction conditions
- Over temperature protection

Easy Design

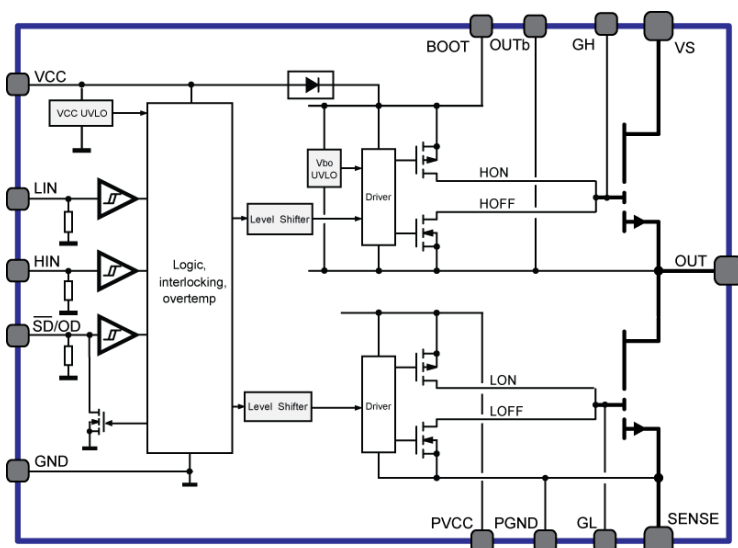
- Smart solution in GQFN 9x9 mm² package
- Input pins extended range -3.3 to 15 V with hysteresis and pull-down- allows easy interfacing with microcontrollers, DSP units or Hall effect sensors
- Dedicated pin for shutdown functionality
- Accurate internal timing match



MasterGaN4

Advanced power solution integrating a gate driver and two enhancement mode GaN transistors in half-bridge configuration

Mass production



Compact

- Integrated power GaN
- Embedded gate driver easily supplied by the integrated bootstrap diode



VDS **600 V**
RDS_{ON} **225 mΩ (LS)**
+ 225 mΩ (HS)
IDS_{MAX} **6.5 A (HS) (@25°C)**

Robust

- UVLO protection on both the lower and upper driving sections, preventing the power switches from operating in low efficiency or dangerous conditions, and the interlocking function avoids cross-conduction conditions
- Over temperature protection

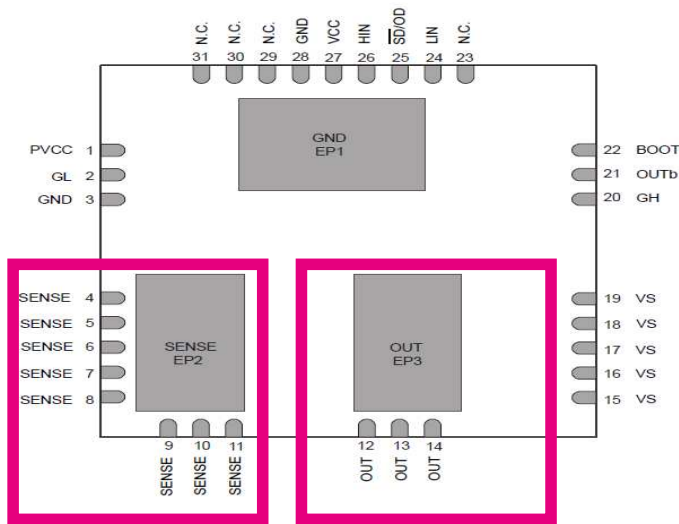
Easy Design

- Smart solution in QFN 9x9 mm² package
- Input pins extended range -3.3 to 15 V with hysteresis and pull-down- allows easy interfacing with microcontrollers, DSP units or Hall effect sensors
- Dedicated pin for shutdown functionality
- Accurate internal timing match



MasterGaN pinout

Figure 2. Pin connection (top view)



**GQFN 9x9 mm²,
pin-to-pin scalable**

Pin Number	Pin Name	Type	Function
15, 16, 17, 18, 19	VS	Power Supply	High voltage supply (high-side GaN Drain)
12, 13, 14, EP3	OUT	Power Output	Half-bridge output
4, 5, 6, 7, 8, 9, 10, 11, EP2	SENSE	Power Supply	Half-bridge sense (low-side GaN Source)
22	BOOT	Power Supply	Gate driver high-side supply voltage
21	OUTb	Power Supply	Gate driver high-side reference voltage, used only for Bootstrap capacitor connection. Internally connected to OUT.
27	VCC	Power Supply	Logic supply voltage
1	PVCC	Power Supply	Gate driver low-side supply voltage
28, EP1	GND	Power Supply	Logic ground
3	PGND	Power Supply	Gate driver low-side driver reference. Internally connected to SENSE.
26	HIN	Logic Input	High-Side driver logic input
24	LIN	Logic Input	Low-Side driver logic input
25	SD/OD	Logic Input-Output	Driver Shutdown input and Over-Temperature
2	GL	Output	Low-Side GaN gate.
20	GH	Output	High-Side GaN gate.
23, 29, 30, 31	N.C.	Not Connected	Leave floating



BOTTOM VIEW

Dimensions and features shown in the bottom view include:

- Overall dimensions: D (width), L (length).
- Component locations: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31.
- Rectangular features: $D3$, $D2$, $D1$, $E1$, $E3$, $E2$.
- Dimensions: 0.85 REF., 1.05 REF., 2.40 BSC., 2.10 ± 0.10 , 2.85 REF., 0.24 REF., 2.10 ± 0.10 , 2.10 ± 0.10 , 2.10 ± 0.10 , 2.10 ± 0.10 , 2.10 ± 0.10 , 2.40 BSC., 1.85 REF., 2.10 ± 0.10 , 2.62 ± 0.10 , 2.92 ± 0.10 , 1.65 REF., 2.25 REF., 1.85 REF.

