LM5113-Q1 汽车 90V、1.2A/5A 半桥 GaN 驱动器

1 特性

- 符合汽车应用 标准
- 具有符合 AEC-Q100 标准的下列特性：
  - 器件温度 1 级：–40°C 至 125°C 的环境工作温度范围
  - 器件 HBM ESD 分类等级 1C
  - 器件带电器件模型 (CDM) ESD 分类等级 C6
- 独立的高侧和低侧TTL 逻辑输入
- 1.2A 峰值拉电流能力，5A 峰值灌电流能力
- 高侧浮动偏置电压轨
  工作电压高达 100VDC
- 内部自举电源电压钳位
- 分离输出实现可调的
  开通和关断应力
- 0.6Ω 下拉电阻，2.1Ω 上拉电阻
- 快速传播时间（典型值为 28ns）
- 优异的传播延迟
  （典型值为 1.5ns)
- 电源轨欠压锁定
- 低功耗

2 应用

- 移动无线充电器
- 音频功率放大器
- 音频电源
- 电流馈入型推挽式转换器
- 半桥和全桥转换器
- 同步降压转换器

3 说明

LM5113-Q1 专为同时驱动采用同步降压、升压或半桥配置的高侧和低侧增强模式氮化镓 (GaN) FET 或硅质 MOSFET 而设计，适用于汽车 应用。此器件具有一个集成于内部的 100V 自举二极管，还为高侧和低侧输出分别提供了独立的输入，可实现最大程度的灵活控制。高侧偏置电压在内部被钳位为 5.2V，可防止栅极电压超过增强模式 GaN FET 的最大栅极/源极电压额定值。器件的输入与 TTL 逻辑兼容，无论 VDD 电压多高，它都能够承受高达 14V 的输入电压。LM5113-Q1 具有分栅输出的能力，可独立灵活地调节开通和关断强度。

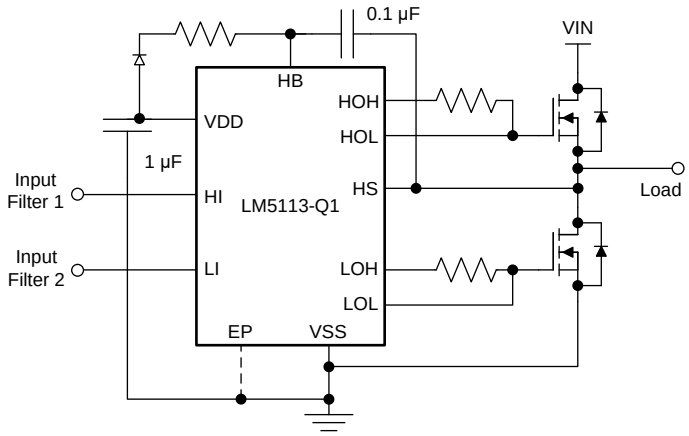
此外，LM5113-Q1 具有非常可靠的灌电流能力，使栅极保持低电平，从而防止开关操作期间发生误导通。LM5113-Q1 的工作频率最高可达数 MHz。LM5113-Q1 采用带有裸露焊盘的标准 10 引脚 WSON 封装，可改善功耗。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
LM5113-Q1	WSON (10)	4.00mm x 4.00mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。

简化应用示意图



目录

1 特性 ... 1
2 应用 ... 1
3 说明 ... 1
4 修订历史记录 ... 2
5 **Pin Configuration and Functions** ... 3
6 **Specifications** ... 4
6.1 Absolute Maximum Ratings ... 4
6.2 ESD Ratings ... 4
6.3 Recommended Operating Conditions ... 4
6.4 Thermal Information ... 4
6.5 Electrical Characteristics ... 5
6.6 Switching Characteristics ... 6
6.7 Typical Characteristics ... 8
7 **Detailed Description** ... 11
7.1 Overview ... 11
7.2 Functional Block Diagram ... 11
7.3 Feature Description ... 11
7.4 Device Functional Modes ... 13
8 **Application and Implementation** ... 14
8.1 Application Information ... 14
8.2 Typical Application ... 15
9 **Power Supply Recommendations** ... 19
10 **Layout** ... 20
10.1 Layout Guidelines ... 20
10.2 Layout Example ... 20
11 器件和文档支持 ... 21
11.1 文档支持 ... 21
11.2 接收文档更新通知 ... 21
11.3 社区资源 ... 21
11.4 商标 ... 21
11.5 静电放电警告 ... 21
11.6 Glossary ... 21
12 机械、封装和可订购信息 ... 21

4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Revision A (November 2017) to Revision B **Page**

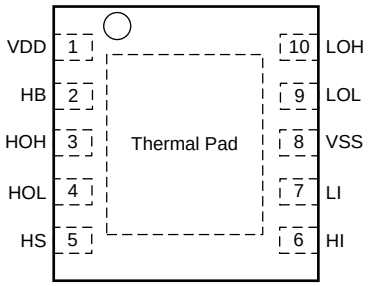
- 将数据表标题从“LM5113-Q1 汽车 90V、1.2A/5A 半桥 GaN 驱动器”更改成了“LM5113-Q1 汽车 90V、1.2A/5A 半桥 GaN 驱动器” ... 1
- 在*简化应用图* 中添加了输入滤波器 ... 1
- Added EXT HI and EXT LO references to the *Functional Block Diagram* ... 11
- Changed the last paragraph and add new images to the *Input and Output* section ... 11

Changes from Original (March 2017) to Revision A **Page**

- 将数据表标题从“LM5113-Q1 汽车 80V、1.2A/5A 半桥 GaN 驱动器”更改成了“LM5113-Q1 汽车 90V、1.2A/5A 半桥 GaN 驱动器” ... 1
- 更改了*简化应用图表* ... 1
- Changed the *Functional Block Diagram* ... 11
- Added content to the *Input and Output* section ... 11
- Added content to the *Start-up and UVLO* section ... 12

5 Pin Configuration and Functions

DPR Package
10-Pin WSON With Exposed Thermal Pad
Top View



Pin Functions

PIN		TYPE (1)	DESCRIPTION
NO.	NAME		
1	VDD	P	5-V positive gate drive supply: locally decouple to VSS using low-ESR/ESL capacitor located as close as possible to the IC.
2	HB	P	High-side gate driver bootstrap rail: connect the positive terminal of the bootstrap capacitor to HB and the negative terminal to HS. The bootstrap capacitor must be placed as close to the IC as possible.
3	HOH	O	High-side gate driver turnon output: connect to the gate of high-side GaN FET with a short, low inductance path. A gate resistor can be used to adjust the turnon speed.
4	HOL	O	High-side gate driver turnoff output: connect to the gate of high-side GaN FET with a short, low inductance path. A gate resistor can be used to adjust the turnoff speed.
5	HS	P	High-side GaN FET source connection: connect to the bootstrap capacitor negative terminal and the source of the high-side GaN FET.
6	HI	I	High-side driver control input. The LM5113-Q1 inputs have TTL type thresholds. Unused inputs must be tied to ground and not left open.
7	LI	I	Low-side driver control input. The LM5113-Q1 inputs have TTL type thresholds. Unused inputs must be tied to ground and not left open.
8	VSS	G	Ground return: all signals are referenced to this ground.
9	LOL	O	Low-side gate driver sink-current output: connect to the gate of the low-side GaN FET with a short, low inductance path. A gate resistor can be used to adjust the turnoff speed.
10	LOH	O	Low-side gate driver source-current output: connect to the gate of high-side GaN FET with a short, low inductance path. A gate resistor can be used to adjust the turnon speed.
EP	—	—	Exposed pad: TI recommends that the exposed pad on the bottom of the package be soldered to ground plane on the printed-circuit board to aid thermal dissipation.

(1) I = Input, O = Output, G = Ground, P = Power

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

	MIN	MAX	UNIT
VDD to VSS	–0.3	7	V
HB to HS	–0.3	7	V
LI or HI input	–0.3	15	V
LOH, LOL output	–0.3	VDD + 0.3	V
HOH, HOL output	V_{HS} – 0.3	V_{HB} + 0.3	V
HS to VSS	–5	93	V
HB to VSS	0	100	V
Operating junction temperature		150	°C
Storage temperature, T_{stg}	–55	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)	±1000	V
		Charged-device model (CDM), per AEC Q100-011	±1500	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
VDD	4.5		5.5	V
LI or HI input	0		14	V
HS	–5		90	V
HB	V_{HS} + 4		V_{HS} + 5.5	V
HS slew rate			50	V/ns
Operating junction temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC(1)		LM5113-Q1 DPR (WSON) 10 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	37.5	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	35.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	14.7	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	14.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	4.1	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

Specifications are T_J = 25°C. Unless otherwise specified: V_{DD} = V_{HB} = 5 V, V_{SS} = V_{HS} = 0 V.
No load on LOL and HOL or HOH and HOL(1).

