TLC59581 具有预充电 FET、LOD Caterpillar 消除功能和显示数据存储器且支持 32 路多路复用的 48 通道 16 位 ES-PWM LED 驱动器

1 特性

- 48 个恒定灌电流输出通道
- 具有最大亮度控制 (BC)/最大颜色亮度控制 (CC) 数据的灌电流：
  - 5 VCC 时为 25mA
  - 3.3 VCC 时为 20mA
- 全局亮度控制 (BC)：3 位（8 步长）
- 每个颜色组的颜色亮度控制 (CC)：9 位（512 步长），分为三组
- 发光二极管 (LED) 电源电压高达 10V
- V_{CC} = 3.0V 至 5.5V
- 恒流精度
  - 通道到通道 = ±1%（典型值），±3%（最大值）
  - 器件到器件 = ±1%（典型值），±2%（最大值）
- 数据传输速率：25MHz
- 灰度时钟频率：33MHz
- 预充电场效应晶体管 (FET) 可避免重影现象
- 增强电路可消除 Caterpillar 效应
- 低灰度增强
- LED 开路检测 (LOD)
- 热关断 (TSD)
- 运行温度：-40°C 至 85°C

2 应用范围

- 采用多路复用系统的 LED视频显示屏
- 采用多路复用系统的 LED 信号板
- 高刷新率、高密度的 LED 面板

3 说明

TLC59581 是一款 48 通道恒定灌电流驱动器。每个通道都具有单独可调的 65536 步长脉宽调制 (PWM) 灰度 (GS) 亮度控制。

输出通道分为三组。各组都具有 512 步长颜色亮度控制 (CC) 功能。CC 可调节颜色之间的亮度。全部 48 通道的最大电流值可通过 8 步长全局亮度控制 (BC) 功能设置。BC 调节 LED 驱动器之间的亮度偏差。可通过一个串行接口端口访问 GS、CC 和 BC 数据。

TLC59581 具有一个错误标志：LED 开路检测 (LOD)。该标志可通过串行接口端口读取。为解决开路 LED 引发的此类 caterpillar 问题，TLC59581 器件具有一个增强型电路。该电路可提供 caterpillar 效应消除、热关断 (TSD) 和 I_{REF} 电阻短路保护 (ISP) 功能，以确保较高的系统稳定性。TLC59581 器件还具有节电模式，可在输出全部关闭后将总流耗降为 0.8mA（典型值）。TLC59581 器件是一款提升多路复用面板低灰度显示模式性能的良好解决方案。

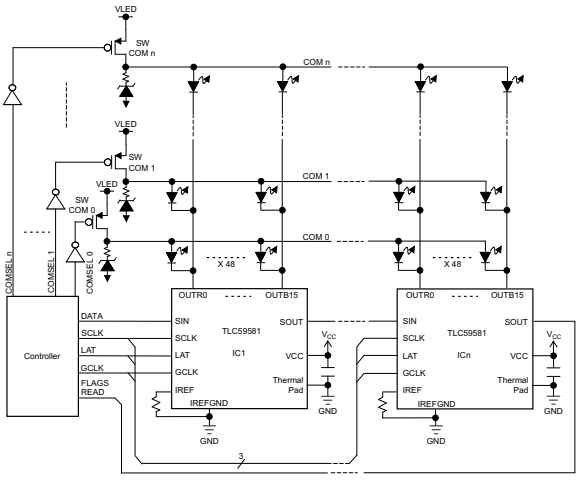
请参见应用笔记《*使用 TLC59581 构建高密度、高刷新率多路复用 LED 面板*》，SLVA744。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
TLC59581	VQFN (56)	8.00mm x 8.00mm

(1) 要了解所有可用封装，请见数据表末尾的可订购产品附录。

典型应用电路原理图（以菊花链方式连接的多个 **TLC59581**）



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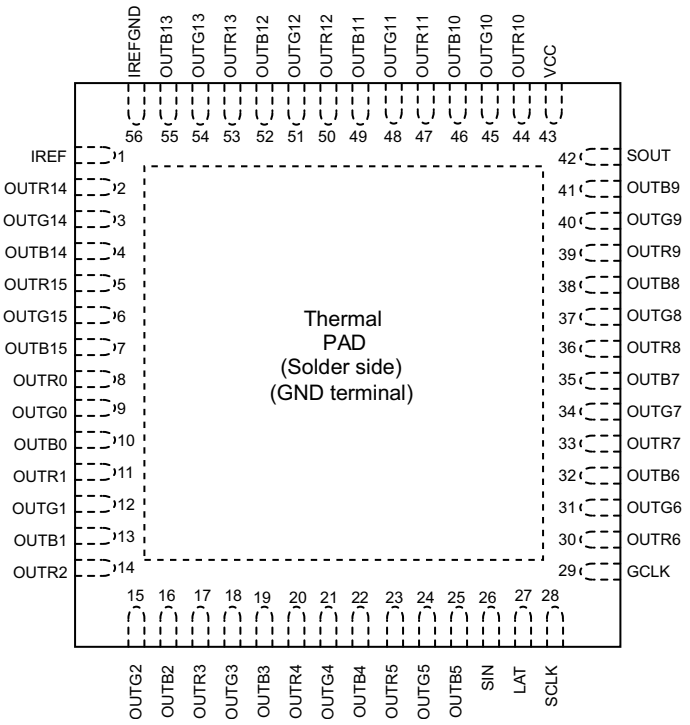
4 修订历史记录

日期	修订版本	注释
2015 年 10 月	*	最初发布版本。

5 Pin Configuration and Functions

RTQ Package with Thermal Pad
56-Pin VQFN
(Top View)



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
GCLK	29	I	Grayscale(GS) pulse width modulation (PWM) reference clock control for OUTXn. Each GCLK rising edge increase the GS counter by 1 for PWM control.
GND	ThermalPad	–	Power ground. The thermal pad must be soldered to GND on PCB.
IREF	1	–	Maximum constant-current value setting. The OUTR0 to OUTB15 maximum constant output current are set to the desired values by connecting an external resistor between IREF and IREFGND. See (1) for more detail. The external resistor should be placed close to the device.
IREFGND	56	–	Analog ground. Dedicated ground pin for the external IREF resistor. This pin should be connected to analog ground trace which is connected to power ground near the common GND point of board.
LAT	27	I	The LAT falling edge latches the data from the common shift register into the GS data memory or function control (FC) register FC1 or FC2.