SIDE VIEW

Dimensions and features shown in the side view include:

- Profile dimensions: A , B .
- Material callouts: $///$, ccc , C .
- Feature callouts: $bbb(M)$, $ddd(M)$, C , A , B .





Active clamp flyback Topology



FROM/TO CONTROLLER

Up to 65W

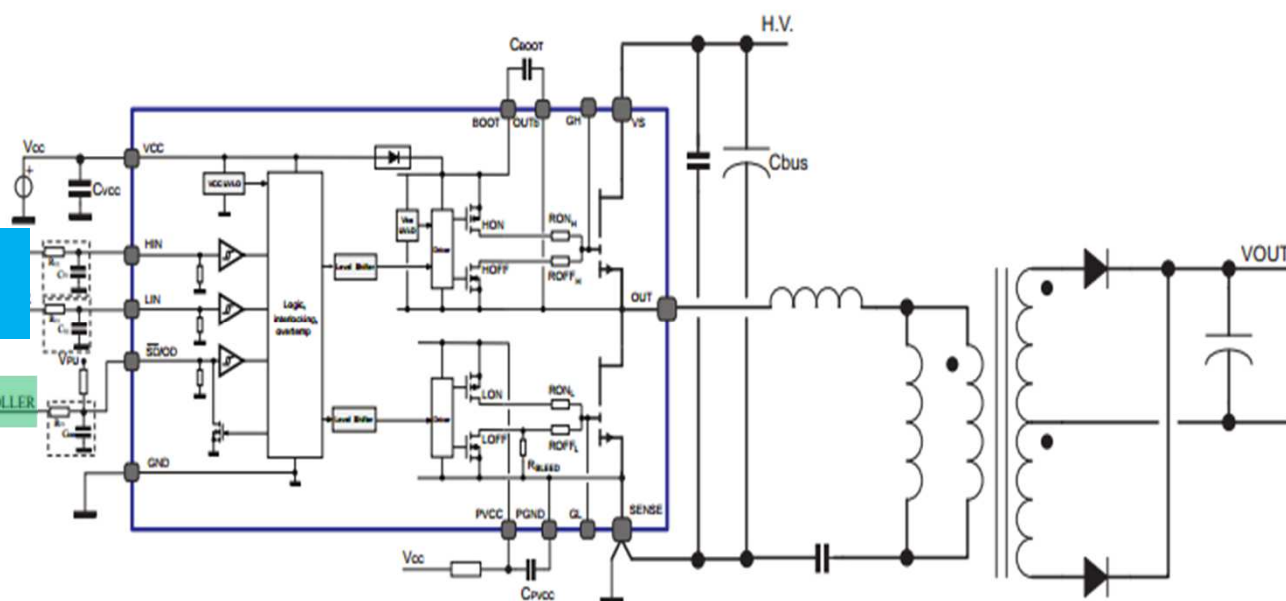
- Chargers and adapters
- Industrial SMPS





MasterGaN Main Topology

LLC Resonant Topology



HB Controller

FROM/TO CONTROLLER

Key applications

- Charger
- Adapter
- Industrial SMPS
- UPS
- Solar systems
- Servers



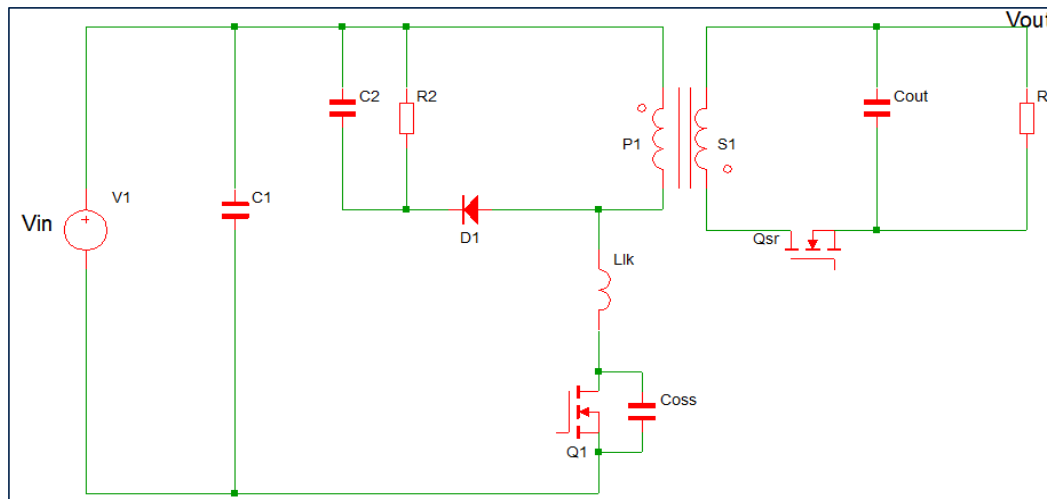
Up to 400W

Application usage of MasterGaN and Design Tips



Drawbacks of traditional Flyback

- High power loss and spike caused by leakage inductance of the transformer
- High switching loss of the main MOSFET due to the spike