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
SUPPLY CURRENTS							
I_{DD}	VDD quiescent current	LI = HI = 0 V	T_J = 25°C		0.07		mA
			T_J = –40°C to 125°C			0.1	
I_{DDO}	VDD operating current	f = 500 kHz	T_J = 25°C		2		mA
			T_J = –40°C to 125°C			3	
I_{HB}	Total HB quiescent current	LI = HI = 0 V	T_J = 25°C		0.08		mA
			T_J = –40°C to 125°C			0.1	
I_{HBO}	Total HB operating current	f = 500 kHz	T_J = 25°C		1.5		mA
			T_J = –40°C to 125°C			2.5	
I_{HBS}	HB to VSS quiescent current	HS = HB = 90 V	T_J = 25°C		0.1		µA
			T_J = –40°C to 125°C			10	
I_{HBSO}	HB to VSS operating current	f = 500 kHz	T_J = 25°C		0.4		mA
			T_J = –40°C to 125°C			1	
INPUT PINS							
V_{IR}	Input voltage threshold	Rising edge	T_J = 25°C		2.06		V
			T_J = –40°C to 125°C	1.89		2.18	
V_{IF}	Input voltage threshold	Falling edge	T_J = 25°C		1.66		V
			T_J = –40°C to 125°C	1.48		1.76	
V_{IHYS}	Input voltage hysteresis				400		mV
R_I	Input pulldown resistance	T_J = 25°C			200		kΩ
		T_J = –40°C to 125°C		100		300	
UNDERVOLTAGE PROTECTION							
V_{DDR}	VDD rising threshold	T_J = 25°C			3.8		V
		T_J = –40°C to 125°C		3.2		4.5	
V_{DDH}	VDD threshold hysteresis				0.2		V
V_{HBR}	HB rising threshold	T_J = 25°C			3.2		V
		T_J = –40°C to 125°C		2.5		3.9	
V_{HBH}	HB threshold hysteresis				0.2		V
BOOTSTRAP DIODE							
V_{DL}	Low-current forward voltage	I_{VDD-HB} = 100 µA	T_J = 25°C		0.45		V
			T_J = –40°C to 125°C			0.65	
V_{DH}	High-current forward voltage	I_{VDD-HB} = 100 mA	T_J = 25°C		0.90		V
			T_J = –40°C to 125°C			1	
R_D	Dynamic resistance	I_{VDD-HB} = 100 mA	T_J = 25°C		1.85		Ω
			T_J = –40°C to 125°C			3.60	
	HB-HS clamp regulation voltage		T_J = 25°C		5.2		V
			T_J = –40°C to 125°C	4.7		5.45	

(1) Parameters that show only a typical value are ensured by design and may not be tested in production.

Electrical Characteristics (continued)

Specifications are T_J = 25°C. Unless otherwise specified: V_{DD} = V_{HB} = 5 V, V_{SS} = V_{HS} = 0 V.
No load on LOL and HOL or HOH and HOL(1).

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
LOW- AND HIGH-SIDE GATE DRIVER							
V_{OL}	Low-level output voltage	I_{HOL} = I_{LOL} = 100 mA	T_J = 25°C		0.06		V
			T_J = –40°C to 125°C			0.10	
V_{OH}	High-level output voltage V_{OH} = VDD – LOH or V_{OH} = HB – HOH	I_{HOH} = I_{LOH} = 100 mA	T_J = 25°C		0.21		V
			T_J = –40°C to 125°C			0.31	
I_{OHL}	Peak source current	HOH, LOH = 0 V			1.2		A
I_{OLL}	Peak sink current	HOL, LOL = 5 V			5		A
I_{OHLK}	High-level output leakage current	HOH, LOH = 0 V	T_J = –40°C to 125°C			1.5	µA
I_{OLLK}	Low-level output leakage current	HOL, LOL = 5 V	T_J = –40°C to 125°C			1.5	µA

6.6 Switching Characteristics

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{LPHL}	LO turnoff propagation delay	LI falling to LOL falling	T_J = 25°C		26.5		ns
			T_J = –40°C to 125°C			45	
t_{LPLH}	LO turnon propagation delay	LI rising to LOH rising	T_J = 25°C		28.0		ns
			T_J = –40°C to 125°C			45	
t_{HPHL}	HO turnoff propagation delay	HI falling to HOL falling	T_J = 25°C		26.5		ns
			T_J = –40°C to 125°C			45	
t_{HPLH}	HO turnon propagation delay	HI rising to HOH rising	T_J = 25°C		28		ns
			T_J = –40°C to 125°C			45.0	
t_{MON}	Delay matching LO on and HO off	T_J = 25°C			1.5		ns
		T_J = –40°C to 125°C				8	
t_{MOFF}	Delay matching LO off and HO on	T_J = 25°C			1.5		ns
		T_J = –40°C to 125°C				8	
t_{HRC}	HO rise time (0.5 V – 4.5 V)	C_L = 1000 pF			7		ns
t_{LRC}	LO rise time (0.5 V – 4.5 V)	C_L = 1000 pF			7		ns
t_{HFC}	HO fall time (0.5 V – 4.5 V)	C_L = 1000 pF			3.5		ns
t_{LFC}	LO fall time (0.5 V – 4.5 V)	C_L = 1000 pF			3.5		ns
t_{PW}	Minimum input pulse width that changes the output				10		ns
t_{BS}	Bootstrap diode reverse recovery time	I_F = 100 mA, I_R = 100 mA			40		ns

