

## LM5100 /LM5101 High Voltage High Side and Low Side Gate Driver

Check for Samples: [LM5100](#), [LM5101](#)

### FEATURES

- Drives Both a High Side and Low Side N-Channel MOSFET
- Independent High and Low Driver Logic Inputs (TTL for LM5101 or CMOS for LM5100)
- Bootstrap Supply Voltage Range up to 118V DC
- Fast Propagation Times (25 ns Typical)
- Drives 1000 pF Load with 15 ns Rise and Fall Times
- Excellent Propagation Delay Matching (3 ns Typical)
- Supply Rail Under-voltage Lockouts
- Low Power Consumption
- Pin Compatible with HIP2100/HIP2101

### TYPICAL APPLICATIONS

- Current Fed Push-pull Converters
- Half and Full Bridge Power Converters
- Synchronous Buck Converters
- Two Switch Forward Power Converters
- Forward with Active Clamp Converters

### PACKAGE

- SOIC-8
- WSON-10 (4 mm x 4 mm)

### DESCRIPTION

The LM5100/LM5101 High Voltage Gate Drivers are designed to drive both the high side and the low side N-Channel MOSFETs in a synchronous buck or a half bridge configuration. The floating high-side driver is capable of operating with supply voltages up to 100V. The outputs are independently controlled with CMOS input thresholds (LM5100) or TTL input thresholds (LM5101). An integrated high voltage diode is provided to charge the high side gate drive bootstrap capacitor. A robust level shifter operates at high speed while consuming low power and providing clean level transitions from the control logic to the high side gate driver. Under-voltage lockout is provided on both the low side and the high side power rails. This device is available in the standard SOIC-8 pin and the WSON-10 pin packages.



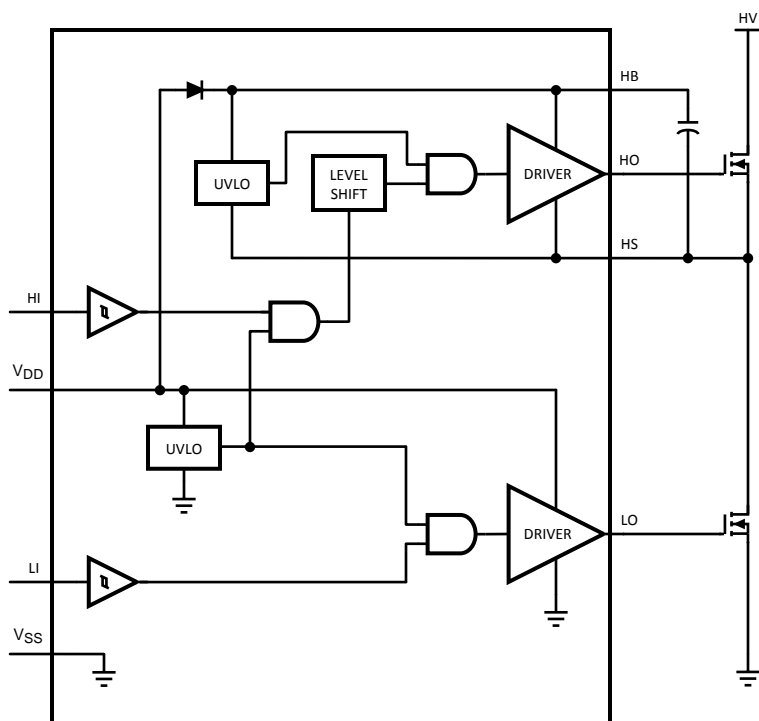
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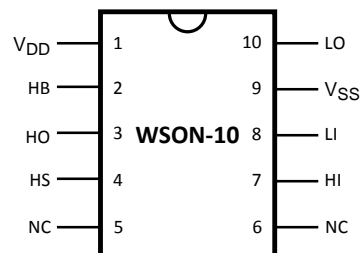
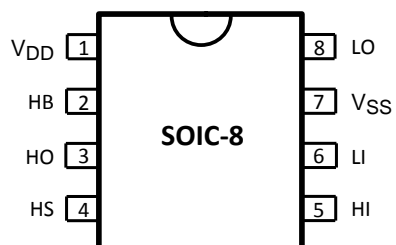
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## Simplified Block Diagram



## Connection Diagrams



**PIN DESCRIPTION<sup>(1)</sup>**

Pin #		Name	Description	Application Information
SO-8	WSO-10			
1	1	V <sub>DD</sub>	Positive gate drive supply	Locally decouple to V <sub>SS</sub> using low ESR/ESL capacitor located as close to IC as possible.
2	2	HB	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 IC as possible.
3	3	HO	High side gate driver output	Connect to gate of high side MOSFET with a short low inductance path.
4	4	HS	High side MOSFET source connection	Connect to bootstrap capacitor negative terminal and the source of the high side MOSFET.
5	7	HI	High side driver control input	The LM5100 inputs have CMOS type thresholds. The LM5101 inputs have TTL type thresholds. Unused inputs should be tied to ground and not left open.
6	8	LI	Low side driver control input	The LM5100 inputs have CMOS type thresholds. The LM5101 inputs have TTL type thresholds. Unused inputs should be tied to ground and not left open.
7	9	V <sub>SS</sub>	Ground return	All signals are referenced to this ground.
8	10	LO	Low side gate driver output	Connect to the gate of the low side MOSFET with a short low inductance path.

- (1) **Note:** For WSON-10 package, it is recommended that the exposed pad on the bottom of the LM5100 / LM5101 be soldered to ground plane on the PC board, and the ground plane should extend out from beneath the IC to help dissipate the heat. Pins 5 and 6 have no connection.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings<sup>(1)(2)</sup>

$V_{DD}$ to $V_{SS}$	-0.3V to +18V
$V_{HB}$ to $V_{HS}$	-0.3V to +18V
LI or HI Inputs	-0.3V to $V_{DD} + 0.3V$
LO Output	-0.3V to $V_{DD} + 0.3V$
HO Output	$V_{HS} - 0.3V$ to $V_{HB} + 0.3V$
$V_{HS}$ to $V_{SS}$	-1V to +100V
$V_{HB}$ to $V_{SS}$	118V
Junction Temperature	+150°C
Storage Temperature Range	-55°C to +150°C
ESD Rating HBM <sup>(3)</sup>	2 kV

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the component may occur. Operating Ratings are conditions under which operation of the device is ensured. Operating Ratings do not imply ensured performance limits. For ensured performance limits and associated test conditions, see the Electrical Characteristics tables.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) The human body model is a 100 pF capacitor discharged through a 1.5kΩ resistor into each pin. 2 kV for all pins except Pin 2, Pin 3 and Pin 4 which are rated at 500V.