$$P_{ON} = I_{P(RMS)}^2 R_{DS(ON)}$$

$$P_{SW-ON(Coss)} = f_{SW} \int_0^{V_{DS(OFF)}} C_{OSS}(V_{ds}) V_{ds} dV_{ds}$$

$$P_{SW-OFF} = \frac{I_P^2 T_{FALL}^2}{6 C_{OSS(eq)}} f_{SW}$$



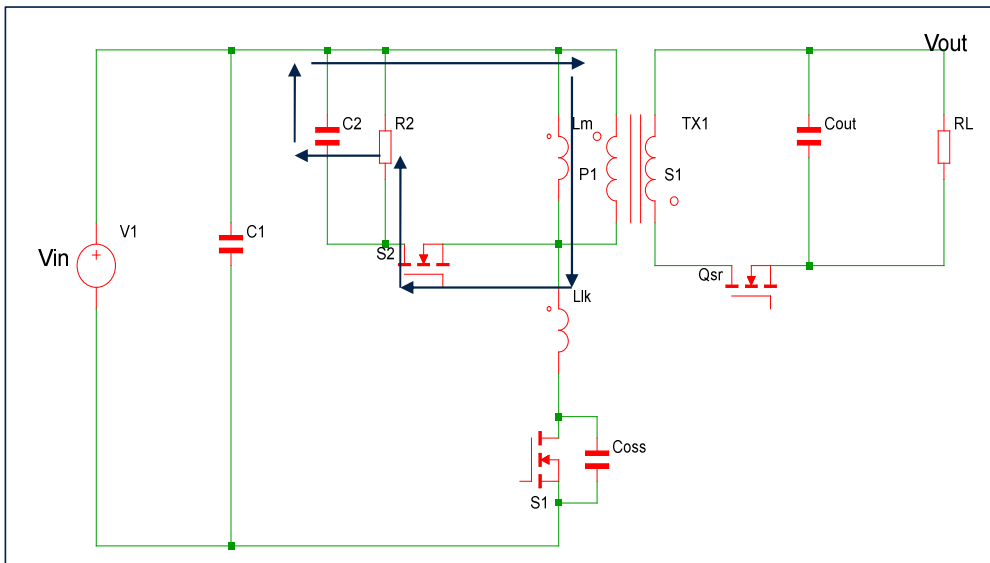
ACF used in smart charger

PROs

- The energy of the leakage inductance is recycled
- ZVS is achieved and switching losses are minimized → High efficiency and high switching frequency achievable
- Soft-switching architecture

CONs

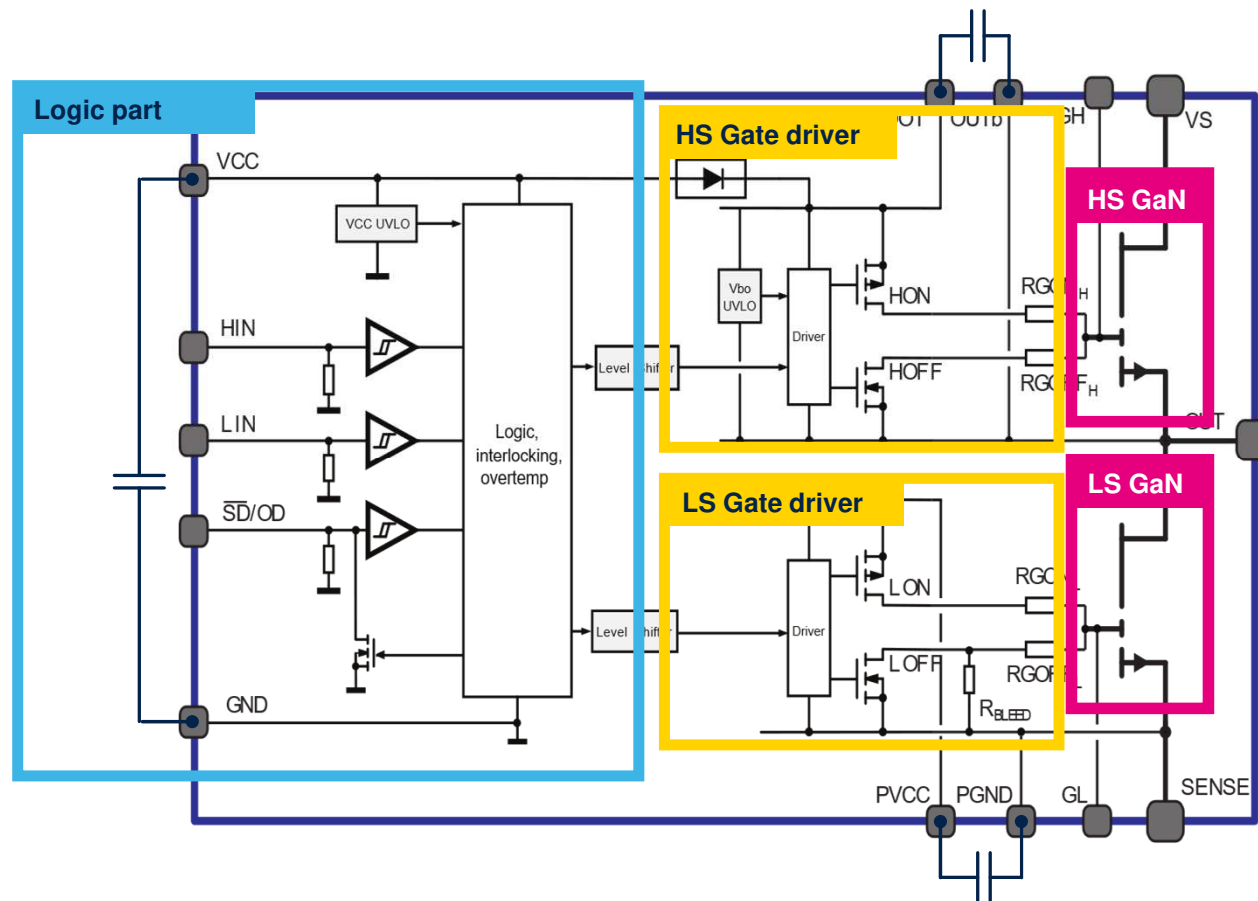
- Additional clamp power switch with dedicated high-side driver
- Increases the complexity of the controller
- Much more difficult to design and optimize compared with a standard flyback







