LM5113-Q1 車載用90V、1.2A、5A、ハーフブリッジGaNドライバ

1 特長

- 車載アプリケーションに対応
- 下記内容でAEC-Q100認定済み:
  - デバイス温度グレード1: 動作時周囲温度範囲 −40°C～125°C
  - デバイスHBM ESD分類レベル1C
  - デバイスCDM ESD分類レベルC6
- ハイサイドとローサイドで独立したTTLロジック入力
- ピーク・ソース1.2A、ピーク・シンク5Aの出力電流
- ハイサイドのフローティング・バイアス電圧レールは最大100VDCで動作可能
- 内部ブートストラップ電源電圧クランプ
- 出力の分割により、ターンオンおよびターンオフの強度を変更可能
- プルダウン0.6Ω、プルアップ2.1Ωの抵抗
- 高速伝搬時間（標準28ns）
- 優れた伝搬遅延マッチング(標準1.5ns)
- 電源レールの低電圧誤動作防止
- 低消費電力

2 アプリケーション

- モバイル・ワイヤレス充電器
- オーディオ・パワー・アンプ
- オーディオ用電源
- 電流供給プッシュプル・コンバータ
- ハーフ/フルブリッジ・コンバータ
- 同期降圧コンバータ

3 概要

LM5113-Q1は、車載用途向けに、同期整流の降圧、昇圧、またはハーフブリッジの構成で、ハイサイドおよびローサイド両方のエンハンスメント・モード窒化ガリウム(GaN) FETまたはシリコンMOSFETを駆動するよう設計されています。このデバイスには100Vのブートストラップ・ダイオード、およびハイサイド出力とローサイド出力用にそれぞれ独立した入力が内蔵され、最大の柔軟性で制御が可能です。ハイサイドのバイアス電圧は内部で5.2Vにクランプされるため、ゲート電圧がエンハンスメント・モードGaN FETの最大ゲート-ソース電圧定格を超過することが防止されます。デバイスの入力はTTLロジック互換で、VDD電圧にかかわらず最高14Vの入力電圧に耐えられます。LM5113-Q1には分割ゲート出力があり、ターンオンとターンオフの強度を別々に設定可能な柔軟性があります。

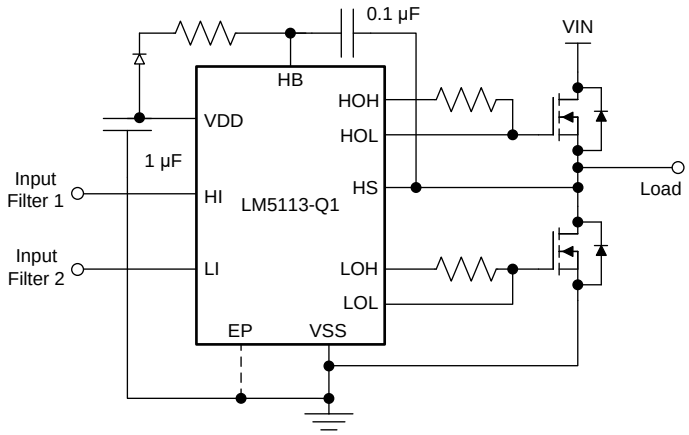
さらに、LM5113-Q1の強力なシンク能力によりゲートがLOW状態で維持され、スイッチング時に意図しないターンオンが防止されます。LM5113-Q1の最大動作周波数は数MHzです。LM5113-Q1は標準の10ピンWSONパッケージで供給され、電力放熱の補助として露出パッドが付属します。

製品情報(1)

型番	パッケージ	本体サイズ(公称)
LM5113-Q1	WSON (10)	4.00mm×4.00mm

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

アプリケーション概略図



目次

4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Revision A (November 2017) から **Revision B** に変更 **Page**

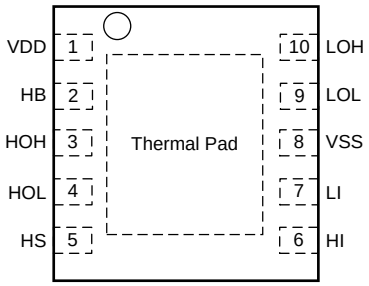
- データシートのタイトルを「LM5113-Q1 車載用90V、1.2A/5A、ハーフブリッジGaNドライバ」から「LM5113-Q1 車載用90V、1.2A、5A、ハーフブリッジGaNドライバ」に変更 ... 1
- 「*アプリケーション概略図*」に入力フィルタの参照を追加 ... 1
- Added EXT HI and EXT LO references to the *Functional Block Diagram* ... 11
- Changed the last paragraph and add new images to the *Input and Output* section ... 11

2017年3月 発行のものから更新 **Page**

- データシートのタイトルを「LM5113-Q1 車載用80V、1.2A/5A、ハーフブリッジGaNドライバ」から「LM5113-Q1 車載用90V、1.2A/5A、ハーフブリッジGaNドライバ」に変更 ... 1
- 「*アプリケーション概略図*」を変更 ... 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

