









LMG5200

Design

JAJSCT8D - MARCH 2015 - REVISED MARCH 2017

LMG5200 80V、10A GaNハーフ・ブリッジ電力スラ -ジ

#### 特長 1

Texas

INSTRUMENTS

- 15mΩ GaN FETおよびドライバを内蔵
- 電圧定格:連続80V、パルス100V
- PCBレイアウトが簡単になるようパッケージを最 適化、アンダーフィル、クリーページ、クリアラ ンスの要件を撤廃
- 共通ソース・インダクタンスが非常に低いため、 ハード・スイッチングのトポロジで過剰なリンギ ングなしに高いスルー・レートのスイッチングを 保証
- 絶縁および非絶縁アプリケーションに最適
- ゲート・ドライバは最高10MHzのスイッチングが 可能
- 内部的なブートストラップ電源電圧クランピング により、GaN FETオーバードライブを防止
- 電源レールの低電圧誤動作防止保護
- 非常に優れた伝搬遅延(標準値29.5ns)およびマッ チング(標準値2ns)
- 低消費電力 ٠

ÆΑ

- 2 アプリケーション
- 広いVINのマルチMHz同期整流降圧コンバータ
- オーディオ用Class-Dアンプ
- テレコム、産業、エンタープライズ・コンピュー ティング用の、48Vのポイント・オブ・ロード (POL)コンバータ
- 電力密度の高い単相および三相モータ・ドライブ

# 3 概要

LMG5200デバイスは80V、10AのドライバにGaNハーフ・ ブリッジ電力ステージを加えたもので、エンハンスメント・ モードの窒化ガリウム(GaN) FETを使用する統合電力ス テージ・ソリューションに使用できます。このデバイスは2 つの80V GaN FETで構成され、1つの高周波数GaN FETドライバによりハーフ・ブリッジ構成で駆動されます。

GaN FETは逆方向回復時間がほぼゼロで、入力容量 Cissが非常に小さいため、電力変換において大きな利点 があります。すべてのデバイスはボンド・ワイヤを一切使用 しないパッケージ・プラットフォームに取り付けられ、パッ ケージの寄生要素は最小限に抑えられます。LMG5200 デバイスは、6mm×8mm×2mmの鉛フリー・パッケージで 供給され、簡単にPCBへ取り付けできます。

TTLロジック互換の入力は、VCC電圧にかかわらず最高 12Vの入力電圧に耐えられます。独自のブートストラップ 電圧クランピング技法により、エンハンスメント・モードGaN FETのゲート電圧が安全な動作範囲内であることが保証さ れます。

このデバイスは、ディスクリートGaN FETに対して、より使 いやすいインターフェイスを提供し、その利点を拡大しま す。小さなフォーム・ファクタで高周波数、高効率の動作が 必要なアプリケーションに理想的なソリューションです。 LMG5200をTPS53632Gコントローラとともに使用すると、 48Vからポイント・オブ・ロード電圧(0.5~1.5V)への直接 変換が可能です。

**刬品情報**<sup>(1)</sup>

2000 111 10				
型番	パッケージ	本体サイズ(公称)		
LMG5200	QFM (9)	6.00mm×8.00mm		

(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。



#### ブロック概略図

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# 目次

1	特長	:1
2	アプ	リケーション1
3	概要	
4	改訂	'履歴2
5	Pin	Configuration and Functions 3
6	Spe	cifications 4
	6.1	Absolute Maximum Ratings 4
	6.2	ESD Ratings 4
	6.3	Recommended Operating Conditions 4
	6.4	Thermal Information5
	6.5	Electrical Characteristics 5
	6.6	Typical Characteristics 7
7	Para	ameter Measurement Information
	7.1	Propagation Delay and Mismatch Measurement 8
8	Deta	ailed Description
	8.1	Overview
	8.2	Functional Block Diagram 10
	8.3	Feature Description 10

Revision C (December 2016) から Revision D に変更

# 4 改訂履歴

2

<ul> <li>         全般的な編集およびSDSの更新        </li></ul>	1
Changed Thermal Information table	5
Revision B (January 2016) から Revision C に変更	Page
- GaNテクノロジのプレビューから量産データへ 変更	1
• 追加 Device Functional Modes Section	12
• 追加 Typical Application Section	12
Updated Power Supply Recommendations Section	15
• 追加 開発サポート・セクションへのリンク	20
Revision A (March 2015) から Revision B に変更	Page
● 変更 part number typographical error in 図 14	16
2015年3月発行のものから更新	Page
<ul> <li>ブロック概略図の誤字を修正</li> </ul>	
Corrected typographical error in 🛛 5	
<ul> <li>Corrected typographical error in          10</li></ul>	
Corrected three reaching over in 11	10