## Recommended Operating Conditions

$V_{DD}$	+9V to +14V
HS	-1V to 100V
HB	$V_{HS} + 8V$ to $V_{HS} + 14V$
HS Slew Rate	< 50 V/ns
Junction Temperature	-40°C to +125°C

## Electrical Characteristics

Specifications in standard typeface are for  $T_J = +25^\circ\text{C}$ , and those in **boldface type** apply over the full **operating junction temperature range**. Unless otherwise specified,  $V_{DD} = V_{HB} = 12V$ ,  $V_{SS} = V_{HS} = 0V$ , No Load on LO or HO.

Symbol	Parameter	Conditions	Min <sup>(1)</sup>	Typ	Max <sup>(1)</sup>	Units
<b>SUPPLY CURRENTS</b>						
$I_{DD}$	$V_{DD}$ Quiescent Current	LI = HI = 0V (LM5100)		0.1	<b>0.2</b>	mA
		LI = HI = 0V (LM5101)		0.25	<b>0.4</b>	
$I_{DDO}$	$V_{DD}$ Operating Current	f = 500 kHz		1.5	<b>3</b>	mA
$I_{HB}$	Total HB Quiescent Current	LI = HI = 0V		0.06	<b>0.2</b>	mA
$I_{HBO}$	Total HB Operating Current	f = 500 kHz		1.3	<b>3</b>	mA
$I_{HBS}$	HB to $V_{SS}$ Current, Quiescent	$V_{HS} = V_{HB} = 100V$		0.05	<b>10</b>	μA
$I_{HBSO}$	HB to $V_{SS}$ Current, Operating	f = 500 kHz		0.08		mA
<b>INPUT PINS</b>						
$V_{IL}$	Low Level Input Voltage Threshold (LM5100)		<b>3</b>	5.0		V
$V_{IL}$	Low Level Input Voltage Threshold (LM5101)		<b>0.8</b>	1.8		V
$V_{IH}$	High Level Input Voltage Threshold (LM5100)			5.5	<b>8</b>	V
$V_{IH}$	High Level Input Voltage Threshold (LM5101)			1.8	<b>2.2</b>	V
$V_{IHYS}$	Input Voltage Hysteresis (LM5100)			0.5		V
$R_I$	Input Pulldown Resistance		<b>100</b>	200	<b>500</b>	kΩ
<b>UNDER VOLTAGE PROTECTION</b>						
$V_{DDR}$	$V_{DD}$ Rising Threshold		<b>6.0</b>	6.9	<b>7.4</b>	V

- (1) Min and Max limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. Limits are used to calculate TI's Average Outgoing Quality Level (AOQL).

## Electrical Characteristics (continued)

Specifications in standard typeface are for  $T_J = +25^{\circ}\text{C}$ , and those in **boldface type** apply over the full **operating junction temperature range**. Unless otherwise specified,  $V_{DD} = V_{HB} = 12\text{V}$ ,  $V_{SS} = V_{HS} = 0\text{V}$ , No Load on LO or HO.

Symbol	Parameter	Conditions	Min <sup>(1)</sup>	Typ	Max <sup>(1)</sup>	Units
$V_{DDH}$	$V_{DD}$ Threshold Hysteresis			0.5		V
$V_{HBR}$	HB Rising Threshold		<b>5.7</b>	6.6	<b>7.1</b>	V
$V_{HBH}$	HB Threshold Hysteresis			0.4		V
<b>BOOT STRAP DIODE</b>						
$V_{DL}$	Low-Current Forward Voltage	$I_{VDD-HB} = 100\text{ }\mu\text{A}$		0.6	<b>0.9</b>	V
$V_{DH}$	High-Current Forward Voltage	$I_{VDD-HB} = 100\text{ mA}$		0.85	<b>1.1</b>	V
$R_D$	Dynamic Resistance	$I_{VDD-HB} = 100\text{ mA}$		0.8	<b>1.5</b>	$\Omega$
<b>LO GATE DRIVER</b>						
$V_{OLL}$	Low-Level Output Voltage	$I_{LO} = 100\text{ mA}$		0.23	<b>0.4</b>	V
$V_{OHL}$	High-Level Output Voltage	$I_{LO} = -100\text{ mA}$ , $V_{OHL} = V_{DD} - V_{LO}$		0.35	<b>0.55</b>	V
$I_{OHL}$	Peak Pullup Current	$V_{LO} = 0\text{V}$		1.6		A
$I_{OLL}$	Peak Pulldown Current	$V_{LO} = 12\text{V}$		1.8		A
<b>HO GATE DRIVER</b>						
$V_{OLH}$	Low-Level Output Voltage	$I_{HO} = 100\text{ mA}$		0.23	<b>0.4</b>	V
$V_{OHH}$	High-Level Output Voltage	$I_{HO} = -100\text{ mA}$ , $V_{OHH} = V_{HB} - V_{HO}$		0.35	<b>0.55</b>	V
$I_{OHH}$	Peak Pullup Current	$V_{HO} = 0\text{V}$		1.6		A
$I_{OLH}$	Peak Pulldown Current	$V_{HO} = 12\text{V}$		1.8		A
<b>THERMAL RESISTANCE</b>						
$\theta_{JA}$ <sup>(2)</sup>	Junction to Ambient	SOIC-8		170		$^{\circ}\text{C/W}$
		WSO-10 <sup>(3)</sup>		40		

(2) The  $\theta_{JA}$  is not a given constant for the package and depends on the printed circuit board design and the operating environment.

(3) 4 layer board with Cu finished thickness 1.5/1/1/1.5 oz. Maximum die size used. 5x body length of Cu trace on PCB top. 50 x 50mm ground and power planes embedded in PCB. See Application Note AN-1187 ([SNOA401](#)).