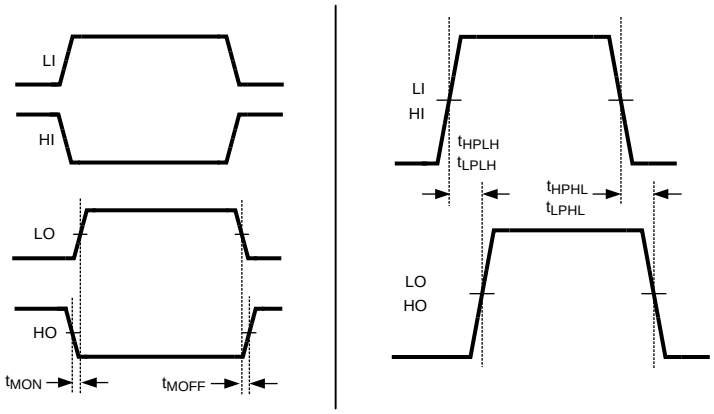


Figure 1. Timing Diagram

6.7 Typical Characteristics

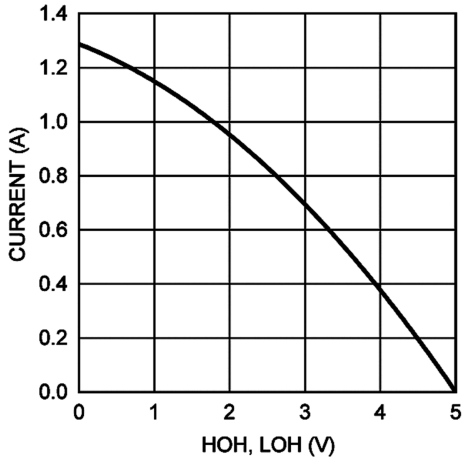


Figure 2. Peak Source Current vs Output Voltage

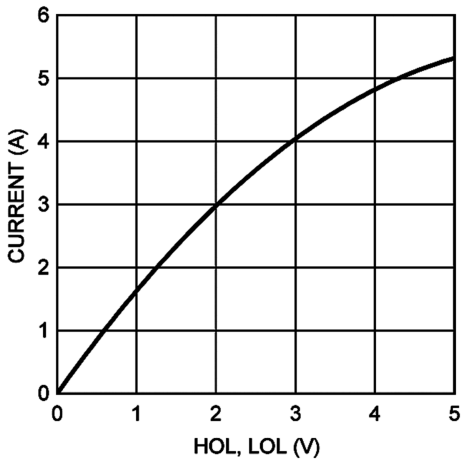


Figure 3. Peak Sink Current vs Output Voltage

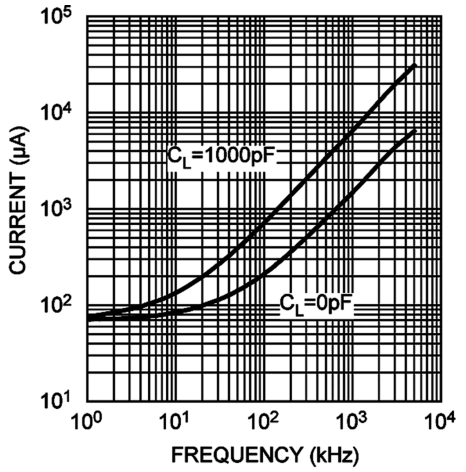


Figure 4. I_{DDO} vs Frequency

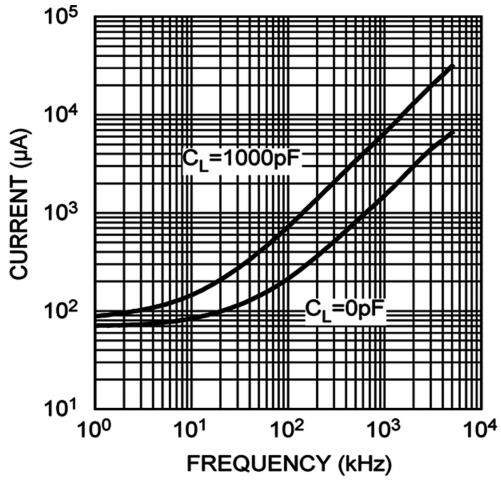


Figure 5. I_{HBO} vs Frequency

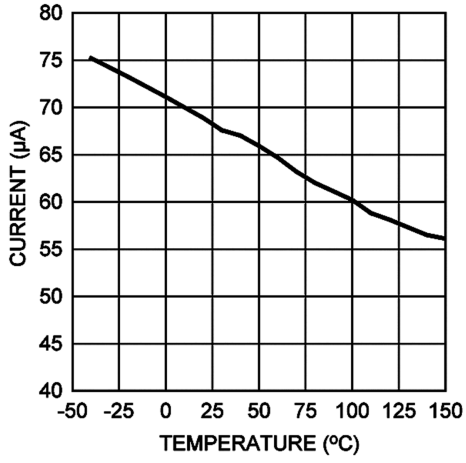


Figure 6. I_{DD} vs Temperature

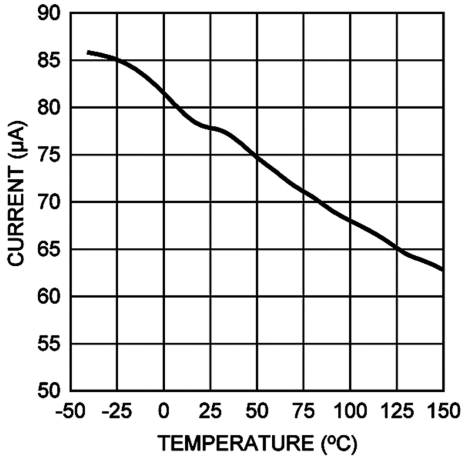


Figure 7. I_{HB} vs Temperature

Typical Characteristics (continued)