MasterGaN block diagram

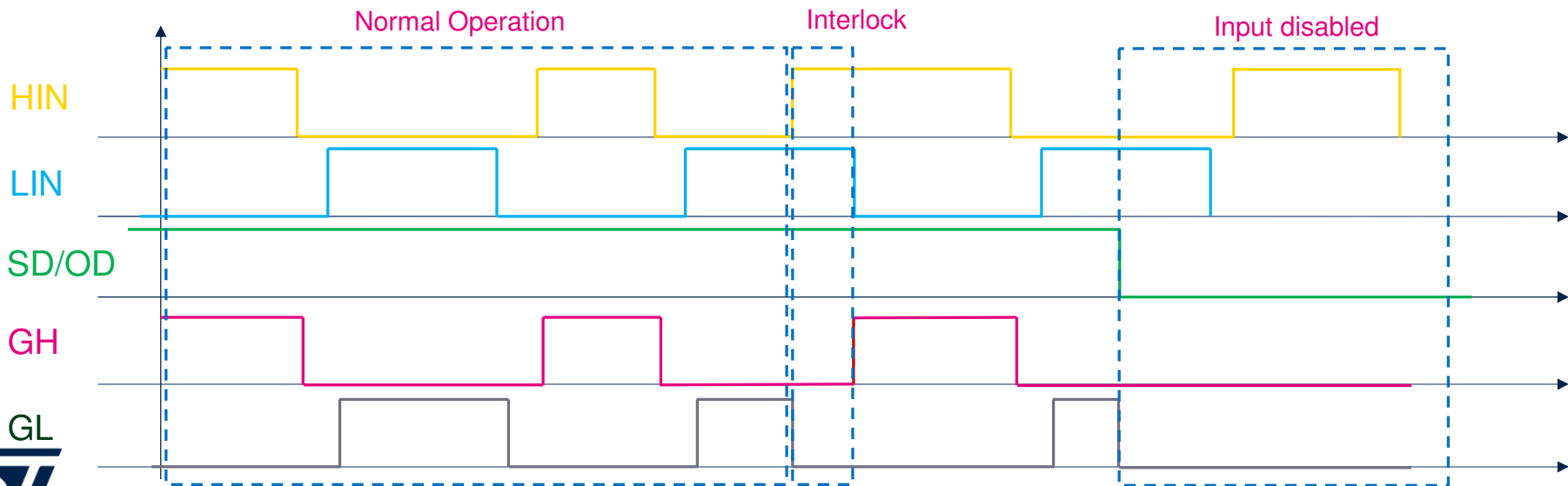




Gate drive logic inputs – truth table

	Input pins			GaN transistors status	
	$\overline{SD}/OD$	LIN	HIN	LS	HS
Disabled input port	L	X	X	OFF	OFF
Normal Operation Configurations	H	L	L	OFF	OFF
	H	L	H	OFF	ON
	H	H	L	ON	OFF
Interlocking	H	H	H	OFF	OFF

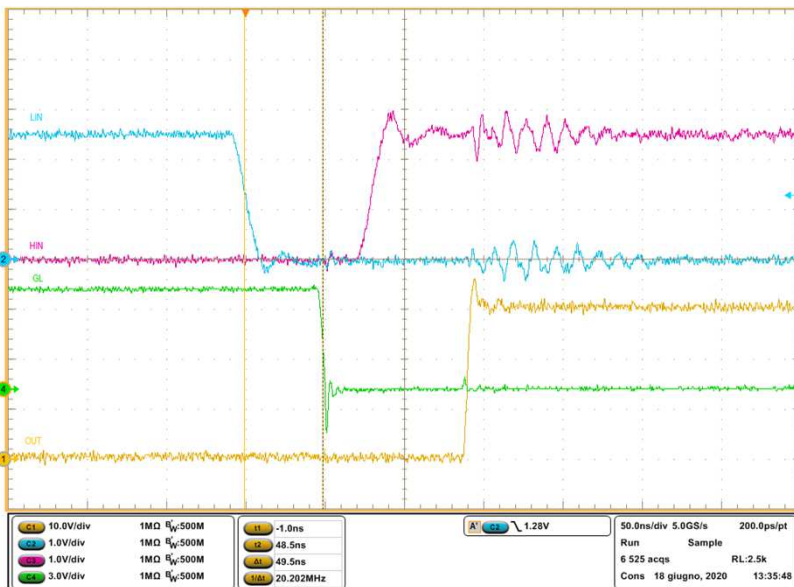
1. X: Don't care





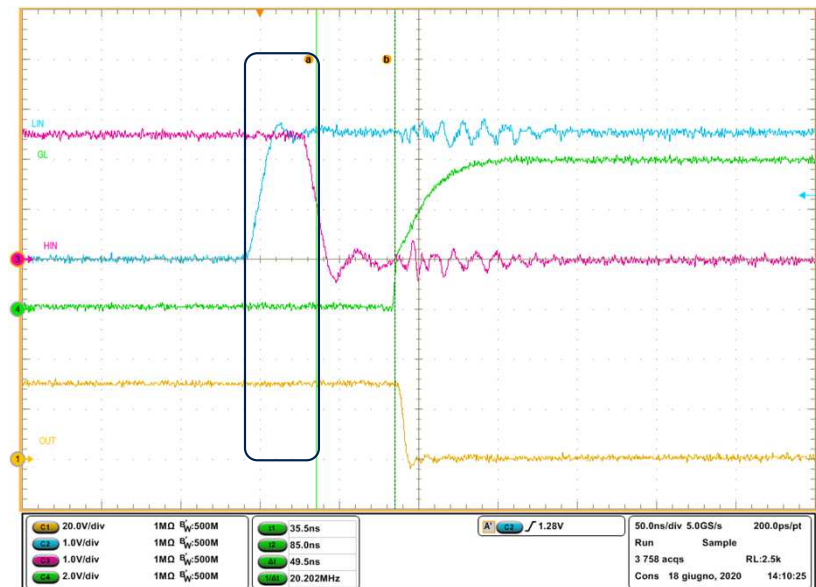
Logic inputs – Interlocking

MASTERGAN has an interlocking feature to prevent contemporary activation of high side and low side.



