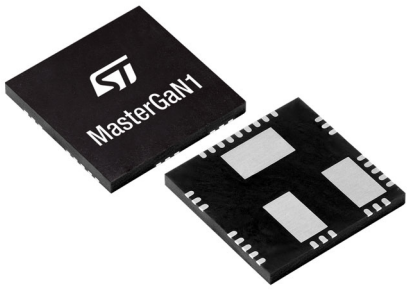
MASTERGAN1

Datasheet

High power density half-bridge high voltage driver with two 650V enhancement mode GaN HEMT



Features

- Power system-in-package integrating half-bridge gate driver and high-voltage GaN transistors:
  - BV_{DSS} = 650 V
  - $R_{DS(ON)}$ = 150 mΩ
  - $I_{DS(MAX)}$ = 10 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.

Application

- Switch-mode power supplies
- Chargers and adapters
- High-voltage PFC, DC-DC and DC-AC Converters
- UPS Systems
- Solar Power

Product status link

MASTERGAN1

Product label

SUSTAINABLE TECHNOLOGY

Description

The MASTERGAN1 is an advanced power system-in-package integrating a gate driver and two enhancement mode GaN transistors in half-bridge configuration.

The integrated power GaNs have $R_{DS(ON)}$ of 150 mΩ and 650 V drain-source breakdown voltage, while the high side of the embedded gate driver can be easily supplied by the integrated bootstrap diode.

The MASTERGAN1 features 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.

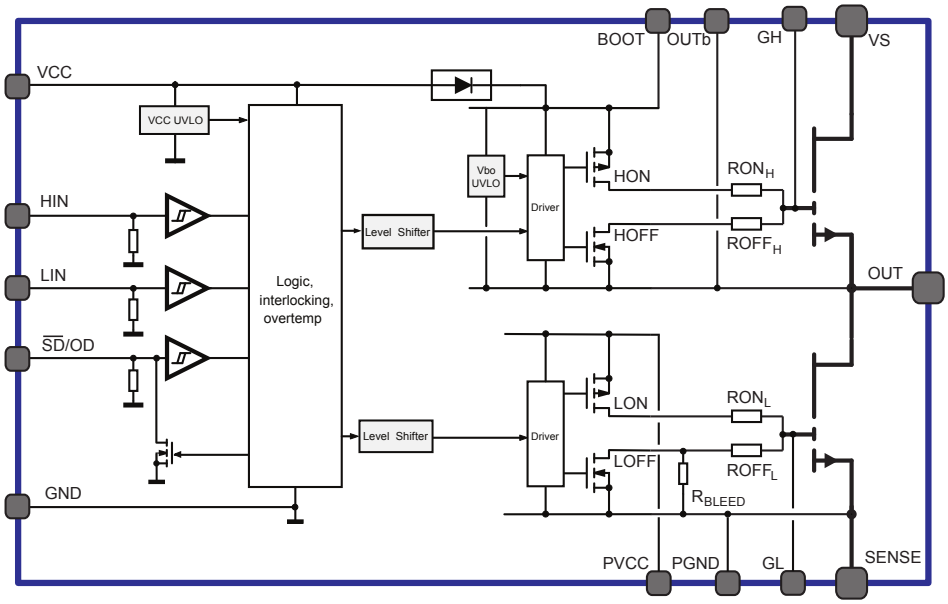
The input pins extended range allows easy interfacing with microcontrollers, DSP units or Hall effect sensors.

The MASTERGAN1 operates in the industrial temperature range, -40°C to 125°C.

The device is available in a compact 9x9 mm QFN package.

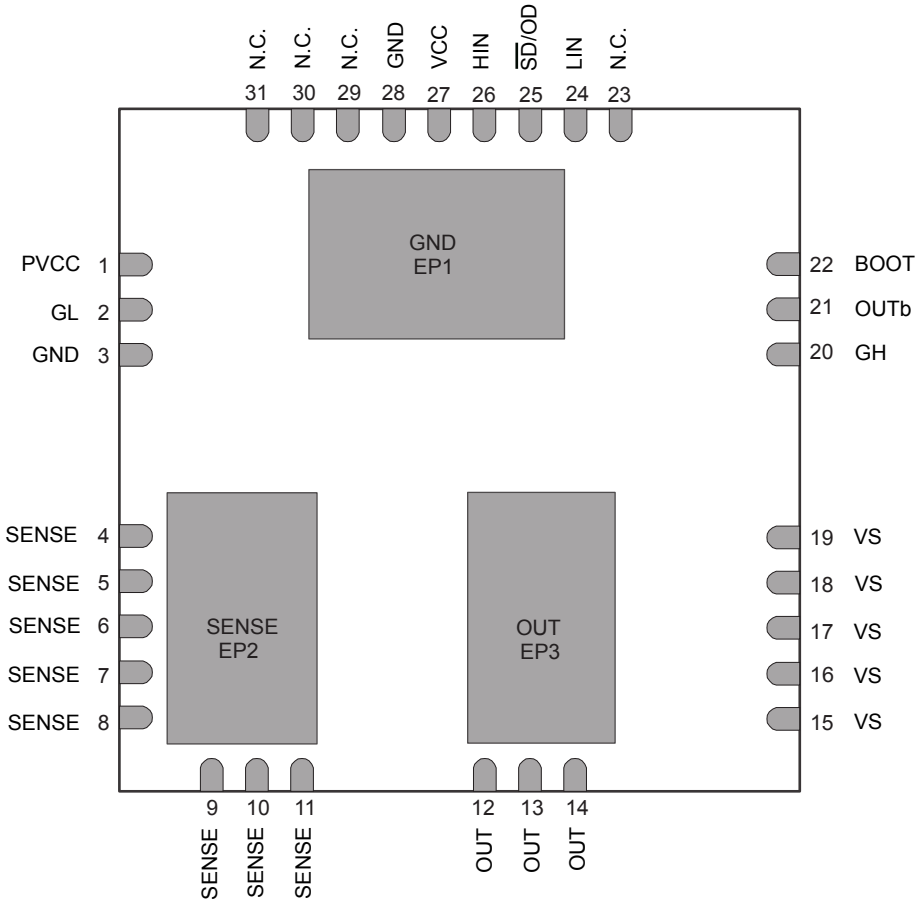
1 Block diagram

Figure 1. **Block diagram**



2 Pin description and connection diagram

Figure 2. **Pin connection (top view)**



2.1 Pin list

Table 1. **Pin description**

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

Pin Number	Pin Name	Type	Function
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	$\overline{SD}$/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

3 Electrical Data

3.1 Absolute maximum ratings

Table 2. Absolute maximum ratings (each voltage referred to GND unless otherwise specified)