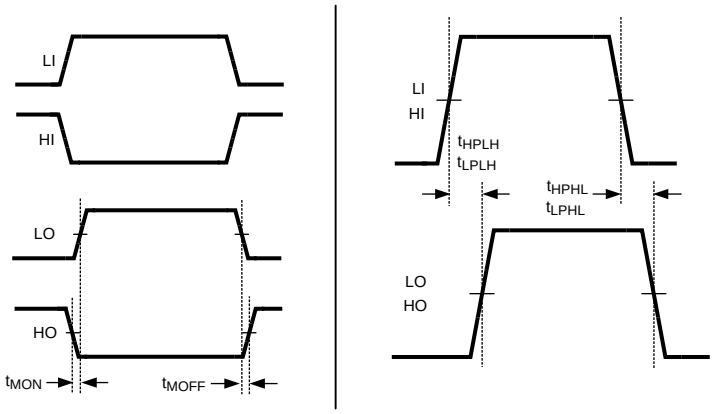


Figure 1. Timing Diagram

6.7 Typical Characteristics

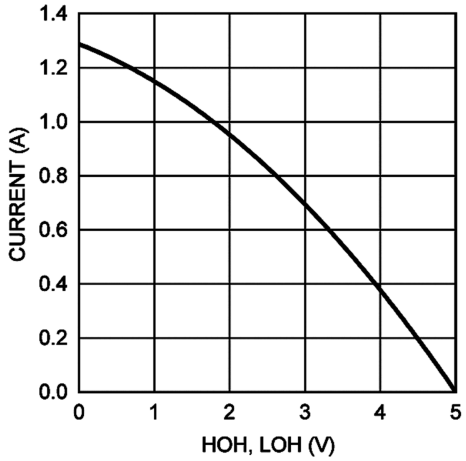


Figure 2. Peak Source Current vs Output Voltage

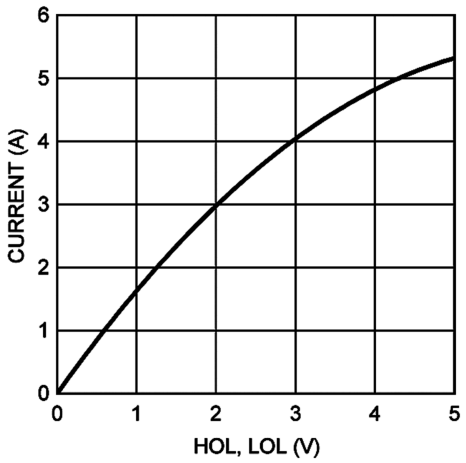


Figure 3. Peak Sink Current vs Output Voltage

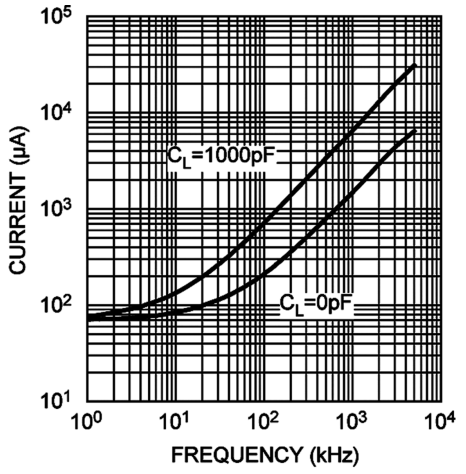


Figure 4. I_{DDO} vs Frequency

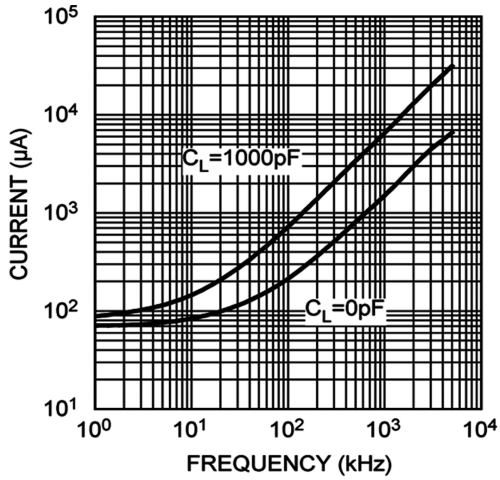


Figure 5. I_{HBO} vs Frequency

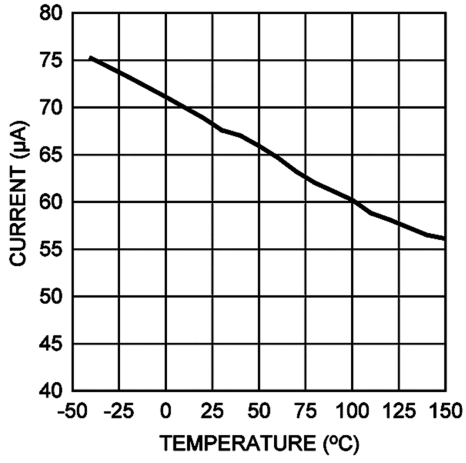


Figure 6. I_{DD} vs Temperature

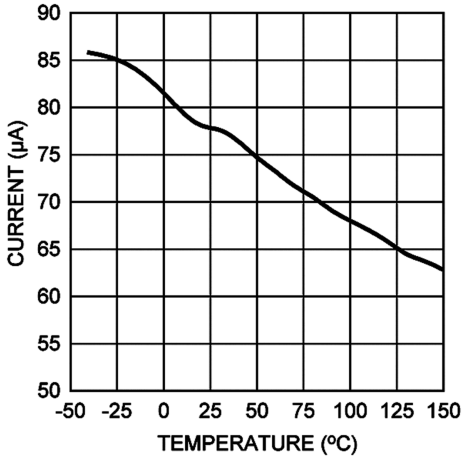


Figure 7. I_{HB} vs Temperature

Typical Characteristics (continued)

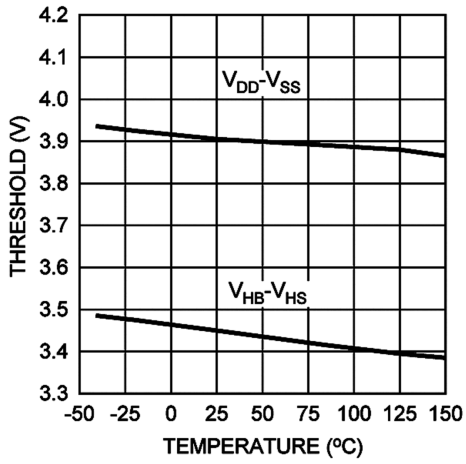


Figure 8. UVLO Rising Thresholds vs Temperature

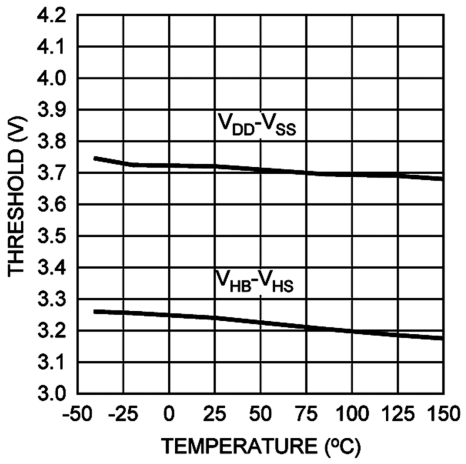


Figure 9. UVLO Falling Thresholds vs Temperature

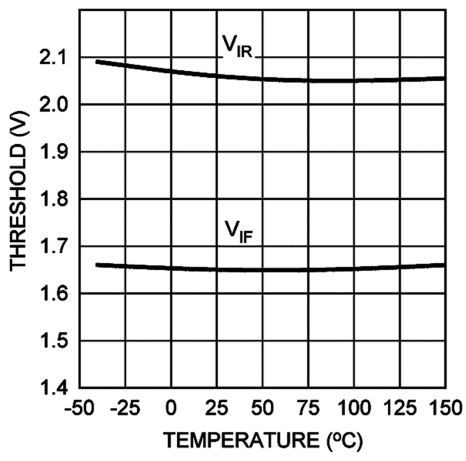


Figure 10. Input Thresholds vs Temperature

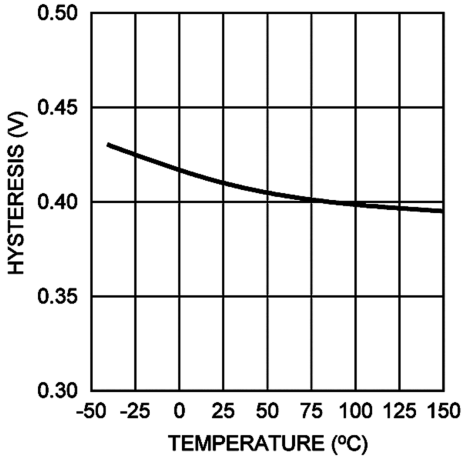


Figure 11. Input Threshold Hysteresis vs Temperature

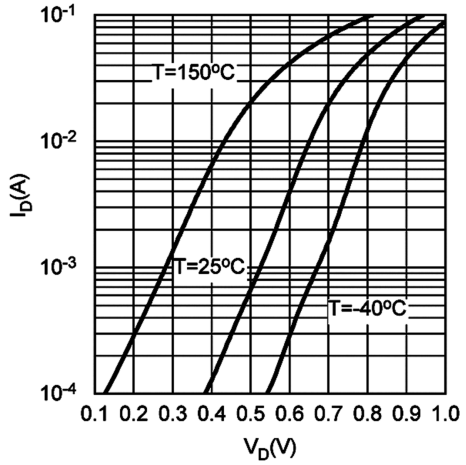


Figure 12. Bootstrap Diode Forward Voltage

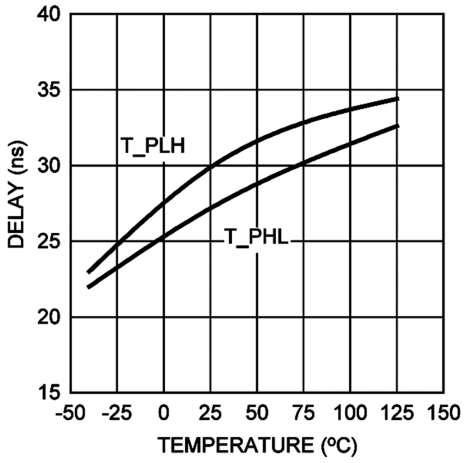
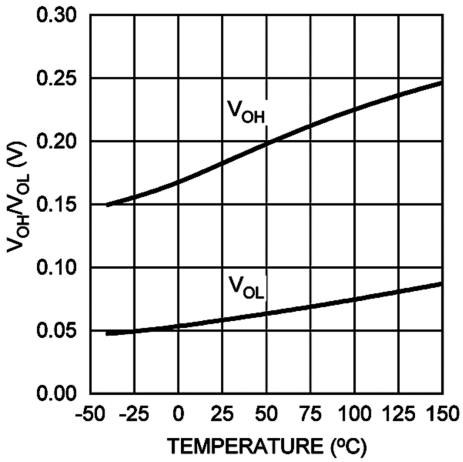


Figure 13. Propagation Delay vs Temperature

Typical Characteristics (continued)



Note: Unless otherwise specified, $V_{DD} = V_{HB} = 5$ V, $V_{SS} = V_{HS} = 0$ V.