HIN and LIN high never occurs, normal condition

HIN
LIN
GL
OUT



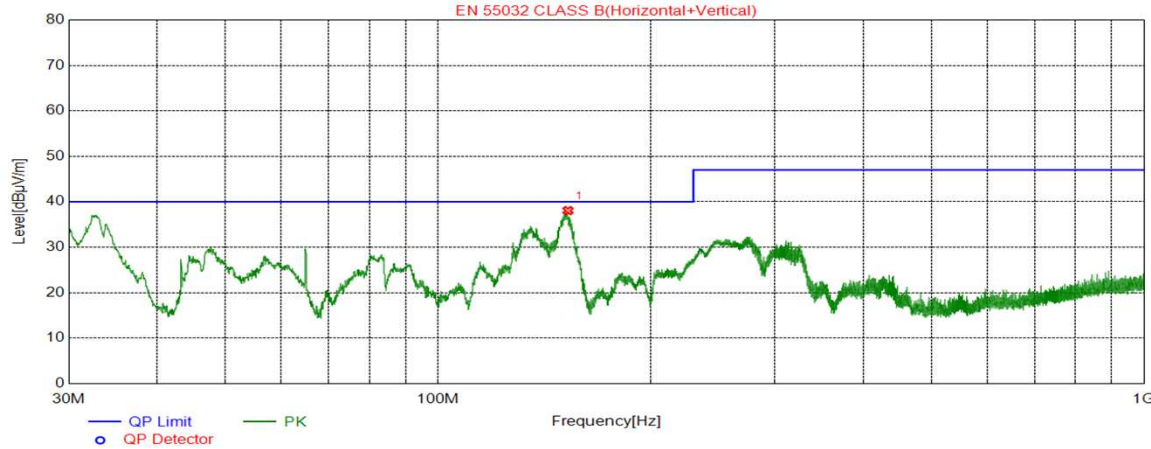
HIN and LIN high in black square → Interlock
GL and GH are both low

- When Interlock condition is applied to the input, the active driver is shut down after T(OFF)
- When Interlock condition is removed from the input, the new input configuration is applied on the output after T(OFF)



dv/dt adjustment

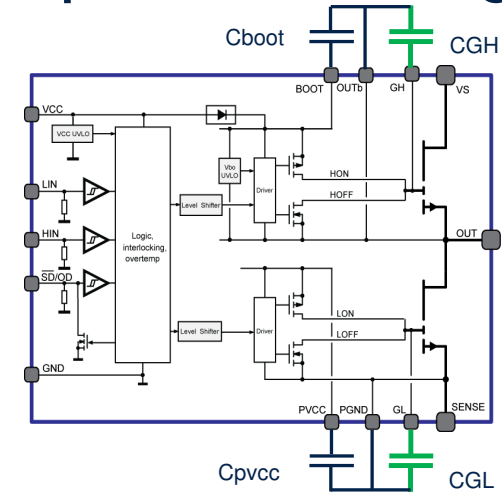
- During the design of power converters, the adjustment of dV/dt of middle point of OUT pin is important to:
 - Reduce EMI
 - To avoid undesired oscillations when parasitic elements cannot be further minimised
 - Reduce secondary side stress





dv/dt adjustment adding cap on GaN's gate

- Adding a capacitor between GL (GH) and PGND (OUTb), is equivalent to increase GaN's Gate Charge
- Maximum value must be found to avoid driver's dynamical overstress and considering the operating frequency F_{sw}
 - $CG_x < 80mW / (P_{vcc}^2 \cdot F_{sw}) - (330pF)$



PROs

- Fine tuning of the obtained effect
- High repeatability of the effect thanks to the accuracy of the available discrete components
- Effect is also on EMI associated with normal operation

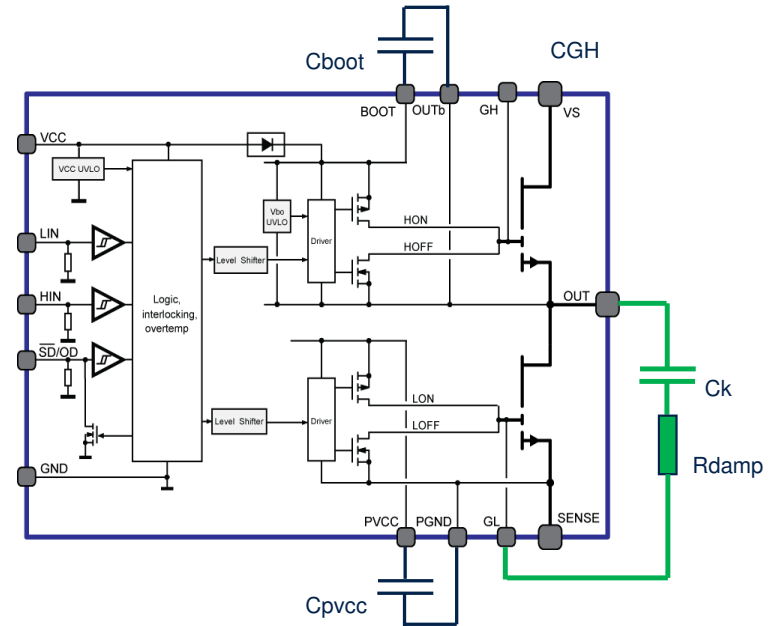
CONs

- Additional operating consumption to PVCC and V_{bo} , especially at high frequency
- Not suitable for very high frequency solutions



dv/dt Adjustment - adding dv/dt killer

- An RC network feedback can be added between OUT node and GL in order to reduce the GL voltage in case of intense negative dV/dt.
- Consider to use PCB, especially for thin PCBs, instead of the added Ck
- Example
- 0.8mm 4 layer PCB, 0.1mm inner core thickness, $\epsilon_r=4.4$
- 10pF -> 30mm²: can fit below MasterGaN



PROs

Acts on high dV/dt only: the dV/dt value is then balanced over entire operating conditions

