

## LMK60XX 高性能低抖动振荡器

### 1 特性

- 低噪声、高性能
  - 抖动:  $F_{out} > 100\text{MHz}$  时的典型值为 150fs (RMS)
  - 电源抑制比 (PSRR): -60dBc, 出色的电源抗扰度
- 支持的输出格式
  - 低压正发射极耦合逻辑 (LVPECL) 和低压差分信令 (LVDS) 高达 800MHz
  - HCSL 高达 400MHz
- 总频率容差为  $\pm 50\text{ppm}$  (LMK60X2) 和  $\pm 25\text{ppm}$  (LMK60X0)
- 3.3V 工作电压
- 工业温度范围 (-40°C 至 +85°C)
- 7mm x 5mm 6 引脚封装, 与行业标准 7050 XO 封装引脚兼容

### 2 应用

- 晶体振荡器、表面声波 (SAW) 振荡器或芯片振荡器的高性能替换产品
- 开关、路由器、网卡、基带装置 (BBU)、服务器、存储/SAN
- 测试和测量
- 医疗成像
- FPGA, 处理器连接

### 3 说明

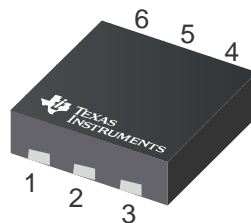
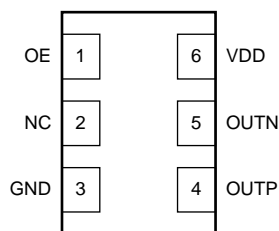
LMK60XX 器件是一款低抖动振荡器, 可生成常用参考时钟。该器件在工厂预编程, 可支持任何参考时钟频率; 支持的输出格式包括 LVPECL、LVDS (最高 800MHz) 和 HCSL (最高 400MHz)。内部电源调节功能提供出色的电源纹波抑制 (PSRR), 降低了供电网络的成本和复杂性。该器件由单个  $3.3\text{V} \pm 5\%$  电源供电。

器件信息<sup>(1)</sup>

器件型号	输出频率 (MHz) 及格式	总频率稳定性 (ppm)	封装/尺寸
LMK60E2-150M	150 LVPECL	$\pm 50$	6 引脚四方扁平无引线模块 (QFM) 封装, 7mm x 5mm
LMK60E0-156257	156.257 LVPECL	$\pm 25$	
LMK60A0-148351	148 + 32/91 LVDS	$\pm 25$	
LMK60A0-148M	148.5 LVDS	$\pm 25$	

(1) 要了解所有可用封装, 请参见数据表末尾的可订购产品附录。

#### 引脚分配



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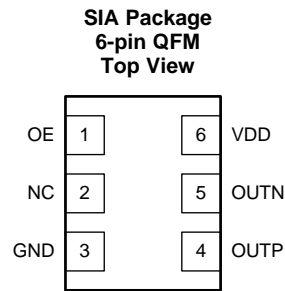
## 4 修订历史记录

Changes from Revision B (December 2016) to Revision C	Page
• LMK60A0-148351 新品发布 .....	1
• LMK60A0-148M 新品发布 .....	1

Changes from Revision A (August 2016) to Revision B	Page
• 将 LMK60E2-150M00 更改为 LMK60E2-150M .....	1
• 删除了 LMK60E2-156M 并将其移动到其他产品说明书 .....	1

Changes from Original (June 2016) to Revision A	Page
• LMK60E0-156257 新品发布 .....	1

## 5 Pin Configuration and Functions



### Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
<b>POWER</b>			
GND	3	Ground	Device ground
VDD	6	Analog	3.3-V power supply
<b>OUTPUT BLOCK</b>			
OUTP, OUTN	4, 5	Universal	Differential output pair (LVPECL, LVDS or HCSSL).
<b>DIGITAL CONTROL / INTERFACES</b>			
NC	2	N/A	No connect
OE	1	LVC MOS	Output enable (internal pullup). When set to low, output pair is disabled and set at high impedance.

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
VDD	Device supply voltage	-0.3	3.6	V
V <sub>IN</sub>	Output voltage for logic inputs	-0.3	VDD + 0.3	V
V <sub>OUT</sub>	Output voltage for clock outputs	-0.3	VDD + 0.3	V
T <sub>J</sub>	Junction temperature		150	°C
T <sub>STG</sub>	Storage temperature	-40	125	°C

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

### 6.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±500

(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
VDD	Device supply voltage	3.135	3.3	3.465	V
T <sub>A</sub>	Ambient temperature	-40	25	85	°C
T <sub>J</sub>	Junction temperature			120	°C
t <sub>RAMP</sub>	VDD power-up ramp time	0.1		100	ms

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>	LMK60XX <sup>(2) (3) (4)</sup>			UNIT	
	SIA (QFM)				
	6 PINS				
	Airflow (LFM) 0	Airflow (LFM) 200	Airflow (LFM) 400		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	55.2	46.4	43.7	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	34.6	n/a	n/a	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	37.7	n/a	n/a	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	11.3	17.6	22.5	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	37.7	41.5	40.1	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	n/a	n/a	n/a	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.
- (2) The package thermal resistance is calculated on a 4 layer JEDEC board.
- (3) Connected to GND with 3 thermal vias (0.3-mm diameter).
- (4) ψ<sub>JB</sub> (junction to board) is used when the main heat flow is from the junction to the GND pad. See the [Layout Guidelines](#) section for more information on ensuring good system reliability and quality.