(1) The deviation of each output in same color group (OUTR0~15 or OUTG0~15 or OUTB0~15) from the average of same color group constant current. The deviation is calculated by the formula. (X = R or G or B, n = 0~15)

$$\Delta(\%) = \left[\frac{\text{IOUTXn}}{\frac{(\text{IOUTX0} + \text{IOUTX1} + \ldots + \text{IOUTX14} + \text{IOUTX15})}{16}} - 1 \right] \times 100$$

Pin Functions (continued)

PIN		I/O	DESCRIPTION
NAME	NO.		
OUTR0	8	O	Constant current output for RED LED. Multiple outputs can be tied together to increase the constant current capability. Different voltages can be applied to each output. These outputs are turned on-off by GCLK signal and the data in GS data memory.
OUTR1	11		
OUTR2	14		
OUTR3	17		
OUTR4	20		
OUTR5	23		
OUTR6	30		
OUTR7	33		
OUTR8	36		
OUTR9	39		
OUTR10	44		
OUTR11	47		
OUTR12	50		
OUTR13	53		
OUTR14	2		
OUTR15	5		
OUTG0	9	O	Constant current output for GREEN LED. Multiple outputs can be tied together to increase the constant current capability. Different voltages can be applied to each output. These outputs are turned on-off by GCLK signal and the data in GS data memory.
OUTG1	12		
OUTG2	15		
OUTG3	18		
OUTG4	21		
OUTG5	24		
OUTG6	31		
OUTG7	34		
OUTG8	37		
OUTG9	40		
OUTG10	45		
OUTG11	48		
OUTG12	51		
OUTG13	54		
OUTG14	3		
OUTG15	6		

Pin Functions (continued)

PIN		I/O	DESCRIPTION
NAME	NO.		
OUTB0	10	O	Constant current output for BLUE LED. Multiple outputs can be tied together to increase the constant current capability. Different voltages can be applied to each output. These outputs are turned on-off by GCLK signal and the data in GS data memory.
OUTB1	13		
OUTB2	16		
OUTB3	19		
OUTB4	22		
OUTB5	25		
OUTB6	32		
OUTB7	35		
OUTB8	38		
OUTB9	41		
OUTB10	46		
OUTB11	49		
OUTB12	52		
OUTB13	55		
OUTB14	4		
OUTB15	7		
SCLK	28	I	Serial data shift clock. Data present on SIN are shifted to the 48-bit common shift register LSB with the SCLK rising edge. Data in the shift register are shifted towards the MSB at each SCLK rising edge. The common shift register MSB appears on SOUT.
SIN	26	I	Serial data input of the 48-bit common shift register. When SIN is high level, the LSB is set to '1' for only one SCLK input rising edge. If two SCLK rising edges are input while SIN is high, then the 48-bit shift register LSB and LSB+1 are set to '1'. When SIN is low, the LSB is set to '0' at the SCLK input rising edge.
SOUT	42	O	Serial data output of the 48-bit common shift register. SOUT is connected to the MSB of the register.
VCC	43	–	Power-supply voltage.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

PARAMETER			MIN	MAX	UNIT
V_{CC}(2)	Supply voltage	VCC	0.3	6.0	V
I_{OUT}	Output current (dc)	OUTx0 to OUTx15, x = R, G, B		30	mA
V_{IN}(2)	Input voltage	SIN, SCLK, LAT, GCLK, IREF	–0.3	V_{CC}+0.3	V
V_{OUT}(2)	Output voltage	SOUT	–0.3	V_{CC}+0.3	V
		OUTx0 to OUTx15, x = R, G, B	–0.3	11	
$T_{J(MAX)}$	Operating junction temperature			150	°C
T_{STG}	Storage temperature range		–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.
(2) All voltage values are with respect to device ground terminal.

6.2 ESD Ratings

			MIN	MAX	UNIT
$V_{(ESD)}$(1)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(2)	0	4000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(3)	0	1000	

(1) Electrostatic discharge (ESD) measures device sensitivity and immunity to damage caused by assembly line electrostatic discharges into the device.
(2) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(3) Level listed above is the passing level per EIA-JEDEC JESD22-C101. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

At T_A = –40°C to 85°C, unless otherwise noted

			MIN	NOM	MAX	UNIT
DC CHARACTERISTICS, VCC = 3 V to 5.5 V						
V_{CC}	Supply voltage		3		5.5	V
V_O	Voltage applied to output	OUTx0 to OUTx15, x = R, G, B			10	V
V_{IH}	High level input voltage	SIN, SCLK, LAT, GCLK	0.7 × VCC		VCC	V
V_{IL}	Low level input voltage	SIN, SCLK, LAT, GCLK	GND		0.3 × VCC	V
I_{OH}	High level output current	SOUT			–2	mA
I_{OL}	Low level output current	SOUT			2	mA
I_{OLC}	Constant output sink current	OUTx0 to OUTx15, x = R, G, B, 3 V ≤ VCC ≤ 3.6 V			20	mA
		OUTx0 to OUTx15, x = R, G, B, 4 V < VCC ≤ 5.5 V			25	
T_A	Operating free air temperature		–40		85	°C
T_J	Operation junction temperature		–40		125	°C