## Switching Characteristics

Specifications in standard typeface are for  $T_J = +25^{\circ}\text{C}$ , and those in **boldface type** apply over the full **operating junction temperature range**. Unless otherwise specified,  $V_{DD} = V_{HB} = 12\text{V}$ ,  $V_{SS} = V_{HS} = 0\text{V}$ , No Load on LO or HO.

Symbol	Parameter	Conditions	Min <sup>(1)</sup>	Typ	Max <sup>(1)</sup>	Units
<b>LM5100</b>						
$t_{LPHL}$	Lower Turn-Off Propagation Delay (LI Falling to LO Falling)			24	<b>45</b>	ns
$t_{HPHL}$	Upper Turn-Off Propagation Delay (HI Falling to HO Falling)			24	<b>45</b>	ns
$t_{LPLH}$	Lower Turn-On Propagation Delay (LI Rising to LO Rising)			24	<b>45</b>	ns
$t_{HPLH}$	Upper Turn-On Propagation Delay (HI Rising to HO Rising)			24	<b>45</b>	ns
$t_{MON}$	Delay Matching: Lower Turn-On and Upper Turn-Off			2	<b>10</b>	ns
$t_{MOFF}$	Delay Matching: Lower Turn-Off and Upper Turn-On			2	<b>10</b>	ns
$t_{RC}, t_{FC}$	Either Output Rise/Fall Time	$C_L = 1000\text{ pF}$		15		ns
$t_R, t_F$	Either Output Rise/Fall Time (3V to 9V)	$C_L = 0.1\text{ }\mu\text{F}$		0.6		$\mu\text{s}$
$t_{PW}$	Minimum Input Pulse Width that Changes the Output			50		ns

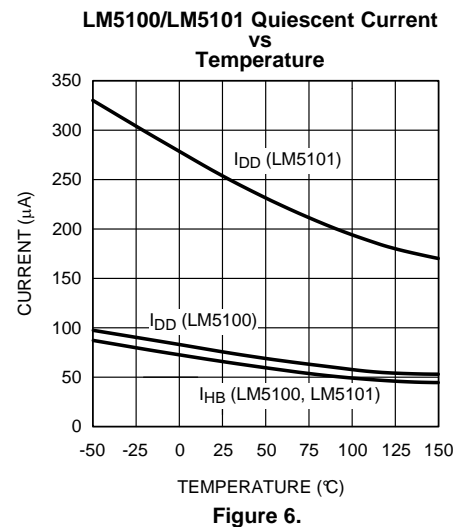
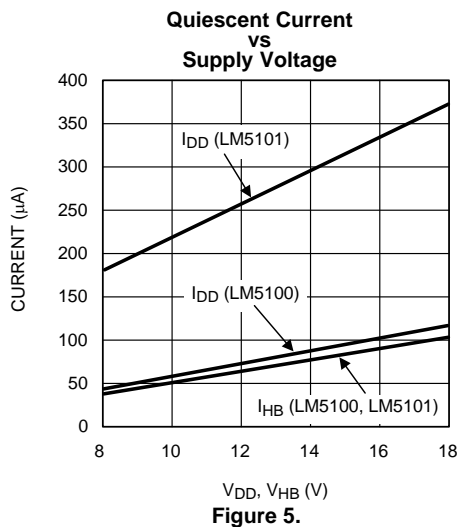
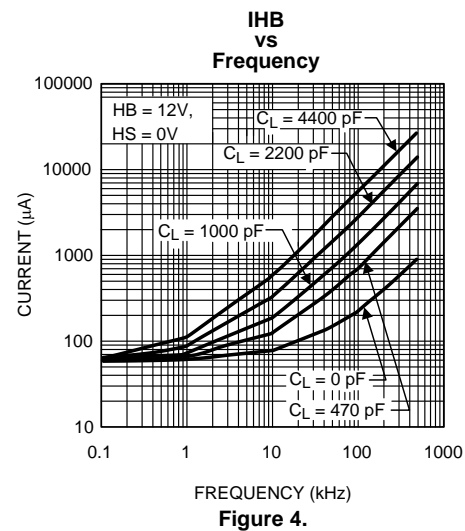
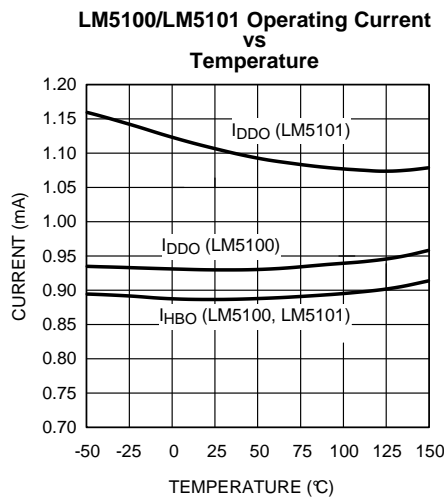
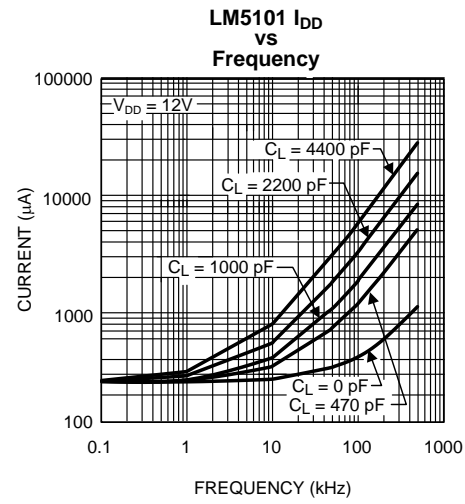
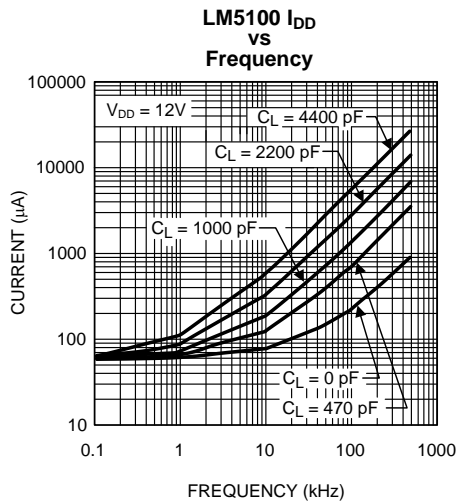
(1) Min and Max limits are 100% production tested at  $25^{\circ}\text{C}$ . Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. Limits are used to calculate TI's Average Outgoing Quality Level (AOQL).