### 6.5 Electrical Characteristics - Power Supply<sup>(1)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40C to 85°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
IDD	Device current consumption	LVPECL <sup>(2)</sup>		162	208	mA
		LVDS		152	196	
		HCSL		155	196	
IDD-PD	Device current consumption when output is disabled	OE = GND		136	mA	

- (1) Refer to [Parameter Measurement Information](#) for relevant test conditions.
- (2) On-chip power dissipation should exclude 40 mW, dissipated in the 150 Ω termination resistors, from total power dissipation.

### 6.6 LVPECL Output Characteristics<sup>(1)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40C to 85°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>OUT</sub>	Output frequency <sup>(2)</sup>	10		800	MHz
V <sub>OD</sub>	Output voltage swing (V <sub>OH</sub> – V <sub>OL</sub> ) <sup>(2)</sup>	700	800	1200	mV
V <sub>OUT, DIFF, PP</sub>	Differential output peak-to-peak swing		2 ×  V <sub>OD</sub>		V
V <sub>OS</sub>	Output common-mode voltage		VDD – 1.55		V
t <sub>R</sub> / t <sub>F</sub>	Output rise/fall time (20% to 80%) <sup>(3)</sup>		150	250	ps
ODC	Output duty cycle <sup>(3)</sup>	45%		55%	

- (1) Refer to [Parameter Measurement Information](#) for relevant test conditions.
- (2) An output frequency over f<sub>OUT</sub> max spec is possible, but output swing may be less than V<sub>OD</sub> min spec.
- (3) Ensured by characterization.

## 6.7 LVDS Output Characteristics<sup>(1)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>OUT</sub>	Output frequency <sup>(1)</sup>		10		800	MHz
V <sub>OD</sub>	Output voltage swing (V <sub>OH</sub> - V <sub>OL</sub> ) <sup>(1)</sup>		300	390	480	mV
V <sub>OUT, DIFF, PP</sub>	Differential output peak-to-peak swing		2 ×  V <sub>OD</sub>			V
V <sub>OS</sub>	Output common-mode voltage		1.2			V
t <sub>R</sub> / t <sub>F</sub>	Output rise/fall time (20% to 80%) <sup>(2)</sup>		150		250	ps
ODC	Output duty cycle <sup>(2)</sup>		45%		55%	
R <sub>OUT</sub>	Differential output impedance		125			Ω

(1) An output frequency over f<sub>OUT</sub> max spec is possible, but output swing may be less than V<sub>OD</sub> min spec.

(2) Ensured by characterization.

## 6.8 HCSL Output Characteristics<sup>(1)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>OUT</sub>	Output frequency		10		400	MHz
V <sub>OH</sub>	Output high voltage		600		850	mV
V <sub>OL</sub>	Output low voltage		-100		100	mV
V <sub>CROSS</sub>	Absolute crossing voltage <sup>(2)(3)</sup>		250		475	mV
V <sub>CROSS-DELTA</sub>	Variation of V <sub>CROSS</sub> <sup>(2)(3)</sup>		0		140	mV
dV/dt	Slew rate <sup>(4)</sup>		0.8		2	V/ns
ODC	Output duty cycle <sup>(4)</sup>		45%		55%	

(1) Refer to [Parameter Measurement Information](#) for relevant test conditions.

(2) Measured from -150 mV to +150 mV on the differential waveform with the 300 mVpp measurement window centered on the differential zero crossing.

(3) Ensured by design.

(4) Ensured by characterization.

## 6.9 OE Input Characteristics

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>IH</sub>	Input high voltage		1.4			V
V <sub>IL</sub>	Input low voltage				0.6	V
I <sub>IH</sub>	Input high current	V <sub>IH</sub> = VDD	-40		40	μA
I <sub>IL</sub>	Input low current	V <sub>IL</sub> = GND	-40		40	μA
C <sub>IN</sub>	Input capacitance			2		pF

## 6.10 Frequency Tolerance Characteristics<sup>(1)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>T</sub>	Total frequency tolerance	LMK60X2: All output formats, frequency bands and device junction temperature up to 125°C; includes initial freq tolerance, temperature & supply voltage variation, solder reflow and aging (10 years)	-50		50	ppm
		LMK60X0: All output formats, frequency bands and device junction temperature up to 115°C; includes initial freq tolerance, temperature & supply voltage variation, solder reflow and aging (5 years at 40°C)	-25		25	ppm

(1) Ensured by characterization.

## 6.11 Power-On/Reset Characteristics (VDD)

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>THRESH</sub>	Threshold voltage <sup>(1)</sup>	2.72		2.95	V
V <sub>DROOP</sub>	Allowable voltage droop <sup>(2)</sup>			0.1	V
t <sub>STARTUP</sub>	Start-up time <sup>(1)</sup>	Time elapsed from VDD at 3.135 V to output enabled		10	ms
t <sub>OE-EN</sub>	Output enable time <sup>(2)</sup>	Time elapsed from OE at V <sub>IH</sub> to output enabled		50	μs
t <sub>OE-DIS</sub>	Output disable time <sup>(2)</sup>	Time elapsed from OE at V <sub>IL</sub> to output disabled		50	μs

(1) Ensured by characterization.