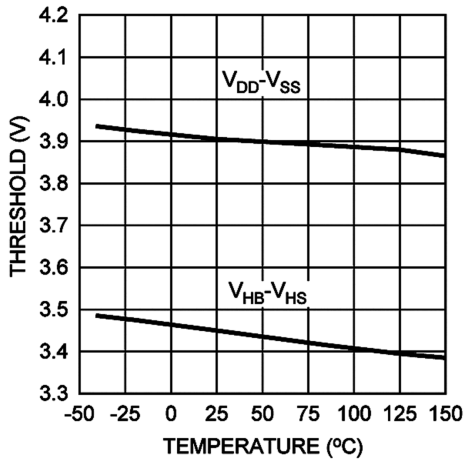


Figure 8. UVLO Rising Thresholds vs Temperature

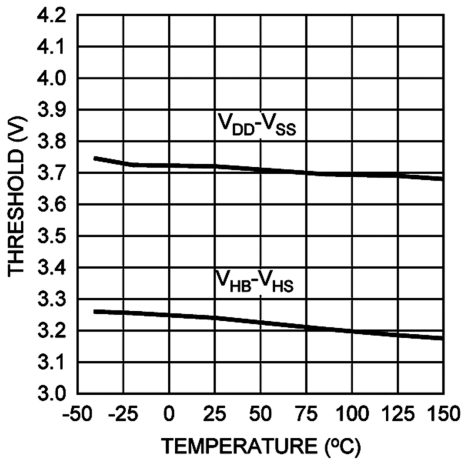


Figure 9. UVLO Falling Thresholds vs Temperature

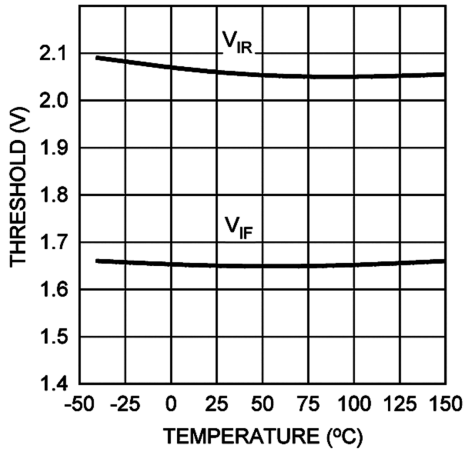


Figure 10. Input Thresholds vs Temperature

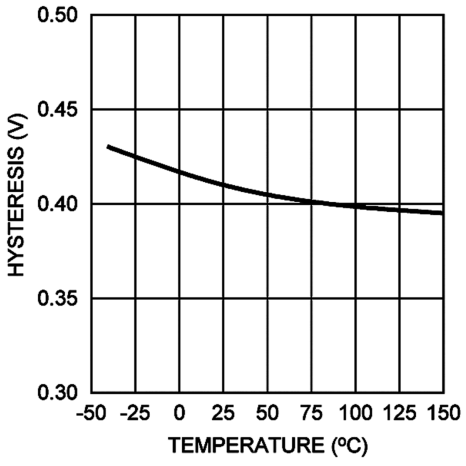


Figure 11. Input Threshold Hysteresis vs Temperature

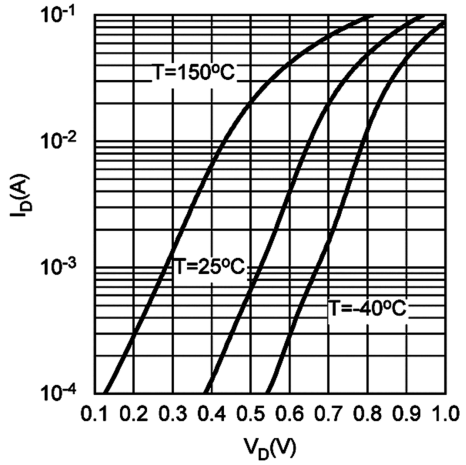


Figure 12. Bootstrap Diode Forward Voltage

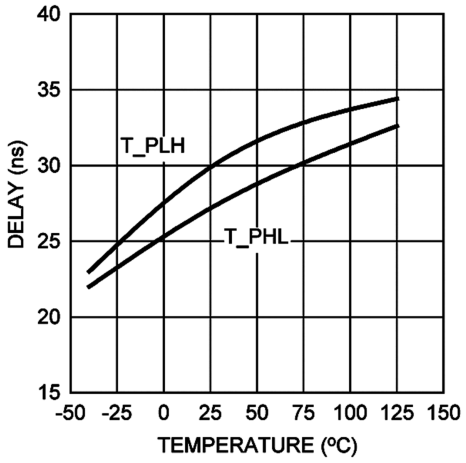
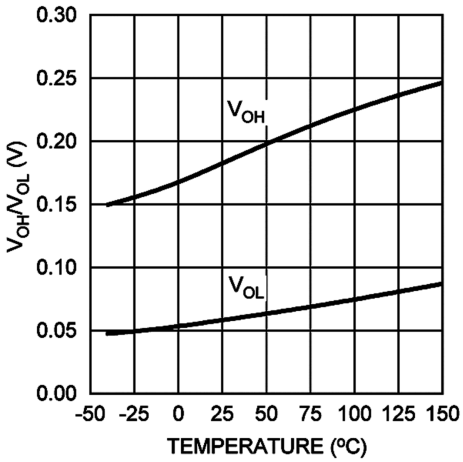