Symbol	Parameter	Test Condition	Value	Unit
V_{DS}	GaN Drain-to-Source Voltage	T_J = 25 °C	620	V
VCC	Logic supply voltage		-0.3 to 11	V
PVCC-PGND	Low-side driver supply voltage (1)		-0.3 to 7	V
VCC-PGND	Logic supply vs. Low-side driver ground		-0.3 to 18.3	V
PVCC	Low-side driver supply vs. logic ground		-0.3 to 18.3	V
PGND	Low-side driver ground vs. logic ground		-7.3 to 11.3	V
V_{BO}	BOOT to OUTb voltage (2)		-0.3 to 7	V
BOOT	Bootstrap voltage		-0.3 to 620	V
CGL, CGH	Maximum external capacitance between GL and PGND and between GH and OUTb	(3)	680	pF
RGL, RGH	Minimum external pull-down resistance between GL and PGND and GH and OUTb		6.8	kΩ
I_D	Drain current (per GaN transistor)	DC @ T_{CB} = 25°C (4), (5)	9.7	A
		DC @ T_{CB} = 100°C(4)), (5)	6.4	A
		Peak @ T_{CB} = 25°C(4), (5), (6)	17	A
S_{Rout}	Half-bridge outputs slew rate (10% - 90%)		100	V/ns
V_i	Logic inputs voltage range		-0.3 to 21	V
T_J	Junction temperature		-40 to 150	°C
T_s	Storage temperature		-40 to 150	°C

1. *PGND internally connected to SENSE.*
2. *OUTb internally connected to OUT.*
3. *CGx < 0.08/(Pvcc^2*Fsw)-(330*10^{-12}).*
4. *T_{CB} is temperature of case exposed pad.*
5. *Range estimated by characterization, not tested in production.*
6. *Value specified by design factor, pulse duration limited to 50 µs and junction temperature.*

3.2 Recommended operating conditions

Table 3. Recommended operating conditions (Each voltage referred to GND unless otherwise specified)

Symbol	Parameter	Note	Min	Max	Unit
VS	High voltage bus		0	520	V
VCC	Supply voltage		4.75	9.5	V
PVCC-PGND	PVCC to PGND low side supply(1)		4.75	6.5	V
		Best performance	5	6.5	V
PVCC	Low-side driver supply		3	8.5	V
VCC-PVCC	VCC to PVCC pin voltage		-3	3	V
PGND	Low-side driver ground(1)		-2	2	V
DT	Suggested minimum deadtime		5		ns
T_{IN_MIN}	Minimum duration of input pulse to obtain undistorted output pulse		120		ns
V_{BO}	BOOT to OUTb pin voltage(2)		4.4	6.5	V
		Best performance	5	6.5	V
BOOT	BOOT to GND voltage		0(3)	530	V
V_i	Logic inputs voltage range		0	20	V
T_J	Junction temperature		-40	125	°C

1. *PGND internally connected to SENSE.*
2. *OUTb internally connected to OUT.*
3. *5 V is recommended during high-hide turn-on.*

3.3 Thermal data

Table 4. Thermal data

Symbol	Parameter	Value	Unit
$R_{th(J-CB)}$	Thermal resistance junction to each GaN transistor exposed pad, typical	1.9	°C/W
$R_{th(J-A)}$	Thermal resistance junction-to-ambient(1)	17.5	°C/W

1. *The junction to ambient thermal resistance is obtained simulating the device mounted on a 2s2p (4 layer) FR4 board as JESD51-5,7 with 6 thermal vias for each exposed pad. Power dissipation uniformly distributed over the two GaN transistors.*

4 Electrical characteristics

4.1 Driver

Table 5. Driver electrical characteristics : VCC = PVCC = 6 V; SENSE = GND; T_J = 25°C, unless otherwise specified (Each voltage referred to GND unless otherwise specified.)

Symbol		Parameter	Test condition	Min	Typ	Max	Unit
Logic section supply							
VCC_{thON}	VCC vs. GND	VCC UV turn ON threshold(1)		4.2	4.5	4.75	V
VCC_{thOFF}		VCC UV turn OFF threshold(1)		3.9	4.2	4.5	V
VCC_{hys}		VCC UV hysteresis(1)		0.2	0.3	0.45	V
I_{QVCCU}		VCC undervoltage quiescent supply current	VCC = PVCC = 3.8 V		320	410	µA
I_{QVCC}		VCC quiescent supply current	$\overline{SD}$/OD = LIN = 5 V; HIN = 0 V; BOOT = 7 V		680	900	µA
I_{SVCC}		VCC switching supply current	$\overline{SD}$/OD = 5 V; V_{BO} = 6.5 V; VS = 0 V; F_{SW} = 500 kHz		0.8		mA
Low-side driver section supply							
I_{QPVCC}	PVCC vs. PGND	PVCC quiescent supply current	$\overline{SD}$/OD = LIN = 5 V		150		µA
I_{SPVCC}		PVCC switching supply current	VS = 0 V; F_{SW} = 500 kHz		1.4		mA
R_{BLEED}	GL vs. PGND	Low side gate bleeder	PVCC = PGND	75	100	125	kΩ
RON_L		|Low side turn on resistor			50		Ω
$ROFF_L$		|Low side turn off resistor			2		Ω
High-side floating section supply							
V_{BOthON}	BOOT vs. OUTb	V_{BO} UV turn ON threshold(2)		3.6	4.0	4.4	V
$V_{BOthOFF}$		V_{BO} UV turn OFF threshold(2)		3.4	3.7	4.0	V
V_{BOhys}		V_{BO} UV hysteresis(2)		0.1	0.3	0.5	V
I_{QBOU}		V_{BO} undervoltage quiescent supply current(2)	V_{BO} = 3.4 V		140	200	µA
I_{QBO}		V_{BO} quiescent supply current(2)	V_{BO} = 6 V; LIN = GND; $\overline{SD}$/OD = HIN = 5 V;		217		µA
I_{SBO}	BOOT	BOOT switching supply current	V_{BO} = 6 V; $\overline{SD}$/OD = 5 V; VS = 0 V; F_{SW} = 500 kHz		2		mA
I_{LK}	BOOT vs. SGND	High voltage leakage current	BOOT = OUT = 600 V			11	µA
R_{DBoot}	VCC vs. BOOT	Bootstrap diode on resistance(3)	$\overline{SD}$/OD = LIN = 5 V; HIN = GND = PGND		140	175	Ω