(2) Ensured by design.

## 6.12 PSRR Characteristics<sup>(1)</sup>

VDD = 3.3 V, T<sub>A</sub> = 25°C, FS[1:0] = NC, NC

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
PSRR	Sine wave at 50 kHz		-60		dBc
	Sine wave at 100 kHz		-60		
	Sine wave at 500 kHz		-60		
	Sine wave at 1 MHz		-60		
Spurs induced by 50-mV power supply ripple <sup>(2)(3)</sup> at 156.25-MHz output, all output types					

(1) Refer to Parameter Measurement Information for relevant test conditions.

(2) Measured max spur level with 50 mVpp sinusoidal signal between 50 kHz and 1 MHz applied on VDD pin

(3)  $DJ_{SPUR} (ps, pk-pk) = [2 \cdot 10 \cdot (SPUR/20) / (\pi \cdot f_{OUT})] \cdot 1e6$ , where PSRR or SPUR in dBc and f<sub>OUT</sub> in MHz.

## 6.13 PLL Clock Output Jitter Characteristics<sup>(1)(2)</sup>

VDD = 3.3 V ± 5%, T<sub>A</sub> = -40°C to 85°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
RJ	RMS phase jitter <sup>(3)</sup> (12 kHz – 20 MHz)	f <sub>OUT</sub> ≥ 100 MHz, All output types		150	250	fs RMS

(1) Refer to Parameter Measurement Information for relevant test conditions.

(2) Phase jitter measured with Agilent E5052 signal source analyzer using a differential-to-single ended converter (balun or buffer).

(3) Ensured by characterization.

## 6.14 Additional Reliability and Qualification

PARAMETER	CONDITION / TEST METHOD
Mechanical Shock	MIL-STD-202, Method 213
Mechanical Vibration	MIL-STD-202, Method 204
Moisture Sensitivity Level	J-STD-020, MSL3