Figure 13. Propagation Delay vs Temperature

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

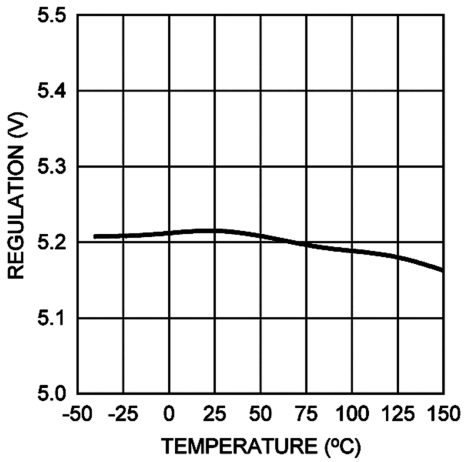


Figure 15. HB Regulation Voltage vs Temperature

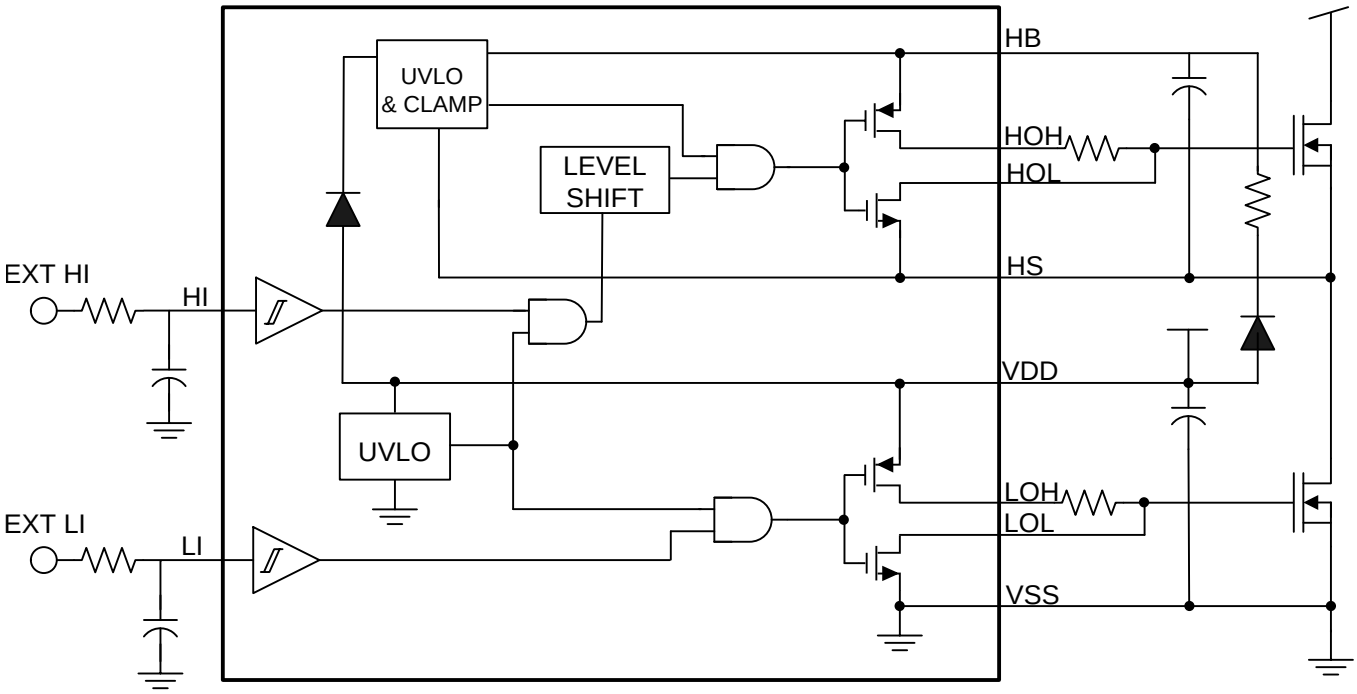
7 Detailed Description

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.

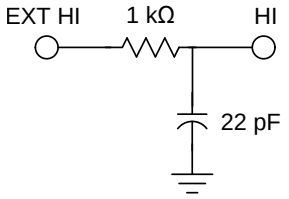


Figure 16. Input Filter 1 (High-Side Input Filter)

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

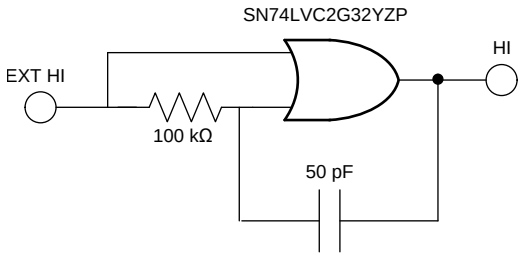


Figure 17. Input Filter 1 for Short Pulses (High-Side Input Filter)

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.

