

LM5113 80V、1.2A/5A、ハーフブリッジ GaN ドライバ

1 特長

- 互いに独立したハイサイドおよびローサイド TTL ロジック入力
- 1.2A/5A のピーク・ソース/シンク電流
- ハイサイドのフローティング・バイアス電圧レールは最高 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
- 0.6Ω/2.1Ω のプルダウン/プルアップ抵抗
- 短い伝播遅延 (標準値 28ns)
- 優れた伝搬遅延マッチング (標準値 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

- 商用テレコム整流器
- 商用 DC/DC
- 閉ループのステッパ・モータ・ドライブ
- ベースバンド・ユニット (BBU)
- マクロ・リモート無線ユニット (RRU)

3 概要

LM5113 デバイスは、同期降圧またはハーフブリッジの構成で、ハイサイドとローサイドの両方のエンハンスメント・モード窒化ガリウム(GaN) FETを駆動できるように設計されています。フローティング・ハイサイド・ドライバは、最大 100V で動作するハイサイドのエンハンスメント・モード GaN FET を駆動できます。ハイサイドのバイアス電圧は、ブートストラップ手法によって生成され、内部で 5.2V にクランプされています。これによって、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・ソース間電圧定格を超えるのを防ぎます。LM5113 の入力は TTL ロジック互換であり、VDD 電圧に関係なく最大 14V の入力電圧に耐えることができます。LM5113 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独立に調整できる柔軟性があります。

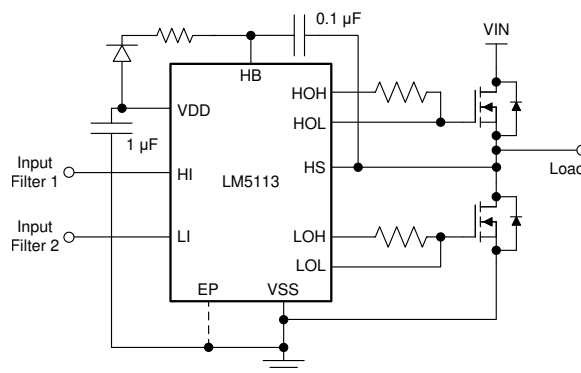
LMG1205 は、LM5113 の拡張版です。LMG1205 は LM5113 のデザインを基礎として、スタートアップ・ロジック、レベル・シフタ、電源オフ Vgs クランプの拡張により、さらに堅牢なソリューションを可能にします。

製品情報⁽¹⁾

| 型番 | パッケージ | 本体サイズ(公称) |
|--------|------------|---------------|
| LM5113 | WSON (10) | 4.00mm×4.00mm |
| | DSBGA (12) | 2.00mm×2.00mm |

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。

アプリケーション概略図



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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 H (January 2018) から Revision I に変更 | Page |
|---|------|
| • データシートのタイトルから「NRND」を削除 | 1 |
| • NRDN 公開声明を削除 | 1 |

| Revision G (January 2016) から Revision H に変更 | Page |
|--|------|
| • データシートのタイトルを「LM5113 100V、1.2A/5A、エンハンスメント・モード GaN FET 用ハーフブリッジ・ゲート・ドライバ」から「LM5113 80V、1.2V、5A、ハーフブリッジ GaN ドライバ」に変更 | 1 |
| • データシートに「新規設計用に推奨されていません」の注意事項を追加 | 1 |
| • 「概要」セクションに内容を追加 | 1 |
| • 表紙のキー・グラフィックを変更 | 1 |
| • Removed HB to VDD parameter from the <i>Absolute Maximum Ratings</i> table | 6 |
| • Changed the HS to VSS maximum from: 100 V to: 93 V | 6 |
| • Changed the HB to VSS maximum from: 107 V to: V(HS) + 7 V | 6 |
| • Changed the human-body model value from: ± 2000 to: ± 1000 | 6 |
| • Changed HS maximum from: 100 V to: 90 V | 6 |
| • Changed the <i>Functional Block Diagram</i> | 12 |
| • Changed the last paragraph and add new images to the <i>Input and Output</i> section | 12 |
| • Added content to the <i>Start-up and UVLO</i> section | 13 |

| Revision F (April 2013) から Revision G に変更 | Page |
|--|------|
| • 「ESD定格」の表、「機能説明」、「デバイスの機能モード」、「アプリケーションと実装」、「電源に関する推奨事項」、「レイアウト」、「デバイスとドキュメントのサポート」、「メカニカル、パッケージ、および注文情報」を追加 | 4 |

Revision E (April 2013) から Revision F に変更**Page**

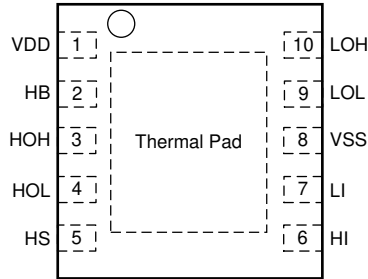
-
- ナショナル セミコンダクターのデータシートのレイアウトを TI 形式に変更 1
-

5 概要（続き）

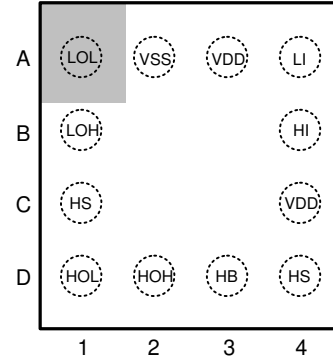
また、LM5113の強力なシンク能力によりゲートがLOW状態で維持され、スイッチング時に意図しないターンオンが防止されます。LM5113の最大動作周波数は数MHzです。LM5113は、標準のWSO_N-10ピン・パッケージおよび12バンプDSBGAパッケージで供給されます。WSO_N-10ピン・パッケージには、電力消費能力を高めるための露出したパッドが備えられています。DSBGAパッケージはコンパクトで占有面積が小さく、パッケージのインダクタンスが最小化されています。

6 Pin Configuration and Functions

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



**YFX Package
12-Pin DSBGA
Top View**



Pin Functions

| NAME | PIN | | TYPE ⁽¹⁾ | DESCRIPTION |
|-------------|------|-----------------------|---------------------|--|
| | WSON | DSBGA | | |
| VDD | 1 | A3, C4 ⁽²⁾ | P | 5-V Positive gate drive supply: locally decouple to VSS using low ESR/ESL capacitor located as close to the IC as possible. |
| HB | 2 | D3 | 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 should be placed as close to the IC as possible. |
| HOH | 3 | D2 | 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. |
| HOL | 4 | D1 | 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. |
| HS | 5 | C1, D4 ⁽²⁾ | P | High-side GaN FET source connection: connect to the bootstrap capacitor negative terminal and the source of the high-side GaN FET. |
| HI | 6 | B4 | I | High-side driver control input. The LM5113 inputs have TTL type thresholds. Unused inputs should be tied to ground and not left open. |
| LI | 7 | A4 | I | Low-side driver control input. The LM5113 inputs have TTL type thresholds. Unused inputs should be tied to ground and not left open. |
| VSS | 8 | A2 | G | Ground return: all signals are referenced to this ground. |
| LOL | 9 | A1 | 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. |
| LOH | 10 | B1 | 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. |
| Exposed Pad | 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

(2) A3 and C4, C1 and D4 are internally connected

7 Specifications

7.1 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 | V _{HS} + 7 | 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.

7.2 ESD Ratings

| | | VALUE | UNIT |
|--|--|-------|------|
| V _(ESD) Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±2000 | V |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±1000 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
 (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 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 |

7.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | LM5113 | | UNIT |
|--|------------|-------------|------|
| | DPR (WSON) | YFX (DSBGA) | |
| | 10 PINS | 12 PINS | |
| R _{θJA} Junction-to-ambient thermal resistance | 37.5 | 76.8 | °C/W |
| R _{θJC(top)} Junction-to-case (top) thermal resistance | 35.8 | 0.6 | °C/W |
| R _{θJB} Junction-to-board thermal resistance | 14.7 | 12.0 | °C/W |
| ψ _{JT} Junction-to-top characterization parameter | 0.3 | 1.6 | °C/W |
| ψ _{JB} Junction-to-board characterization parameter | 14.9 | 12.0 | °C/W |
| R _{θJC(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.