## 6.15 Typical Characteristics

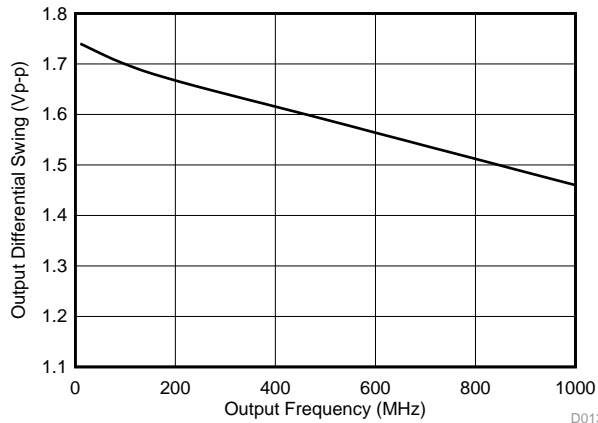


Figure 1. LVPECL Differential Output Swing vs Frequency

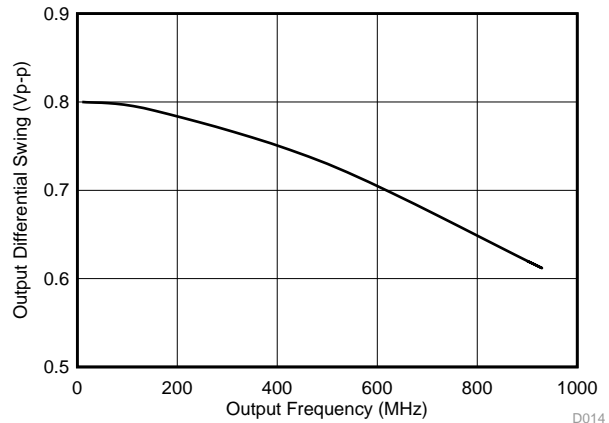


Figure 2. LVDS Differential Output Swing vs Frequency

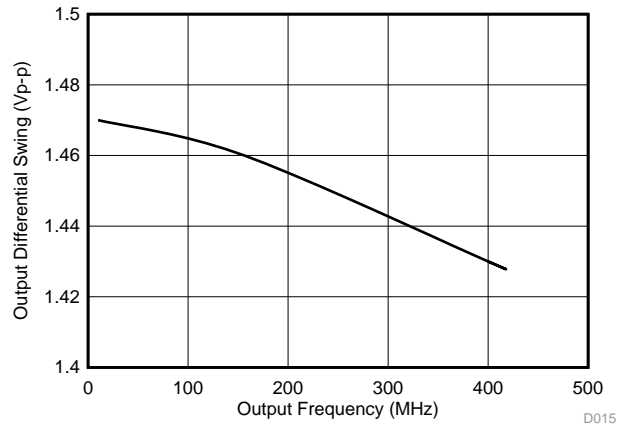


Figure 3. HCSL Differential Output Swing vs Frequency

## 7 Parameter Measurement Information

### 7.1 Device Output Configurations

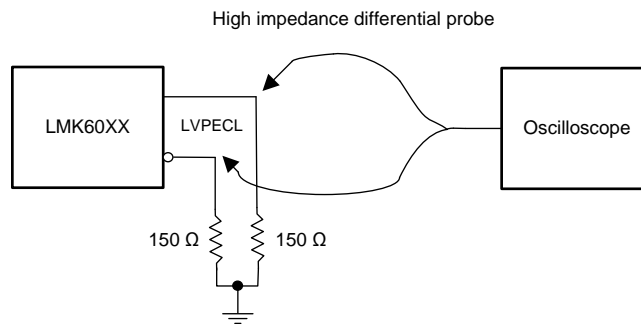


Figure 4. LVPECL Output DC Configuration During Device Test

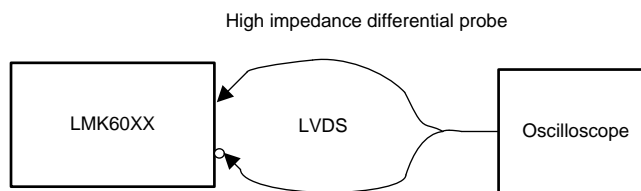


Figure 5. LVDS Output DC Configuration During Device Test

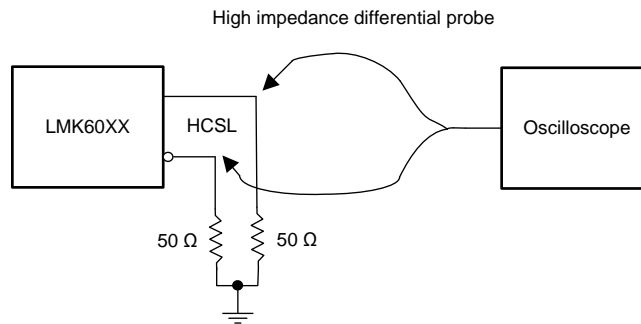


Figure 6. HCSL Output DC Configuration During Device Test

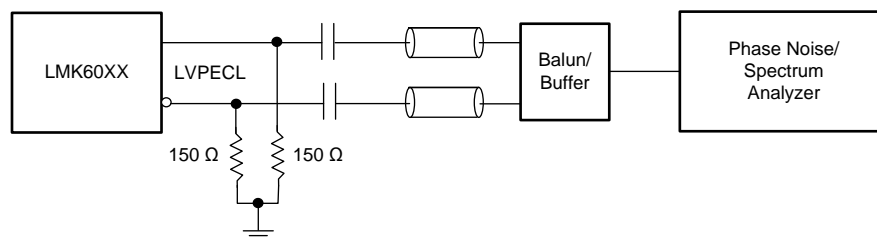


Figure 7. LVPECL Output AC Configuration During Device Test

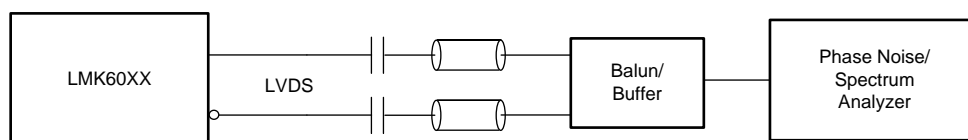


Figure 8. LVDS Output AC Configuration During Device Test



Device Output Configurations (continued)