Symbol		Parameter	Test condition	Min	Typ	Max	Unit
			VCC – BOOT = 0.5 V				
RON_H		High side turn on resistor			50		Ω
$ROFF_H$		High side turn off resistor			2		Ω
Logic inputs							
V_{il}	LIN, HIN, $\overline{SD}$/OD	Low level logic threshold voltage	T_J = 25°C	1.1	1.31	1.45	V
			Full Temperature range(4)	0.8			
V_{ih}		High level logic threshold voltage	T_J = 25°C	2	2.17	2.5	V
			Full Temperature range(4)			2.7	
V_{ihys}		Logic input threshold hysteresis		0.7	0.96	1.2	V
I_{INh}	LIN, HIN	Logic '1' input bias current	LIN, HIN = 5 V	23	33	55	µA
I_{INl}		Logic '0' input bias current	LIN, HIN = GND			1	µA
R_{PD_IN}		Input pull-down resistor	LIN, HIN = 5 V	90	150	220	kΩ
I_{SDh}	$\overline{SD}$/OD	Logic "1" input bias current	$\overline{SD}$/OD = 5 V	11	15	20	µA
I_{SDl}	$\overline{SD}$/OD	Logic "0" input bias current	$\overline{SD}$/OD = 0 V			1	µA
R_{PD_SD}	$\overline{SD}$/OD	Pull-down resistor	$\overline{SD}$/OD = 5 V OpenDrain OFF	250	330	450	kΩ
V_{TSD}	$\overline{SD}$/OD	Thermal shutdown unlatch threshold	T_J = 25°C(5)	0.5	0.75	1	V
R_{ON_OD}	$\overline{SD}$/OD	Open drain ON resistance	T_J = 25°C; I_{OD} = 400 mV(5)	8	10	18	Ω
I_{OL_OD}	$\overline{SD}$/OD	Open Drain low level sink current	T_J = 25°C; V_{OD} = 400 mV(5)	22	40	50	mA
Over temperature protection							
T_{TSD}		Shutdown temperature	(4)		175		°C
T_{HYS}		Temperature hysteresis	(4)		20		°C

1. *VCC UVLO is referred to VCC - GND.*
2. *V_{BO} = V_{BOOT} - V_{OUT}.*
3. *$R_{BD(on)}$ is tested in the following way:*

   $R_{BD(on)}$ = [(VCC - V_{BOOTa}) - (VCC - V_{BOOTb})] / [I_a - I_b]

   Where: I_a is BOOT pin current when V_{BOOT} = V_{BOOTa}; I_b is BOOT pin current when V_{BOOT} = V_{BOOTb}
4. *Range estimated by characterization, not tested in production.*
5. *Tested on wafer.*

4.2 GaN power transistor

Table 6. GaN power transistor electrical characteristics (V_{GS} = 6 V; T_J = 25°C, unless otherwise specified.)

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
GaN on/off states						
$V_{(BR)DS}$	Drain-source breakdown voltage	I_{DSS} < 18 µA(1) V_{GS} = 0 V	650			V

Symbol	Parameter	Test condition		Min	Typ	Max	Unit
I_{DSS}	Zero gate voltage drain current	V_{DS} = 600 V V_{GS} = 0 V			0.7		µA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = $V_{GS, ID}$ = 2.5 mA (1)			1.7		V
I_{GS}	Gate to source voltage	V_{DS} = 0 V(2)			57		µA
$R_{DS(on)}$	Static drain-source on-resistance	I_D = 3.2 A	T_J = 25°C		150	220	mΩ
			T_J = 125°C (2)		330		

1. *Tested on wafer.*
2. *Value estimated by characterization, not tested in production.*

5 Device characterization values

The information in Table 7 and Table 8 represents typical values based on characterization and simulation results and are not subject to the production test.

Table 7. GaN power transistor characterization values

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
Q_G	Total gate charge	V_{GS} = 6 V, T_J = 25°C V_{DS} = 0 to 400 V		2		nC
Q_{OSS}	Output charge	V_{GS} = 0 V, V_{DS} = 400 V		20		nC
E_{OSS}	Output capacitance stored energy			2.7		µJ
C_{OSS}	Output capacitance			20		pF
$C_{O(ER)}$	Effective output capacitance energy related(1)	V_{GS} = 0 V, V_{DS} = 0 to 400 V		31		pF
$C_{O(TR)}$	Effective output capacitance time related(2)			50		pF
Q_{RR}	Reverse recovery charge			0		nC
I_{RRM}	Reverse recovery current			0		A

1. *$C_{O(ER)}$ is the fixed capacitance that would give the same stored energy as C_{OSS} while V_{DS} is rising from 0 V to the stated V_{DS}*
2. *$C_{O(TR)}$ is the fixed capacitance that would give the same charging time as C_{OSS} while V_{DS} is rising from 0 V to the stated V_{DS}*

Table 8. Inductive load switching characteristics

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$t_{(on)}$(1)	Turn-on time	VS = 400 V, V_{GS} = 6 V, I_D = 3.2 A See Figure 3		70		ns
$t_{C(on)}$(2)	Crossover time (on)			15		ns
t(off)(1)	Turn-off time			70		ns
$t_{C(off)}$(2)	Crossover time (off)			15		ns
t_{SD}	Shutdown to high/low-side propagation delay			70		ns
E_{on}	Turn-on switching losses			12.5		µJ
E_{off}	Turn-off switching losses			2.5		µJ

1. *$t_{(on)}$ and $t_{(off)}$ include the propagation delay time of the internal driver*
2. *$t_{C(on)}$ and $t_{C(off)}$ are the switching times of GaN transistor itself under the internally given gate driving conditions*