Recommended Operating Conditions (continued)

At T_A = –40°C to 85°C, unless otherwise noted

			MIN	NOM	MAX	UNIT
AC CHARACTERISTICS, VCC = 3 V to 5.5 V(1)						
$F_{CLK(SCLK)}$	Data shift clock frequency	SCLK			25	MHz
$F_{CLK(GCLK)}$	Grayscale control clock frequency	GCLK			33	MHz
t_{WH0}	Pulse duration	SCLK	10			ns
t_{WL0}		SCLK	10			
t_{WH1}		GCLK	15			
t_{WL1}		GCLK	10			
t_{SU0}	Setup time	SIN - SCLK↑	2			ns
t_{SU1}		LAT↑ - SCLK↑	3			
t_{SU2}		LAT↓ - SCLK↑	5			
		LAT↓ - SCLK↑, for READSID, READFC1, and READFC2	50			
t_{SU3}		LAT↓ (Vsync command) - GCLK↑	2500			
t_{SU4}		The last LAT↓ for no all '0' data latching to resume normal mode – GCLK↑, PSAVE_ENA bit = '1b'	50			µS
t_{SU5}		The last GCLK↑ - the 1st GCLK↑ of next line	20			ns
t_{H0}	Hold time	SCLK↑ - SIN	2			ns
t_{H1}		SCLK↑ - LAT↑	2			
t_{H2}		SCLK↑ - LAT↓	13			

(1) Specified by design

6.4 Thermal Information

THERMAL METRIC(1)		TLC59581 RTQ 56 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	27.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	13.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	5.5	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.2	°C/W
ψ_{JB}	Junction-to-board characterization parameter	5.5	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	0.8	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics

At V_{CC} = 3.0 V to 5.5 V and T_A = –40°C to 85°C, VLED = 5.0 V; Typical values are at V_{CC} = 3.3 V, T_A = 25°C (unless otherwise noted).

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OH}	Output voltage	High	I_{OH} = –2 mA at SOUT	V_{CC}–0.4		V_{CC}	V
V_{OL}		Low	I_{OL}= 2 mA at SOUT			0.4	V
V_{LOD0}	LED open detection threshold		LODVTH = 00b	0.12	0.2	0.28	V
V_{LOD1}			LODVTH = 01b	0.32	0.4	0.48	
V_{LOD2}			LODVTH = 10b	0.52	0.6	0.68	
V_{LOD3}			LODVTH = 11b	0.72	0.8	0.88	
V_{IREF}	Reference voltage output		R_{IREF} = 6.2 kΩ (1 mA target), BC = 0h, CCR/G/B = 81h	1.19	1.209	1.228	V
I_{IN}	Input current (SIN, SCLK)		V_{IN} = V_{CC} or GND	–1		1	µA
I_{CC0}	Supply current (V_{CC})		SIN/SCLK/LAT/GSCLK = GND, GSn = 0000h, BC = 0h, CCR/G/B = 100h, PCHG_EN = 0, VOUTn = V_{CC}, RIREF = OPEN		9	11	mA
I_{CC1}			SIN/SCLK/LAT/GSCK = GND, GSn = 0000h, BC = 4h, CCR/G/B = 140h,VOUTn Floating, PCHG_EN = 0, RIREF = 7.5 kΩ (Io = 10 mA target)		11	13	
I_{CC2}			SIN/SCLK/LAT = GND, GCLK = 33 MHz, T_{SU5} = 200 nS, 8+8 mode, GSn = FFFFh, BC = 4h, CCR/G/B = 140h, VOUTn = 1 V when channel on, VOUTn = V_{CC} when channel off. PCHG_EN = 0		25	31	
I_{CC3}			SIN/SCLK/LAT = GND, GCLK = 33 MHz, TSU5 = 200 nS, 8+8 mode, GSn = FFFFh, BC = 7h, CCR/G/B = 1FFh, VOUTn = 1 V when channel on, VOUTn = V_{CC} when channel off. PCHG_EN = 0		28	33	
I_{CC4}			In power save mode and PCHG_EN = 1		1	1.4	
ΔI_{OLC0}	Constant current error (OUTx0-15, x = R/G/B)	Channel-to-channel(1)	All OUTn = on, BC = 0h, CCR/G/B = 81h, VOUTn = VOUTfix = 1 V, RIREF = 6.2 kΩ(1 mA target), T_A = 25°C, at same color grouped output of OUTR0-15, OUTG0-15 and OUTB0-15		±1%	±3%	
ΔI_{OLC1}	Constant current error (OUTx0-15, x = R/G/B)	Device-to-device(2)	All OUTn = on, BC = 0h, CCR/G/B = 81h, VOUTn = VOUTfix = 1 V, RIREF = 6.2 kΩ(1 mA target), T_A = 25°C, at same color grouped output of OUTR0-15, OUTG0-15 and OUTB0-15		±1%	±2%	
ΔI_{OLC2}	Line regulation(3)		V_{CC} = 3.0 to 5.5 V, All OUTn = on, BC = 0h, CCR/G/B = 81h, VOUTn = VOUTfix = 1 V, RIREF = 6.2 kΩ (1 mA target)		±1	±1.5	%/V

(1) The deviation of each output in same color group (OUTR0~15 or OUTG0~15 or OUTB0~15) from the average of same color group constant current. The deviation is calculated by the formula. (X = R or G or B, n = 0~15)

$$\Delta(\%) = \left[\frac{\text{IOUTXn}}{\frac{(\text{IOUTX0} + \text{IOUTX1} + \ldots + \text{IOUTX14} + \text{IOUTX15})}{16}} - 1 \right] \times 100$$

(2) The deviation of the average of constant-current in each color group from the ideal constant-current value. (X = R or G or B) :

$$\Delta(\%) = \left[\frac{\frac{(\text{IOUTX0} + \text{IOUTX1} + \ldots + \text{IOUTX15})}{16} - (\text{Ideal Output Current})}{\text{Ideal Output Current}} \right] \times 100$$

Ideal current is calculated by the following equation:

$$\text{Ideal Output}(\text{mA}) = \text{Gain} \times \left[\frac{V_{IREF}}{R_{IREF}(\Omega)} \right] \times \text{CCR}(\text{or CCG, CCB})/511\text{d, VIREF} = 1.209\text{V (Typ)},$$

Refer to Table 1 for the Gain at chosen BC.