	8.4	Device Functional Modes	. 12
9	Appl	ication and Implementation	12
	9.1	Application Information	. 12
	9.2	Typical Application	. 12
10	Pow	er Supply Recommendations	15
11	Layo	out	16
	11.1	Layout Guidelines	. 16
	11.2	Layout Examples	. 16
12	デバ	イスおよびドキュメントのサポート	20
	12.1	デバイス・サポート	. 20
	12.2	ドキュメントのサポート	. 20
	12.3	ドキュメントの更新通知を受け取る方法	. 20
	12.4	コミュニティ・リソース	. 20
	12.5	商標	20
	12.6	静電気放電に関する注意事項	. 20
	12.7	Glossary	. 20
13	メカニ	ニカル、パッケージ、および注文情報	20
	13.1	パッケージ情報	. 21

#### TEXAS INSTRUMENTS

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Page



#### LMG5200 JAJSCT8D – MARCH 2015 – REVISED MARCH 2017

# 5 Pin Configuration and Functions



#### **Pin Functions**

PIN		<b>UO</b> (1)	DESCRIPTION	
NAME	NO.	1/0	DESCRIPTION	
AGND	7	G	Analog ground. Ground of driver device.	
HB	2	Р	High-side gate driver bootstrap rail.	
HI	4	I	High-side gate driver control input	
HS	3	Р	High-side GaN FET source connection	
LI	5	I	Low-side driver control input	
PGND	9	G	Power ground. Low-side GaN FET source. Electrically shorted to AGND pin.	
SW	8	Р	Switching node. Electrically shorted to HS pin. Ensure low capacitance at this node on PCB.	
VCC	6	Р	5-V positive gate drive supply	
VIN	1	Р	Input voltage pin. Electrically connected to high-side GaN FET drain.	

(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)<sup>(1)</sup>

PARAMETER	MIN	MAX	UNIT
VIN to PGND	0	80	V
VIN to PGND (pulsed, 100-ms maximum duration) <sup>(2)</sup>		100	V
HB to AGND	-0.3	86	V
HS to AGND	-5	80	V
HI to AGND	-0.3	12	V
LI to AGND	-0.3	12	V
VCC to AGND	-0.3	6	V
HB to HS	-0.3	6	V
HB to VCC	0	80	V
SW to PGND	-5	80	V
IOUT from SW pin		10	А
Junction temperature, T <sub>J</sub>	-40	125	°C
Storage temperature, T <sub>stg</sub>	-40	150	°C

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.

(2) Device can withstand 1000 pulses up to 100 V of 100-ms duration and less than 1% duty cycle over its lifetime.

### 6.2 ESD Ratings

			VALUE	UNIT
		Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±1000	V
V <sub>(ESD)</sub>	Electrostatic discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±500	V

(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.

#### 6.3 Recommended Operating Conditions

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

	MIN	NOM MAX	UNIT
VCC	4.75	5 5.25	V
LI or HI Input	0	12	V
VIN	0	80	V
HS, SW	-5	80	V
НВ	V <sub>HS</sub> + 4	V <sub>HS</sub> + 5.25	V
HS, SW slew rate <sup>(1)</sup>		50	V/ns
Junction temperature, T <sub>J</sub>	-40	125	°C

(1) This parameter is ensured by design. Not tested in production.

# 6.4 Thermal Information

	LMG5200		
	THERMAL METRIC <sup>(1)</sup> <sup>(2)</sup>	MOF (QFM)	UNIT
		9 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	35	°C/W
R <sub>0JC(top)</sub>	Junction-to-case (top) thermal resistance	18	°C/W
R <sub>0JB</sub>	Junction-to-board thermal resistance	16	°C/W
ΤΙ Ψ	Junction-to-top characterization parameter	1.8	°C/W
ΨЈВ	Junction-to-board characterization parameter	16	°C/W

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

(2) For thermal estimates of this device based on PCB copper area, see the *TI PCB Thermal Calculator*.