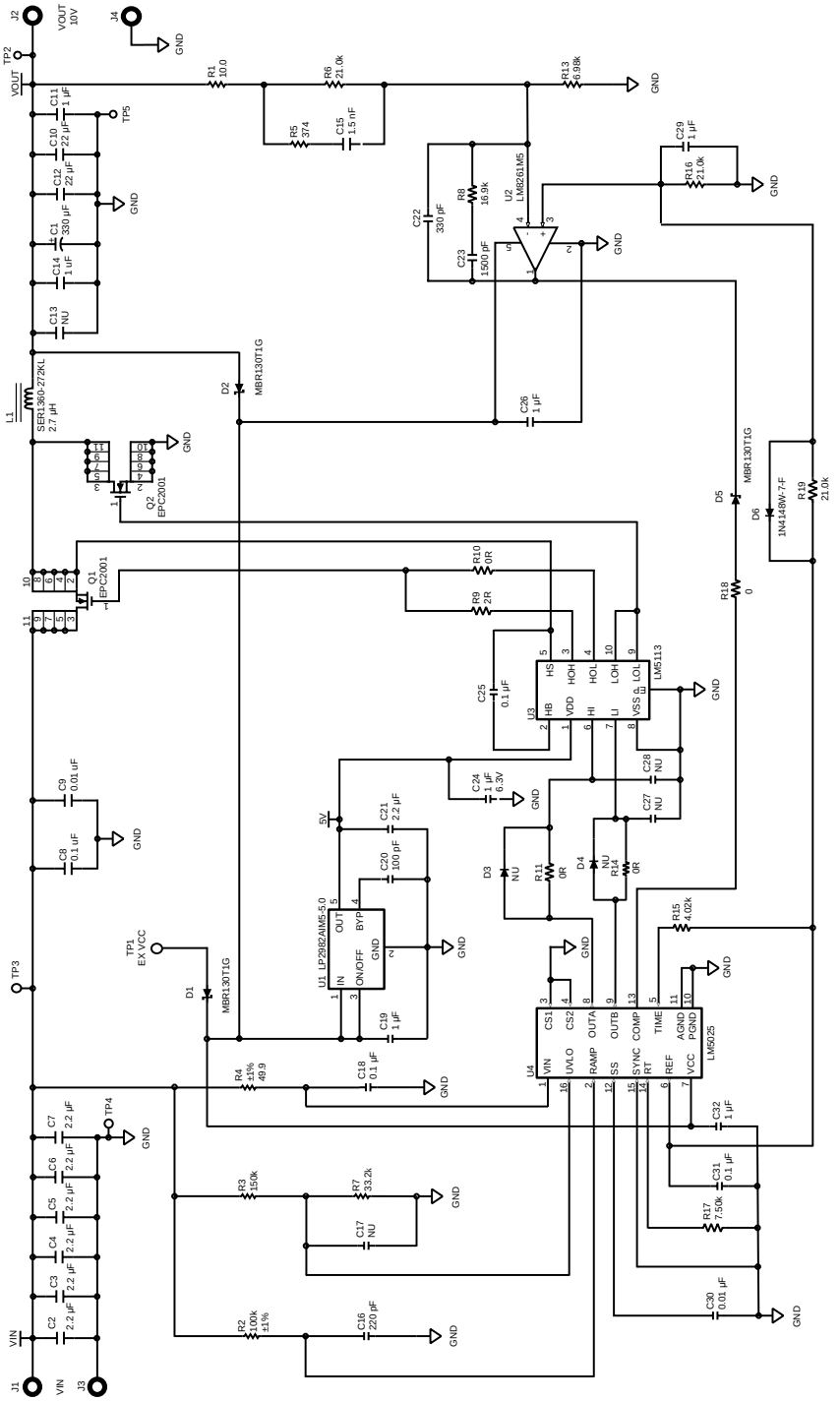
8.1 Application Information

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:

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

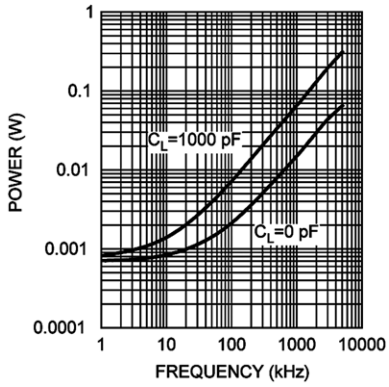
where

- 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.

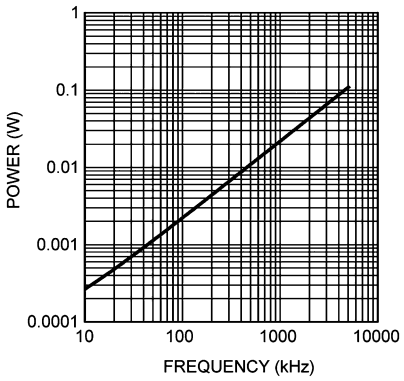


Gate-driver power dissipation (LO+HO), VDD = +5 V

Figure 19. Neglecting Bootstrap Diode Losses

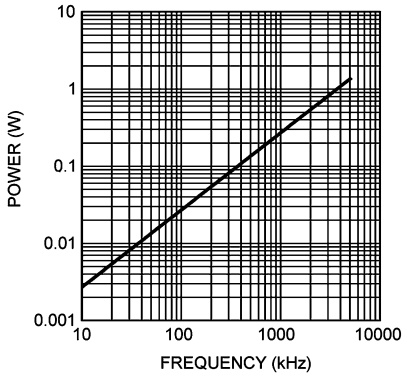
The bootstrap diode power loss is the sum of the forward bias power loss that occurs while charging the bootstrap capacitor and the reverse bias power loss that occurs during reverse recovery. Because each of these events happens once per cycle, the diode power loss is proportional to the operating frequency. 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



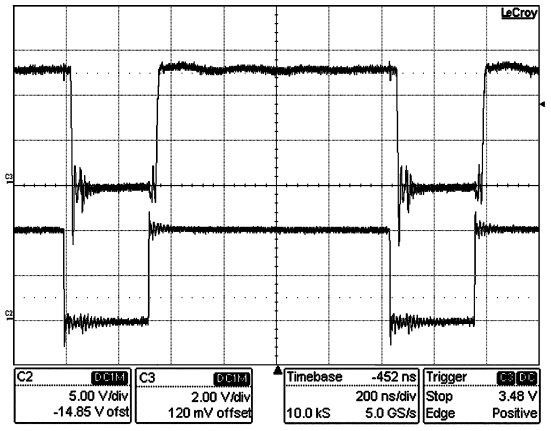
The load of high-side driver is a GaN FET with total gate charge of 10 nC.