Figure 3. **Switching time definition**

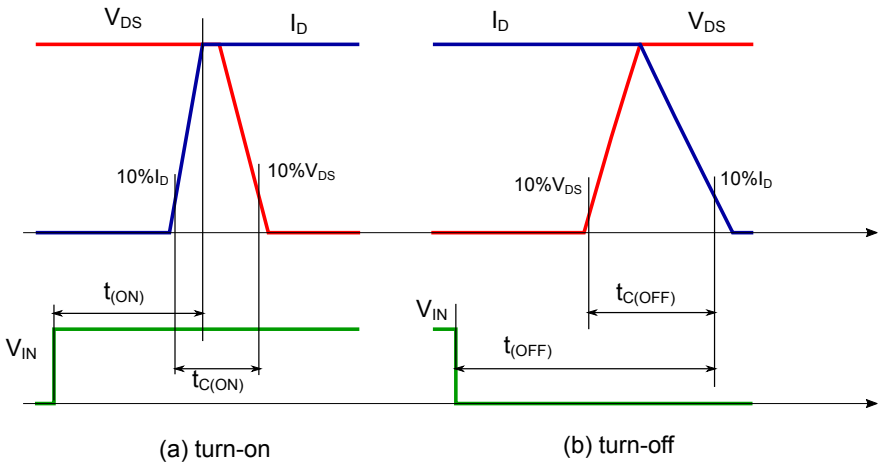


Figure 4. **Typ I_D vs. V_{DS} at T_J=25°C**

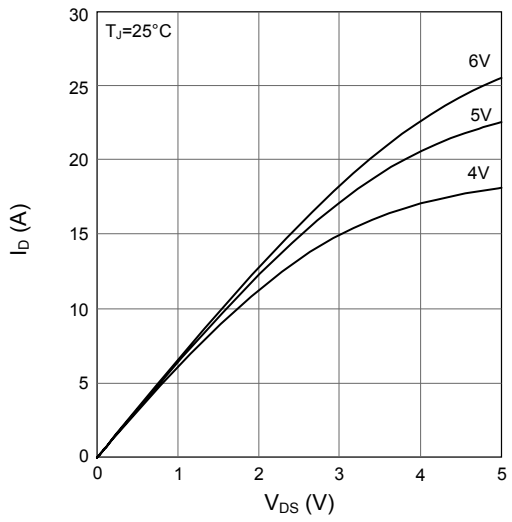


Figure 5. **Typ I_D vs. V_{DS} at T_J=125°C**

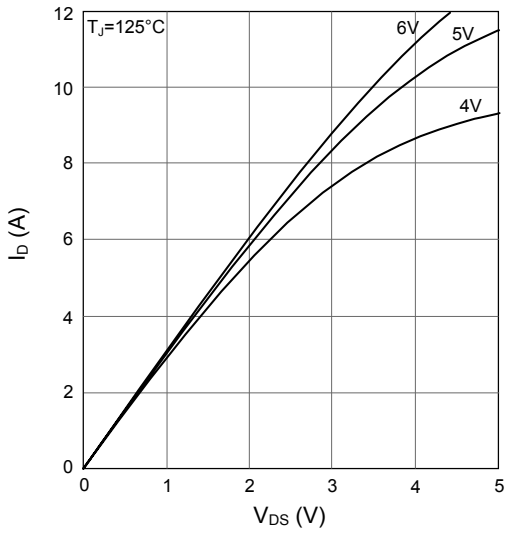


Figure 6. Typ $R_{DS(on)}$ vs. I_D at T_J=25°C

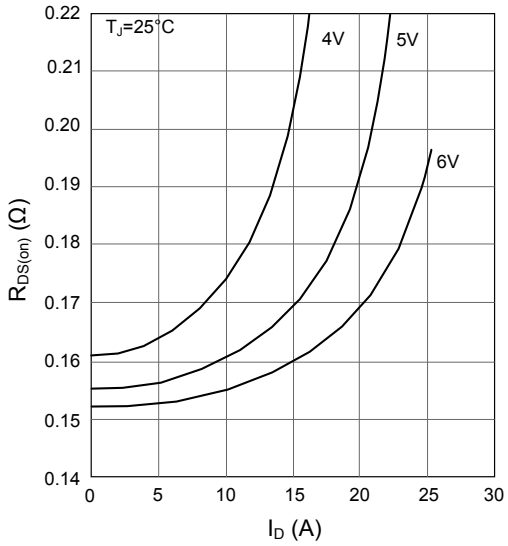


Figure 7. Typ $R_{DS(on)}$ vs. I_D at T_J=125°C

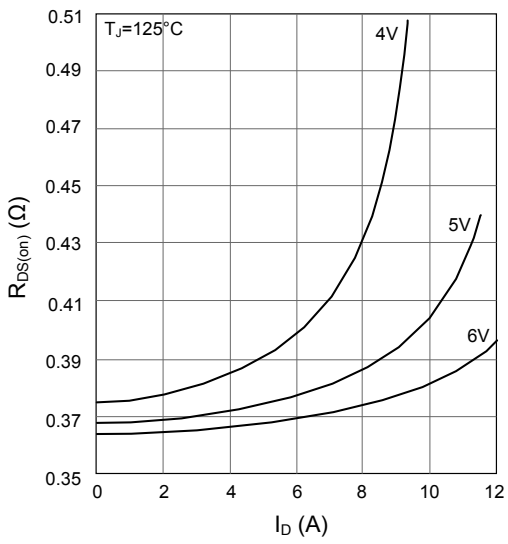


Figure 8. Typ I_D vs. V_{DS}

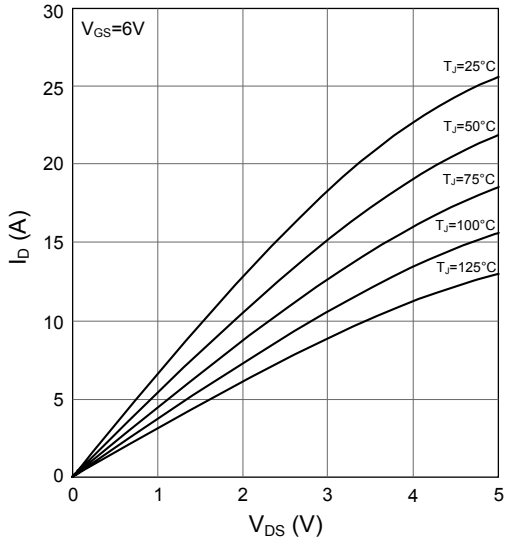


Figure 9. Typ $R_{DS(on)}$ vs. T_J, normalized at 25°C

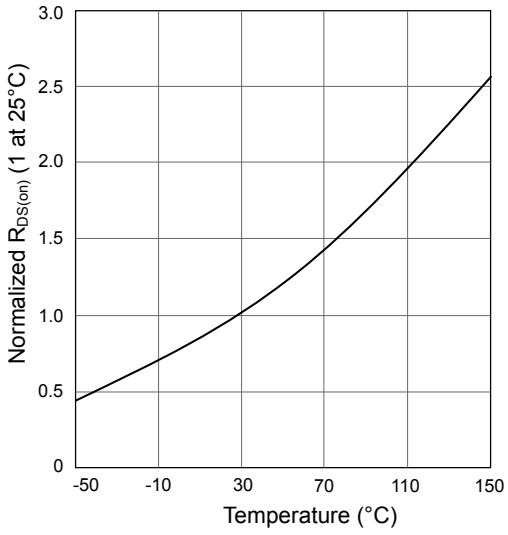


Figure 10. Typ I_{SD} vs. V_{SD}, at T_J=25°C

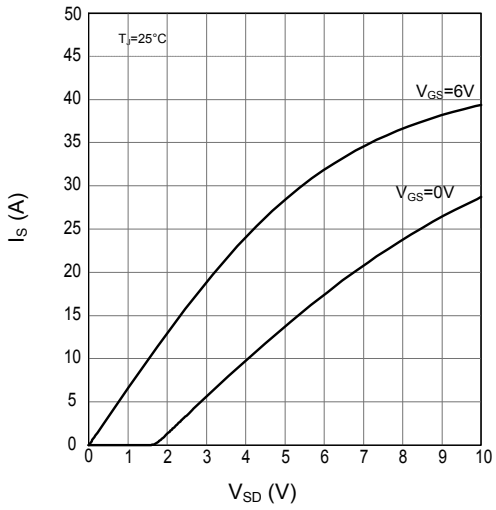


Figure 11. Typ I_{SD} vs. V_{SD}, at T_J=125°C

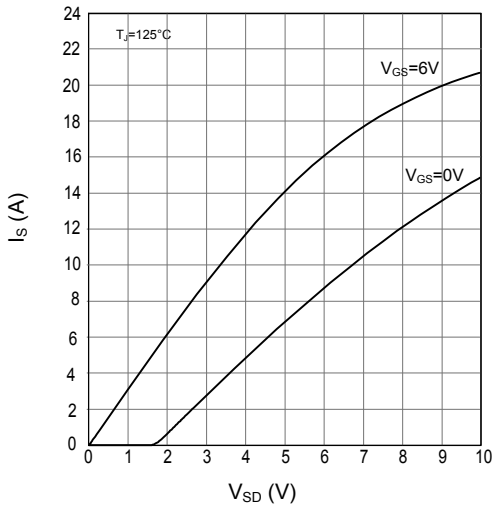


Figure 12. Safe Operating Area at T_J=25°C

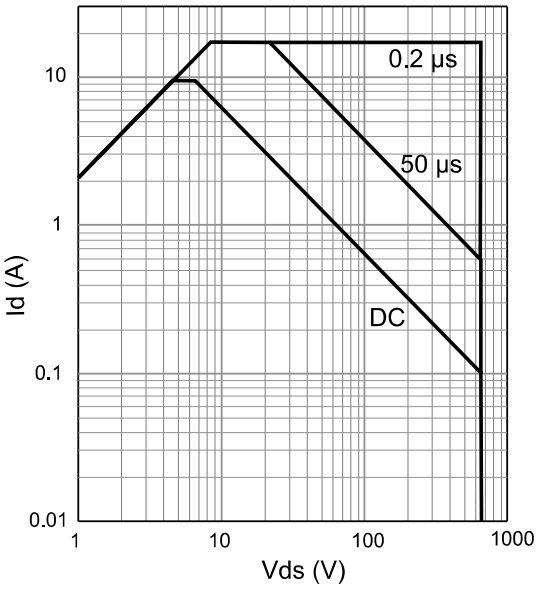


Figure 13. Derating curve

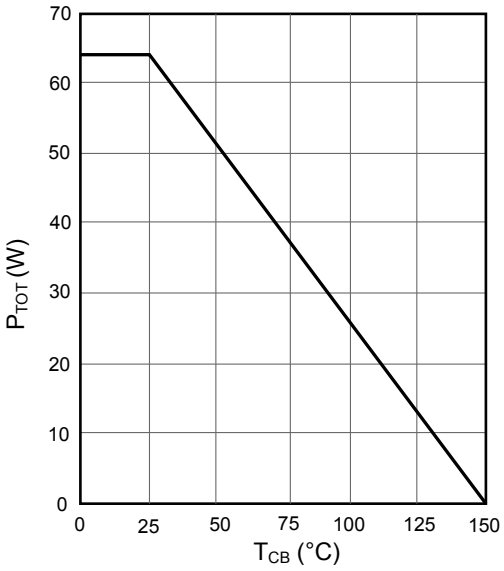


Figure 14. Typ Gate Charge at T_J=25°C