## Switching Characteristics (continued)

Specifications in standard typeface are for  $T_J = +25^\circ\text{C}$ , and those in **boldface type** apply over the full **operating junction temperature range**. Unless otherwise specified,  $V_{DD} = V_{HB} = 12\text{V}$ ,  $V_{SS} = V_{HS} = 0\text{V}$ , No Load on LO or HO.

Symbol	Parameter	Conditions	Min <sup>(1)</sup>	Typ	Max <sup>(1)</sup>	Units
$t_{BS}$	Bootstrap Diode Turn-Off Time	$I_F = 20\text{ mA}$ , $I_R = 200\text{ mA}$		50		ns
<b>LM5101</b>						
$t_{LPHL}$	Lower Turn-Off Propagation Delay (LI Falling to LO Falling)			25	<b>56</b>	ns
$t_{HPHL}$	Upper Turn-Off Propagation Delay (HI Falling to HO Falling)			25	<b>56</b>	ns
$t_{LPLH}$	Lower Turn-On Propagation Delay (LI Rising to LO Rising)			25	<b>56</b>	ns
$t_{HPLH}$	Upper Turn-On Propagation Delay (HI Rising to HO Rising)			25	<b>56</b>	ns
$t_{MON}$	Delay Matching: Lower Turn-On and Upper Turn-Off			2	<b>10</b>	ns
$t_{MOFF}$	Delay Matching: Lower Turn-Off and Upper Turn-On			2	<b>10</b>	ns
$t_{RC}, t_{FC}$	Either Output Rise/Fall Time	$C_L = 1000\text{ pF}$		15		ns
$t_R, t_F$	Either Output Rise/Fall Time (3V to 9V)	$C_L = 0.1\text{ }\mu\text{F}$		0.6		$\mu\text{s}$
$t_{PW}$	Minimum Input Pulse Width that Changes the Output			50		ns
$t_{BS}$	Bootstrap Diode Turn-Off Time	$I_F = 20\text{ mA}$ , $I_R = 200\text{ mA}$		50		ns

## Typical Performance Characteristics



### Typical Performance Characteristics (continued)

**Undervoltage Rising Thresholds  
vs  
Temperature**

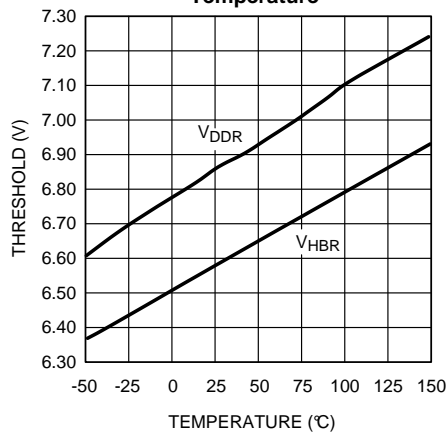


Figure 7.

**LM5100 Undervoltage Threshold Hysteresis  
vs  
Temperature**

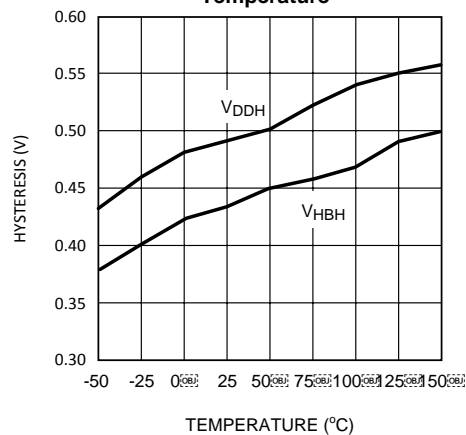


Figure 8.

**Bootstrap Diode Forward Voltage**

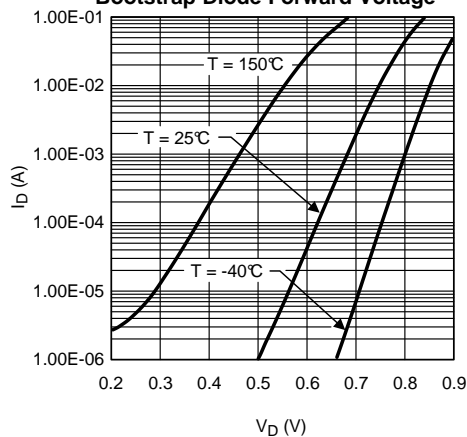


Figure 9.

**HO and LO Peak Output Current  
vs  
Output Voltage**

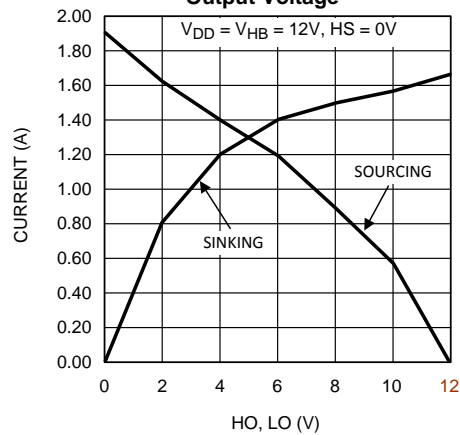


Figure 10.

**LO and HO Gate Drive—High Level Output Voltage  
vs  
Temperature**

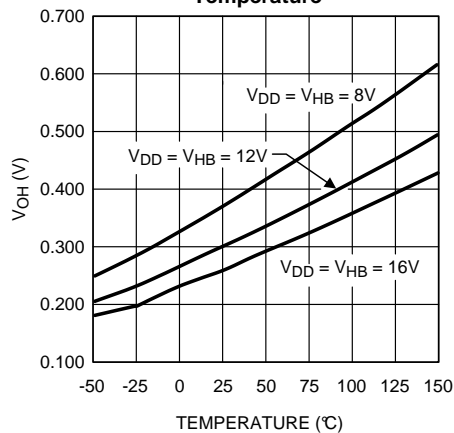


Figure 11.