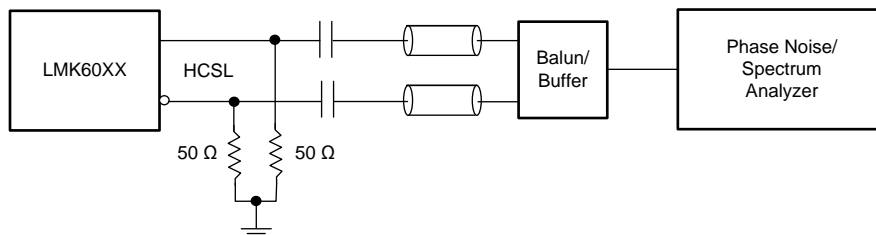


Figure 9. HCSL Output AC Configuration During Device Test

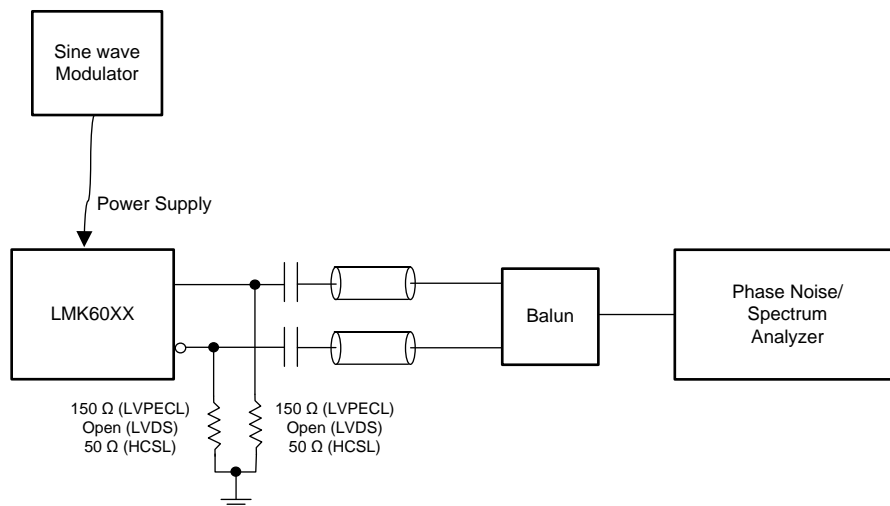


Figure 10. PSRR Test Setup

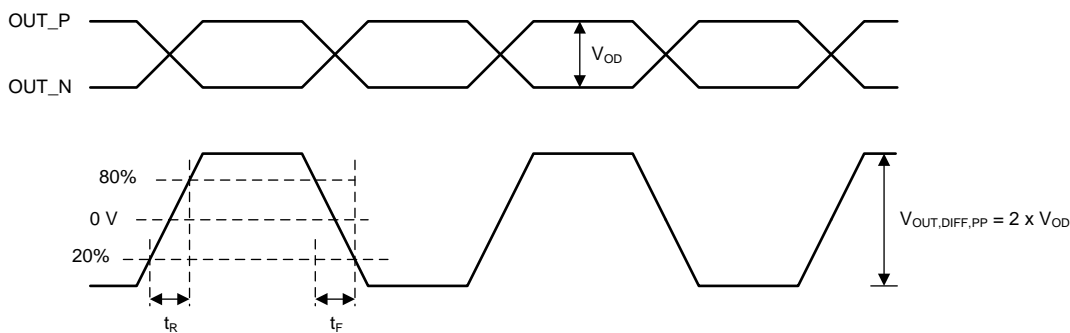


Figure 11. Differential Output Voltage and Rise/Fall Time

## 8 Power Supply Recommendations

For best electrical performance of LMK60XX, TI recommends using a combination of 10  $\mu\text{F}$ , 1  $\mu\text{F}$  and 0.1  $\mu\text{F}$  on its power supply bypass network. TI also recommends using component side mounting of the power supply bypass capacitors, and it is best to use 0201 or 0402 body size capacitors to facilitate signal routing. Keep the connections between the bypass capacitors and the power supply on the device as short as possible. Ground the other side of the capacitor using a low impedance connection to the ground plane. [Figure 12](#) shows the layout recommendation for power supply decoupling of LMK60XX.

## 9 Layout

### 9.1 Layout Guidelines

The following sections provides recommendations for board layout, solder reflow profile and power supply bypassing when using LMK60XX to ensure good thermal / electrical performance and overall signal integrity of entire system.

#### 9.1.1 Ensuring Thermal Reliability

The LMK60XX is a high performance device. Therefore pay careful attention to device configuration and printed-circuit board (PCB) layout with respect to power consumption. The ground pin needs to be connected to the ground plane of the PCB through three vias or more, as shown in [Figure 12](#), to maximize thermal dissipation out of the package.

[Equation 1](#) describes the relationship between the PCB temperature around the LMK60XX and its junction temperature.

$$T_B = T_J - \Psi_{JB} * P$$

where

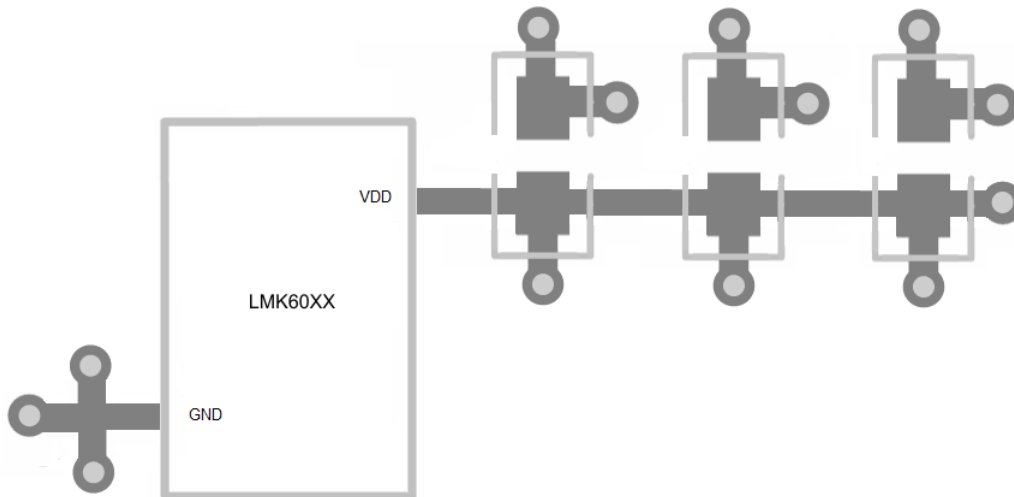
- $T_B$ : PCB temperature around the LMK60XX
  - $T_J$ : Junction temperature of LMK60XX
  - $\Psi_{JB}$ : Junction-to-board thermal resistance parameter of LMK60XX (37.7°C/W without airflow)
  - $P$ : On-chip power dissipation of LMK60XX
- (1)

To ensure that the maximum junction temperature of LMK60XX is below 120°C, it can be calculated that the maximum PCB temperature without airflow should be at 90°C or below when the device is optimized for best performance resulting in maximum on-chip power dissipation of 0.68 W.