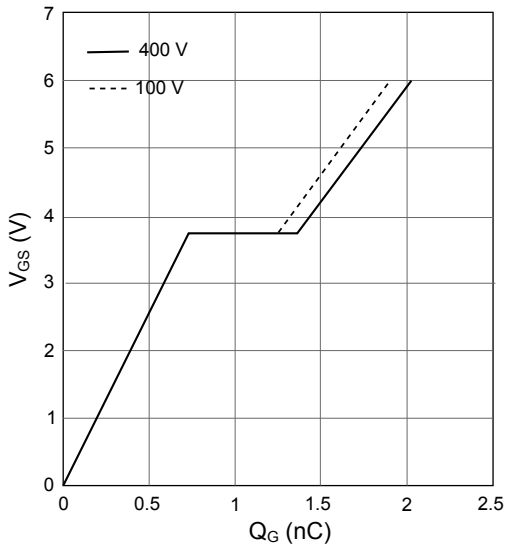
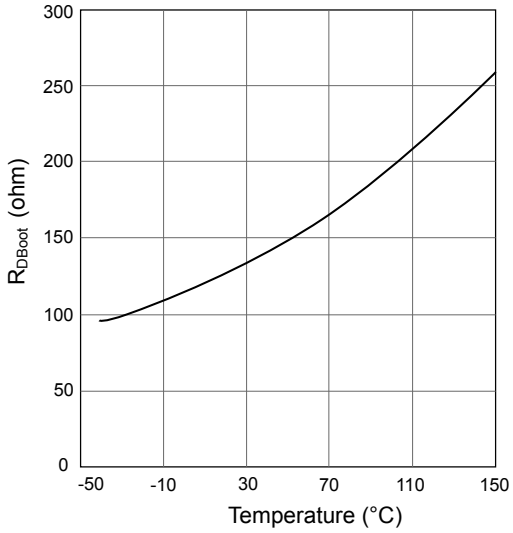


Figure 15. Typ R_{Dboot} vs T_J



6 Functional description

6.1 Logic inputs

The MASTERGAN1 features a half-bridge gate driver with three logic inputs to control the internal high-side and low-side GaN transistors.

The devices are controlled through the following logic inputs:

- $\overline{SD}$/OD: Shutdown input, active low;
- LIN: low-side driver inputs, active high;
- HIN: high-side driver inputs, active high.

Table 9. Inputs truth table (applicable when device is not in UVLO)

Input pins			GaN transistors status	
$\overline{SD}$/OD	LIN	HIN	LS	HS
L	X(1)	X(1)	OFF	OFF
H	L	L	OFF	OFF
H	L	H	OFF	**ON**
H	H	L	**ON**	OFF
H	H(2)	H(2)	OFF	OFF

1. *X: Don't care*
2. *Interlocking*

The logic inputs have internal pull-down resistors. The purpose of these resistors is to set a proper logic level in case, for example, there is an interruption in the logic lines or the controller outputs are in tri-state conditions.