**LO and HO Gate Drive—Low Level Output Voltage  
vs  
Temperature**

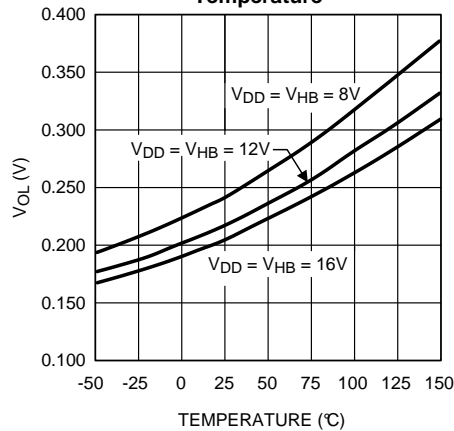
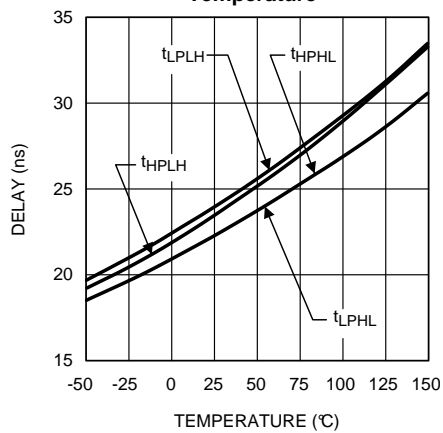


Figure 12.

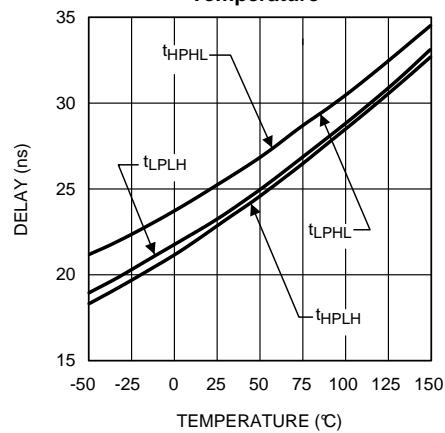
# **Typical Performance Characteristics (continued)**

**LM5100 Propagation Delay  
vs  
Temperature**



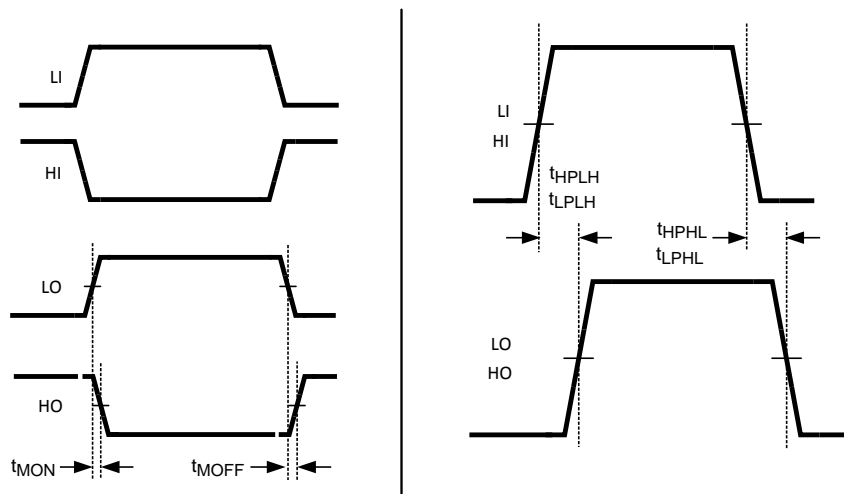
**Figure 13.**

**LM5101 Propagation Delay  
vs  
Temperature**



**Figure 14.**

## **Timing Diagram**



**Figure 15.**

## LAYOUT CONSIDERATIONS

The optimum performance of high and low side gate drivers cannot be achieved without taking due considerations during circuit board layout. Following points are emphasized.

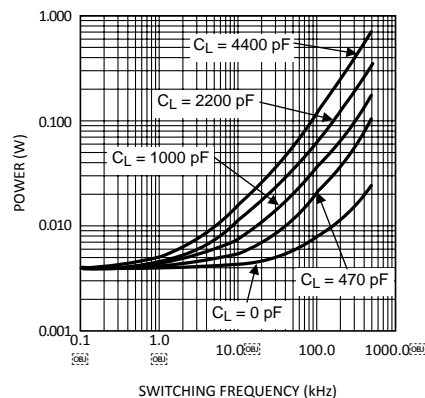
1. A low ESR / ESL capacitor must be connected close to the IC, and between  $V_{DD}$  and  $V_{SS}$  pins and between HB and HS pins to support high peak currents being drawn from  $V_{DD}$  during turn-on of the external MOSFET.
2. To prevent large voltage transients at the drain of the top MOSFET, a low ESR electrolytic capacitor must be connected between MOSFET drain and ground ( $V_{SS}$ ).
3. In order to avoid large negative transients on the switch node (HS) pin, the parasitic inductances in the source of top MOSFET and in the drain of the bottom MOSFET (synchronous rectifier) must be minimized.
4. Grounding Considerations:
  - a) The first priority in designing grounding connections is to confine the high peak currents from charging and discharging the MOSFET gate in a minimal physical area. This will decrease the loop inductance and minimize noise issues on the gate terminal of the MOSFET. The MOSFETs should be placed as close as possible to the gate driver.
  - b) The second high current path includes the bootstrap capacitor, the bootstrap diode, the local ground referenced bypass capacitor and low side MOSFET body diode. The bootstrap capacitor is recharged on the cycle-by-cycle basis through the bootstrap diode from the ground referenced  $V_{DD}$  bypass 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.