Figure 14. LO and HO Gate Drive – High/Low Level Output Voltage vs Temperature

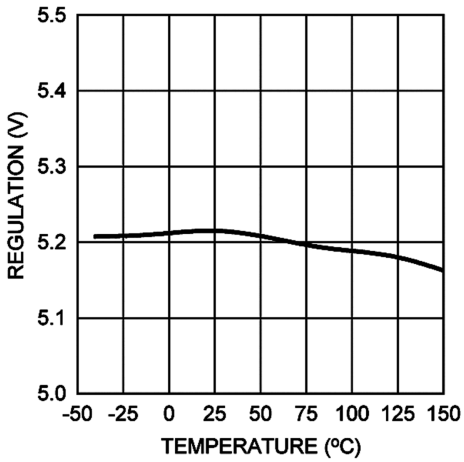


Figure 15. HB Regulation Voltage vs Temperature

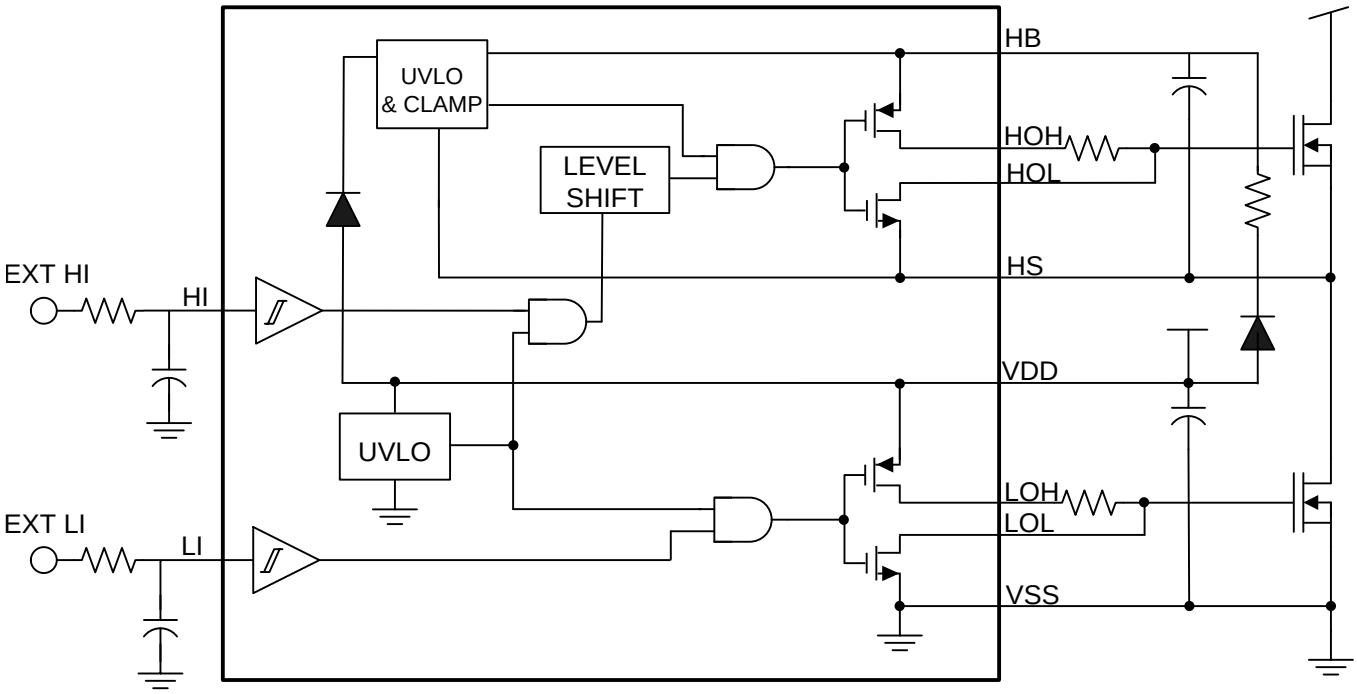
7 Detailed Description

7.1 Overview

The LM5113-Q1 is a high-frequency, high- and low- side gate driver for enhancement mode Gallium Nitride (GaN) FETs in a synchronous buck, boost, or half bridge configuration. The high-side bias voltage is generated using a bootstrap technique and is internally clamped at 5.2 V, which prevents the gate voltage from exceeding the maximum gate-source voltage rating of enhancement mode GaN FETs. The LM5113-Q1 has split-gate outputs with strong sink capability, providing flexibility to adjust the turnon and turnoff strength independently.

The LM5113-Q1 can operate up to several MHz, and is available in a standard 10-pin WSON package that contains an exposed pad to aid power dissipation.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Input and Output

The input pins of the LM5113-Q1 are independently controlled with TTL input thresholds and can withstand voltages up to 12 V regardless of the VDD voltage. This allows the inputs to be directly connected to the outputs of an analog PWM controller with up to 12-V power supply, eliminating the need for a buffer stage

The output pulldown and pullup resistance of LM5113-Q1 is optimized for enhancement mode GaN FETs to achieve high frequency and efficient operation. The 0.6-Ω pulldown resistance provides a robust low impedance turnoff path necessary to eliminate undesired turnon induced by high dv/dt or high di/dt. The 2.1-Ω pullup resistance helps reduce the ringing and over-shoot of the switch node voltage. The split outputs of the LM5113-Q1 offer flexibility to adjust the turnon and turnoff speed by independently adding additional impedance in either the turnon path, the turnoff path, or both.

If the input signal for either of the two channels, HI or LI, is not used, the control pin must be tied to either VDD or VSS. These inputs must not be left floating.

Feature Description (continued)

Additionally, the input signals avoid pulses shorter than 3 ns by using the input filter to the HI and LI input pins. The values and part numbers of the circuit components are shown in the Figure 16.

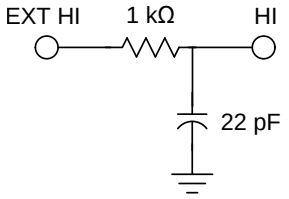


Figure 16. Input Filter 1 (High-Side Input Filter)

If short pulses or short delays are required, the circuit in Figure 17 is recommended.

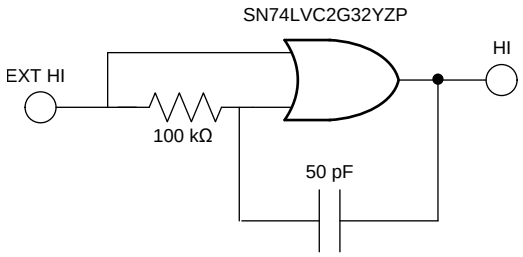


Figure 17. Input Filter 1 for Short Pulses (High-Side Input Filter)

7.3.2 Start-Up and UVLO

The LM5113-Q1 has an undervoltage lockout (UVLO) on both the VDD and bootstrap supplies. When the VDD voltage is below the threshold voltage of 3.8 V, both the HI and LI inputs are ignored to prevent the GaN FETs from being partially turned on. Also, if there is insufficient VDD voltage, the UVLO actively pulls the LOL and HOL low. When the VDD voltage is above its UVLO threshold, but the HB to HS bootstrap voltage is below the UVLO threshold of 3.2 V, only HOL is pulled low. Both UVLO threshold voltages have 200 mV of hysteresis to avoid chattering.

The startup voltage sequencing for this device is as follows: VDD voltage first, with the VIN voltage present thereafter.

The LM5113-Q1 requires an external bootstrap diode with a 100 Ω series resistor from VDD to HB to charge the high side supply on a cycle by cycle basis. The recommended bootstrap diode options are BAT46, BAT41, or LL4148.

Table 1. VDD UVLO Feature Logic Operation

CONDITION ($V_{HB-HS} > V_{HBR}$ for all cases below)	HI	LI	HO	LO
$V_{DD} – V_{SS} < V_{DDR}$ during device start-up	H	L	L	L
$V_{DD} – V_{SS} < V_{DDR}$ during device start-up	L	H	L	L
$V_{DD} – V_{SS} < V_{DDR}$ during device start-up	H	H	L	L
$V_{DD} – V_{SS} < V_{DDR}$ during device start-up	L	L	L	L
$V_{DD} – V_{SS} < V_{DDR} – V_{DDH}$ after device start-up	H	L	L	L
$V_{DD} – V_{SS} < V_{DDR} – V_{DDH}$ after device start-up	L	H	L	L
$V_{DD} – V_{SS} < V_{DDR} – V_{DDH}$ after device start-up	H	H	L	L
$V_{DD} – V_{SS} < V_{DDR} – V_{DDH}$ after device start-up	L	L	L	L

Table 2. V_{HB-HS} UVLO Feature Logic Operation

CONDITION (V_{DD} > V_{DDR} for all cases below)	HI	LI	HO	LO
V_{HB-HS} < V_{HBR} during device start-up	H	L	L	L
V_{HB-HS} < V_{HBR} during device start-up	L	H	L	H
V_{HB-HS} < V_{HBR} during device start-up	H	H	L	H
V_{HB-HS} < V_{HBR} during device start-up	L	L	L	L
V_{HB-HS} < V_{HBR} – V_{HBH} after device start-up	H	L	L	L
V_{HB-HS} < V_{HBR} – V_{HBH} after device start-up	L	H	L	H
V_{HB-HS} < V_{HBR} – V_{HBH} after device start-up	H	H	L	H
V_{HB-HS} < V_{HBR} – V_{HBH} after device start-up	L	L	L	L

7.3.3 HS Negative Voltage and Bootstrap Supply Voltage Clamping

Due to the intrinsic nature of enhancement mode GaN FETs, the source-to-drain voltage of the bottom switch is usually higher than a diode forward voltage drop when the gate is pulled low. This causes negative voltage on HS pin. Moreover, this negative voltage transient may become even more pronounces due to the effects of board layout and device drain/source parasitic inductances. With high-side driver using the floating bootstrap configuration, negative HS voltage can lead to an excessive bootstrap voltage, which can damage the high-side GaN FET. The LM5113-Q1 solves this problem with an internal clamping circuit that prevents the bootstrap voltage from exceeding 5.2 V typical.