If logic inputs are left floating, the gate driver outputs are set to low level and the correspondent GaN transistors are turned off.

The internal logic is able to transfer the control signal pulse longer than T_{IN_MIN} = 120 ns and introduces a very short propagation delay to output.

6.2 Bootstrap structure

A bootstrap circuitry is typically used to supply the high-voltage section. MASTERGAN1 integrates this structure, realized by a patented integrated high-voltage DMOS, to reduce the external components.

The Boostrap integrated circuit is connected to VCC pin and is driven synchronously with the low-side driver.

The use of an external bootstrap diode in parallel to the integrated structure is possible, in particular if the operating frequency is approximately higher than 500 kHz.

6.3 VCC supply pins and UVLO function

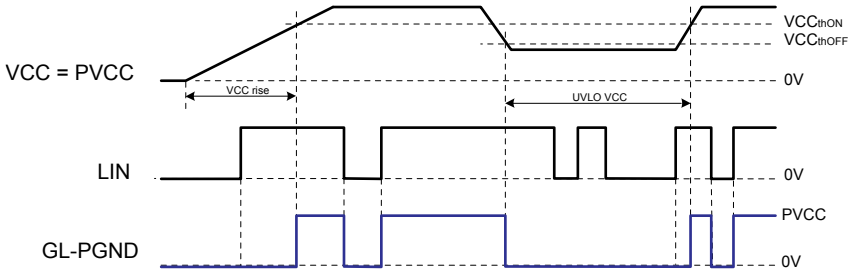
The VCC pin supplies current to the logic circuit, level-shifters in the low-side section and the integrated bootstrap diode.

The PVCC pin supplies low-side output buffer. During output commutations the average current used to provide gate charge to the high-side and low-side GaN transistors flows through this pin.

The PVCC pin can be connected either to the same supply voltage of the VCC pin or to a separated voltage source. In case the same voltage source is used, it is suggested to connect VCC and PVCC pins by means of a small decoupling resistance. The use of dedicated bypass ceramic capacitors located as close as possible to each supply pin is highly recommended.

The MASTERGAN1 VCC supply voltage is continuously monitored by an under-voltage lockout (UVLO) circuitry that turns both the high-side and low-side GaN transistors off when the supply voltage goes below the V_{CC_thOFF} threshold. The UVLO circuitry turns on the GaN, according to LIN and HIN status, as soon as the supply voltage goes above the V_{CCthON} voltage. A V_{CChys} hysteresis is provided for noise rejection purpose.

Figure 16. VCC UVLO and Low Side

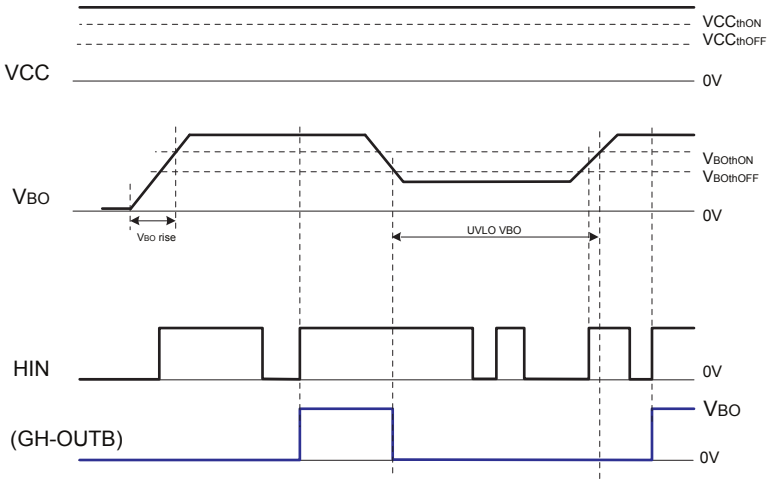


6.4 V_{BO} UVLO protection

Dedicated undervoltage protection is available on the bootstrap section between BOOT and OUTb supply pins. In order to avoid intermittent operation, a hysteresis sets the turn-off threshold with respect to the turn-on threshold.

When V_{BO} voltage goes below $V_{BOthOFF}$ threshold the high-side GaN transistor is switched off. When V_{BO} voltage reaches V_{BOthON} threshold the device returns to normal operation and the output remains off until the detection of the HIN pin's rising edge, that activates the high side transistor's turn-on.

Figure 17. V_{BO} UVLO and High Side



6.5 Thermal shutdown

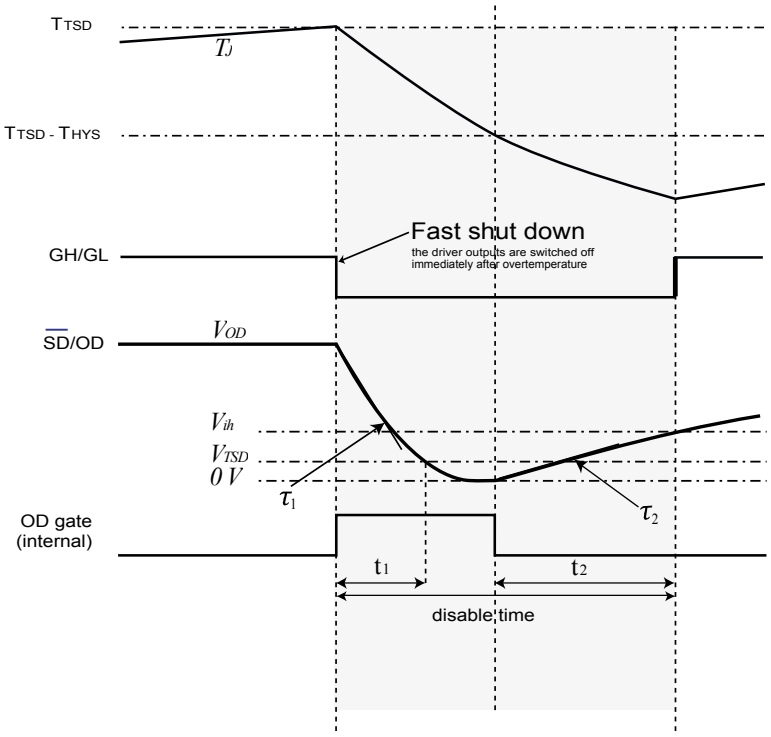
The integrated gate driver has a thermal shutdown protection.