# 6.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT		
SUPPLY	SUPPLY CURRENTS							
I <sub>CC</sub>	VCC quiescent current	LI = HI = 0 V, VCC = 5 V, HB-HS = 4.6 V		0.08	0.125	mA		
I <sub>CCO</sub>	Total VCC operating current	f = 500 kHz		3	5	mA		
I <sub>HB</sub>	HB quiescent current	LI = HI = 0 V, VCC = 5 V, HB-HS = 4.6 V		0.09	0.15	mA		
I <sub>HBO</sub>	HB operating current	f = 500 kHz, 50% Duty cycle, $V_{DD}$ = 5 V		1.5	2.5	mA		
INPUT PI	NS				·			
V <sub>IH</sub>	High-level input voltage threshold	Rising edge	1.87	2.06	2.22	V		
V <sub>IL</sub>	Low-level input voltage threshold	Falling edge	1.48	1.66	1.76	V		
V <sub>HYS</sub>	Hysteresis between rising and falling threshold			400		mV		
RI	Input pulldown resistance		100	200	300	kΩ		
UNDERV	OLTAGE PROTECTION				i			
V <sub>CCR</sub>	V <sub>CC</sub> Rising edge threshold	Rising	3.2	3.8	4.5	V		
V <sub>CC(hyst)</sub>	$V_{CC}$ UVLO threshold hysteresis			200		mV		
V <sub>HBR</sub>	HB Rising edge threshold	Rising	2.5	3.2	3.9	V		
V <sub>HB(hyst)</sub>	HB UVLO threshold hysteresis			200		mV		
BOOTST	RAP DIODE							
V <sub>DL</sub>	Low-current forward voltage	I <sub>VDD-HB</sub> = 100 μA		0.45	0.65	V		
$V_{DH}$	High current forward voltage	$I_{VDD-HB} = 100 \text{ mA}$		0.9	1.0	V		
R <sub>D</sub>	Dynamic resistance	I <sub>VDD-HB</sub> = 100 mA		1.85	2.8	Ω		
	HB-HS clamp	Regulation Voltage	4.65	5	5.2	V		
t <sub>BS</sub>	Bootstrap diode reverse recovery time	I <sub>F</sub> = 100 mA, IR = 100 mA		40		ns		
Q <sub>RR</sub>	Bootstrap diode reverse recovery charge	V <sub>VIN</sub> = 50 V		2		nC		

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

# **Electrical Characteristics (continued)**

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

	PARAMETER	TEST CONDITIONS	MIN TYP	MAX	UNIT		
POWER STAGE							
R <sub>DS(ON)H</sub> s	High-side GaN FET on- resistance	$\label{eq:LI} \begin{array}{l} LI = 0 \ V, \ HI = VCC = 5 \ V, \ HB \text{-} HS = 5 \ V, \\ VIN \text{-} SW = 10 \ A, \ T_J = 25^\circ C \end{array}$	15	20	mΩ		
R <sub>DS(ON)LS</sub>	Low-side GaN FET on- resistance	LI = VCC = 5V, HI = 0 V, HB-HS = 5 V, SW-PGND = 10 A, $T_J = 25^{\circ}C$	15	20	mΩ		
V <sub>SD</sub>	GaN 3rd quadrant conduction drop	$I_{SD}$ = 500 mA, V_{IN} floating, V_{VCC} = 5 V, HI = LI = 0 V	2		V		
I <sub>L-VIN-SW</sub>	Leakage from VIN to SW when the high-side GaN FET and low- side GaN FET are off	VIN = 80 V, HI = LI = 0 V, $V_{VCC}$ = 5 V, $T_{J}$ = 25°C	25	150	μA		
I <sub>L-SW-GND</sub>	Leakage from SW to GND when the high-side GaN FET and low- side GaN FET are off	SW = 80 V, HI = LI = 0 V, $V_{VCC}$ = 5V, $T_{J}$ = 25°C	25	150	μA		
C <sub>OSS</sub>	Output capacitance of high-side GaN FET and low-side GaN FET	V <sub>DS</sub> =40 V, V <sub>GS</sub> = 0V (HI = LI = 0 V)	266		pF		
Q <sub>G</sub>	Total gate charge	$V_{DS}$ =40 V, I <sub>D</sub> = 10A, V <sub>GS</sub> = 5 V	3.8		nC		
Q <sub>OSS</sub>	Output charge	V <sub>DS</sub> =40 V, I <sub>D</sub> = 10 A	21		nC		
Q <sub>RR</sub>	Source-to-drain reverse recovery charge	Not including internal driver bootstrap diode	0		nC		
t <sub>HIPLH</sub>	Propagation delay: HI rising <sup>(2)</sup>	LI = 0 V, VCC = 5 V, HB-HS = 5 V, VIN = 30 V	29.5	50	ns		
t <sub>HIPHL</sub>	Propagation delay: HI falling <sup>(2)</sup>	LI = 0 V, VCC = 5 V, HB-HS = 5 V, VIN = 30 V	29.5	50	ns		
t <sub>LPLH</sub>	Propagation delay: LI rising <sup>(2)</sup>	HI = 0 V, VCC = 5 V, HB-HS = 5 V, VIN = 30 V	29.5	50	ns		
t <sub>LPHL</sub>	Propagation delay: LI falling <sup>(2)</sup>	HI = 0 V, VCC = 5 V, HB-HS = 5 V, VIN = 30 V	29.5	50	ns		
t <sub>MON</sub>	Delay matching: LI high and HI $\log^{(2)}$		2	8	ns		
t <sub>MOFF</sub>	Delay matching: LI low and HI high <sup>(2)</sup>		2	8	ns		
t <sub>PW</sub>	Minimum input pulse width that changes the output		10		ns		