7.5 Electrical Characteristics

Specifications are $T_J = 25^\circ\text{C}$. Unless otherwise specified: $V_{DD} = V_{HB} = 5\text{ V}$, $V_{SS} = V_{HS} = 0\text{ V}$. 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 | $T_J = 25^\circ\text{C}$ | 0.07 | | mA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 0.1 | |
| I_{DDO} | VDD operating current | f = 500 kHz | $T_J = 25^\circ\text{C}$ | 2.0 | | mA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 3.0 | |
| I_{HB} | Total HB quiescent current | LI = HI = 0 V | $T_J = 25^\circ\text{C}$ | 0.08 | | mA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 0.1 | |
| I_{HBO} | Total HB operating current | f = 500 kHz | $T_J = 25^\circ\text{C}$ | 1.5 | | mA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 2.5 | |
| I_{HBS} | HB to VSS quiescent current | HS = HB = 100 V | $T_J = 25^\circ\text{C}$ | 0.1 | | μA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 8 | |
| I_{HBSO} | HB to VSS operating current | f = 500 kHz | $T_J = 25^\circ\text{C}$ | 0.4 | | mA |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 1.0 | |
| INPUT PINS | | | | | | |
| V_{IR} | Input voltage threshold | Rising edge | $T_J = 25^\circ\text{C}$ | 2.06 | | V |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | 1.89 | 2.18 | |
| V_{IF} | Input voltage threshold | Falling edge | $T_J = 25^\circ\text{C}$ | 1.66 | | V |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | 1.48 | 1.76 | |
| V_{IHYS} | Input voltage hysteresis | | | 400 | | mV |
| R_I | Input pulldown resistance | $T_J = 25^\circ\text{C}$ | | 200 | | k Ω |
| | | $T_J = -40^\circ\text{C}$ to 125°C | 100 | | 300 | |
| UNDERVOLTAGE PROTECTION | | | | | | |
| V_{DDR} | VDD rising threshold | $T_J = 25^\circ\text{C}$ | | 3.8 | | V |
| | | $T_J = -40^\circ\text{C}$ to 125°C | 3.2 | | 4.5 | |
| V_{DDH} | VDD threshold hysteresis | | | 0.2 | | V |
| V_{HBR} | HB rising threshold | $T_J = 25^\circ\text{C}$ | | 3.2 | | V |
| | | $T_J = -40^\circ\text{C}$ to 125°C | 2.5 | | 3.9 | |
| V_{HBH} | HB threshold hysteresis | | | 0.2 | | V |
| BOOTSTRAP DIODE | | | | | | |
| V_{DL} | Low-current forward voltage | $I_{VDD-HB} = 100\ \mu\text{A}$ | $T_J = 25^\circ\text{C}$ | 0.45 | | V |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 0.65 | |
| V_{DH} | High-current forward voltage | $I_{VDD-HB} = 100\ \text{mA}$ | $T_J = 25^\circ\text{C}$ | 0.90 | | V |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 1.00 | |
| R_D | Dynamic resistance | $I_{VDD-HB} = 100\ \text{mA}$ | $T_J = 25^\circ\text{C}$ | 1.85 | | Ω |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | | 3.60 | |
| | HB-HS clamp | Regulation voltage | $T_J = 25^\circ\text{C}$ | 5.2 | | V |
| | | | $T_J = -40^\circ\text{C}$ to 125°C | 4.7 | 5.45 | |

(1) Minimum and maximum limits are 100% production tested at 25°C . Limits over the operating temperature range are ensured through correlation using Statistical Quality Control (SQC) methods. Limits are used to calculate Average Outgoing Quality Level (AOQL).

Electrical Characteristics (continued)

Specifications are $T_J = 25^\circ\text{C}$. Unless otherwise specified: $V_{DD} = V_{HB} = 5\text{ V}$, $V_{SS} = V_{HS} = 0\text{ V}$.
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 | $I_{HOL} = I_{LOL} = 100\text{ mA}$ | $T_J = 25^\circ\text{C}$ | | 0.06 | | V |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 0.10 | |
| V_{OH} | High-level output voltage $V_{OH} = V_{DD} - LOH$ or $V_{OH} = HB - HOH$ | $I_{HOH} = I_{LOH} = 100\text{ mA}$ | $T_J = 25^\circ\text{C}$ | | 0.21 | | V |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 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 | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 1.5 | μA |
| I_{OLLK} | Low-level output leakage current | HOL, LOL = 5 V | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 1.5 | μA |

7.6 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 | $T_J = 25^\circ\text{C}$ | | 26.5 | | ns |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 45.0 | |
| t_{LPLH} | LO turnon propagation delay | LI rising to LOH rising | $T_J = 25^\circ\text{C}$ | | 28.0 | | ns |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 45.0 | |
| t_{HPHL} | HO turnoff propagation delay | HI falling to HOL falling | $T_J = 25^\circ\text{C}$ | | 26.5 | | ns |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 45.0 | |
| t_{HPLH} | HO turnon propagation delay | HI rising to HOH rising | $T_J = 25^\circ\text{C}$ | | 28.0 | | ns |
| | | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | 45.0 | |
| t_{MON} | Delay matching LO on & HO off | $T_J = 25^\circ\text{C}$ | | | 1.5 | | ns |
| | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | | 8.0 | |
| t_{MOFF} | Delay matching LO off & HO on | $T_J = 25^\circ\text{C}$ | | | 1.5 | | ns |
| | | $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ | | | | 8.0 | |
| t_{HRC} | HO rise time (0.5 V – 4.5 V) | $C_L = 1000\text{ pF}$ | | | 7.0 | | ns |
| t_{LRC} | LO rise time (0.5 V – 4.5 V) | $C_L = 1000\text{ pF}$ | | | 7.0 | | ns |
| t_{HFC} | HO fall time (0.5 V – 4.5 V) | $C_L = 1000\text{ pF}$ | | | 1.5 | | ns |
| t_{LFC} | LO fall time (0.5 V – 4.5 V) | $C_L = 1000\text{ pF}$ | | | 1.5 | | ns |
| t_{PW} | Minimum input pulse width that changes the output | | | | 10 | | ns |
| t_{BS} | Bootstrap diode reverse recovery time | $I_F = 100\text{ mA}$, $I_R = 100\text{ mA}$ | | | 40 | | ns |

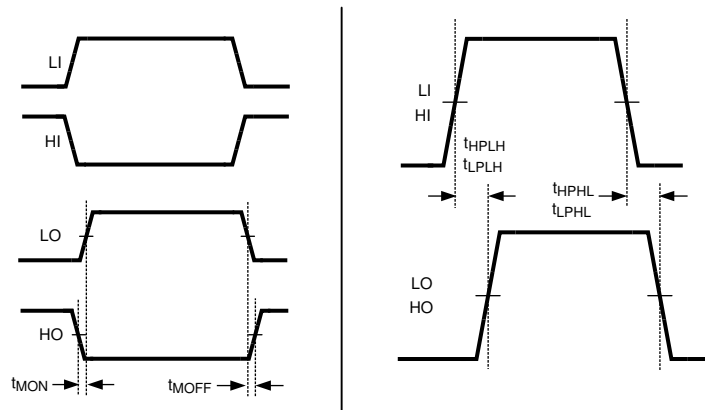
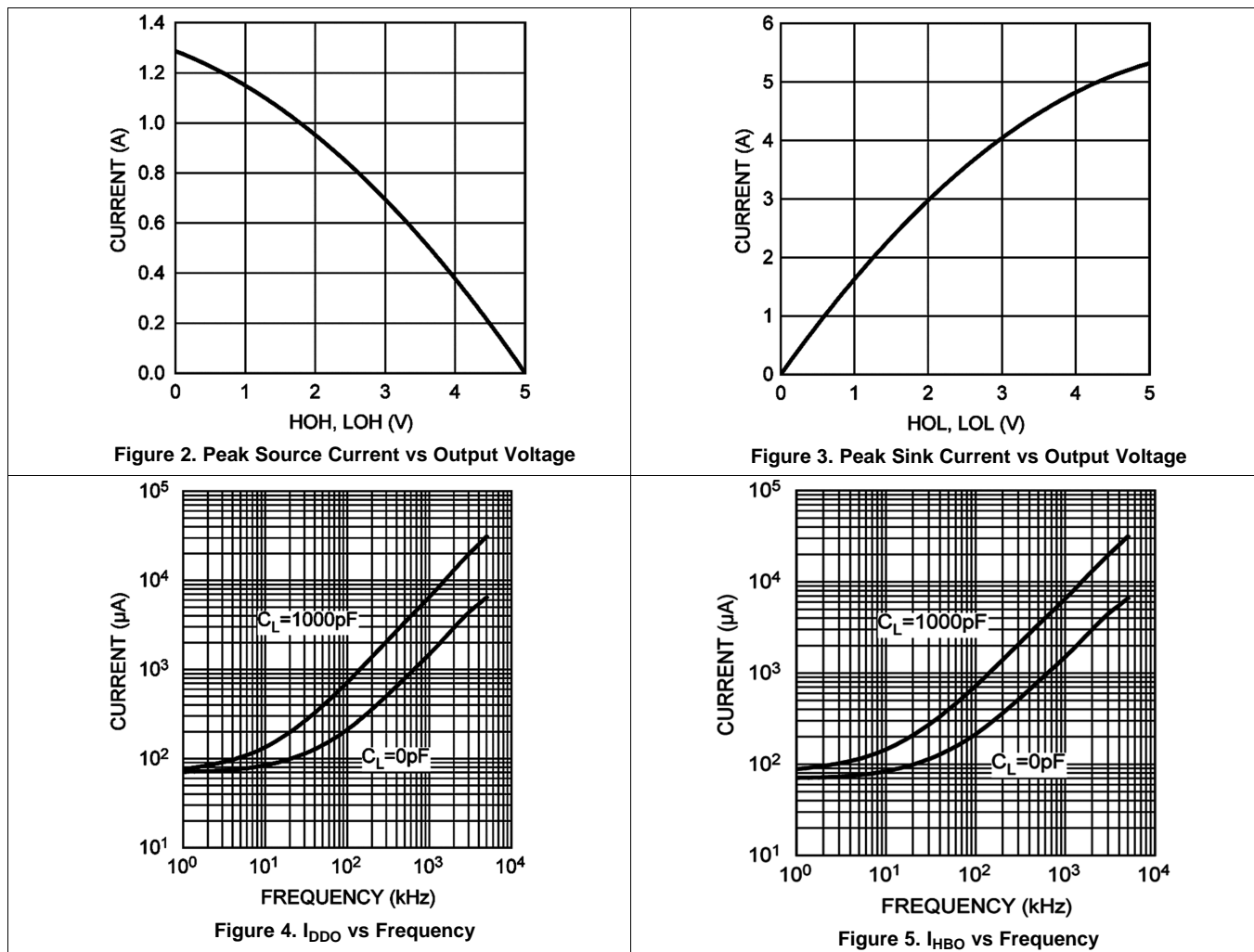