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.

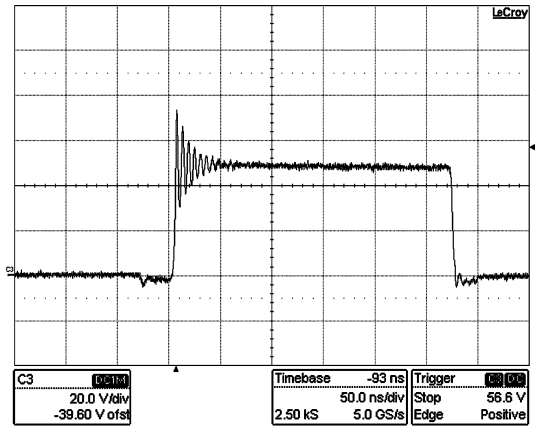
$$P = \frac{(T_J - T_A)}{\theta_{JA}} \quad (5)$$

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

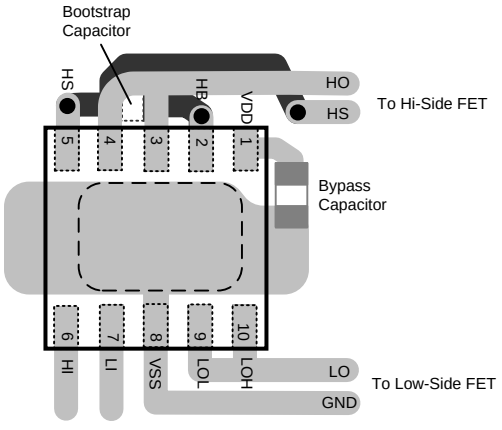


Figure 24. 10-Pin WSON Without Gate Resistors

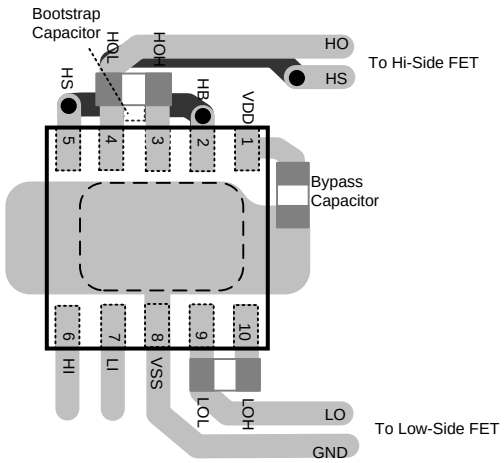


Figure 25. 10-Pin WSON With HOH and LOH Gate Resistors

11 デバイスおよびドキュメントのサポート

11.1 ドキュメントのサポート

11.1.1 関連資料

関連資料については、以下を参照してください。

『AN-2149 LM5113評価ボード』(SNVA484)

11.2 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、ti.comのデバイス製品フォルダを開いてください。右上の隅にある「*通知を受け取る*」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

11.3 コミュニティ・リソース

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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11.6 Glossary

SLYZ022 — *TI Glossary*.

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

12 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM5113QDPRRQ1	Active	Production	WSON (DPR) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	L5113Q
LM5113QDPRRQ1.A	Active	Production	WSON (DPR) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	L5113Q

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

OTHER QUALIFIED VERSIONS OF LM5113-Q1 :

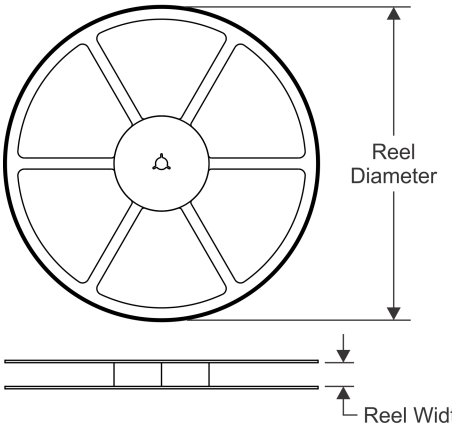
- Catalog : LM5113

NOTE: Qualified Version Definitions:

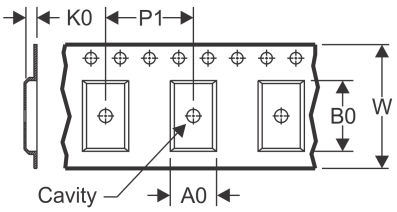
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