(2) See Propagation Delay and Mismatch Measurement.



#### 6.6 Typical Characteristics

All the curves are based on measurements made on a PCB design with dimensions of 3.2 inches (W)  $\times$  2.7 inches (L)  $\times$  0.062 inch (T) and 4 layers of 2 oz copper.

The safe operating area (SOA) curves displays the temperature boundaries within an operating system by incorporating the thermal resistance and system power loss. A buck converter is used for measuring the SOA. 2 outlines the temperature and airflow conditions required for a given load current. The area under the curve dictates the SOA for different airflow conditions.



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# 7 Parameter Measurement Information

#### 7.1 Propagation Delay and Mismatch Measurement

⊠ 5 shows the typical test setup used to measure the propagation mismatch. As the gate drives are not accessible, pullup and pulldown resistors in this test circuit are used to indicate when the low-side GaN FET turns ON and the high-side GaN FET turns OFF and vice versa to measure the t<sub>MON</sub> and t<sub>MOFF</sub> parameters. Resistance values used in this circuit for the pullup and pulldown resistors are in the order of 1 kΩ; the current sources used are 2 A.

⊠ 6 through ⊠ 9 show propagation delay measurement waveforms. For turnon propagation delay measurements, the current sources are not used. For turnoff time measurements, the current sources are set to 2 A, and a voltage clamp limit is also set, referred to as  $VIN_{(CLAMP)}$ . When measuring the high-side component turnoff delay, the current source across the high-side FET is turned on, the current source across the low-side FET is off, HI transitions from high-to-low, and output voltage transitions from  $V_{IN}$  to  $V_{IN(CLAMP)}$ . Similarly, for low-side component turnoff propagation delay measurements, the high-side component current source is turned off, and the low-side component current source is turned on, LI transitions from high to low and the output transitions from GND potential to  $V_{IN(CLAMP)}$ . The time between the transition of LI and the output change is the propagation delay time.



図 5. Propagation Delay and Propagation Mismatch Measurement



#### Propagation Delay and Mismatch Measurement (continued)



# 8 Detailed Description

#### 8.1 Overview

⊠ 10 shows the LMG5200, half-bridge, GaN power stage with highly integrated high-side and low-side gate drivers, which includes built-in UVLO protection circuitry and an overvoltage clamp circuitry. The clamp circuitry limits the bootstrap refresh operation to ensure that the high-side gate driver overdrive does not exceed 5.4 V. The device integrates two, 15-mΩ GaN FETs in a half-bridge configuration. The device can be used in many isolated and non-isolated topologies allowing very simple integration. The package is designed to minimize the loop inductance while keeping the PCB design simple. The drive strengths for turnon and turnoff are optimized to ensure high voltage slew rates without causing any excessive ringing on the gate or power loop.

LMG5200 JAJSCT8D – MARCH 2015 – REVISED MARCH 2017

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### 8.2 Functional Block Diagram

☑ 10 shows the functional block diagram of the LMG5200 device with integrated high-side and low-side GaN FETs.



図 10. Functional Block Diagram

# 8.3 Feature Description

The LMG5200 device brings ease of designing high power density boards without the need for underfill while maintaining creepage and clearance requirements. The propagation delays between the high-side gate driver and low-side gate driver are matched to allow very tight control of dead time. Controlling the dead time is critical in GaN-based applications to maintain high efficiency. HI and LI can be independently controlled to minimize the third quadrant conduction of the low-side FET for hard switched buck converters. A very small propagation mismatch between the HI and LI to the drivers for both the falling and rising thresholds ensures dead times of < 10 ns. Co-packaging the GaN FET half-bridge with the driver ensures minimized common source inductance. This minimized inductance has a significant performance impact on hard-switched topologies.