7.3.4 Level Shift

The level-shift circuit is the interface from the high-side input to the high-side driver stage, which is referenced to the switch node (HS). The level shift allows control of the HO output, which is referenced to the HS pin and provides excellent delay matching with the low-side driver. Typical delay matching between LO and HO is around 1.5 ns.

7.4 Device Functional Modes

Table 3 shows the device truth table.

Table 3. Truth Table

HI	LI	HOH	HOL	LOH	LOL
L	L	Open	L	Open	L
L	H	Open	L	H	Open
H	L	H	Open	Open	L
H	H	H	Open	H	Open

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

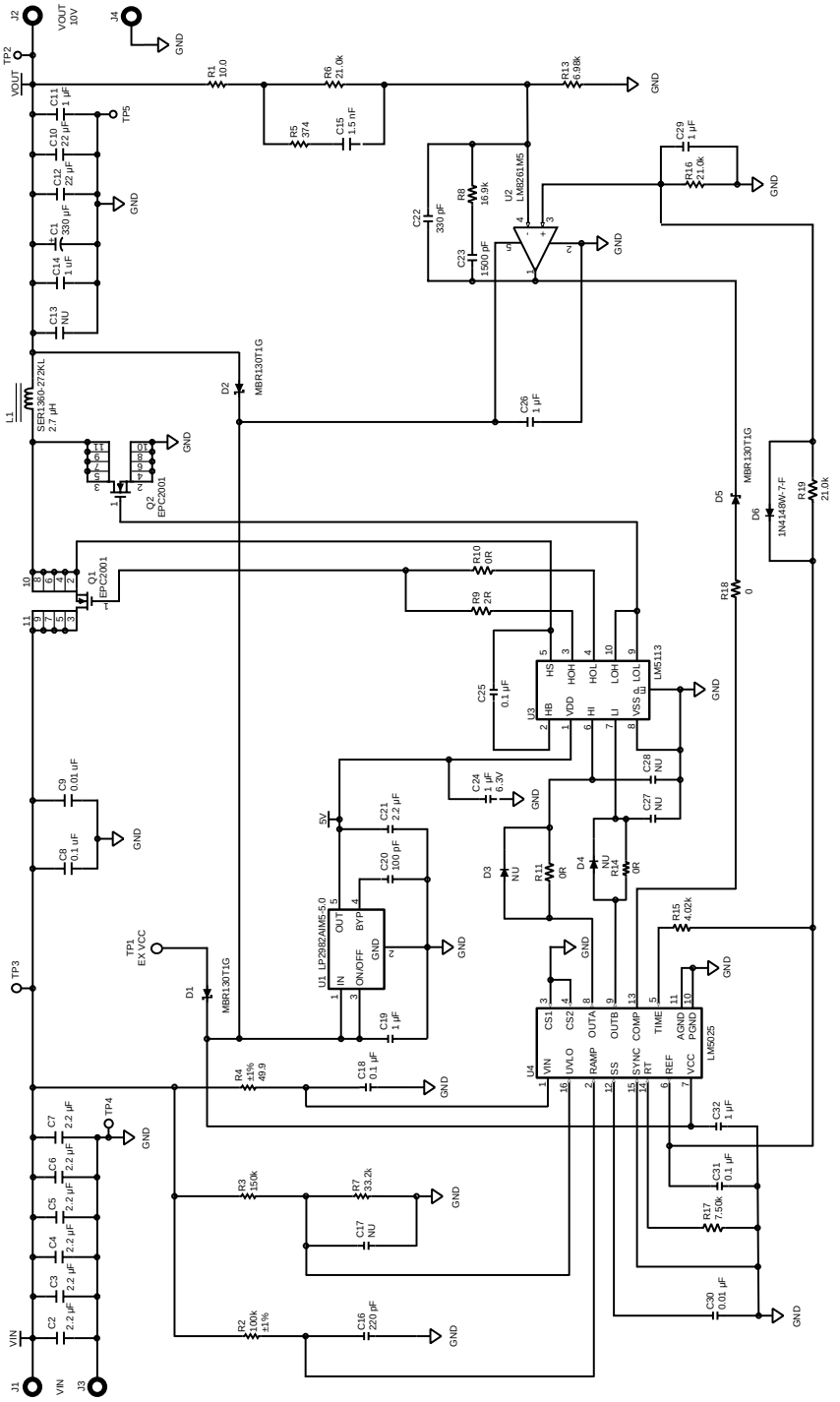
8.1 Application Information

To operate GaN transistors at very high switching frequencies and to reduce associated switching losses, a powerful gate driver is employed between the PWM output of controller and the gates of the GaN transistor. Also, gate drivers are indispensable when the outputs of the PWM controller do not meet the voltage or current levels needed to directly drive the gates of the switching devices. With the advent of digital power, this situation is often encountered because the PWM signal from the digital controller is often a 3.3-V logic signal, which cannot effectively turn on a power switch. A level-shift circuit is needed to boost the 3.3-V signal to the gate-drive voltage (such as 12 V) to fully turn on the power device and minimize conduction losses. Traditional buffer-drive circuits based on NPN/PNP bipolar transistors in totem-pole arrangement prove inadequate with digital power because they lack level-shifting capability. Gate drivers effectively combine both the level-shifting and buffer-drive functions. Gate drivers also address other needs such as minimizing the effect of high-frequency switching noise (by placing the high-current driver IC physically close to the power switch), driving gate-drive transformers and controlling floating power-device gates, reducing power dissipation and thermal stress in controllers by moving gate-charge power losses from the controller into the driver.

The LM5113-Q1 is a MHz high- and low-side gate driver for enhancement mode GaN FETs in a synchronous buck, boost, or half-bridge configuration. The high-side bias voltage is generated using a bootstrap technique and is internally clamped at 5.2 V, which prevents the gate voltage from exceeding the maximum gate-source voltage rating of enhancement mode GaN FETs. The LM5113-Q1 has split gate outputs with strong sink capability, providing flexibility to adjust the turnon and turnoff strength independently.

8.2 Typical Application

The circuit in Figure 18 shows a synchronous buck converter to evaluate the LM5113-Q1 device. Detailed synchronous buck converter specifications are listed in *Design Requirements*. The active clamping voltage mode controller LM5025 is used for close-loop control and generates the PWM signals of the buck switch and the synchronous switch. For more information, see *Figure 18*.



Input 15 V to 60 V, output 10 V, 800 kHz

Figure 18. LP5113-Q1 Application Circuit

Typical Application (continued)

8.2.1 Design Requirements

Table 4 lists the design requirements for the typical application.

Table 4. Design Parameters

PARAMETER	SPECIFICATION
Input operating range	15 – 60 V
Output voltage	10 V
Output current, 48-V input	10 A
Output current, 60-V input	7 A
Efficiency at 48 V, 10 A	>90%
Frequency	800 kHz

8.2.2 Detailed Design Procedure

This procedure outlines the design considerations of LM5113-Q1 in a synchronous buck converter with enhancement mode GaN FET. Refer to Figure 18 for component names and network locations. For additional design help, see *Figure 18*.

8.2.2.1 VDD Bypass Capacitor

The VDD bypass capacitor provides the gate charge for the low-side and high-side transistors and to absorb the reverse recovery charge of the bootstrap diode. The required bypass capacitance can be calculated with Equation 1.

$$C_{VDD} > \frac{Q_{gH} + Q_{gL} + Q_{rr}}{\Delta V} \quad (1)$$

where

- Q_{gH} and Q_{gL} are gate charge of the high-side and low-side transistors, respectively.
- Q_{rr} is the reverse recovery charge of the bootstrap diode, which is typically around 4 nC.
- ΔV is the maximum allowable voltage drop across the bypass capacitor.

TI recommends a 0.1-µF or larger value, good quality, ceramic capacitor. The bypass capacitor must be placed as close as possible to the pins of the ICto minimize the parasitic inductance.