Figure 1. Timing Diagram

7.7 Typical Characteristics



Typical Characteristics (continued)

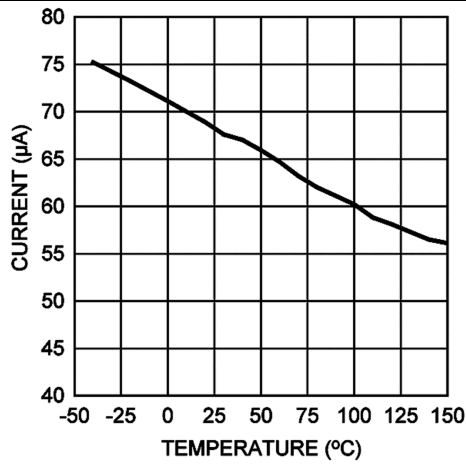


Figure 6. I_{DD} vs Temperature

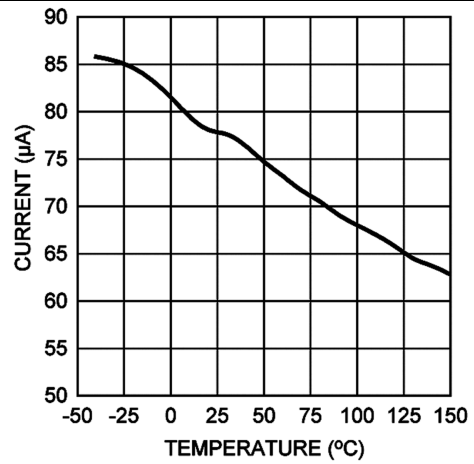


Figure 7. I_{HB} vs Temperature

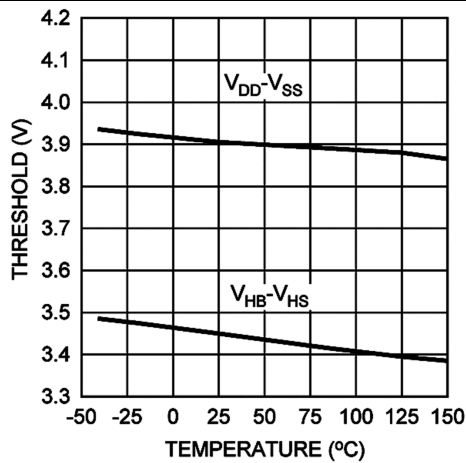


Figure 8. UVLO Rising Thresholds vs Temperature

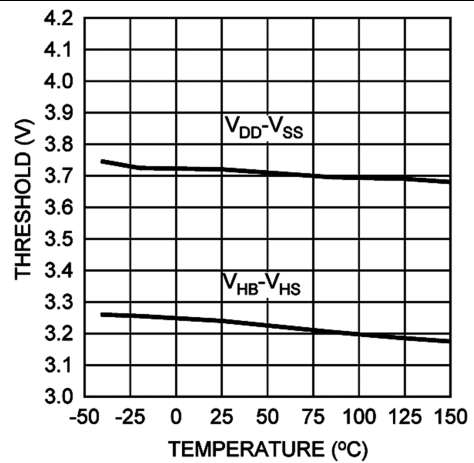


Figure 9. UVLO Falling Thresholds vs Temperature

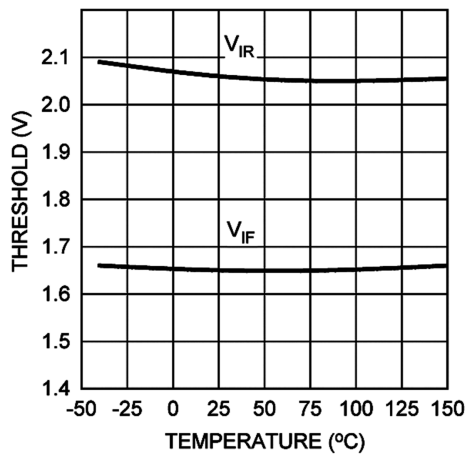


Figure 10. Input Thresholds vs Temperature

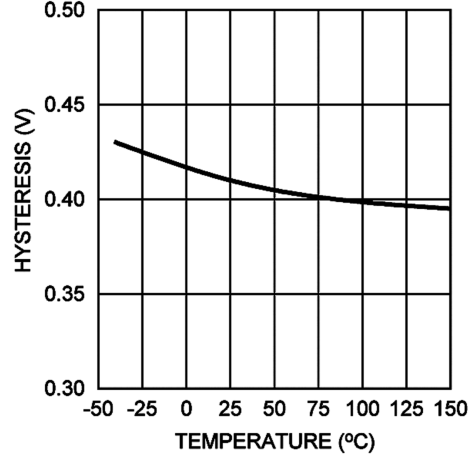


Figure 11. Input Threshold Hysteresis vs Temperature

Typical Characteristics (continued)

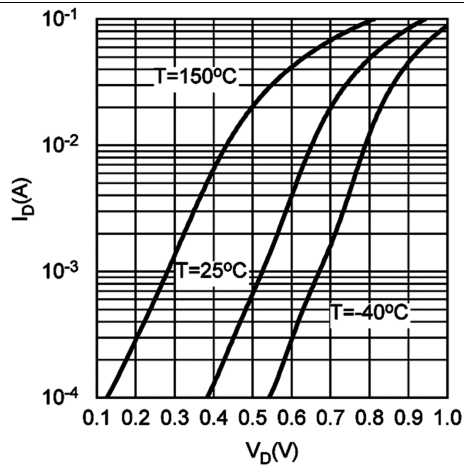


Figure 12. Bootstrap Diode Forward Voltage

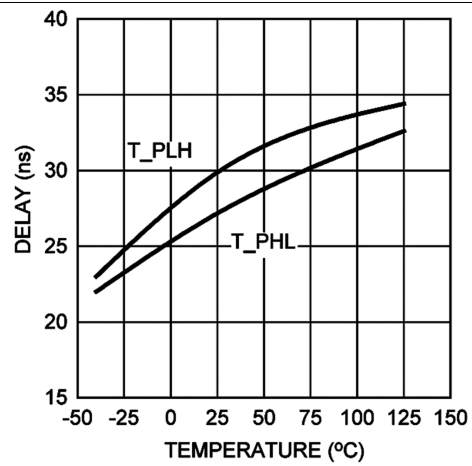
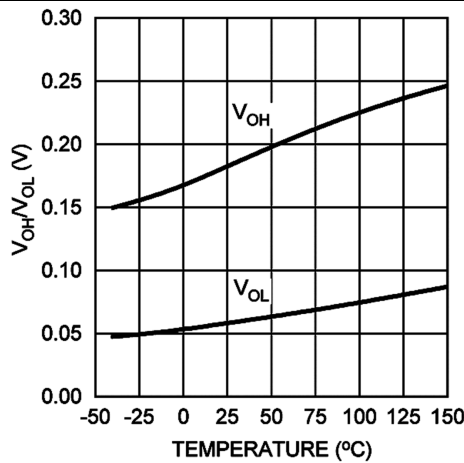
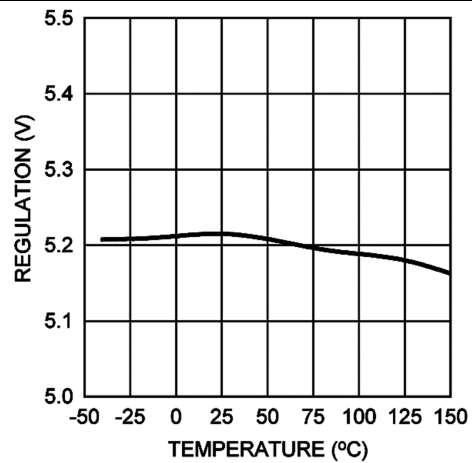


Figure 13. Propagation Delay vs Temperature



Note: Unless otherwise specified,
VDD = VHB = 5 V, VSS = VHS = 0 V.