(3) Line regulation is calculated by the following equation. (X = R or G or B, n = 0~15):

$$\Delta(\%\text{V}) = \left[\frac{(\text{IOUTXn at VCC} = 5.5\text{V}) - (\text{IOUTXn at VCC} = 3.0\text{V})}{(\text{IOUTXn at VCC} = 3.0\text{V})} \right] \times \frac{100}{5.5\text{V} - 3\text{V}}$$

Electrical Characteristics (continued)

At V_{CC} = 3.0 V to 5.5 V and T_A = –40°C to 85°C, VLED = 5.0 V; Typical values are at V_{CC} = 3.3 V, T_A = 25°C (unless otherwise noted).

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
ΔI_{OLC3}	Load regulation(4)		All OUTn = on, BC = 0h, CCR/G/B = 81h, VOUTn = 1 to 3 V, VOUTfix = 1 V, RIREF = 6.2 kΩ (1 mA target)		±1	±1.5	%/V
ΔI_{OLC4}	Constant current error (OUTx0-15, x = R/G/B)	Channel-to-channel(1)	All OUTn = on, BC = 7h, CCR/G/B = 1F7h, VOUTn = VOUTfix = 1 V, RIREF = 7.5 kΩ(25 mA target), T_A = 25°C, at same color grouped output of OUTR0-15, OUTG0-15 & OUTB0-15		±1%	±3%	
ΔI_{OLC5}	Constant current error (OUTx0-15, x = R/G/B)	Device-to-device(2)	All OUTn = on, BC = 7h, CCR/G/B = 1F7h, VOUTn = VOUTfix = 1 V, RIREF = 7.5 kΩ(25 mA target), T_A = 25°C, at same color grouped output of OUTR0-15, OUTG0-15 and OUTB0-15		±1%	±2%	
ΔI_{OLC6}	Line regulation(3)		V_{CC} = 3.0 to 5.5 V, All OUTn = on, BC = 7h, CCR/G/B = 1F7h, VOUTn = VOUTfix = 1 V, RIREF = 7.5 kΩ (25 mA target)		±1	±1.5	%/V
ΔI_{OLC7}	Load regulation(4)		All OUTn = on, BC = 7h, CCR/G/B = 1F7h, VOUTn = 1 to 3 V, VOUTfix = 1 V, RIREF = 7.5 kΩ (25 mA target)		±1	±1.5	%/V
T_{TSD}	Thermal shutdown threshold(5)			160	170	180	°C
T_{HYS}	Thermal shutdown hysterisis				10		°C
$V_{ISP(in)}$	IREF resistor short protection threshold			0.15	0.195		V
$V_{ISP(out)}$	IREF resistor short-protection release threshold				0.325	0.4	V
R_{PDWN}	Pull-down resistor		LAT	250	500	750	kΩ
R_{PUP}	Pull-up resistor		GCLK	250	500	750	kΩ
V_{knee} (5)	Knee voltage (OUTX 0~15), X = R/G/B		All OUTn = on, BC = 4h, CCR/G/B = 137h, RIREF = 7.5 kΩ. (Io = 10 mA target)		0.32	0.35	V

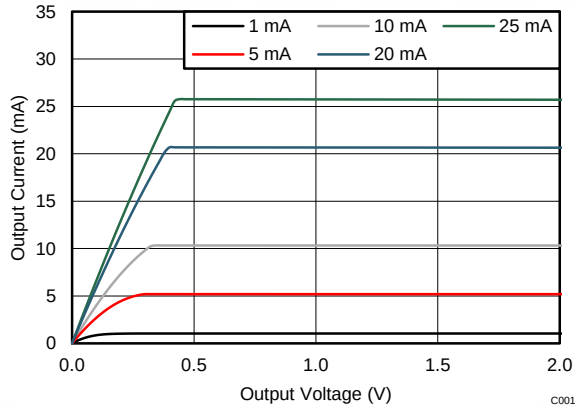
(4) Load regulation is calculated by the following equation. (X = R or G or B, n = 0~15):

$$\Delta(\%V) = \left[\frac{(IOUTXn \text{ at } VOUTXn = 3V) - (IOUTXn \text{ at } VOUTXn = 1V)}{(IOUTXn \text{ at } VOUTXn = 1V)} \right] \times \frac{100}{3V - 1V}$$

(5) Specified by design.

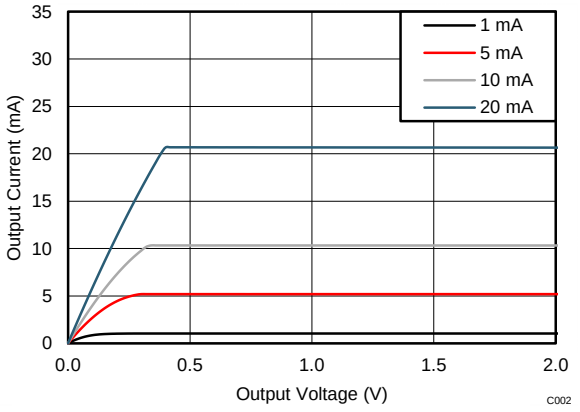
6.6 Typical Characteristics

V_{CC} = 3.3 V and T_A = 25°C, unless otherwise noted.