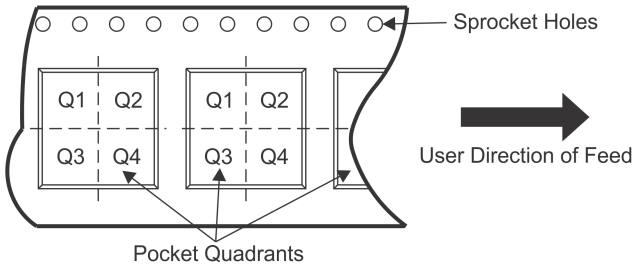


TAPE DIMENSIONS



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

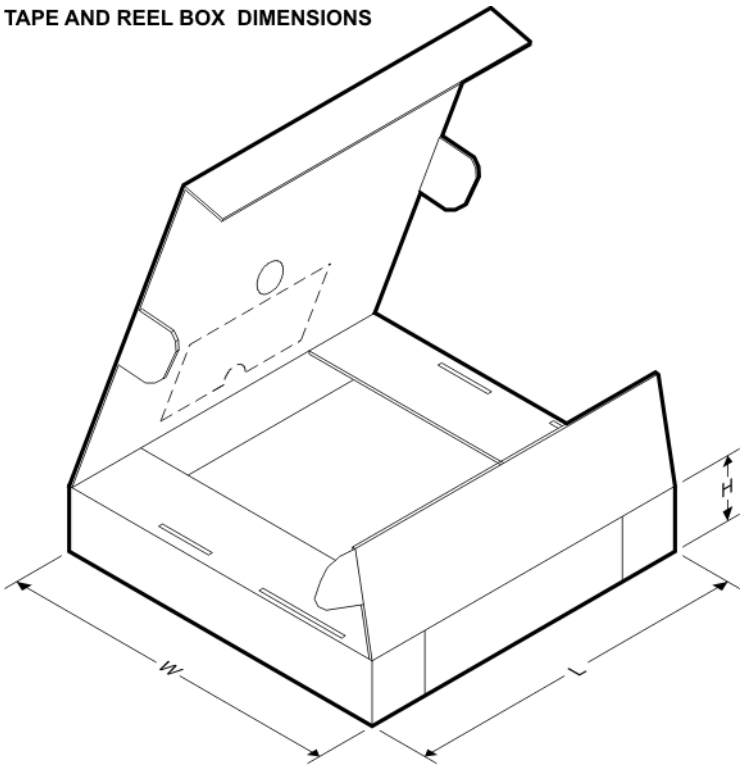
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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

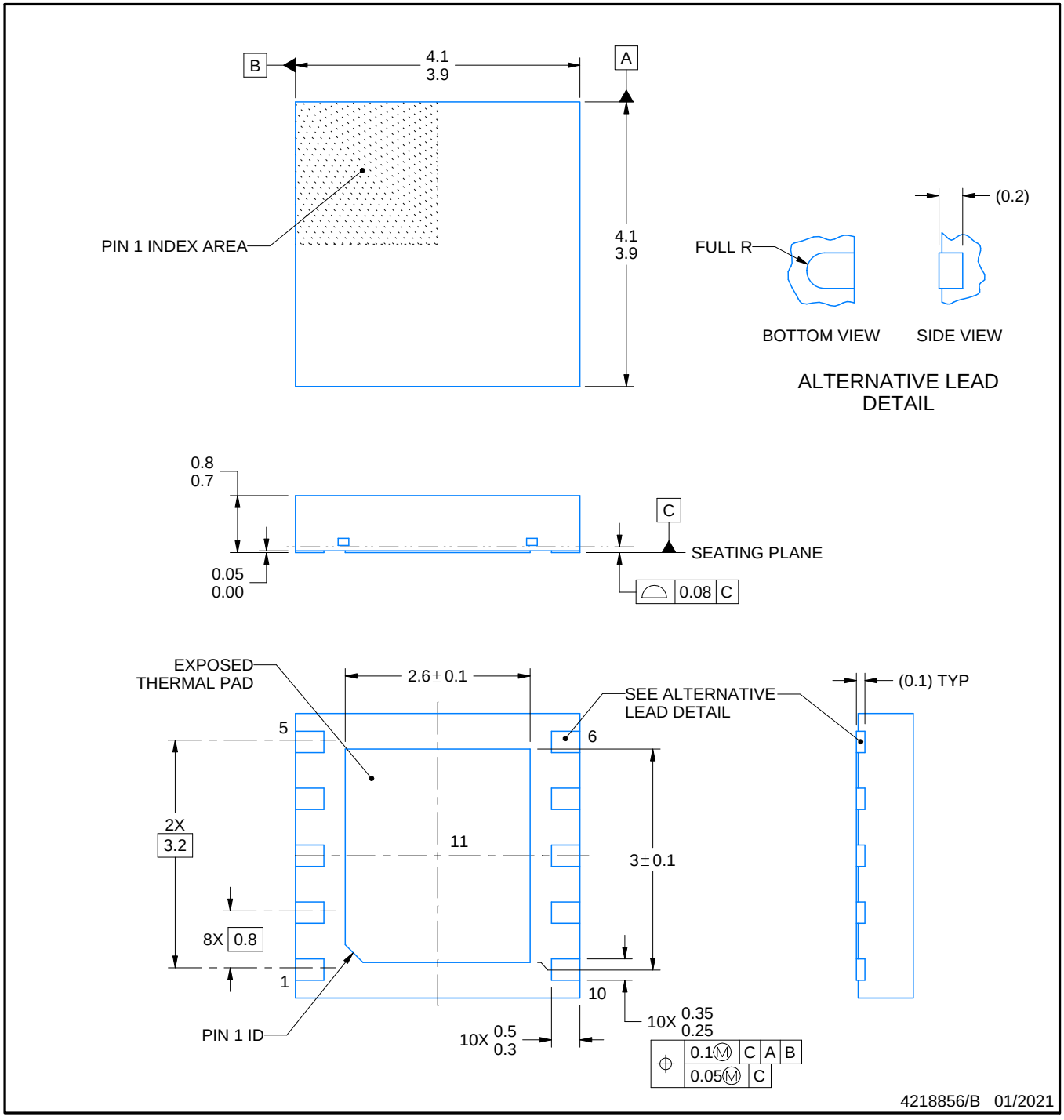
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM5113QDPRRQ1	WSON	DPR	10	4500	367.0	367.0	35.0