#### 9.1.2 Best Practices for Signal Integrity

For best electrical performance and signal integrity of entire system with LMK60XX, TI recommends routing vias into decoupling capacitors and then into the LMK60XX. TI also recommends increasing the via count and width of the traces wherever possible. These steps ensure lowest impedance and shortest path for high-frequency current flow. [Figure 12](#) shows the layout recommendation for LMK60XX.

## Layout Guidelines (接下页)



**Figure 12. LMK60XX Layout Recommendation for Power Supply and Ground**

### 9.1.3 Recommended Solder Reflow Profile

TI recommends following the solder paste supplier's recommendations to optimize flux activity and to achieve proper melting temperatures of the alloy within the guidelines of J-STD-20. It is preferable for the LMK60XX to be processed with the lowest peak temperature possible while also remaining below the components peak temperature rating as listed on the MSL label. The exact temperature profile would depend on several factors including maximum peak temperature for the component as rated on the MSL label, Board thickness, PCB material type, PCB geometries, component locations, sizes, densities within PCB, as well solder manufactures recommended profile, and capability of the reflow equipment to as confirmed by the SMT assembly operation.

## 10 器件和文档支持

### 10.1 相关链接

下面的表格列出了快速访问链接。类别包括技术文档、支持与社区资源、工具和软件，以及申请样片或购买产品的快速链接。

表 1. 相关链接

器件	产品文件夹	样片与购买	技术文档	工具和软件	支持和社区
LMK60E2-150M	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>
LMK60E0-156257	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>	<a href="#">请单击此处</a>

### 10.2 接收文档更新通知

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

### 10.3 社区资源

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

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### 10.4 商标

E2E is a trademark of Texas Instruments.  
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### 10.5 静电放电警告



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

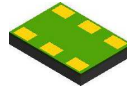
### 10.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 11 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知和修订此文档。如欲获取此数据表的浏览器版本，请参阅左侧的导航。