8.2.2.2 Bootstrap Capacitor

The bootstrap capacitor provides the gate charge for the high-side switch, DC bias power for HB UVLO circuit, and the reverse recovery charge of the bootstrap diode. The required bypass capacitance can be calculated with Equation 2.

$$C_{BST} > \frac{Q_{gH} + I_{HB} \times t_{ON} + Q_{rr}}{\Delta V} \quad (2)$$

where

- I_{HB} is the quiescent current of the high-side driver.
- t_{on} is the maximum on-time period of the high-side transistor.

A good-quality, ceramic capacitor must be used for the bootstrap capacitor. TI recommends placement of the bootstrap capacitor as close as possible to the HB and HS pin.

8.2.2.3 Power Dissipation

The power consumption of the driver is an important measure that determines the maximum achievable operating frequency of the driver. It must be kept below the maximum power-dissipation limit of the package at the operating temperature. The total power dissipation of the LM5113-Q1 is the sum of the gate driver losses and the bootstrap diode power loss.

The gate driver losses are incurred by charge and discharge of the capacitive load. It can be approximated as:

$$P = \left(C_{LoadH} + C_{LoadL}\right) \times V_{DD}^2 \times f_{SW} \quad (3)$$

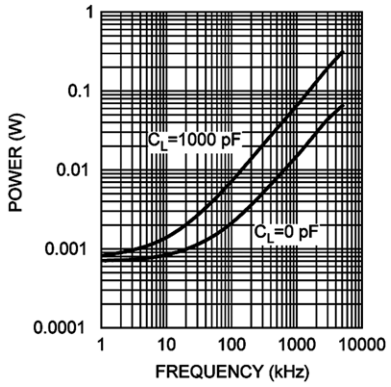
where

- C_{LoadH} and C_{LoadL} are the high-side and the low-side capacitive loads, respectively.

It can also be calculated with the total input gate charge of the high-side and the low-side transistors as:

$$P = \left(Q_{gH} + Q_{gL}\right) \times V_{DD} \times f_{SW} \quad (4)$$

There are some additional losses in the gate drivers due to the internal CMOS stages used to buffer the LO and HO outputs. Figure 19 shows the measured gate-driver power dissipation versus frequency and load capacitance. At higher frequencies and load capacitance values, the power dissipation is dominated by the power losses driving the output loads and agrees well with the above equations. This plot can be used to approximate the power losses due to the gate drivers.

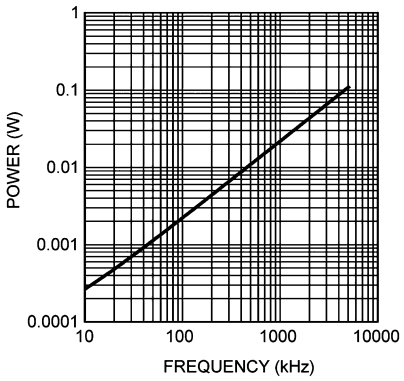


Gate-driver power dissipation (LO+HO), VDD = +5 V

Figure 19. Neglecting Bootstrap Diode Losses

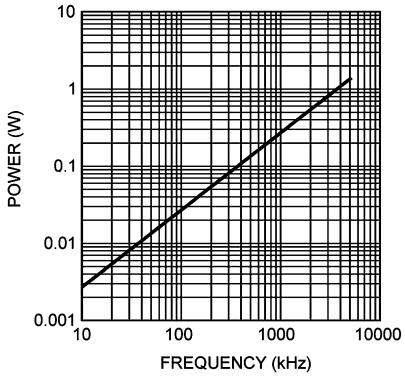
The bootstrap diode power loss is the sum of the forward bias power loss that occurs while charging the bootstrap capacitor and the reverse bias power loss that occurs during reverse recovery. Because each of these events happens once per cycle, the diode power loss is proportional to the operating frequency. Larger capacitive loads require more energy to recharge the bootstrap capacitor resulting in more losses. Higher input voltages (V_{IN}) to the half bridge also result in higher reverse recovery losses.

Figure 20 and Figure 21 show the forward bias power loss and the reverse bias power loss of the bootstrap diode, respectively. The plots are generated based on calculations and lab measurements of the diode reverse time and current under several operating conditions. The plots can be used to predict the bootstrap diode power loss under different operating conditions.



The load of high-side driver is a GaN FET with total gate charge of 10 nC.

Figure 20. Forward Bias Power Loss of Bootstrap Diode V_{IN} = 50 V



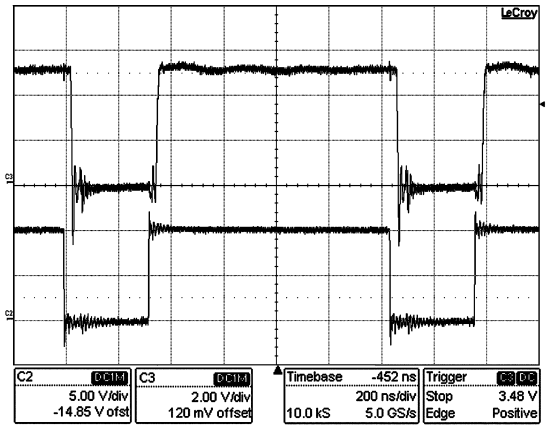
The load of high-side driver is a GaN FET with total gate charge of 10 nC.

Figure 21. Reverse Recovery Power Loss of Bootstrap Diode V_{IN} = 50 V

The sum of the driver loss and the bootstrap diode loss is the total power loss of the IC. For a given ambient temperature, the maximum allowable power loss of the IC can be defined as Equation 5.

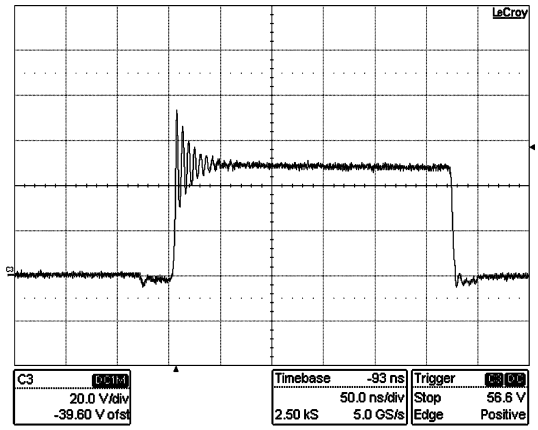
$$P = \frac{(T_J - T_A)}{\theta_{JA}} \tag{5}$$

8.2.3 Application Curves



Conditions:
Input Voltage = 48 V DC, Load Current = 5 A
Traces:
Top Trace: Gate of Low-Side eGaN FET, Volt/div = 2 V
Bottom Trace: LI of LM5113-Q1, Volt/div = 5 V
Bandwidth Limit = 600 MHz
Horizontal Resolution = 0.2 µs/div

Figure 22. Low-Side Driver Input and Output



Conditions:
Input Voltage = 48 V DC,
Load Current = 10 A
Traces:
Trace: Switch-Node Voltage, Volts/div = 20 V
Bandwidth Limit = 600 MHz
Horizontal Resolution = 50 ns/div

Figure 23. Switch-Node Voltage

9 Power Supply Recommendations

The recommended bias supply voltage range for LM5113-Q1 is from 4.5 V to 5.5 V. The lower end of this range is governed by the internal undervoltage lockout (UVLO) protection feature of the VDD supply circuit. TI recommends keeping proper margin to allow for transient voltage spikes while not violating the LM5113-Q1 absolute maximum VDD voltage rating and the GaN transistor gate breakdown voltage limit.

The UVLO protection feature also involves a hysteresis function. This means that once the device is operating in normal mode, if the VDD voltage drops, the device continues to operate in normal mode as far as the voltage drop do not exceeds the hysteresis specification, VDDH. If the voltage drop is more than hysteresis specification, the device shuts down. Therefore, while operating at or near the 4.5-V range, the voltage ripple on the VDD power supply output must be smaller than the hysteresis specification of LM5113-Q1 UVLO to avoid triggering device shutdown.

A local bypass capacitor must be placed between the VDD and VSS pins. This capacitor must be located as close as possible to the device. A low-ESR, ceramic surface-mount capacitor is recommended. TI recommends using 2 capacitors across VDD and GND: a 100-nF ceramic surface-mount capacitor for high frequency filtering placed very close to VDD and GND pin, and another surface-mount capacitor, 220-nF to 10-μF, for IC bias requirements.

10 Layout

10.1 Layout Guidelines

Small gate capacitance and miller capacitance enable enhancement mode GaN FETs to operate with fast switching speed. The induced high dv/dt and di/dt, coupled with a low gate-threshold voltage and limited headroom of enhancement mode GaN FETs gate voltage, make the circuit layout crucial to the optimum performance. Following are some recommendations.