PACKAGE OUTLINE

DPR0010A

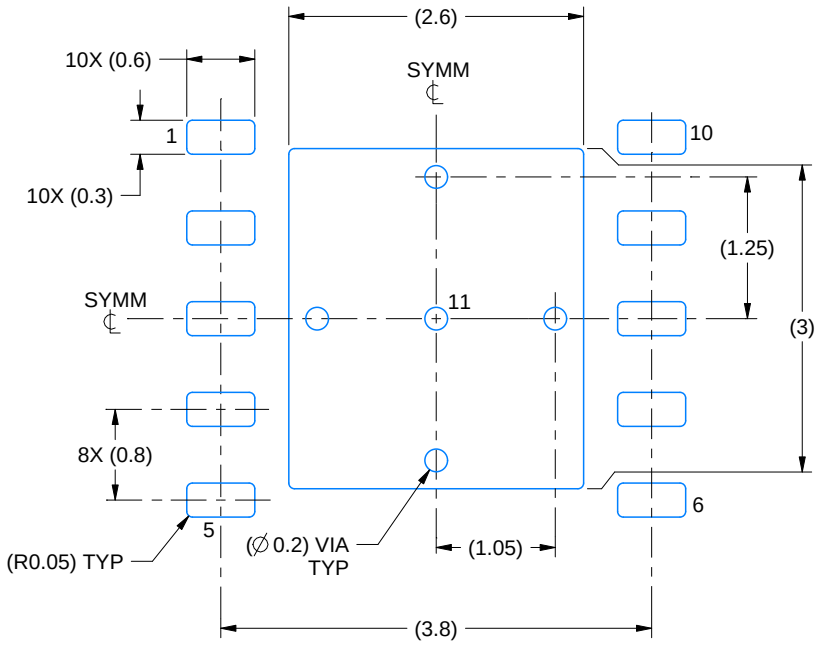
WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

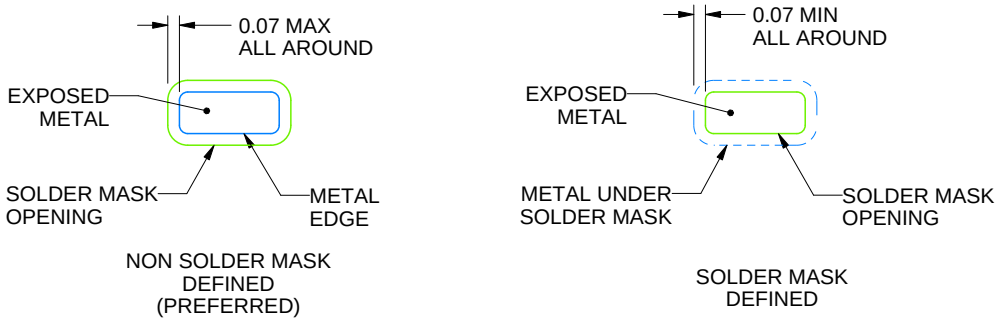


NOTES:

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

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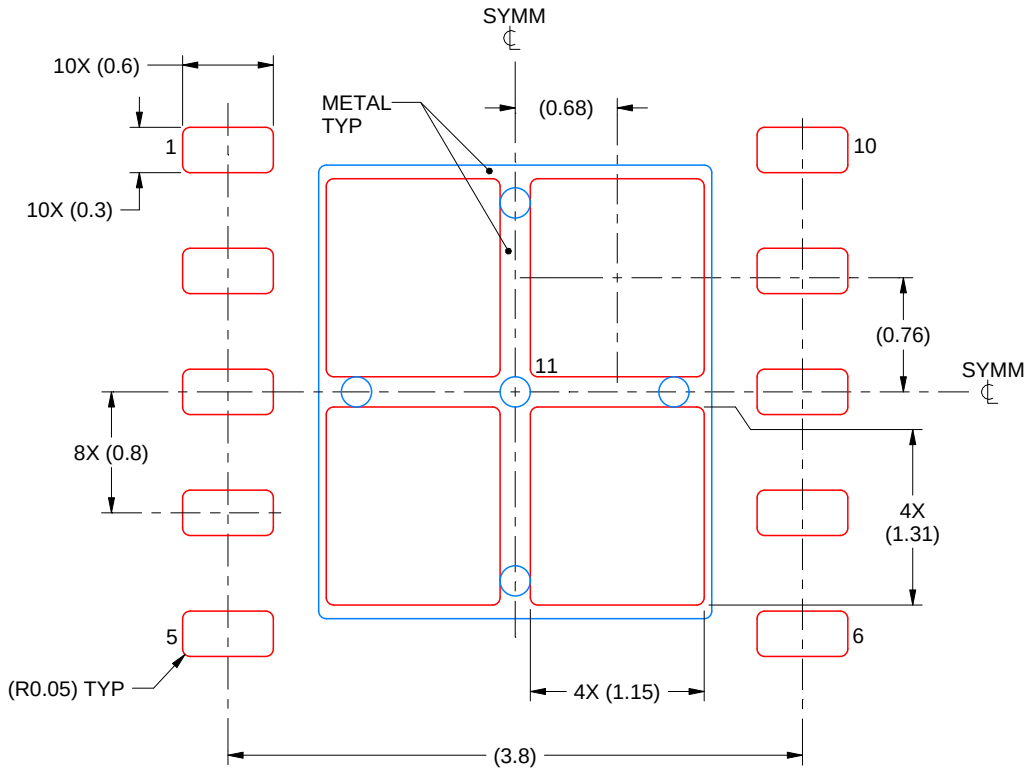
NOTES: (continued)

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

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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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