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



Note: Unless otherwise specified,
VDD = VHB = 5 V, VSS = VHS = 0 V.

Figure 15. HB Regulation Voltage vs Temperature

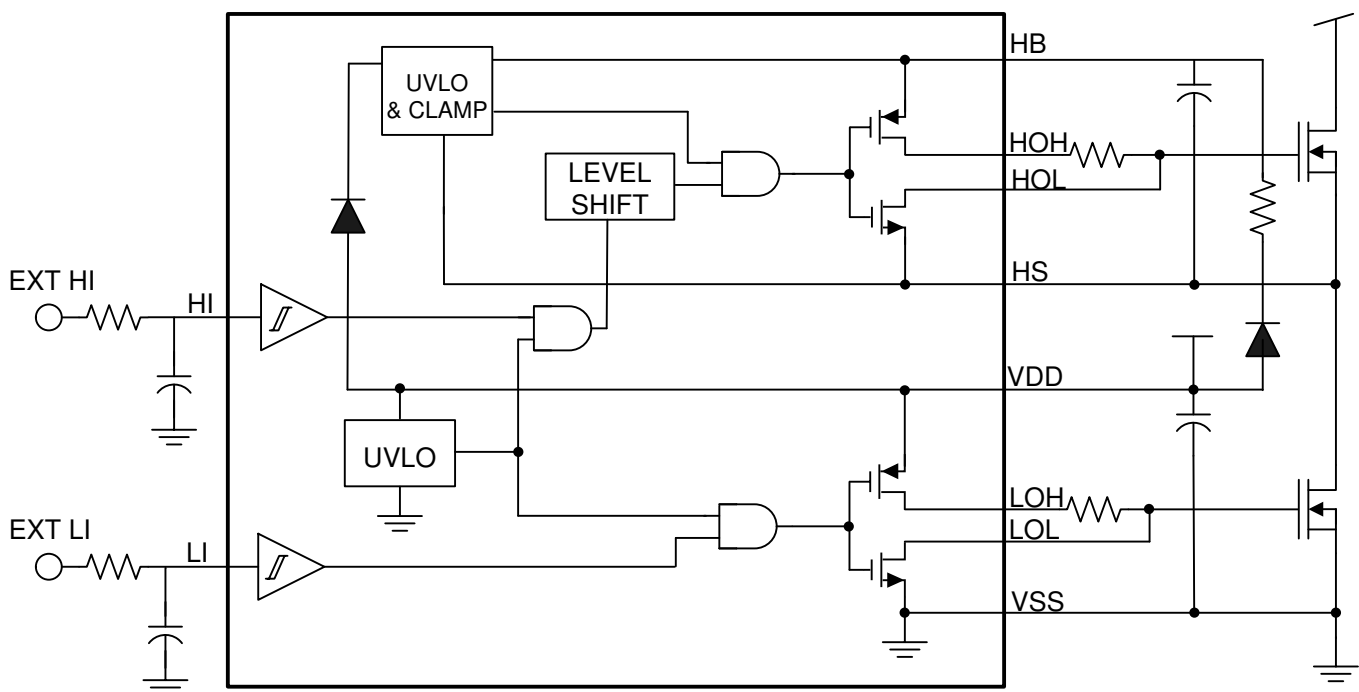
8 Detailed Description

8.1 Overview

The LM5113 is a high frequency high- and low- side gate driver for enhancement mode Gallium Nitride (GaN) FETs in a synchronous buck or a half bridge configuration. The floating high-side driver is capable of driving a high-side enhancement mode GaN FET operating up to 100 V. 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 has split gate outputs with strong sink capability, providing flexibility to adjust the turnon and turnoff strength independently.

The LM5113 can operate up to several MHz, and available in a standard WSON-10 pin package and a 12-bump DSBGA package. The WSON-10 pin package contains an exposed pad to aid power dissipation. The DSBGA package offers a compact footprint and minimized package inductance.

8.2 Functional Block Diagram



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8.3 Feature Description

8.3.1 Input and Output

The inputs are independently controlled with TTL input thresholds, and can withstand voltages up to 14 V regardless of the VDD voltage, which means it could be directly connected to the outputs of PWM controllers with up to 14-V power supply, saving a buffer stage between output of higher-voltage powered controller, for example LM5025 with 10 V, and input of the LM5113.

The output pulldown and pullup resistance of LM5113 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 offer flexibility to adjust the turnon and turnoff speed by independently adding additional impedance in either the turnon path, the turnoff path, or both.

Feature Description (continued)

It is very important that the input signal of the two channels HI and LI, which has logic compatible threshold and hysteresis, must be tied to either VDD or VSS if they are not used. This inputs must not be left floating.

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](#).

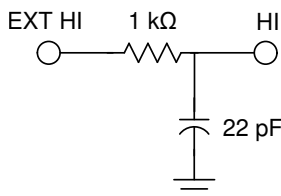
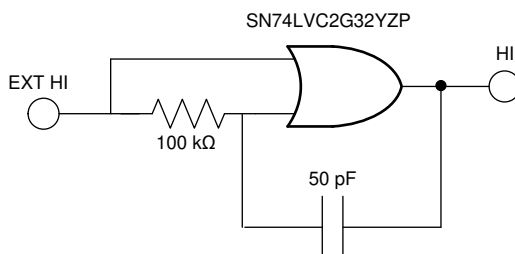


Figure 16. Input Filter 1 (High-Side Input Filter)

If short pulses or short delays are required, the circuit in [Figure 17](#) is recommended.



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

8.3.2 Start-Up and UVLO

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

The LM5113 requires an external bootstrap diode with a 20-Ω series resistor to charge the high-side supply on a cycle-by-cycle basis. The recommended bootstrap diode options are BAT46, BAT41, or LL4148.

The LM5113 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 will actively pull the LOL and HOL low. When 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.

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 |

8.3.3 HS Negative Voltage and Bootstrap Supply Voltage Clamping

Due to the intrinsic feature 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 will cause negative voltage on HS pin. Moreover, this negative voltage transient will be even worse, considering 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 solves this problem with an internal clamping circuit that prevents the bootstrap voltage from exceeding 5.2 V typical.

8.3.4 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.

8.4 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 |

9 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.