1. The first priority in designing the layout of the driver is to confine the high peak currents that charge and discharge the GaN FETs gate into a minimal physical area. This decreases the loop inductance and minimize noise issues on the gate terminal of the GaN FETs. The GaN FETs must be placed close to the driver.
2. The second high current path includes the bootstrap capacitor, the local ground referenced VDD bypass capacitor, and low-side GaN FET. The bootstrap capacitor is recharged on a cycle-by-cycle basis through the bootstrap diode from the ground referenced VDD capacitor. The recharging occurs in a short time interval and involves high peak current. Minimizing this loop length and area on the circuit board is important to ensure reliable operation.
3. The parasitic inductance in series with the source of the high-side FET and the low-side FET can impose excessive negative voltage transients on the driver. TI recommends connecting the HS pin and VSS pin to the respective source of the high-side and low-side transistors with a short and low-inductance path.
4. The parasitic source inductance, along with the gate capacitor and the driver pulldown path, can form an LCR resonant tank, resulting in gate voltage oscillations. An optional resistor or ferrite bead can be used to damp the ringing.
5. Low ESR/ESL capacitors must be connected close to the IC, between VDD and VSS pins and between the HB and HS pins to support the high peak current being drawn from VDD during turnon of the FETs. Keeping guideline number 1 above (minimized GaN FETs gate driver loop) as the first priority, it is also desirable to place the VDD decoupling capacitor and the HB to HS bootstrap capacitor on the same side of the PC board as the driver. The inductance of vias can impose excessive ringing on the IC pins.
6. To prevent excessive ringing on the input power bus, good decoupling practices are required by placing low-ESR ceramic capacitors adjacent to the GaN FETs.

Figure 24 and Figure 25 show recommended layout patterns for the 10-pin WSON package. Two cases are considered: (1) Without any gate resistors, and (2) with an optional turnon gate resistor. Note that 0402 surface mount package is assumed for the passive components in Figure 24 and Figure 25.

10.2 Layout Example

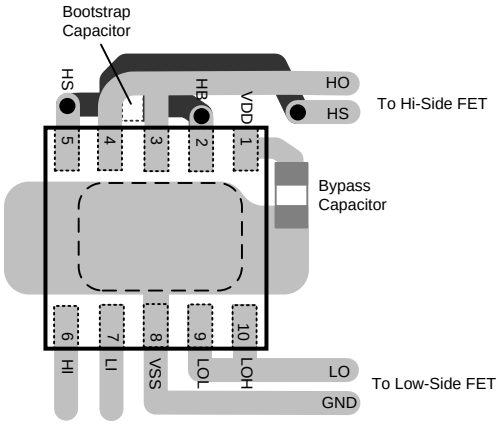


Figure 24. 10-Pin WSON Without Gate Resistors

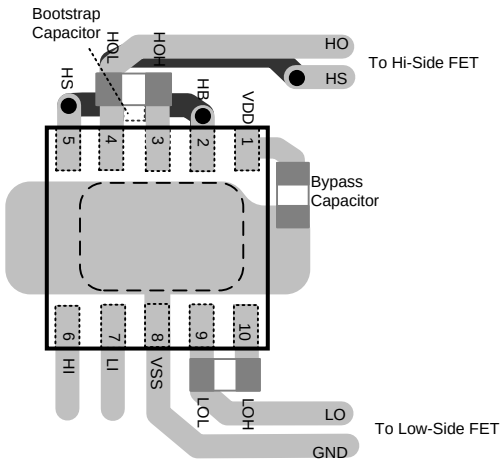


Figure 25. 10-Pin WSON With HOH and LOH Gate Resistors

11 器件和文档支持

11.1 文档支持

11.1.1 相关文档

相关文档如下：

AN-2149 LM5113 评估板 (SNVA484)

11.2 接收文档更新通知

要接收文档更新通知，请导航至 TI.com.cn 上的器件产品文件夹。请单击右上角的*提醒我* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.3 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 《使用条款》。

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11.4 商标

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All other trademarks are the property of their respective owners.

11.5 静电放电警告

这些装置包含有限的内置 ESD 保护。 存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

11.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM5113QDPRRQ1	ACTIVE	WSON	DPR	10	4500	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	L5113Q	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

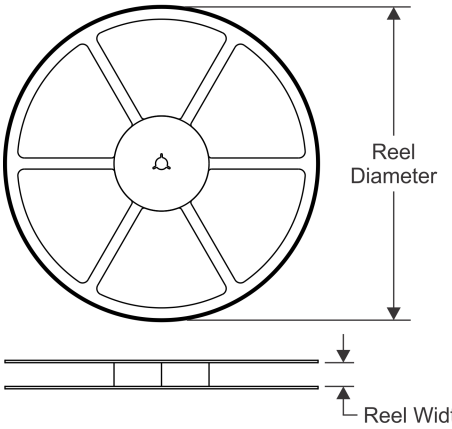
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

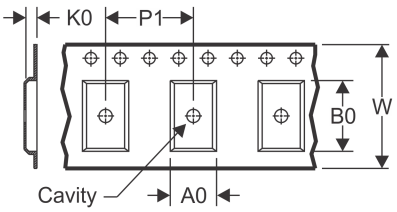
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

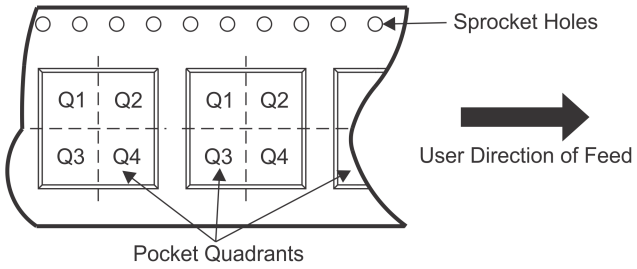


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

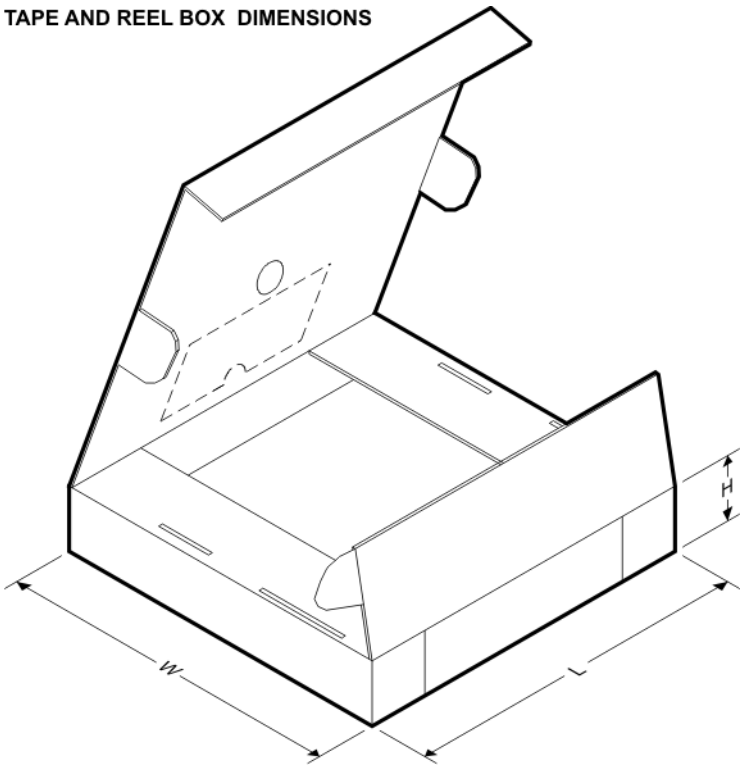
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM5113QDPRRQ1	WSON	DPR	10	4500	330.0	12.4	4.3	4.3	1.3	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