The built-in bootstrap circuit with clamp prevents the high-side gate drive from exceeding the GaN FETs maximum gate-to-source voltage (Vgs) without any additional external circuitry. The built-in driver has an undervoltage lockout (UVLO) on the VDD and bootstrap (HB-HS) rails. When the voltage is below the UVLO threshold voltage, the device ignores both the HI and LI signals to prevent the GaN FETs from being partially turned on. Below UVLO, if there is sufficient voltage ( $V_{VCC} > 2.5 V$ ), the driver actively pulls the high-side and low-side gate driver output low. The UVLO threshold hysteresis of 200 mV prevents chattering and unwanted turnon due to voltage spikes. Use an external VCC bypass capacitor with a value of 0.1 µF or higher. TI recommends a size of 0402 to minimize trace length to the pin. Place the bypass and bootstrap capacitors as close as possible to the device to minimize parasitic inductance.

#### 8.3.1 Control Inputs

The LMG5200's inputs pins are independently controlled with TTL input thresholds and can withstand voltages up to 12V regardless of the VDD voltage. This allows the inputs to be directly connected to the outputs of an analog PWM controller with up to 12V power supply, eliminating the need for a buffer stage.

In order to allow flexibility to optimize deadtime according to design needs, the LMG5200 does not implement an overlap protection functionality. If both HI and LI are asserted, both the high-side and low-side GaN FETs are turned on. Careful consideration must be applied to the control inputs in order to avoid a shoot-through condition.



#### Feature Description (continued)

#### 8.3.2 Start-up and UVLO

The LMG5200 has an UVLO on both the V<sub>CC</sub> and HB (bootstrap) supplies. When the V<sub>CC</sub> 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 V<sub>CC</sub> voltage, the UVLO actively pulls the high- and low-side GaN FET gates low. When the HB to HS bootstrap voltage is below the UVLO threshold of 3.2 V, only the high-side GaN FET

	• •		
CONDITION (V <sub>HB-HS</sub> > V <sub>HBR</sub> for all cases below)	н	LI	SW
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ during device start-up	Н	L	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ during device start-up	L	Н	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ during device start-up	Н	Н	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ during device start-up	L	L	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ - $V_{CC(hyst)}$ after device start-up	Н	L	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ - $V_{CC(hyst)}$ after device start-up	L	Н	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ - $V_{CC(hyst)}$ after device start-up	Н	Н	Hi-Z
$V_{CC}$ - $V_{SS}$ < $V_{CCR}$ - $V_{CC(hyst)}$ after device start-up	L	L	Hi-Z

#### 表 1. V<sub>CC</sub> UVLO Feature Logic Operation

gate is pulled low. Both UVLO threshold voltages have 200 mV of hysteresis to avoid chattering.

### 表 2. V<sub>HB-HS</sub> UVLO Feature Logic Operation

CONDITION (V <sub>CC</sub> > V <sub>CCR</sub> for all cases below)	н	LI	SW
V <sub>HB-HS</sub> < V <sub>HBR</sub> during device start-up	Н	L	Hi-Z
V <sub>HB-HS</sub> < V <sub>HBR</sub> during device start-up	L	Н	PGND
V <sub>HB-HS</sub> < V <sub>HBR</sub> during device start-up	н	Н	PGND
V <sub>HB-HS</sub> < V <sub>HBR</sub> during device start-up	L	L	Hi-Z
V <sub>HB-HS</sub> < V <sub>HBR</sub> - V <sub>HB(hyst)</sub> after device start-up	н	L	Hi-Z
V <sub>HB-HS</sub> < V <sub>HBR</sub> - V <sub>HB(hyst)</sub> after device start-up	L	Н	PGND
V <sub>HB-HS</sub> < V <sub>HBR</sub> - V <sub>HB(hyst)</sub> after device start-up	Н	Н	PGND
V <sub>HB-HS</sub> < V <sub>HBR</sub> - V <sub>HB(hyst)</sub> after device start-up	L	L	Hi-Z

#### 8.3.3 Bootstrap Supply Voltage Clamping

The high-side bias voltage is generated using a bootstrap technique and is internally clamped at 5 V (typical). This clamp prevents the gate voltage from exceeding the maximum gate-source voltage rating of the enhancement-mode GaN FETs.

#### 8.3.4 Level Shift

The level-shift circuit is the interface from the high-side input HI to the high-side driver stage, which is referenced to the switch node (HS). The level shift allows control of the high-side GaN FET gate driver output, which is referenced to the HS pin and provides excellent delay matching with the low-side driver.