When junction temperature reaches the T_{TSD} temperature threshold, the device turns off both GaN transistors leaving the half-bridge in 3-state and signaling the state forcing $\overline{SD}$/OD pin low. $\overline{SD}$/OD pin is released when junction temperature is below T_{TSD}-T_{HYS} and $\overline{SD}$/OD is below V_{TSD}.

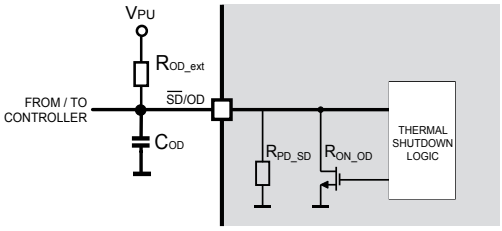
GaN are driven again according to inputs when $\overline{SD}$/OD rises above V_{ih}.

The thermal smart shutdown system gives the possibility to increase the time constant of the external RC network (that determines the disable time after the overtemperature event) up to very large values without delaying the protection.

Figure 18. Thermal shutdown timing waveform



THERMAL SHUTDOWN CIRCUIT



7 Typical application diagrams

Figure 19. **Typical application diagram – Resonant LLC converter**

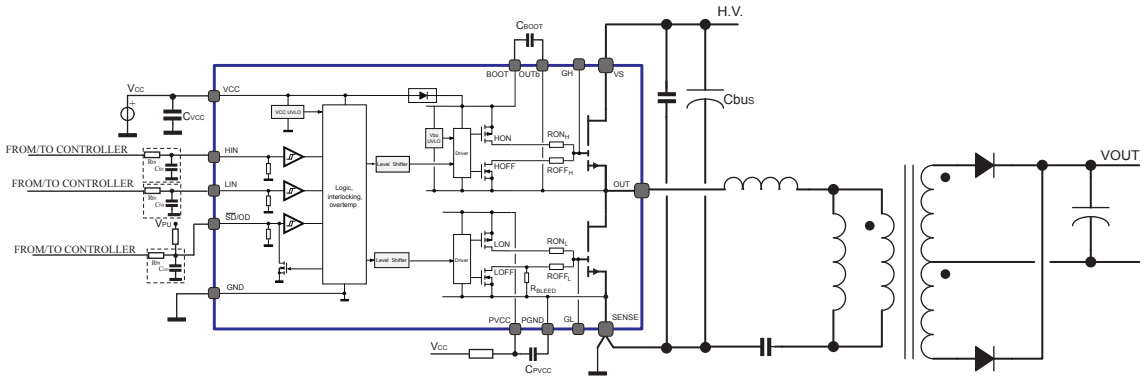
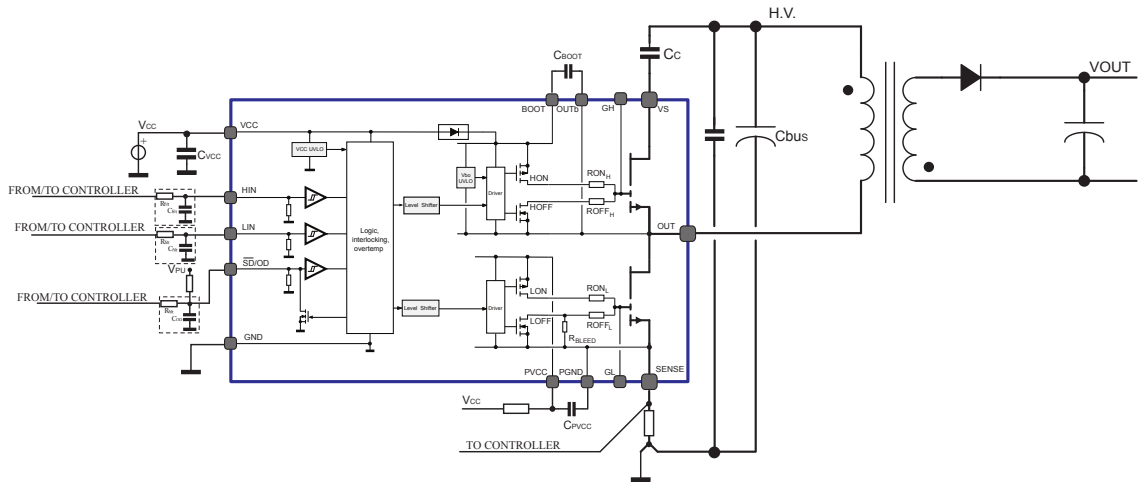


Figure 20. **Typical application diagram – Active clamp flyback**



8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

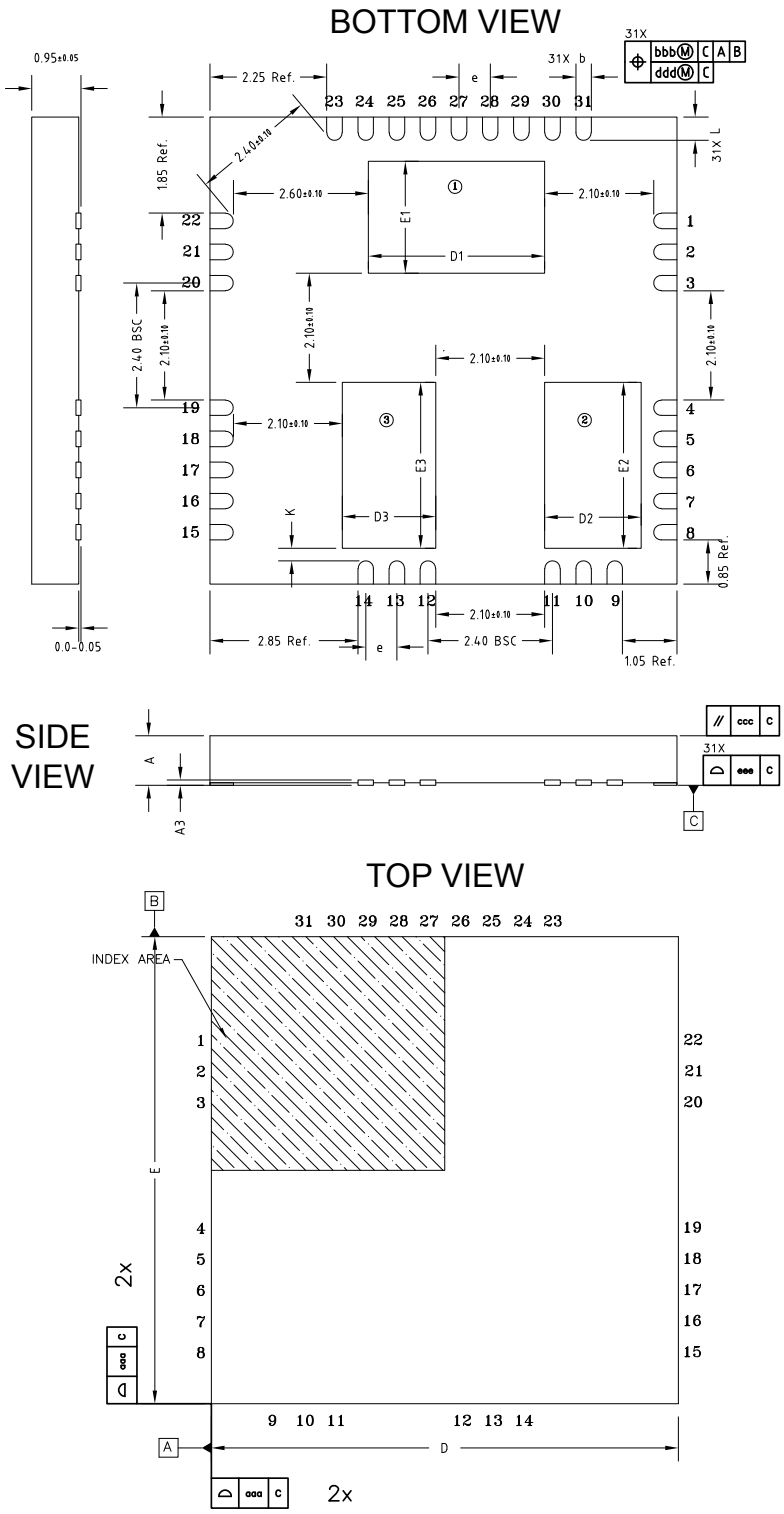
8.1 QFN 9 x 9 x 1 mm, 31 leads, pitch 0.6 mm package information