## Power Dissipation Considerations

The total IC power dissipation is the sum of the gate driver losses and the bootstrap diode losses. The gate driver losses are related to the switching frequency (f), output load capacitance on LO and HO ( $C_L$ ), and supply voltage ( $V_{DD}$ ) and can be roughly calculated as:

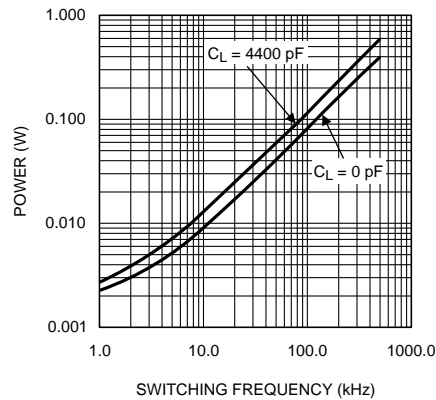
$$P_{DGATES} = 2 \cdot f \cdot C_L \cdot V_{DD}^2$$

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 equation. This plot can be used to approximate the power losses due to the gate drivers.

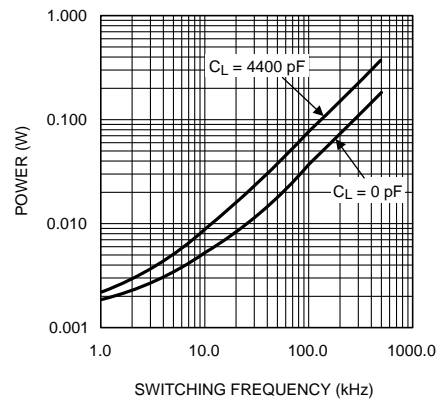


**Figure 16. Gate Driver Power Dissipation (LO + HO)**  
 $V_{CC} = 12V$ , Neglecting Diode Losses

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. Since each of these events happens once per cycle, the diode power loss is proportional to frequency. Larger capacitive loads require more current to recharge the bootstrap capacitor resulting in more losses. Higher input voltages ( $V_{IN}$ ) to the half bridge result in higher reverse recovery losses. The following plot was generated based on calculations and lab measurements of the diode recovery time and current under several operating conditions. This can be useful for approximating the diode power dissipation.

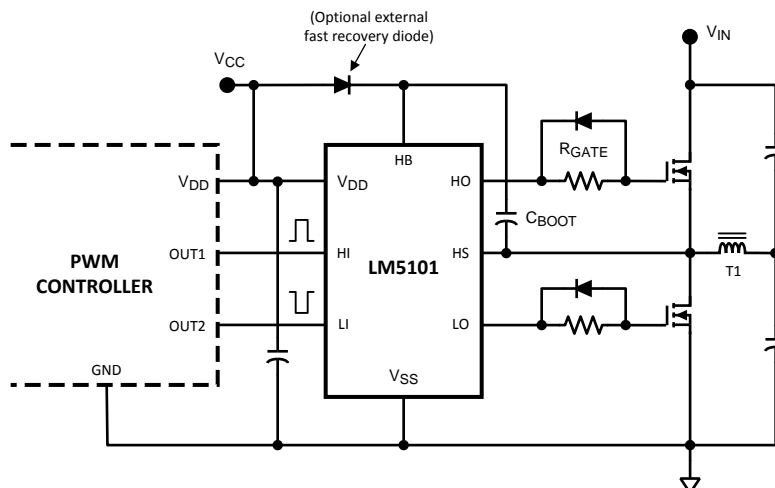


**Figure 17. Diode Power Dissipation  $V_{IN} = 80V$**



**Figure 18. Diode Power Dissipation  $V_{IN} = 40V$**

The total IC power dissipation can be estimated from the previous plots by summing the gate drive losses with the bootstrap diode losses for the intended application. Because the diode losses can be significant, an external diode placed in parallel (refer to [Figure 19](#)) with the internal bootstrap diode can be helpful in removing power from the IC. For this to be effective, the external diode must be placed close to the IC to minimize series inductance and have a significantly lower forward voltage drop than the internal diode.



**Figure 19. LM5101 Driving MOSFETs Connected in Half-Bridge Configuration**

## 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
LM5101M/NOPB	LIFEBUY	SOIC	D	8	95	RoHS & Green	NIPDAU   SN	Level-1-260C-UNLIM		5101 M	
LM5101MX/NOPB	LIFEBUY	SOIC	D	8	2500	RoHS & Green	NIPDAU   SN	Level-1-260C-UNLIM		5101 M	

(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.