LMG5200 JAJSCT8D – MARCH 2015–REVISED MARCH 2017

#### 8.4 Device Functional Modes

The LMG5200 operates in normal mode and UVLO mode. See *Start-up and UVLO* for information on UVLO operation mode. In the normal mode, the output state is dependent on the states of the HI and LI pins. 表 3 lists the output states for different input pin combinations. Note that when both HI and LI are asserted, both GaN FETs in the power stage are turned on. Careful consideration must be applied to the control inputs in order to avoid this state, as it will result in a shoot-through condition, which can permanently damage the device.

HI	LI	HIGH-SIDE GaN FET	LOW-SIDE GaN FET	SW
L	L	OFF	OFF	Hi-Z
L	Н	OFF	ON	PGND
Н	L	ON	OFF	VIN
Н	Н	ON	ON	

#### 表 3. Truth Table

#### **9** Application and Implementation

注 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

The LMG5200 GaN power stage is a versatile building block for various types of high-frequency, switch-mode power applications. The high-performance gate driver IC integrated in the package helps minimize the parasitics and results in extremely fast switching of the GaN FETs. The device design is highly optimized for synchronous buck converters and other half-bridge configurations.

#### 9.2 Typical Application

☑ 11 shows a synchronous buck converter application with  $V_{CC}$  connected to a 5-V supply. It is critical to optimize the power loop (loop impedance from VIN capacitor to PGND). Having a high power loop inductance causes significant ringing in the SW node and also causes the associated power loss. Refer to the *Layout Guidelines* section for information on how to minimize this power loop.



図 11. Typical Connection Diagram For a Synchronous Buck Converter

#### Typical Application (continued)

#### 9.2.1 Design Requirements

When designing a synchronous buck converter application that incorporates the LMG5200 power stage, some design considerations must be evaluated first to make the most appropriate selection. Among these considerations are the input voltages, passive components, operating frequency, and controller selection.  $\pm 4$  shows some sample values for a typical application. See *Power Supply Recommendations, Layout*, and *Power Dissipation* for other key design considerations for the LMG5200.

	-
PARAMETER	SAMPLE VALUE
Half-bridge input supply voltage, $V_{IN}$	48 V
Output voltage, V <sub>OUT</sub>	12 V
Output current	8 A
V <sub>HB-HS</sub> bootstrap capacitor	0.1 uF, X5R
Switching frequency	1 MHz
Dead time	8 ns
Inductor	4.7 μH
Controller	TPS40400

表 4. Design Parameters

#### 9.2.2 Detailed Design Procedure

This procedure outlines the design considerations of LMG5200 in a synchronous buck converter. For additional design help, see *関連資料*.

#### 9.2.2.1 V<sub>CC</sub> Bypass Capacitor

The V<sub>CC</sub> 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  $\pm$  1.

$$C_{VCC} = (Q_{qH} + Q_{qL} + Q_{rr}) / \Delta V$$

 $Q_{gH}$  and  $Q_{gL}$  are the gate charge of the high-side and low-side transistors, respectively.  $Q_{rr}$  is the reverse recovery charge of the bootstrap diode.  $\Delta V$  is the maximum allowable voltage drop across the bypass capacitor. A 0.1- $\mu$ F or larger value, good-quality, ceramic capacitor is recommended. Place the bypass capacitor as close as possible to the V<sub>CC</sub> and AGND pins of the device to minimize the parasitic inductance.

#### 9.2.2.2 Bootstrap Capacitor

The bootstrap capacitor provides the gate charge for the high-side gate drive, dc bias power for HB UVLO circuit, and the reverse recovery charge of the bootstrap diode. The required bypass capacitance can be calculated using  $\pm 2$ .

$$C_{BST} = (Q_{qH} + Q_{rr} + I_{HB} * t_{ON(max)}) / \Delta V$$

where

- $I_{HB}$  is the quiescent current of the high-side gate driver (150  $\mu$ A, maximum)
- t<sub>ON</sub>(maximum) is the maximum on-time period of the high-side gate driver
- Q<sub>rr</sub> is the reverse recovery charge of the bootstrap diode
- $Q_{gH}$  is the gate charge of the high-side GaN FET
- ΔV is the permissible ripple in the bootstrap capacitor (< 100 mV, typical)</li>

A 0.1- $\mu$ F, 16-V, 0402 ceramic capacitor is suitable for most applications. Place the bootstrap capacitor as close as possible to the HB and HS pins.

(1)

(2)

#### 9.2.2.3 Power Dissipation

Ensure that the power loss in the driver and the GaN FETs is maintained below the maximum power dissipation limit of the package at the operating temperature. The smaller the power loss in the driver and the GaN FETs, the higher the maximum operating frequency that can be achieved in the application. The total power dissipation of the LMG5200 device is the sum of the gate driver losses, the bootstrap diode power loss and the switching and conduction losses in the FETs.