9.1 Application Information

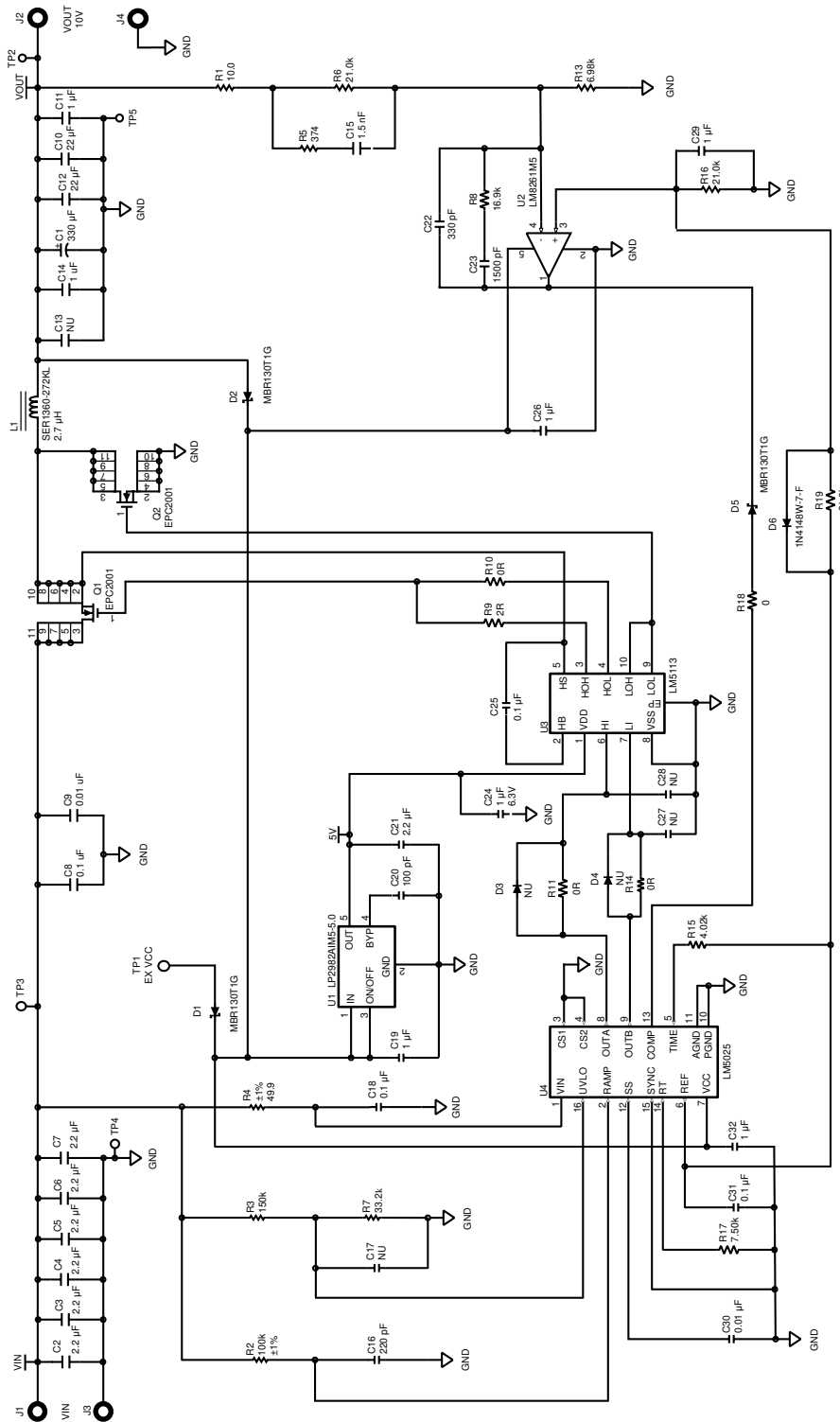
To operate GaN transistors at very high switching frequencies and to reduce associated switching losses, a powerful gate driver is employed between the PWM output of controller and the gates of the GaN transistor. Also, gate drivers are indispensable when it is impossible for the PWM controller to directly 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. Level shift circuit is required to boost the 3.3-V signal to the gate-drive voltage (such as 12 V) in order 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 find 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 is a MHz high- and low-side gate driver for enhancement mode Gallium Nitride (GaN) FETs in a synchronous buck or a half bridge configuration. The floating high-side driver is capable of driving a high-side enhancement mode GaN FET operating up to 100 V. 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 has split gate outputs with strong sink capability, providing flexibility to adjust the turnon and turnoff strength independently.

9.2 Typical Application

The circuit in [Figure 18](#) shows a synchronous buck converter to evaluate LM5113. 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, refer to the [関連資料](#) section.

Typical Application (continued)



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

Figure 18. Application Circuit

Typical Application (continued)

9.2.1 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 |

9.2.2 Detailed Design Procedure

This procedure outlines the design considerations of LM5113 in a synchronous buck converter with enhancement mode Gallium Nitride (GaN) FET. Refer to Figure 18 for component names and network locations. For additional design help, see [関連資料](#).

9.2.2.1 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.

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

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. A 0.1- μ F or larger value, good-quality, ceramic capacitor is recommended. The bypass capacitor should be placed as close to the pins of the IC as possible to minimize the parasitic inductance.

9.2.2.2 Bootstrap Capacitor

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

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

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 should be used for the bootstrap capacitor. TI recommends placing the bootstrap capacitor as close to the HB and HS pins as possible.

9.2.2.3 Power Dissipation

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

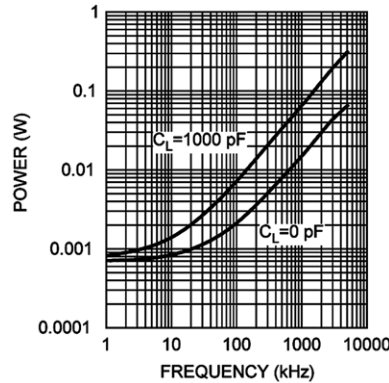
The gate driver losses are incurred by charge and discharge of the capacitive load. It can be approximated as:

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

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:

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

There are some additional losses in the gate drivers due to the internal CMOS stages used to buffer the LO and HO outputs. The following plot 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.

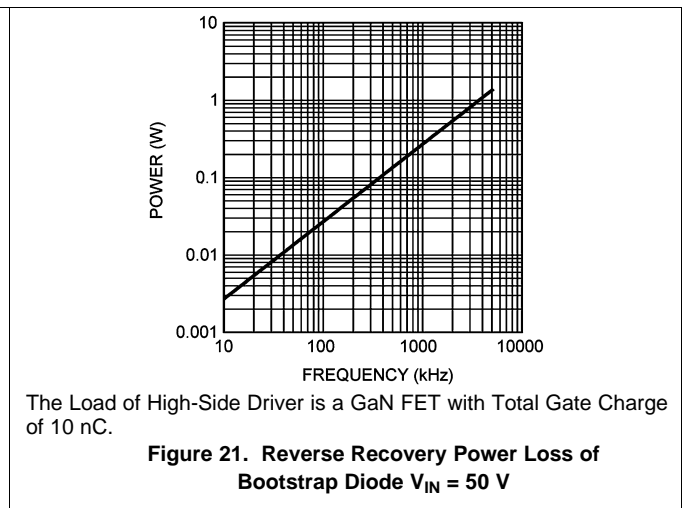
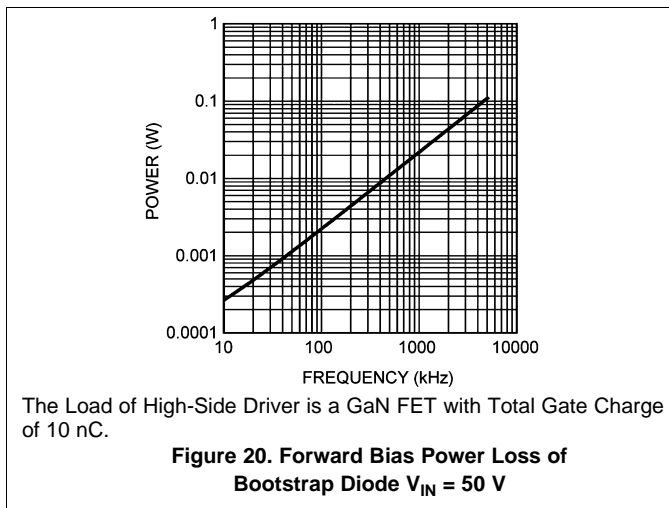


Gate Driver Power Dissipation (LO+HO), VDD = +5 V

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.

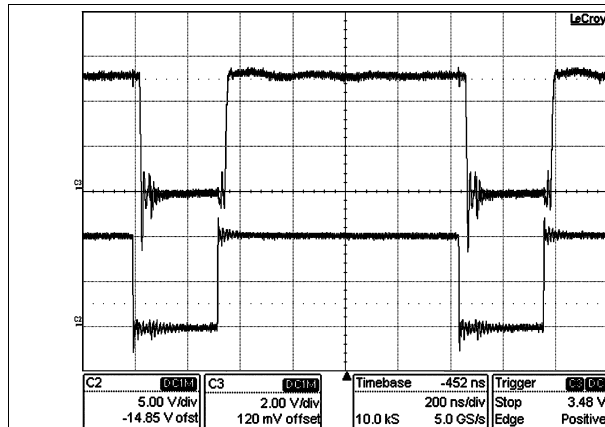
The following two plots illustrate the forward bias power loss and the reverse bias power loss of the bootstrap diode respectively. The plots are generated based on calculations and lab measurements of the diode reverse time and current under several operating conditions. The plots can be used to predict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



The 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](#).