Table 10. QFN 9 x 9 x 1 mm package dimensions

Symbol	Dimensions (mm)		
	Min.	Typ.	Max.
A	0.90	0.95	1.00
A3		0.10	
b	0.25	0.30	0.35
D	8.96	9.00	9.04
E	8.96	9.00	9.04
D1	3.30	3.40	3.50
E1	2.06	2.16	2.26
D2	1.76	1.86	1.96
E2	3.10	3.20	3.30
D3	1.70	1.80	1.90
E3	3.10	3.20	3.30
e		0.60	
K		0.24	
L	0.35	0.45	0.55
N	31		
aaa	0.10		
bbb	0.10		
ccc	0.10		
ddd	0.05		
eee	0.08		

Note:
1. *Dimensioning and tolerances conform to ASME Y14.5-2009.*
2. *All dimensions are in millimeters.*
3. *N total number of terminals.*
4. *Dimensions do not include mold protrusion, not to exceed 0.15 mm.*
5. *Package outline exclusive of metal burr dimensions.*

Figure 21. QFN 9 x 9 x 1 mm package dimensions

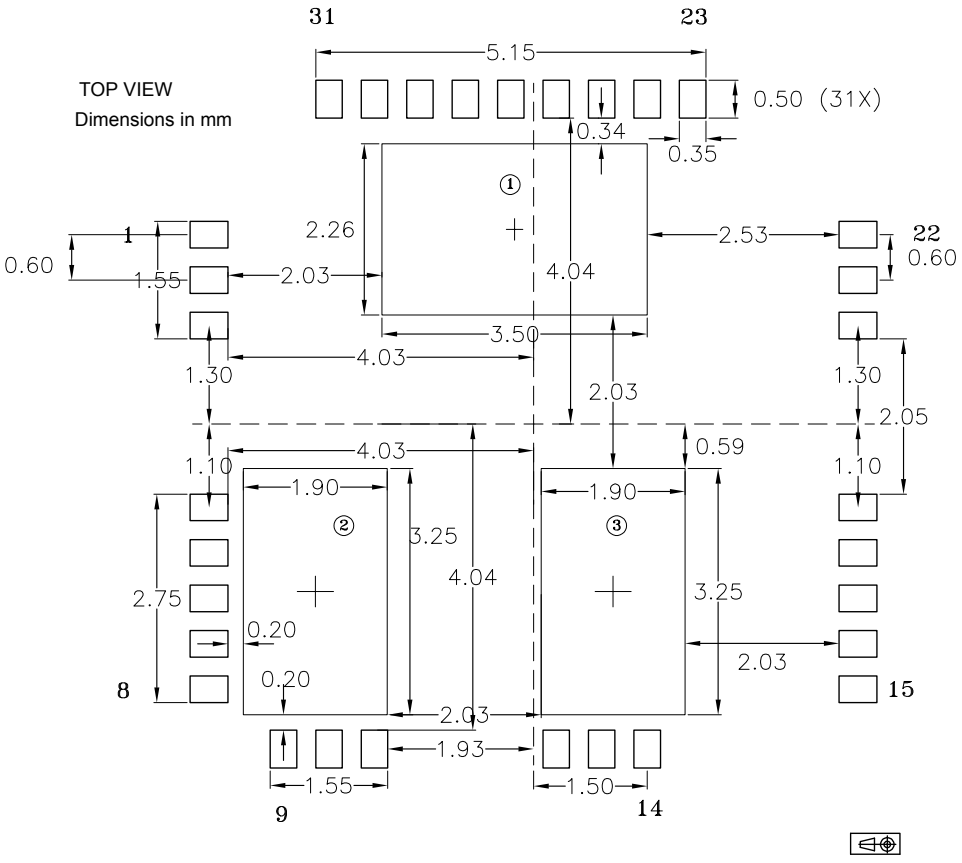


9 Suggested footprint

The MASTERGAN1 footprint for the PCB layout is usually defined based on several design factors such as assembly plant technology capabilities and board component density. For easy device usage and evaluation, ST provides the following footprint design, which is suitable for the largest variety of PCBs.

The following footprint indicates the copper area which should be free from the solder mask, while the copper area shall extend beyond the indicated areas especially for EP2 and EP3. To aid thermal dissipation, it is recommended to add thermal vias under these EPADs to transfer and dissipate device heat to the other PCB copper layers. A PCB layout example is available with the MASTERGAN1 evaluation board.

Figure 22. Suggested footprint (top view drawing)



10 Ordering information

Table 11. **Order codes**

Order code	Package	Package Marking	Packaging
MASTERGAN1	QFN 9 x 9 x 1 mm	MASTERGAN1	Tray
MASTERGAN1TR	QFN 9 x 9 x 1 mm	MASTERGAN1	Tape and Reel

Revision history

Table 12. **Document revision history**

Date	Version	Changes
15-Jul-2020	1	Initial release.
10-Aug-2020	2	Changed $R_{DS(on)}$ unit in Table 6

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