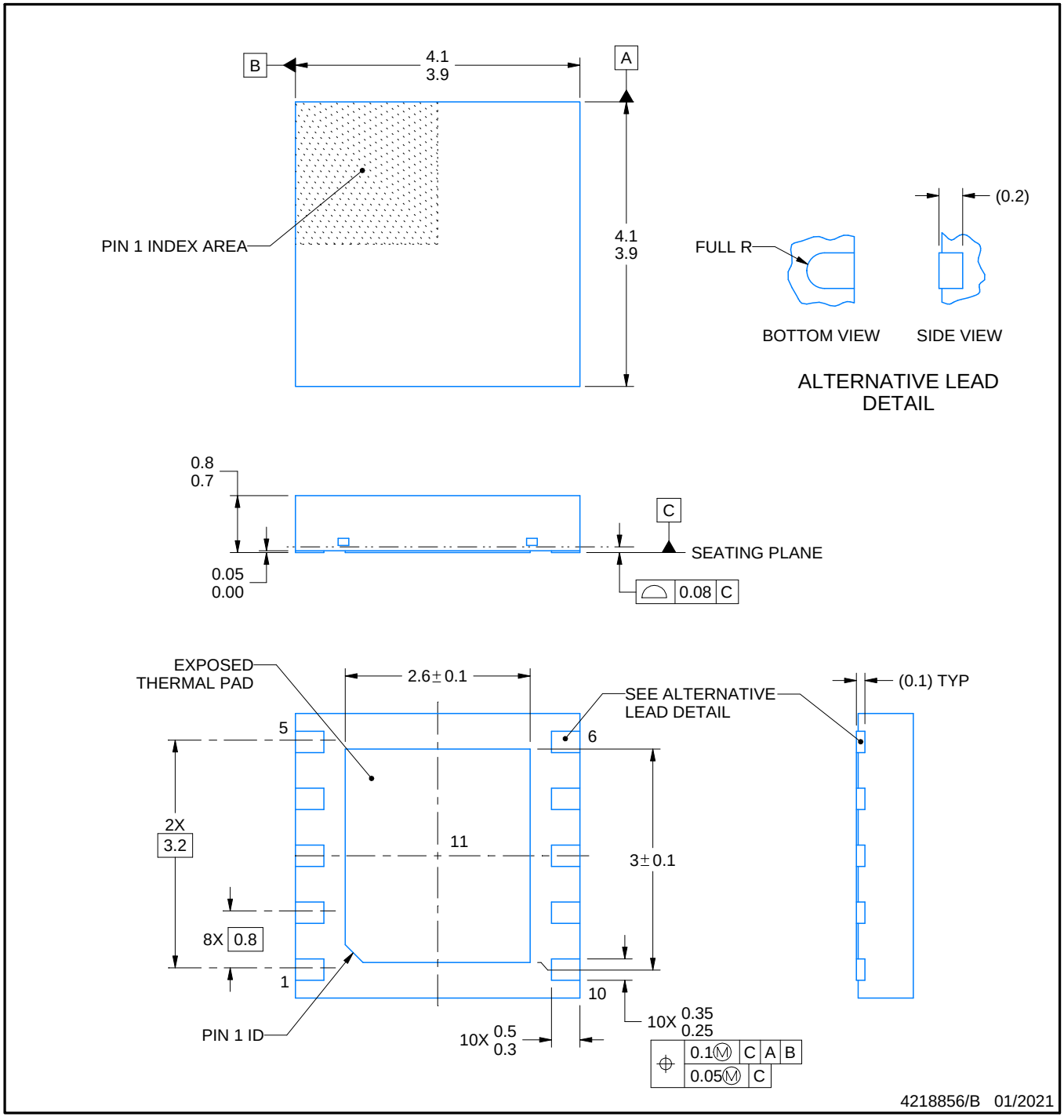
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM5113QDPRRQ1	WSON	DPR	10	4500	367.0	367.0	35.0

PACKAGE OUTLINE

DPR0010A

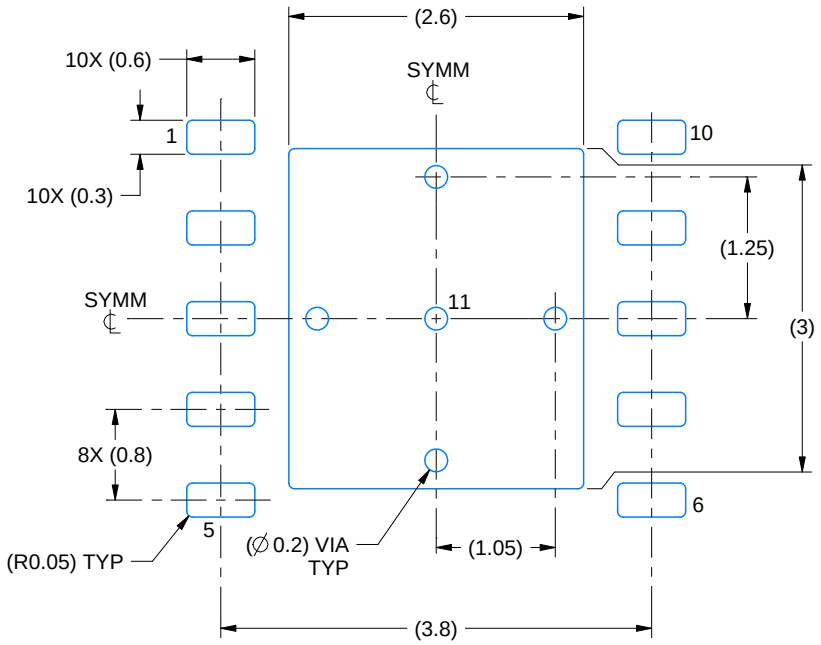
WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

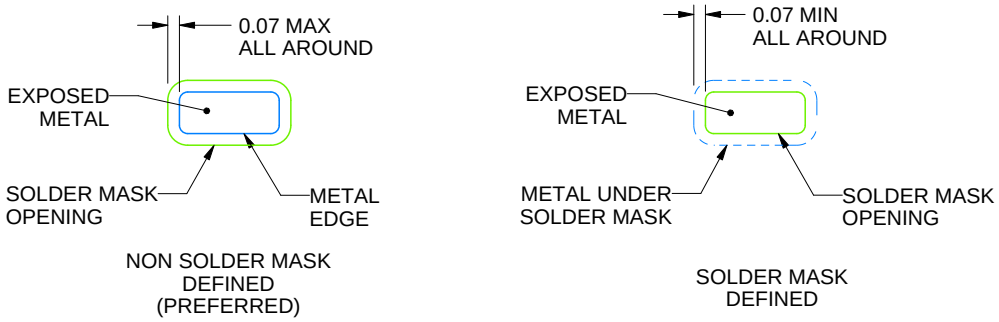


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

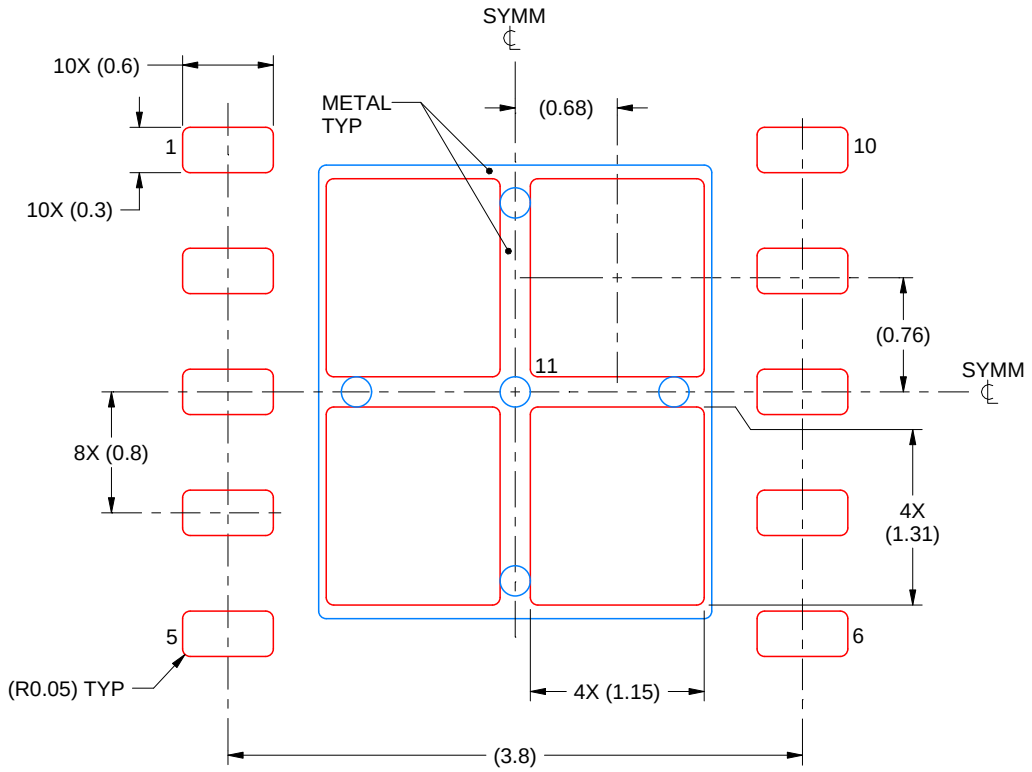


SOLDER MASK DETAILS

4218856/B 01/2021

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 11:
77% PRINTED SOLDER COVERAGE BY AREA
SCALE:20X

4218856/B 01/2021

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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