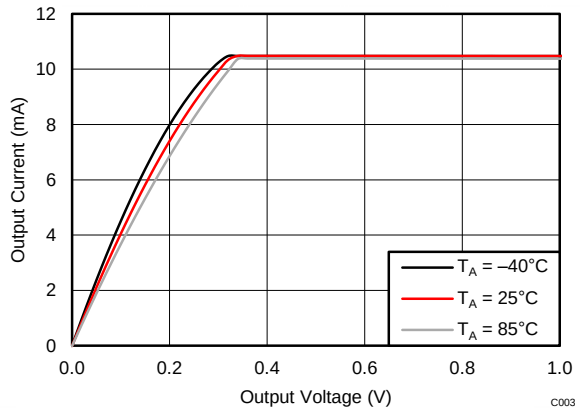
V_{CC} = 5 V CCR/G/B = 1FFh, BC = 0

Figure 1. Output Current vs Output Voltage



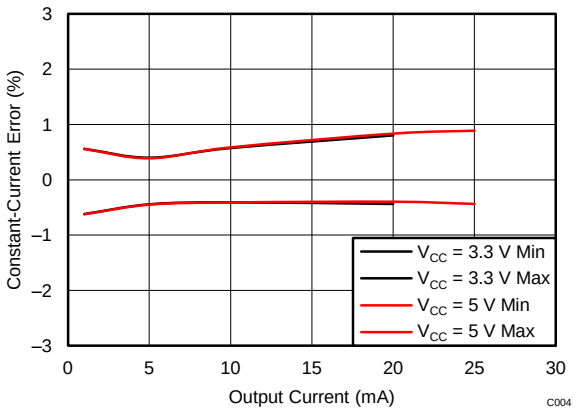
V_{CC} = 3.3 V CCR/G/B = 1FFh, BC = 0

Figure 2. Output Current vs Output Voltage



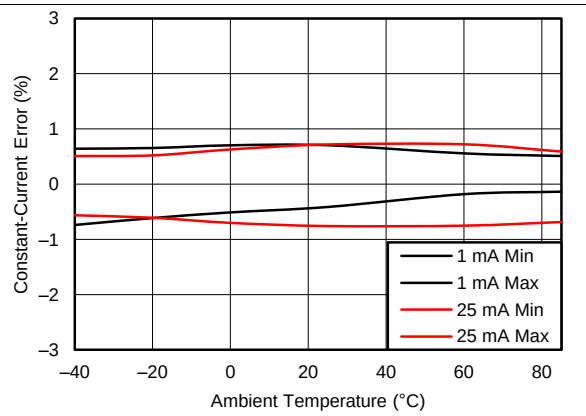
V_{CC} = 5 V Temperature Changing CCR/G/B = 1FFh, BC = 0

Figure 3. Output Current vs Output Voltage



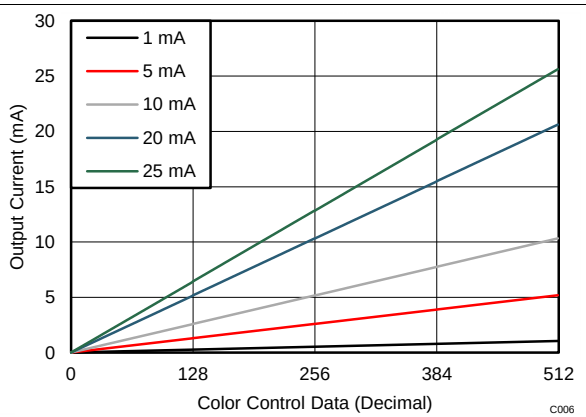
V_{OUTXn} = 0.8 V CCR/G/B = 1FFh, BC = 0

Figure 4. Constant Current Error (CH-to-CH) vs Output Current



V_{CC} = 5 V V_{OUTXn} = 0.8 V CCR/G/B = 1FFh, BC = 0

Figure 5. Constant-Current Error (CH-to-CH) vs Temperature

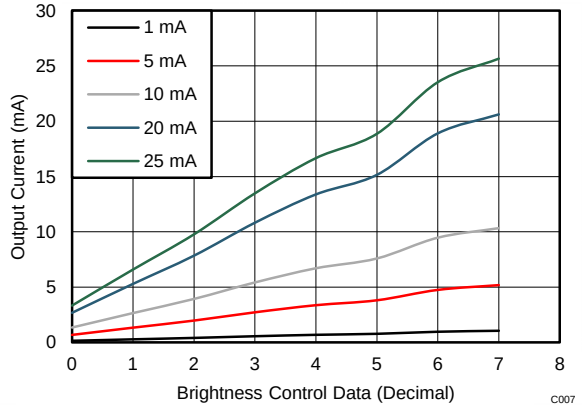


V_{CC} = 5 V V_{OUTXn} = 0.8 V BC = 7

Figure 6. Color Control (CC) vs Output Current

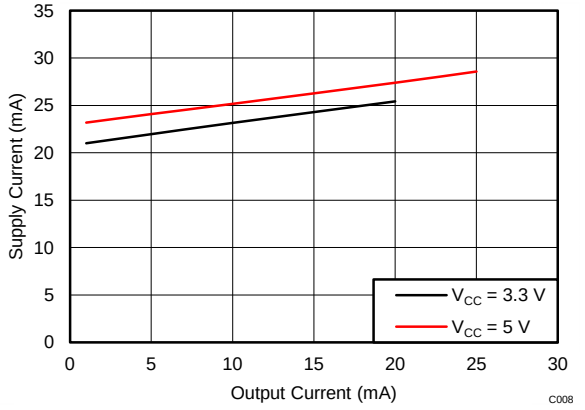
Typical Characteristics (continued)

V_{CC} = 3.3 V and T_A = 25°C, unless otherwise noted.