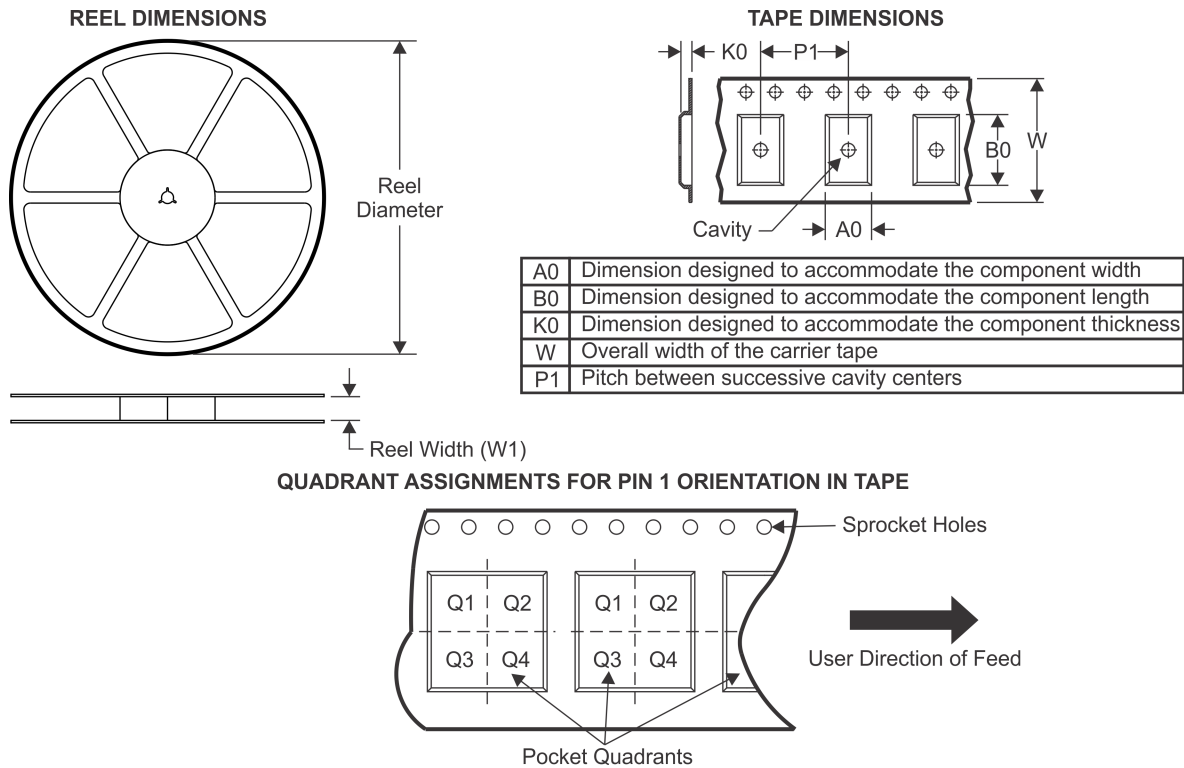
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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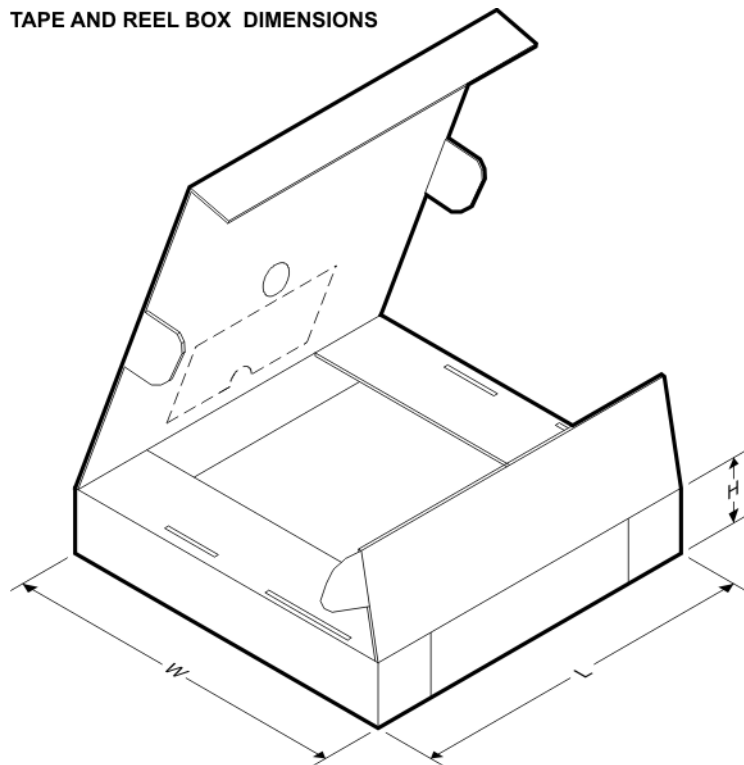
## TAPE AND REEL INFORMATION



\*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
LM5101MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1

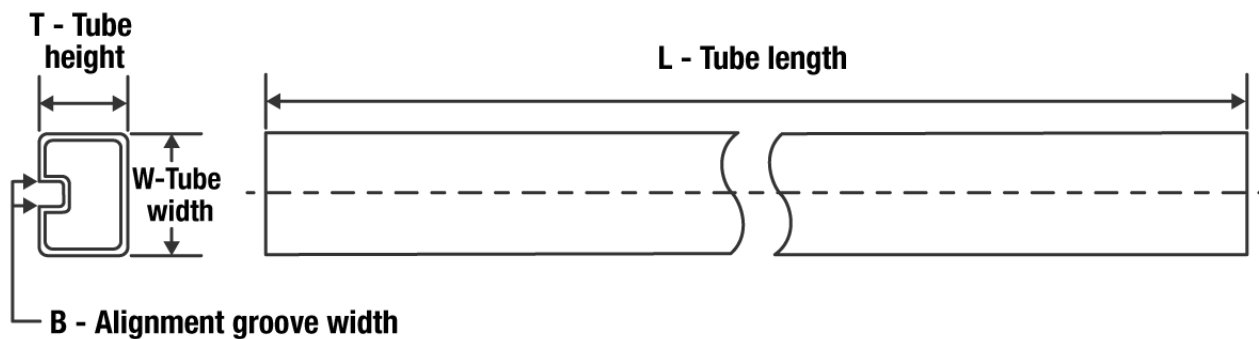
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

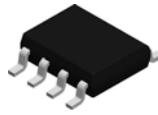
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM5101MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0