The gate driver losses are incurred by charge and discharge of the capacitive load. It can be approximated using 式 3.

$$\mathsf{P} = (2 \times \mathsf{Q}_{\mathsf{q}}) \times \mathsf{V}_{\mathsf{DD}} \times \mathsf{f}_{\mathsf{SW}}$$

where

- Q<sub>a</sub> is the gate charge
- V<sub>DD</sub> is the bias supply
- f<sub>SW</sub> is the switching frequency

There are some additional losses in the gate drivers due to the internal CMOS stages used to buffer the outputs. 1 shows the measured gate driver power dissipation versus frequency and load capacitance. Use this graph to approximate the power losses due to the gate drivers.

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. Higher input voltages (V<sub>IN</sub>) to the half bridge also result in higher reverse recovery losses.

The power losses due to the GaN FETs can be divided into conduction losses and switching losses. Conduction losses are resistive losses and can be calculated using  $\pm 4$ .

$$P_{\text{COND}} = \left[ (I_{\text{RMS(HS)}})^2 \times \text{RDS}_{(\text{on})\text{HS}} \right] + \left[ (I_{\text{RMS(LS)}})^2 \times \text{RDS}_{(\text{on})\text{LS}} \right]$$

where

- R<sub>DS(on)HS</sub> is the high-side GaN FET on-resistance
- R<sub>DS(on)LS</sub> is the low-side GaN FET on-resistance
- $I_{RMS(HS)}$  is the high-side GaN FET RMS current
- I<sub>RMS(LS)</sub> and low-side GaN FET RMS current

The switching losses can be computed to a first order using  $\pm 5$ .

 $P_{SW} = V_{IN} \times I_{OUT} \times f_{SW} \times t_{TR}$ 

where

14

•  $t_{TR}$  is the switch transition time from ON to OFF and from OFF to ON

Note that the low-side FET does not suffer from this loss. The third quadrant loss in the low-side device is ignored in this first order loss calculation.

As described previously, switching frequency has a direct effect on device power dissipation. Although the gate driver of the LMG5200 device is capable of driving the GaN FETs at frequencies up to 10 MHz, careful consideration must be applied to ensure that the running conditions for the device meet the recommended operating temperature specification. Specifically, hard-switched topologies tend to generate more losses and selfheating than soft-switched applications.

The sum of the driver loss, the bootstrap diode loss, and the switching and conduction losses in the GaN FETs is the total power loss of the device. Careful board layout with an adequate amount of thermal vias close to the power pads (VIN and PGND) allows optimum power dissipation from the package. A top-side mounted heat sink with airflow can also improve the package power dissipation.

(5)

(4)

(3)



#### 9.2.3 Application Curves



# **10 Power Supply Recommendations**

The recommended bias supply voltage range for LMG5200 is from 4.75 V to 5.25 V. The lower end of this range is governed by the internal undervoltage lockout (UVLO) protection feature of the V<sub>CC</sub> supply circuit. The upper end of this range is driven by the 6 V absolute maximum voltage rating of V<sub>CC</sub>. Note that the gate voltage of the low-side GaN FET is not clamped internally. Hence, it is important to keep the V<sub>CC</sub> bias supply within the recommended operating range to prevent exceeding the low-side GaN transistor gate breakdown voltage.

The UVLO protection feature also involves a hysteresis function. This means that once the device is operating in normal mode, if the  $V_{CC}$  voltage drops, the device continues to operate in normal mode as far as the voltage drop does not exceeds the hysteresis specification,  $V_{CC(hyst)}$ . 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 must be smaller than the hysteresis specification of LMG5200 to avoid triggering device-shutdown.

Place a local bypass capacitor 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  $\mu$ F, for IC bias requirements.



# 11 Layout

#### 11.1 Layout Guidelines

To maximize the efficiency benefits of fast switching, it is extremely important to optimize the board layout such that the power loop impedance is minimal. When using a multilayer board (more than 2 layers), power loop parasitic impedance is minimized by having the return path to the input capacitor (between VIN and PGND), small and directly underneath the first layer as shown in ⊠ 14 and ⊠ 15. Loop inductance is reduced due to flux cancellation as the return current is directly underneath and flowing in the opposite direction. It is also critical that the VCC capacitors and the bootstrap capacitors are as close as possible to the device and in the first layer. Carefully consider the AGND connection of LMG5200 device. It must NOT be directly connected to PGND so that PGND noise does not directly shift AGND and cause spurious switching events due to noise injected in HI and LI signals.