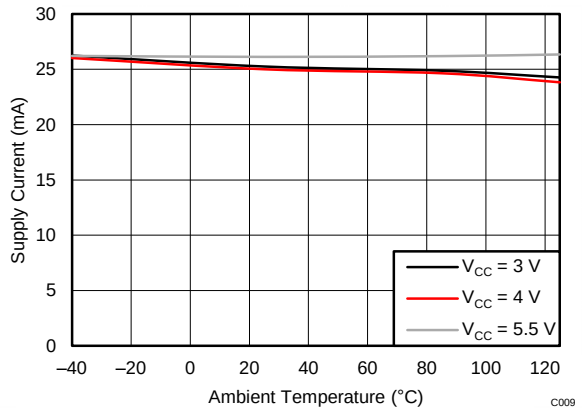
V_{CC} = 5 V V_{OUTXn} = 0.8 V CCR/G/B = 1FFh

Figure 7. Brightness Control (BC) vs Output Current



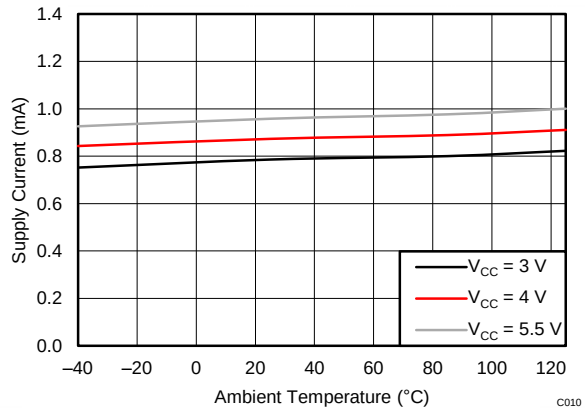
VOUTXn = 0.8 V GCLK = 33 MHz, GSXn = FFFFh CCR/G/B = 1FFh, BC = 0

Figure 8. Supply Current (Icc) vs Output Current



V_{OUTXn} = 0.8 V CCR/G/B = 137h, BC = 4, GCLK = 33 MHz GSXn = FFFFh, R_{IREF} = 7.5 kΩ (10-mA target)

Figure 9. Supply Current (Icc) vs Temperature



V_{OUTXn} = 0.8 V CCR/G/B = 137h, BC = 4 GCLK = GND, GSXn = 0h

Figure 10. Supply Current in Power Save Mode (Icc) vs Temperature

7 Parameter Measurement Information

7.1 Pin Equivalent Input and Output Schematic Diagrams

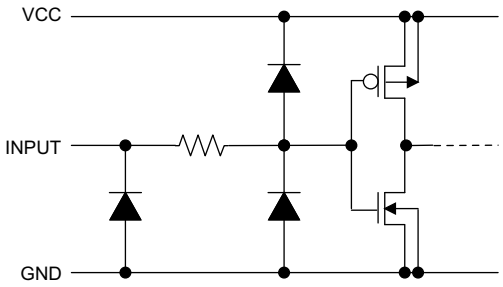


Figure 11. SIN, SCLK

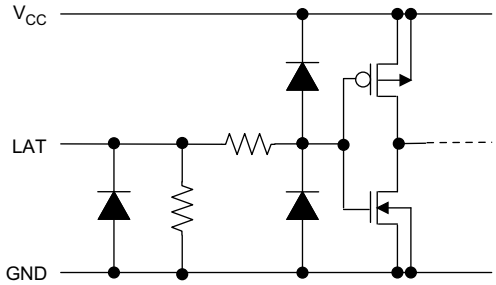


Figure 12. LAT

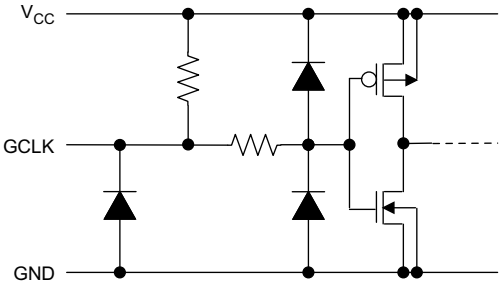


Figure 13. GCLK

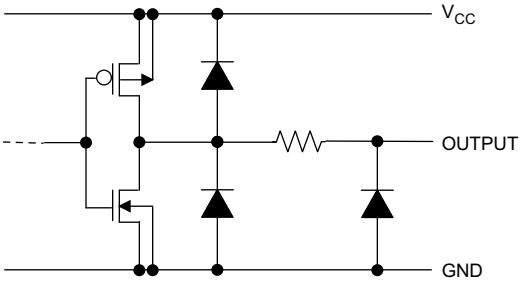


Figure 14. SOUT

(1) X = R or G or B, n = 0~15

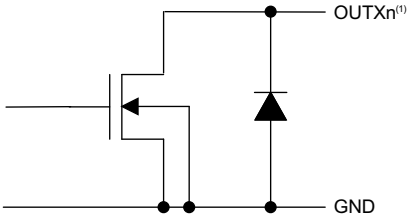


Figure 15. OUTR0/G0/B0 Through OUTR15/G15/B15

Pin Equivalent Input and Output Schematic Diagrams (continued)

7.1.1 Test Circuits

(1) CL includes measurement probe and jig capacitance.

(2) X = R or G or B, n = 0~15

(1) CL includes measurement probe and jig capacitance.