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

9.2.3 Application Curves


Conditions:

Input Voltage = 48 V DC, Load Current = 5 A

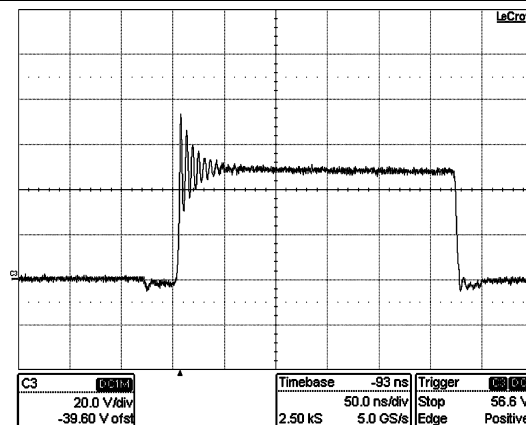
Traces:

Top Trace: Gate of Low-Side eGaN FET, Volt/div = 2 V

Bottom Trace: LI of LM5113, Volt/div = 5 V

Bandwidth Limit = 600 MHz

Horizontal Resolution = 0.2 μ s/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

10 Power Supply Recommendations

The recommended bias supply voltage range for LM5113 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. The upper end of this range is driven by the 7-V absolute maximum voltage rating of the VDD or the GaN transistor gate breakdown voltage limit, whichever is lower. TI recommends keeping a proper margin to allow for transient voltage spikes.

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 auxiliary power supply output should be smaller than the hysteresis specification of LM5113 to avoid triggering device shutdown.

A local bypass capacitor should be placed between the VDD and VSS pins. And this capacitor should be located as close to the device as possible. 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- μ F, for IC bias requirements.

11 Layout

11.1 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 hints.

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 will decrease the loop inductance and minimize noise issues on the gate terminal of the GaN FETs. The GaN FETs should 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 a 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 bullet #1 (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 printed-circuit 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.

The following figures show recommended layout patterns for WSON-10 package and DSBGA package, respectively. Two cases are considered: (1) Without any gate resistors; (2) With an optional turnon gate resistor. It should be noted that 0402 DSBGA package is assumed for the passive components in the drawings. For information on DSBGA package assembly, refer to [関連資料](#).

11.2 Layout Examples

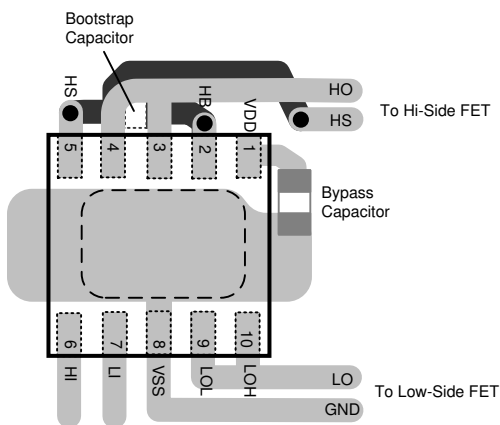


Figure 24. WSON-10 Without Gate Resistors

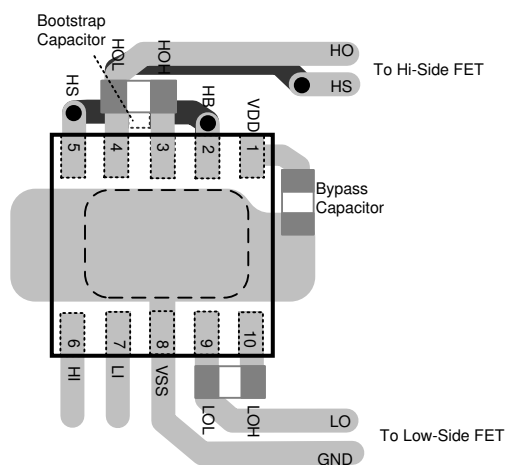


Figure 25. WSON-10 With HOH and LOH Gate Resistors

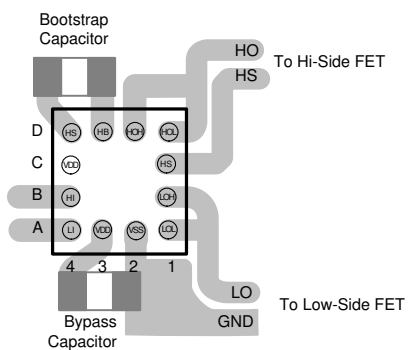


Figure 26. DSBGA Without Gate Resistors

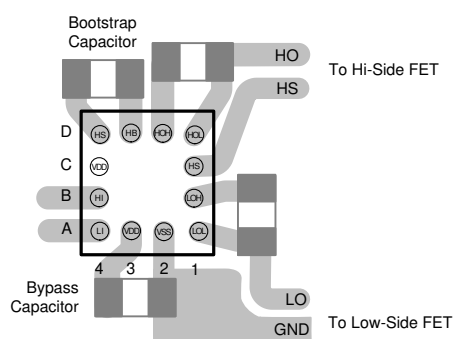


Figure 27. DSBGA With HOH and LOH Gate Resistors

12 デバイスおよびドキュメントのサポート

12.1 ドキュメントのサポート

12.1.1 関連資料

関連資料については、以下を参照してください。

- テキサス・インスツルメンツ、『[AN-1112 DSBGA Wafer Level Chip Scale Package](#)』アプリケーション・レポート (英語)
- テキサス・インスツルメンツ、『[AN-2149 LM5113 Evaluation Board](#)』アプリケーション・レポート (英語)

12.2 サポート・リソース

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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12.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

13 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 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 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|---------|
| LM5113SD/NOPB | NRND | WSON | DPR | 10 | 1000 | RoHS & Green | SN | Level-1-260C-UNLIM | -40 to 125 | L5113 | |
| LM5113SDE/NOPB | NRND | WSON | DPR | 10 | 250 | RoHS & Green | SN | Level-1-260C-UNLIM | -40 to 125 | L5113 | |
| LM5113SDX/NOPB | NRND | WSON | DPR | 10 | 4500 | RoHS & Green | SN | Level-1-260C-UNLIM | -40 to 125 | L5113 | |
| LM5113TME/NOPB | NRND | DSBGA | YFX | 12 | 250 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | | 5113 | |
| LM5113TMX/NOPB | NRND | DSBGA | YFX | 12 | 3000 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | | 5113 | |

(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.

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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

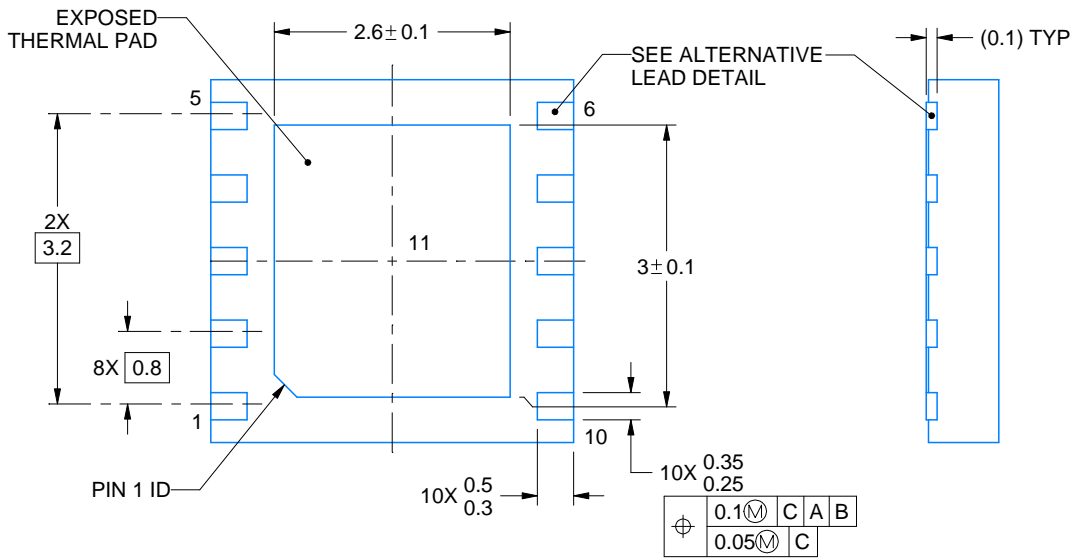
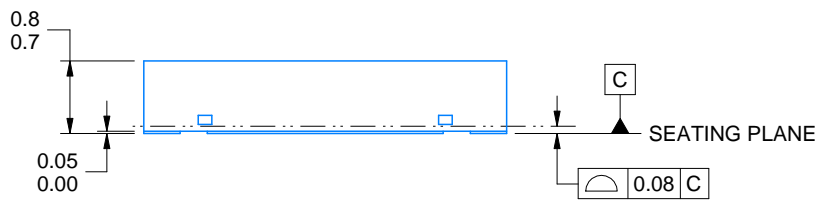
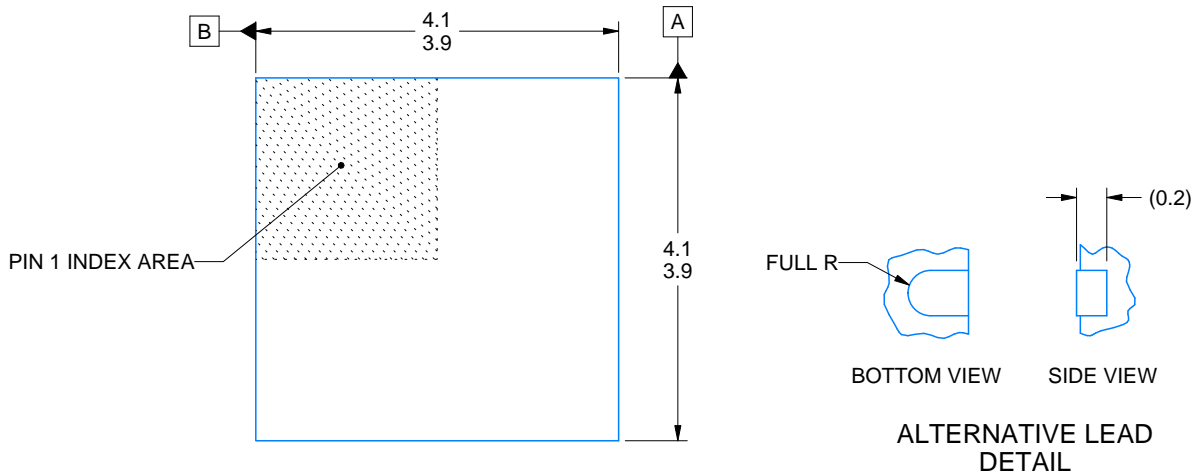
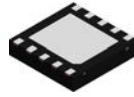