### 11.2 Layout Examples

Placements shown in  $\boxtimes$  14 and in the cross section of  $\boxtimes$  15 show the suggested placement of the device with respect to sensitive passive components, such as VIN, bootstrap capacitors (HS and HB) and VSS capacitors. Use appropriate spacing in the layout to reduce creepage and maintain clearance requirements in accordance with the application pollution level. Inner layers if present can be more closely spaced due to negligible pollution.

The layout must be designed to minimize the capacitance at the SW node. Use as small an area of copper as possible to connect the device SW pin to the inductor, or transformer, or other output load. Furthermore, ensure that the ground plane or any other copper plane has a cutout so that there is no overlap with the SW node, as this would effectively form a capacitor on the printed circuit board. Additional capacitance on this node reduces the advantages of the advanced packaging approach of the LMG5200 and may result in reduced performance. ☑ 16, ☑ 17, ☑ 18, and ☑ 19 show an example of how to design for minimal SW node capacitance on a four-layer board. In these figures, U1 is the LMG5200 device.







# Layout Examples (continued)



図 15. Four-Layer Board Cross Section With Return Path Directly Underneath for Power Loop



図 16. Top Layer

図 17. Ground Plane

LMG5200 JAJSCT8D – MARCH 2015 – REVISED MARCH 2017



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### Layout Examples (continued)



図 20. External Component Placement (Double Layer PCB)



#### Layout Examples (continued)



21. Two-Layer Board Cross Section With Return Path

Two-layer boards are not recommended for use with LMG5200 device due to the larger power loop inductance. However, if design considerations allow only two board layers, place the input decoupling capacitors immediately behind the device on the back-side of the board to minimize loop inductance.  $\boxtimes$  20 and  $\boxtimes$  21 show a layout example for two-layer boards.

TEXAS INSTRUMENTS

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# 12 デバイスおよびドキュメントのサポート

# 12.1 デバイス・サポート

#### 12.1.1 開発サポート

LMG5200 PSpiceトランジェント・モデル LMG5200 TINA-TIトランジェント・リファレンス・デザイン LMG5200 TINA-TIトランジェントSpiceモデル

# 12.2 ドキュメントのサポート

#### 12.2.1 関連資料

『LMG5200 GaN電力ステージ・モジュールのレイアウト・ガイドライン』

『LMG5200の使用法: GaNハーフ・ブリッジ電力モジュール評価モジュール』

# 12.3 ドキュメントの更新通知を受け取る方法

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# 12.7 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

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Orderable part number	Status	Material type	Package   Pins	Package qty   Carrier	RoHS	Lead finish/	MSL rating/	Op temp (°C)	Part marking
	(1)	(2)			(3)	Ball material	Peak reflow		(6)
						(4)	(5)		
LMG5200MOFR	Active	Production	QFM (MOF)   9	2000   LARGE T&R	In-Work	NIAU	Level-3-260C-168 HR	-40 to 125	LMG5200
									513B
LMG5200MOFR.A	Active	Production	QFM (MOF)   9	2000   LARGE T&R	In-Work	NIAU	Level-3-260C-168 HR	-40 to 125	LMG5200
									513B
LMG5200MOFR.B	Active	Production	QFM (MOF)   9	2000   LARGE T&R	-	Call TI	Call TI	-40 to 125	
LMG5200MOFT	Active	Production	QFM (MOF)   9	250   SMALL T&R	Yes	NIAU	Level-3-260C-168 HR	-40 to 125	LMG5200
									513B
LMG5200MOFT.A	Active	Production	QFM (MOF)   9	250   SMALL T&R	Yes	NIAU	Level-3-260C-168 HR	-40 to 125	LMG5200
			. , ,						513B
LMG5200MOFT.B	Active	Production	QFM (MOF)   9	250   SMALL T&R	-	Call TI	Call TI	-40 to 125	

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

<sup>(2)</sup> **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.

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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
LMG5200MOFR	QFM	MOF	9	2000	330.0	16.4	6.3	8.3	2.2	12.0	16.0	Q1



# PACKAGE MATERIALS INFORMATION

5-Dec-2023



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMG5200MOFR	QFM	MOF	9	2000	350.0	350.0	43.0

# **MOF0009A**



# **PACKAGE OUTLINE**

# QFM - 2 mm max height

QUAD FLAT MODULE



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.



# **MOF0009A**

# **EXAMPLE BOARD LAYOUT**

# QFM - 2 mm max height

QUAD FLAT MODULE



NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



# **MOF0009A**

# **EXAMPLE STENCIL DESIGN**

# QFM - 2 mm max height

QUAD FLAT MODULE



NOTES: (continued)

4. 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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