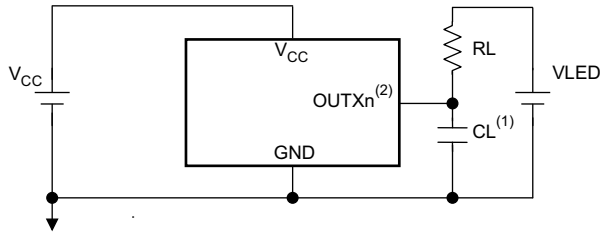


Figure 16. Rise and Fall Time Test Circuit for OUTXn

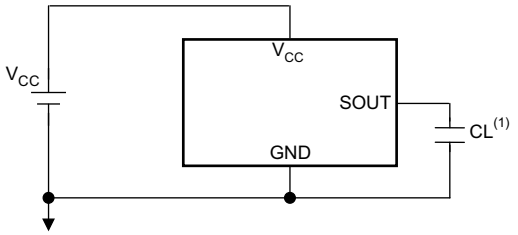


Figure 17. Rise and Fall Time Test Circuit for SOUT

(1) X = R or G or B, n = 0~15

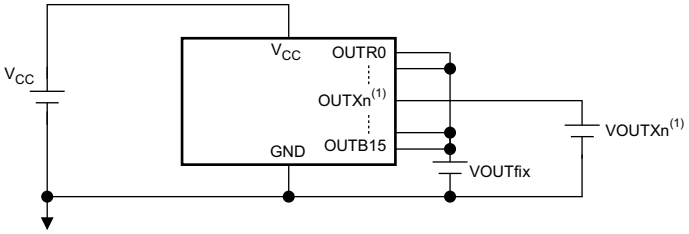
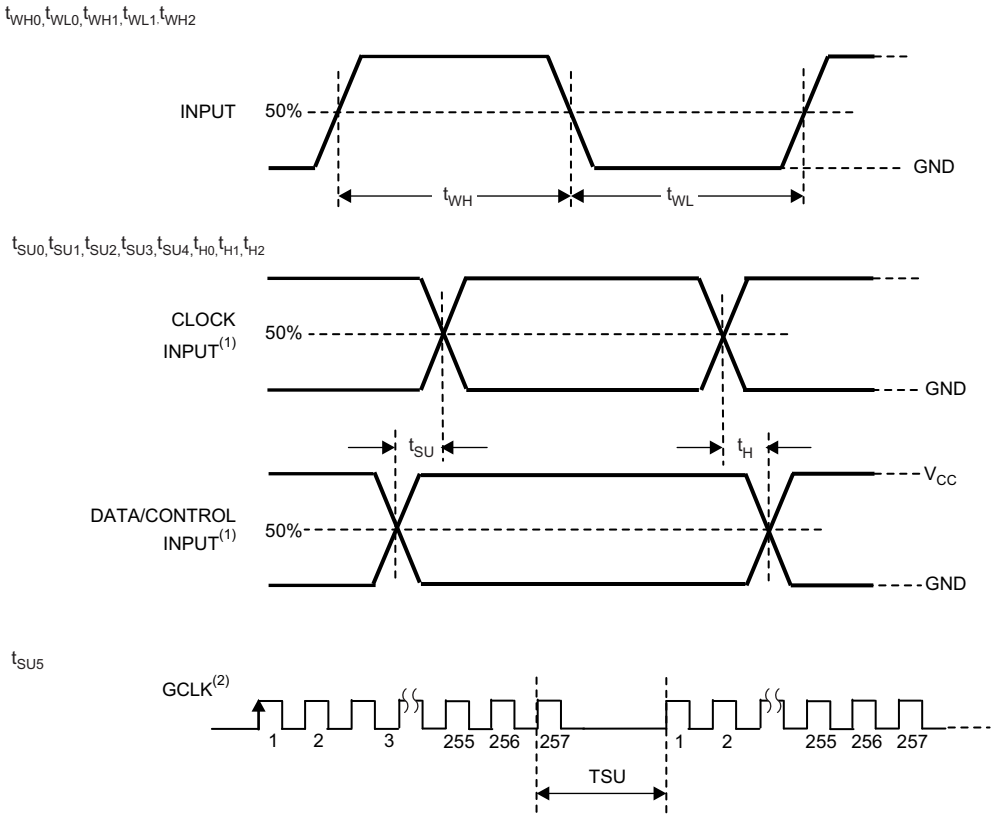


Figure 18. Constant Current Test Circuit for OUTXn

7.2 Timing Diagrams



(1) Input pulse rise and fall time is 1~3ns

(2) 8 + 8 mode (SEL_PWM = 0)

Figure 19. Timing Diagrams

8 Detailed Description

8.1 Overview

The TLC59581 device is a 48-channel constant-current sink driver for multiplexing system with 1 to 32 duty ratio. Each channel has an individually-adjustable, 65536-step, pulse width modulation (PWM) grayscale (GS).