*All dimensions are nominal

| 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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM5113SD/NOPB | WSO | DPR | 10 | 1000 | 178.0 | 12.4 | 4.3 | 4.3 | 1.3 | 8.0 | 12.0 | Q1 |
| LM5113SDE/NOPB | WSO | DPR | 10 | 250 | 178.0 | 12.4 | 4.3 | 4.3 | 1.3 | 8.0 | 12.0 | Q1 |
| LM5113SDX/NOPB | WSO | DPR | 10 | 4500 | 330.0 | 12.4 | 4.3 | 4.3 | 1.3 | 8.0 | 12.0 | Q1 |
| LM5113TME/NOPB | DSBGA | YFX | 12 | 250 | 178.0 | 8.4 | 1.85 | 2.01 | 0.76 | 4.0 | 8.0 | Q1 |
| LM5113TMX/NOPB | DSBGA | YFX | 12 | 3000 | 178.0 | 8.4 | 1.85 | 2.01 | 0.76 | 4.0 | 8.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM5113SD/NOPB | WSON | DPR | 10 | 1000 | 208.0 | 191.0 | 35.0 |
| LM5113SDE/NOPB | WSON | DPR | 10 | 250 | 208.0 | 191.0 | 35.0 |
| LM5113SDX/NOPB | WSON | DPR | 10 | 4500 | 367.0 | 367.0 | 35.0 |
| LM5113TME/NOPB | DSBGA | YFX | 12 | 250 | 208.0 | 191.0 | 35.0 |
| LM5113TMX/NOPB | DSBGA | YFX | 12 | 3000 | 208.0 | 191.0 | 35.0 |



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NOTES:

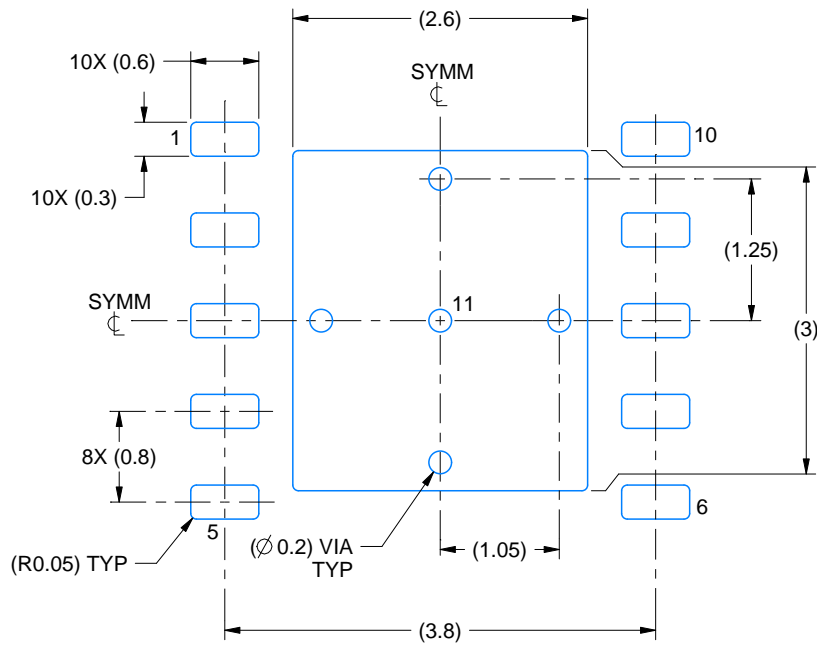
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

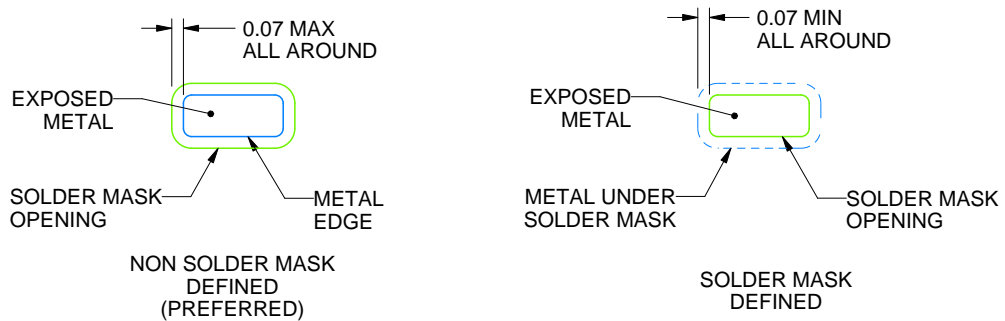
DPR0010A

WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

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NOTES: (continued)

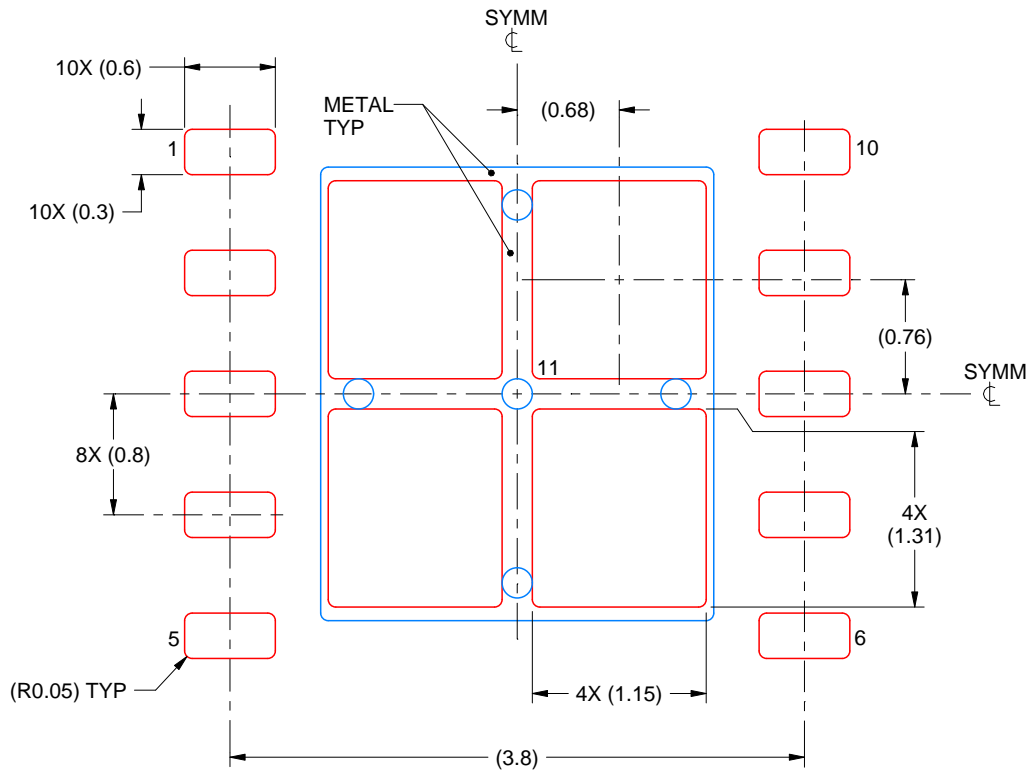
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