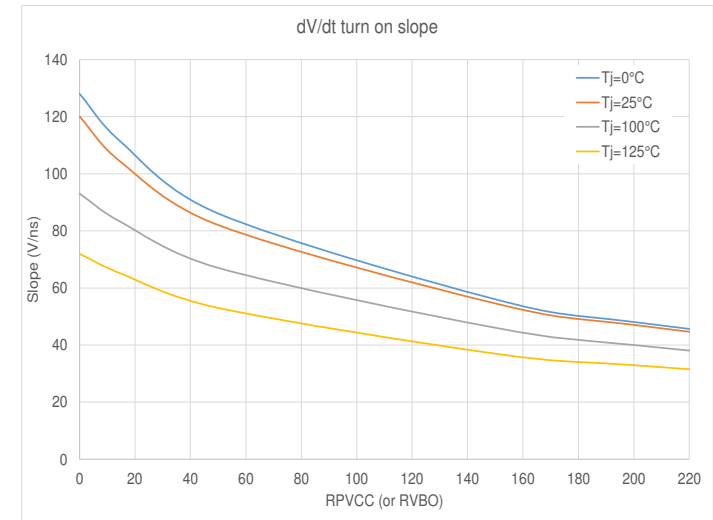
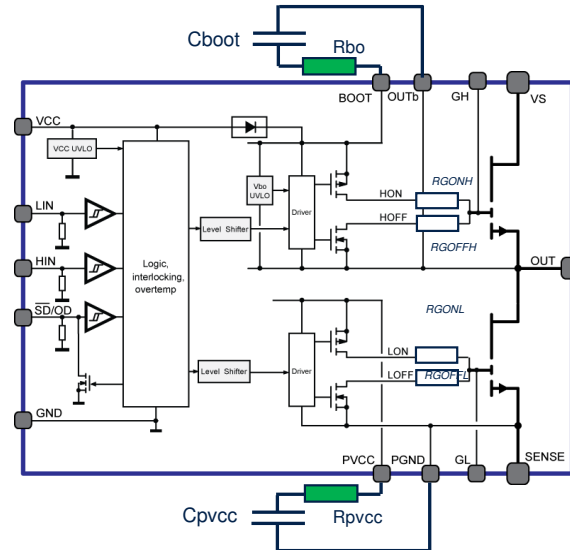
CONs

High voltage component needed



dv/dt adjustment – Adding a resistor on PVCC

- A resistor in series with PVCC or VBO decreases the driving current.
- A very short drop is evident on PVCC / VBO at driver turn on.



PROs

- Fine tuning of the obtained effect
- High repeatability of the effect thanks to the accuracy of the available discrete components
- Effect is also on EMI associated with normal operation

CONs

- PVCC / VBO drop can increase the propagation delay
- Short-on time can result into worse Rdson because of the reduced Gan's gate overdrive voltage (i.e. PVCC-Vgsth)
- Duration of VBO drop must be shorter than 2 μ s to prevent UVLO activation



Adding dV/dt limiter – design tips

- The value of the Capacitor (C_k) limits the dV/dt during hard switching thanks to Miller effect
 - During turn on the rate is limited to $\sim \frac{V_{PVCC} - V_{TH}}{R_{ONG} C_k} = \frac{V_{PVCC} - 1.7}{50 \cdot C_k}$
 - During turn off, it is limited to $\sim \frac{V_{TH}}{R_{OFFG} C_k} = \frac{0.85}{C_k}$
- A resistor in series is required to avoid oscillations due to stray inductance
 - $R_{DAMP} \gg \sqrt{\frac{L_{stray}}{C_k}}$
- Capacitor required is typically 5pF to 10pF (600V rated)
 - E.g.: Using $PVCC = 6V$ and $\max dV/dt = 10V/ns \rightarrow C_k = 8.6pF$

The MasterGaN Ecosystems





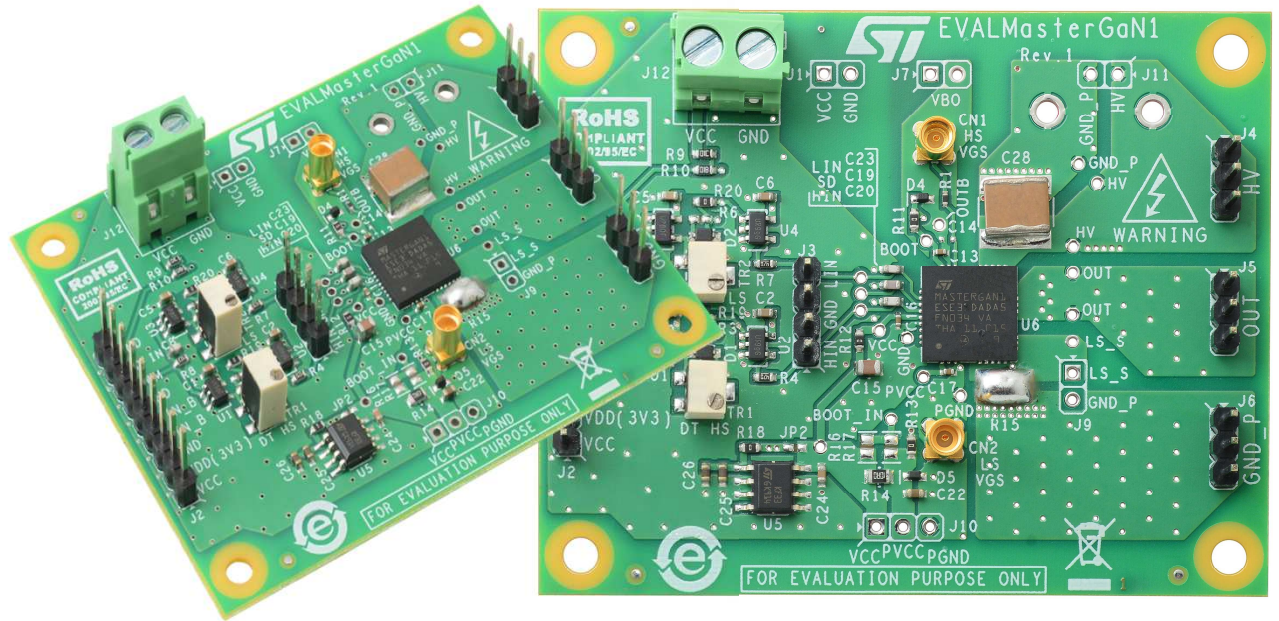
MasterGaN1 development ecosystem

Evaluation board & ecosystem: www.st.com/mastergan



Key applications

- Switch-mode power supplies
- Chargers and adapters
- High-voltage PFC
- DC-DC and DC-AC converters
- UPS systems
- Solar power