## TUBE

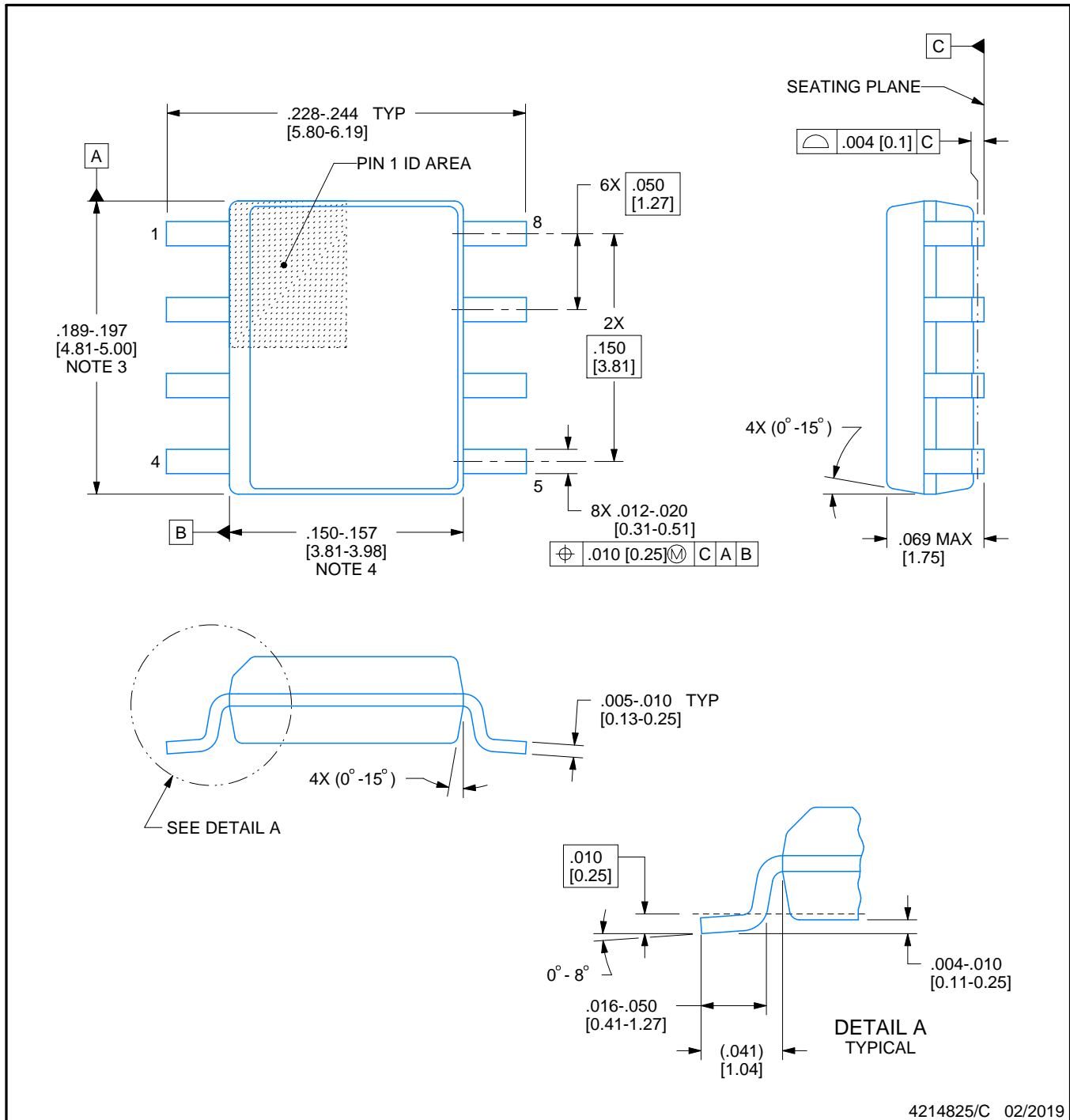


\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
LM5101M/NOPB	D	SOIC	8	95	495	8	4064	3.05

**D0008A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



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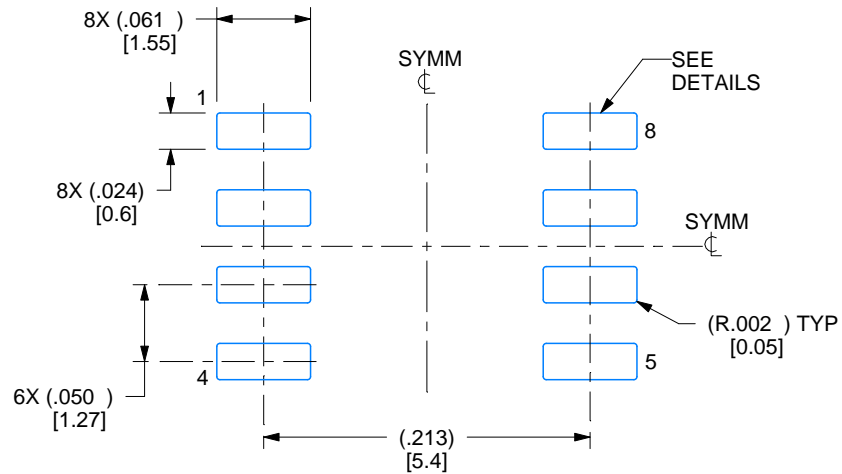
**NOTES:**

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

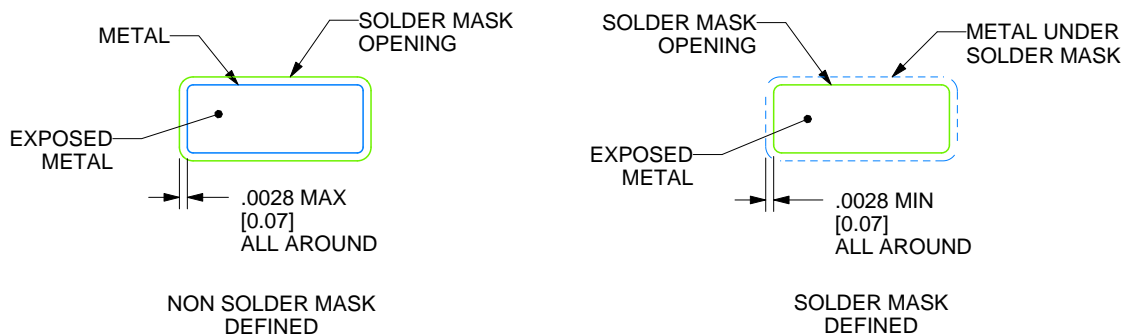
**D0008A**

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



## SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

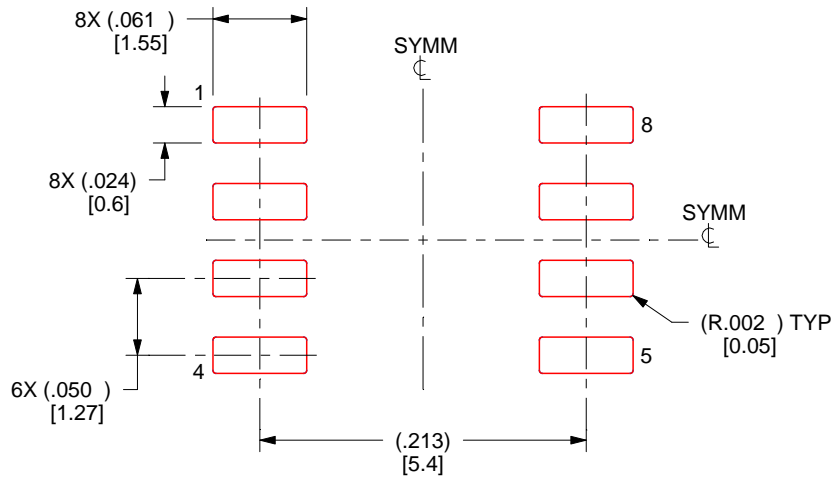
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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