EXAMPLE STENCIL DESIGN

DPR0010A

WSN - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



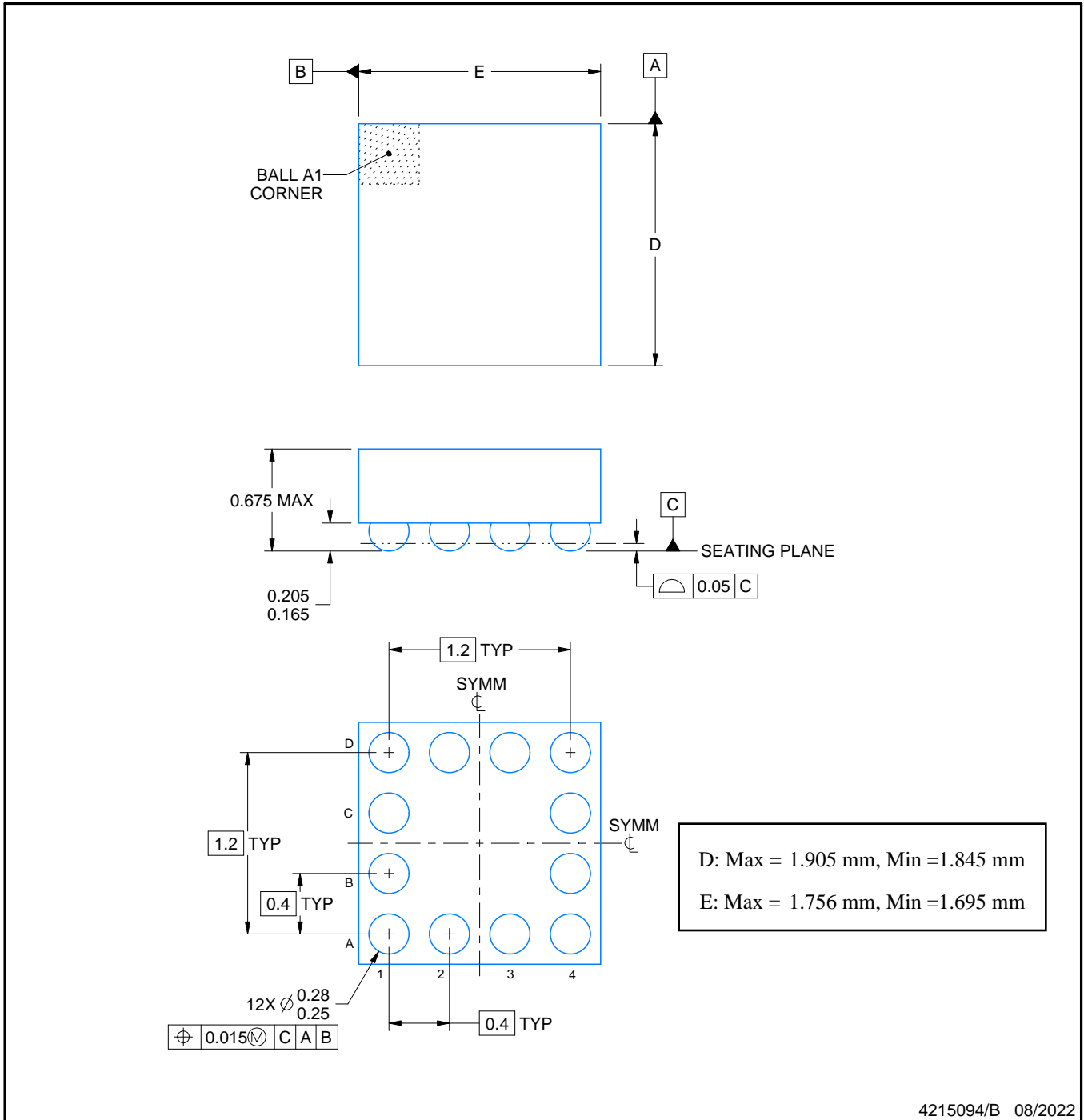
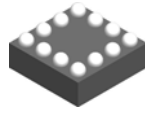
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

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.



NOTES:

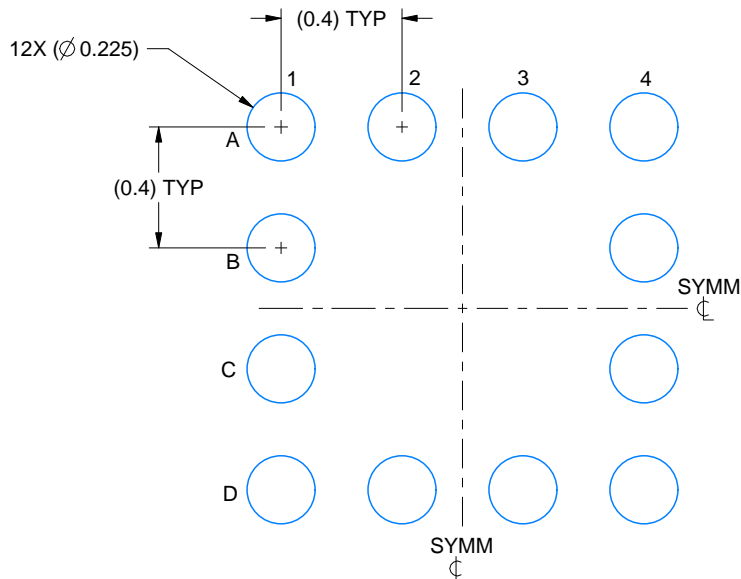
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

EXAMPLE BOARD LAYOUT

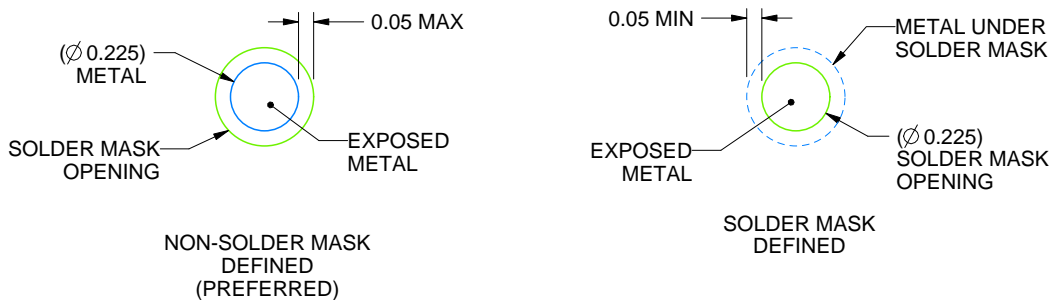
YFX0012

DSBGA - 0.675 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 40X



SOLDER MASK DETAILS
NOT TO SCALE

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NOTES: (continued)

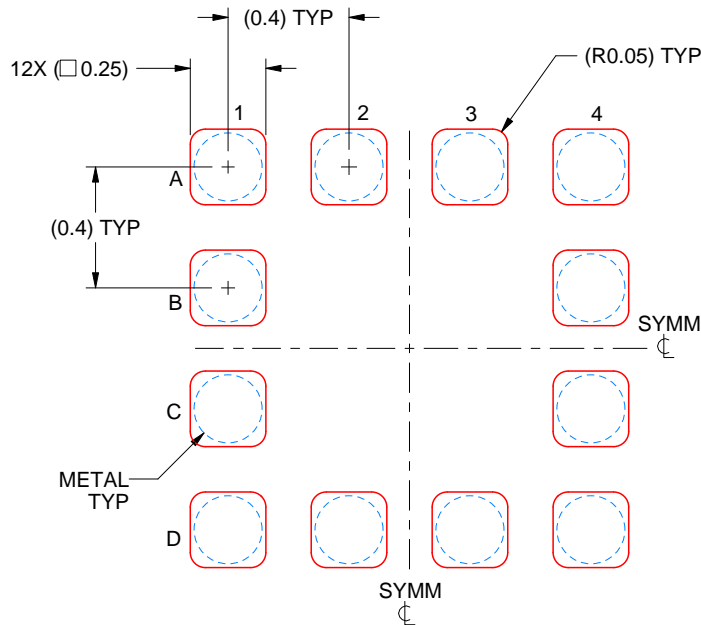
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. See Texas Instruments Literature No. SNVA009 (www.ti.com/lit/snva009).

EXAMPLE STENCIL DESIGN

YFX0012

DSBGA - 0.675 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE: 40X

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NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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