EVALMASTERGAN1



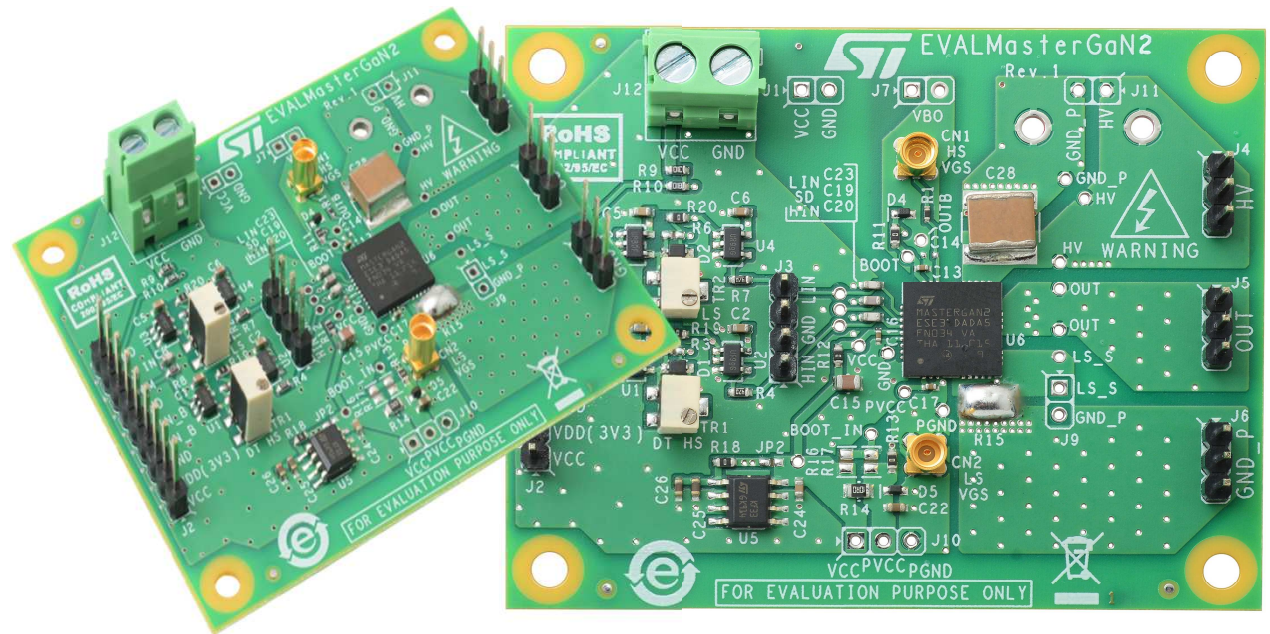
MasterGaN2 development ecosystem

Evaluation board & ecosystem: www.st.com/mastergan



Key applications

- Switch-mode power supplies
- Chargers and adapters
- High-voltage PFC
- DC-DC converters



EVALMASTERGAN2



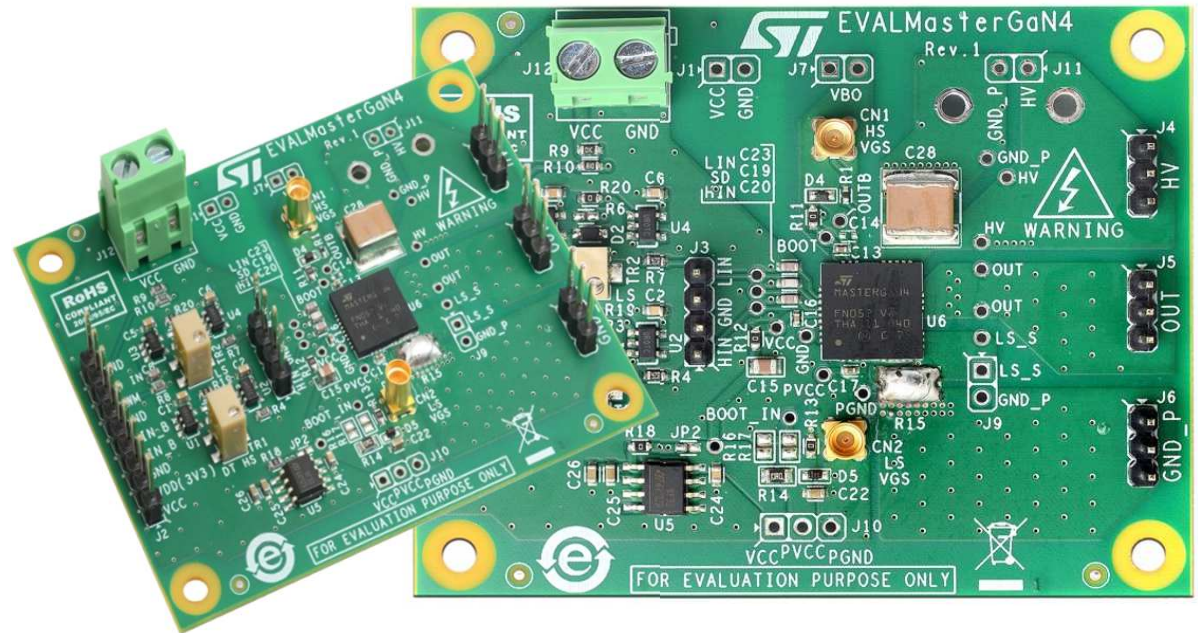
MasterGaN4 development ecosystem

Evaluation board & ecosystem: www.st.com/mastergan



Key applications

- Switch-mode power supplies
- Chargers and adapters
- High-voltage PFC
- DC-DC converters
- DC-AC converters