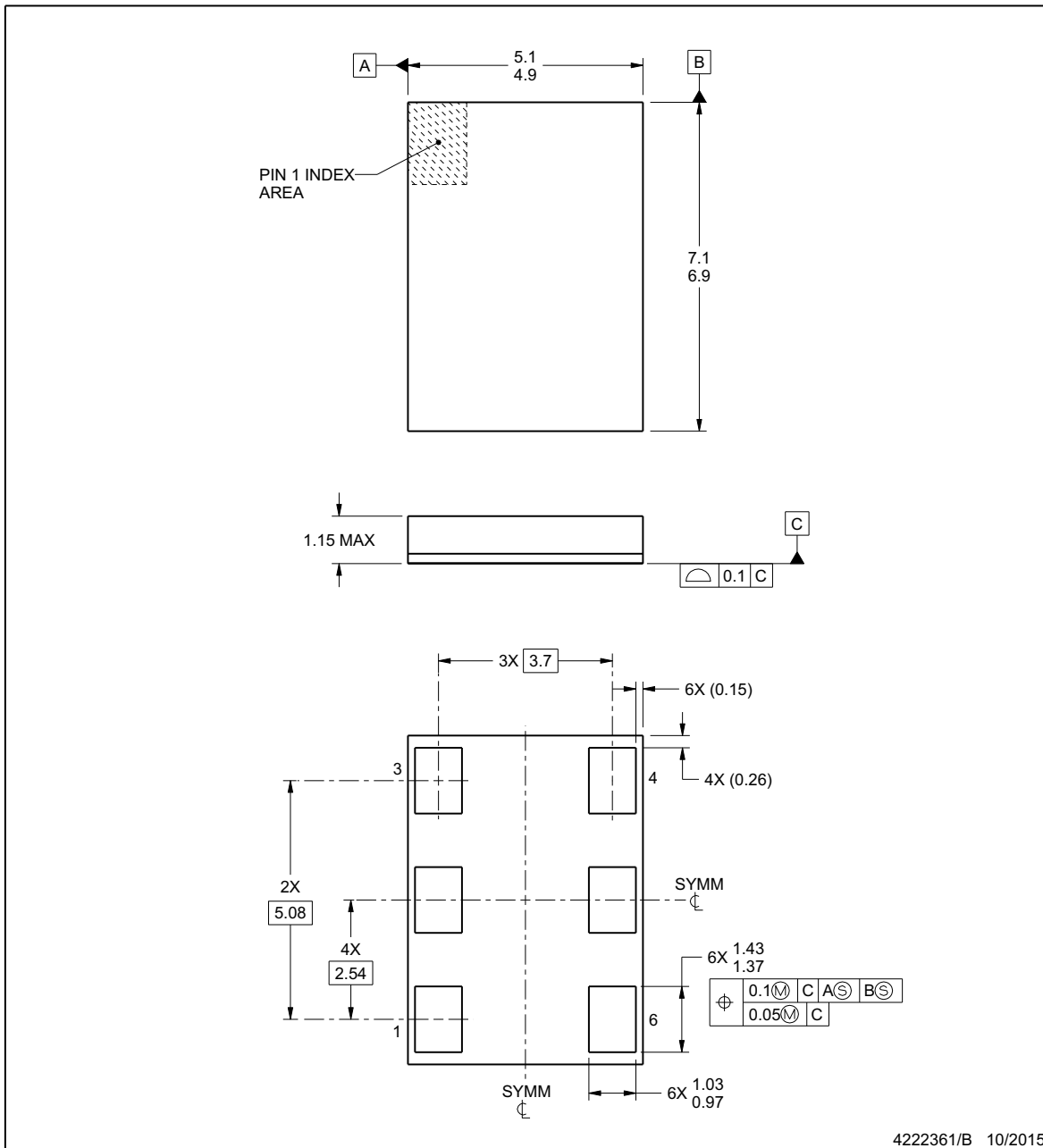


## PACKAGE OUTLINE

SIA0006A

QFM - 1.15 mm max height

QUAD FLAT MODULE



NOTES:

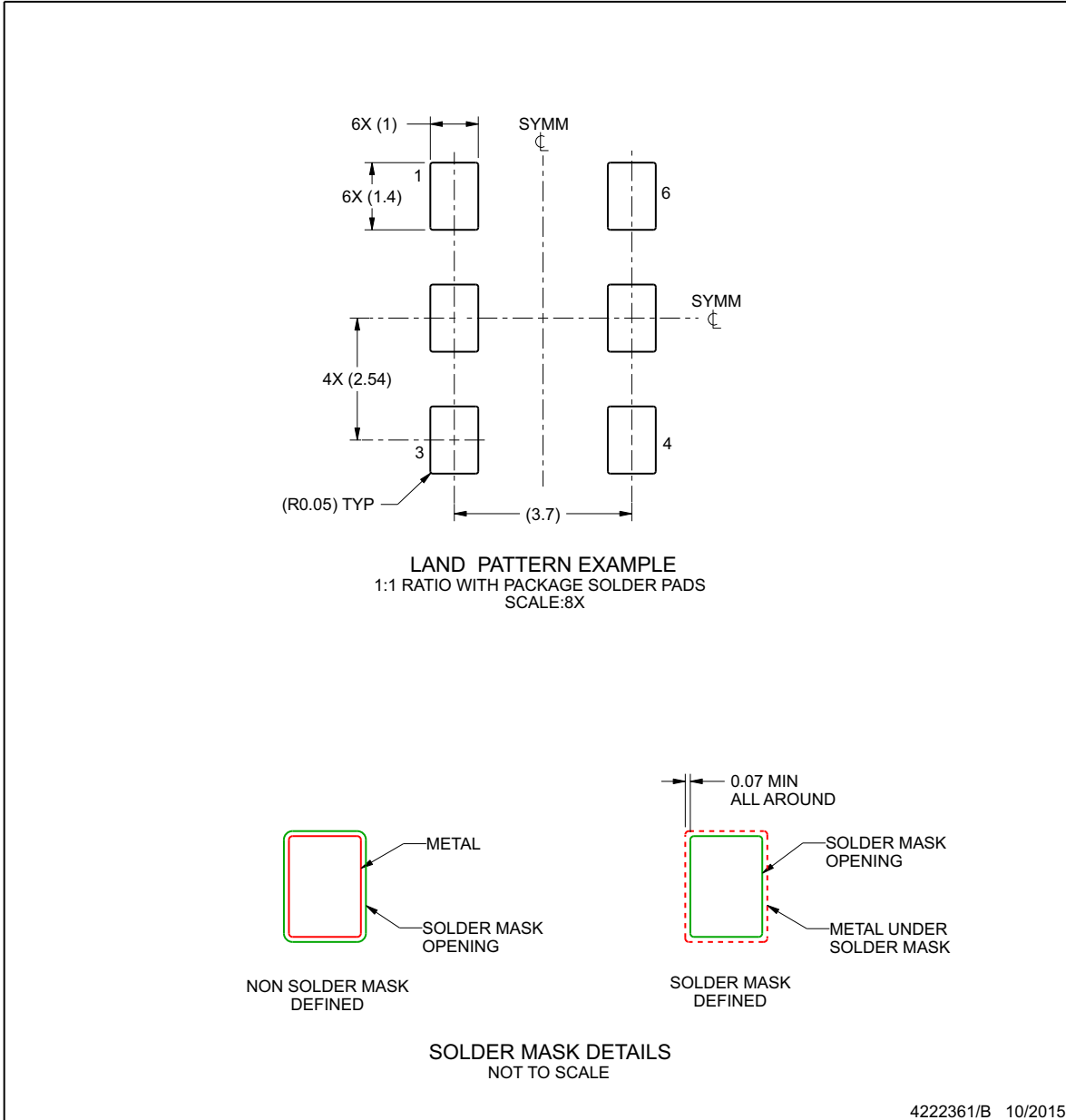
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

**EXAMPLE BOARD LAYOUT**

**SIA0006A**

**QFM - 1.15 mm max height**

QUAD FLAT MODULE



NOTES: (continued)

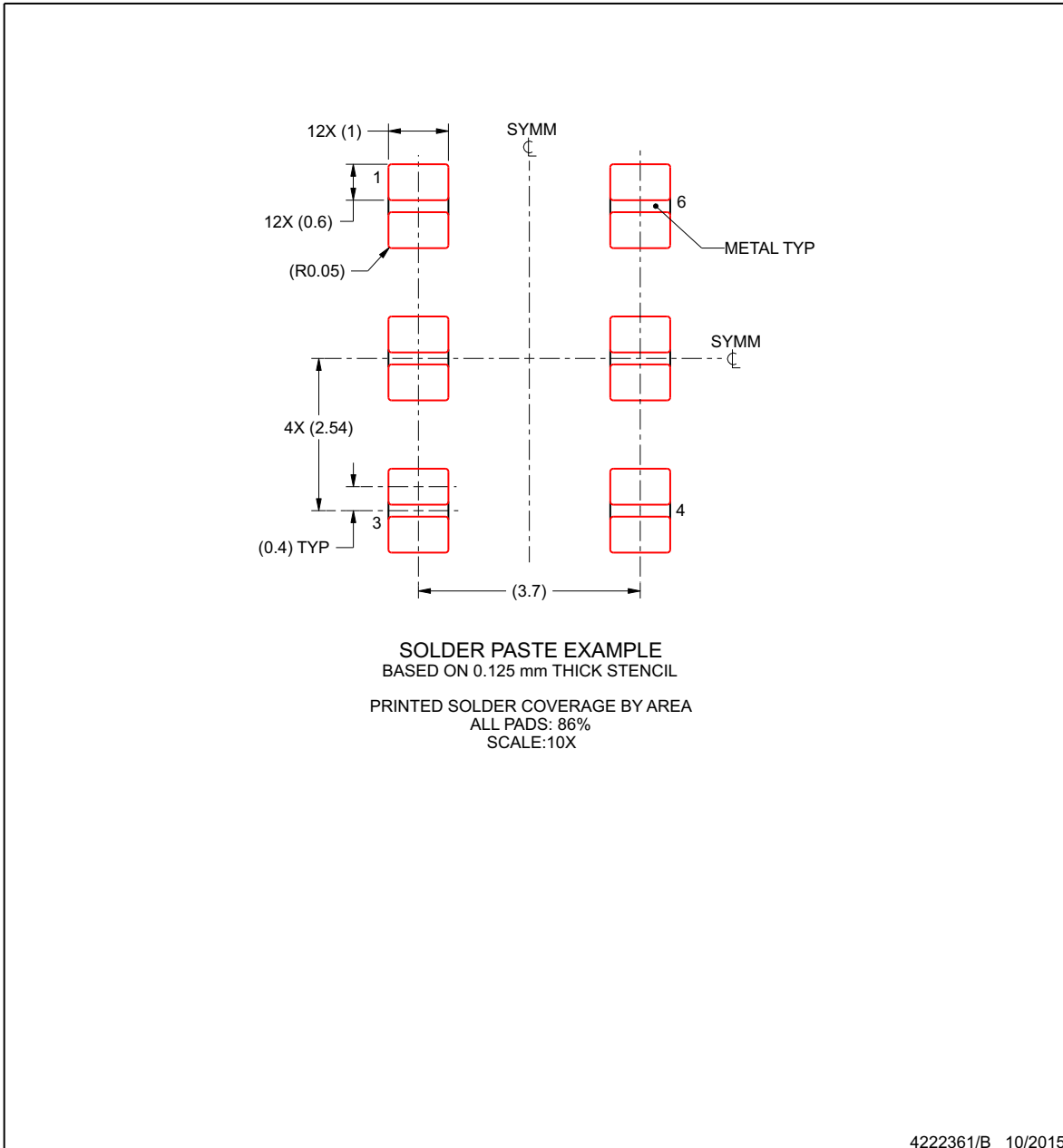
3. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).

## EXAMPLE STENCIL DESIGN

**SIA0006A**

**QFM - 1.15 mm max height**

QUAD FLAT MODULE



4222361/B 10/2015

NOTES: (continued)

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



**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
LMK60A0-148M35SIAR	ACTIVE	QFM	SIA	6	2500	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60A0 148M35	<a href="#">Samples</a>
LMK60A0-148M35SIAT	ACTIVE	QFM	SIA	6	250	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60A0 148M35	<a href="#">Samples</a>
LMK60A0-148M50SIAR	ACTIVE	QFM	SIA	6	2500	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60A0 148M50	<a href="#">Samples</a>
LMK60A0-148M50SIAT	ACTIVE	QFM	SIA	6	250	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60A0 148M50	<a href="#">Samples</a>
LMK60E0-156257SIAR	ACTIVE	QFM	SIA	6	2500	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60E0 156257	<a href="#">Samples</a>
LMK60E0-156257SIAT	ACTIVE	QFM	SIA	6	250	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60E0 156257	<a href="#">Samples</a>
LMK60E2-150M00SIAR	ACTIVE	QFM	SIA	6	2500	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60E2 150M00	<a href="#">Samples</a>
LMK60E2-150M00SIAT	ACTIVE	QFM	SIA	6	250	RoHS & Green	NIAU	Level-3-260C-168 HR	-40 to 85	LMK60E2 150M00	<a href="#">Samples</a>

(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.

**OBSELETE:** 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.

<sup>(5)</sup> 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.

<sup>(6)</sup> 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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