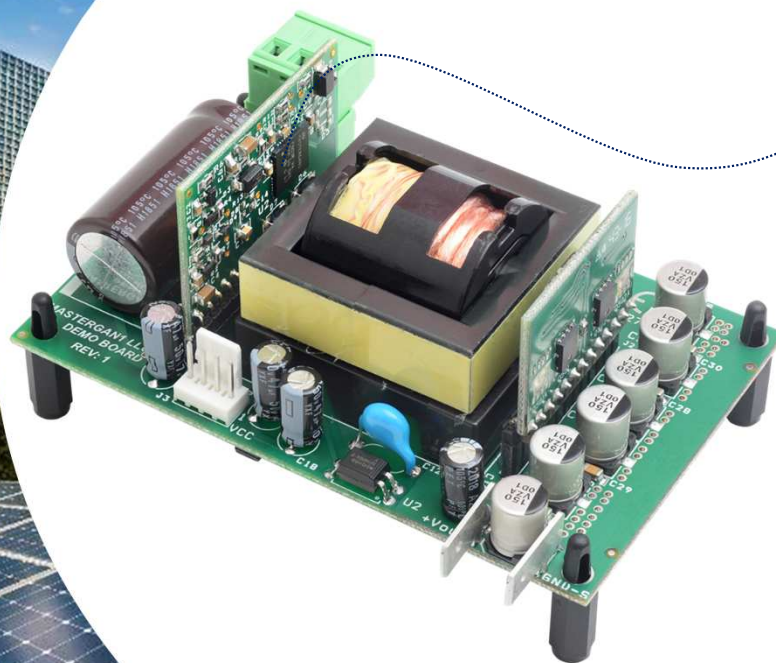


EVALMASTERGAN4



EVLMG1-250WLLC: MasterGaN1 250W Resonant demo board

Resonant application based on MasterGaN1, it allows to reduce transformer size, to increase efficiency and to remove heatsink



EVLMG1-250WLLC

250W Resonant Demo Board

- L6599A + **MasterGaN1** + SRK2001
- $V_{out}=24V$ $I_{out}=10A$
- Freq switching **~250 kHz**
- Dimension: 105 x 65 x 35 (H) mm

Benefits:

- **Higher switching frequency** compared to Si MOSFETs
=> **smaller transformer**
- Higher efficiency (~95%)
- **No heatsink required** for MasterGaN1 heat dissipation

KEY APPLICATIONS

Ultra-fast and ultra-compact switch-mode power supplies in the range of 250 Watts for applications such as:

- Industrial DC-DC applications
- Adapters
- Consumer SMPS

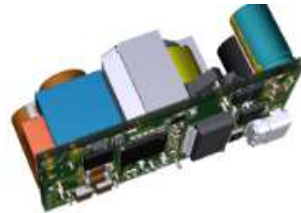


MasterGaN solutions under development

Under development (Q2'21)

65W STOne Compact Board

STOne + MasterGaN1 USB-PD
RM8 Transformer
Power density: 30W/in^3 (uncased)



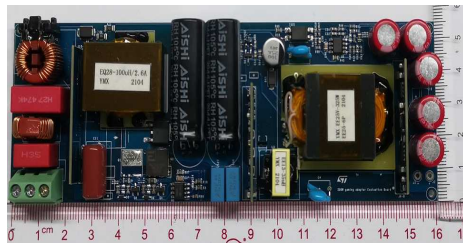
Available for selected customers

65W STOne Evaluation Board

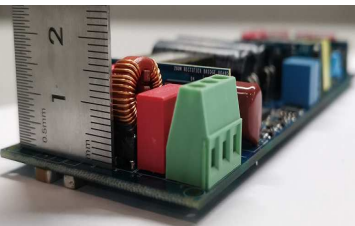
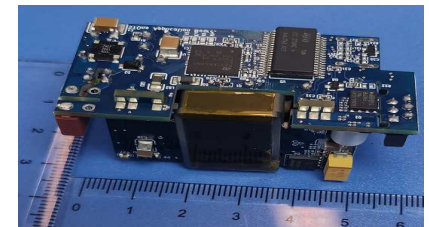
STOne + MasterGaN1 USB-PD
RM8 Transformer
Customizable board to specific customer requirements



200W TM PFC+LLC Board Gaming NoteBook STCMB1 + MasterGaN2



65W STOne Planar Compact Board for TA charger STOne + MasterGaN2 USB-PD Planar Transformer



Takeaways





MasterGaN End applications

MasterGaN solutions for SMPS applications from 65 to 400 W in high-end, high-efficiency topologies

In Mass Production

Active Clamp Flyback/ Forward	65 W	Smartphone ultra-fast and wireless chargers, USB-PD compact adapters for pc and gaming
Totem-pole PFC, Resonant	100 W	Industrial power supplies like solar-energy storage systems, uninterruptible power supplies (UPS)
Totem-pole PFC, Resonant	400 W	High-end OLED TVs, server cloud



MasterGaN family roadmap

QFN 9x9 mm² pin-to-pin scalable

One driver, many standard transistors for HB configuration



From 45 up to 400 W

MasterGaN1

Symmetrical

150 + 150 mΩ

Mass production

MasterGaN2

Asymmetrical

150 + 225 mΩ

Mass production

MasterGaN3

Asymmetrical

225 + 450 mΩ

ES ready

MasterGaN4

Symmetrical

225 + 225 mΩ

Mass production

MasterGaN5

Symmetrical

450 + 450 mΩ

ES ready

Whole product family to be released by H1 2021

MasterGaN rides the new wave of GaN Power

Increasing efficiency & power density is a clear trend

GaN HEMT make a quantum leap
in power conversion

Smart GaN ICs maximize the benefits
of the new technology

MasterGaN® takes the challenge first

Smart GaN innovation leverages
ST leadership in power conversion





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Power & SPIN Microsite



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