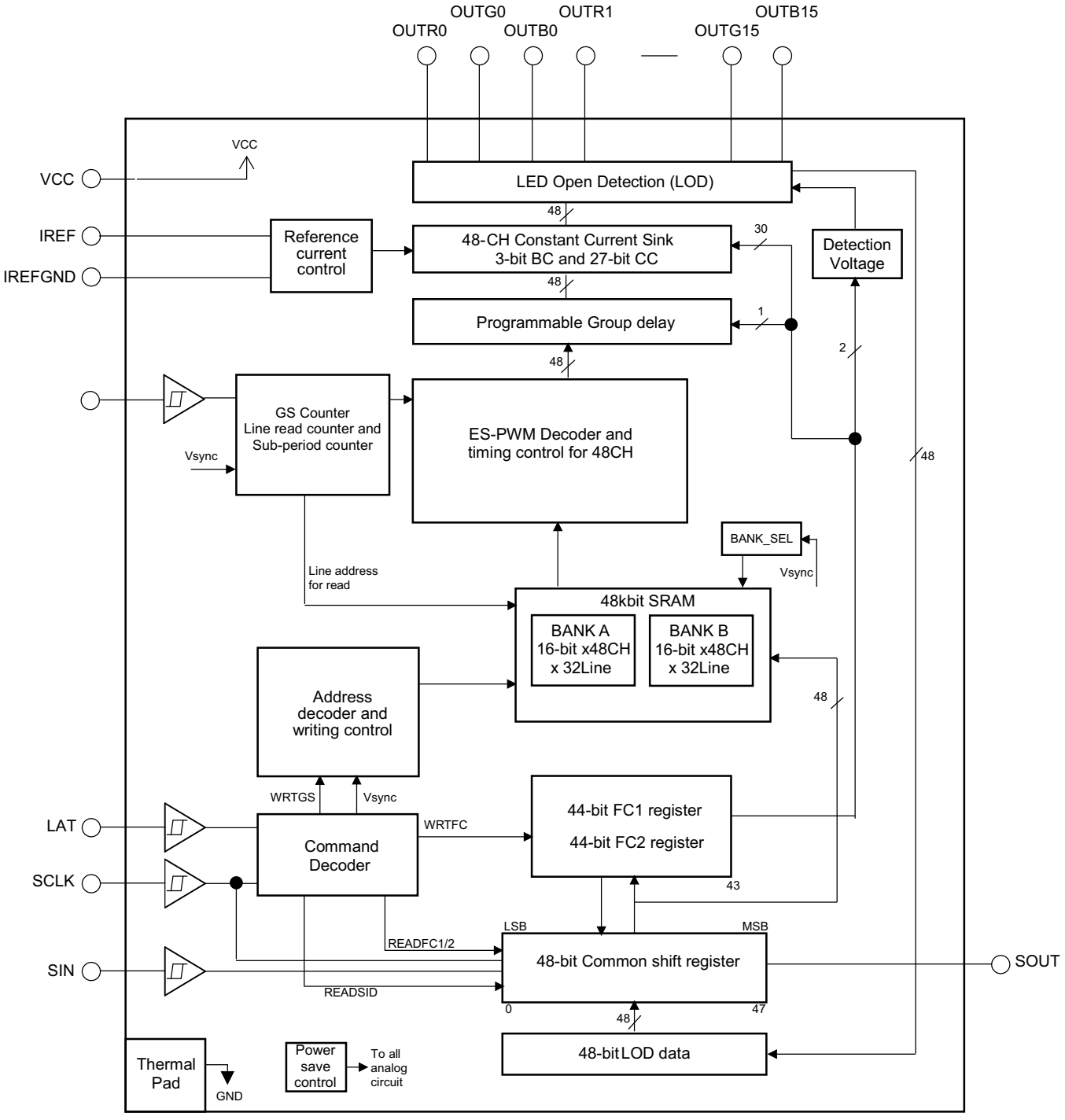
48-kbit display memory is implemented to increase the visual refresh rate and to decrease the GS data writing frequency.

The TLC59581 device's support output current ranges from 1 mA to 25 mA; channel-to-channel accuracy is 3% max, and device-to-device accuracy is 2% max in all current range. The device also implements Low Gray Scale Enhancement (LGSE) technology to improve the display quality at low grayscale condition. These features make the TLC59581 device more suitable for high-density multiplexing application.

The output channels are divided into three groups. Each group has a 512-step color brightness control (CC). CC adjusts brightness control between colors. The maximum current value of all 48 channels can be set by 8-step global brightness control (BC). BC adjusts brightness deviation between LED drivers. GS, CC and BC data are accessible through a serial interface port.

The TLC59581 device has one error flag: the LED open detection (LOD), which can be read through a serial interface port. The TLC59581 device has an enhanced circuit to resolve this caterpillar issue caused by an open LED. Thermal shut down (TSD) and I_{REF} resistor short protection (ISP) ensure a higher system reliability. The TLC59581 device also has a power-save mode that sets the total current consumption to 0.8 mA (typical) when all outputs are off.

8.2 Functional Block Diagram



8.3 Device Functional Modes

After power on, all OUTXn of the TLC59581 device are turned off. All the internal counters and function control registers (FC1/FC2) are initialized. The following list is a brief summary of the sequence to operate the TLC59581 driver that gives users a general idea of how the device works. The function block related to each step is detailed in subsequent sections.

1. According to required LED current, choose BC & CC code, select the current-programming resistor R_{IREF}.
2. Send WRTFC command to set FC1/2 register value if the default value need be changed.
3. Write GS data of all lines (max 32 lines) into one of the two memory BANKs.
4. Send Vsync command, the BANK with the GS data written just now will be displayed.
5. Input GCLK continuously, 257GCLK (or 129GCLK) as a segment. Between the interval of two segments, supply voltage should be switched from one line to next line accordingly.
6. During the same period of step 5, GS data for next frame should be written into another BANK.
7. When the time of one frame ends, Vsync command should be input to swap the purpose of the two BANKs.

Repeat step 5 through 7.

8.3.1 Brightness Control (BC) Function

The TLC59581 device is able to adjust the output current of all constant-current outputs simultaneously. This function is called global brightness control (BC). The global BC for all outputs is programmed with a 3-bit word, thus all output currents can be adjusted in 8 steps from 12.9% to 100% for a given current-programming resistor, R_{IREF} (See Table 2).

BC data can be set through the serial interface. When the BC data changes, the output current also changes immediately. When the device is powered on, the BC data in the function control (FC) register FC1 is set to 4h as the initial value.

8.3.2 Color Brightness Control (CC) Function

The TLC59581 device is able to adjust the output current of each of the three color groups OUTR0-OUTR15, OUTG0-OUTG15, and OUTB0-OUTB15 separately. This function is called color brightness control (CC). For each color, it has 9-bit data latch CCR, CCG, or CCB in FC1 register. Thus, all color group output currents can be adjusted in 512 steps from 0% to 100% of the maximum output current, I_{OLCMax}. (See the next section for more detail about I_{OLCMax}). The CC data are entered through the serial interface. When the CC data change, the output current also changes immediately.

When the IC is powered on, the CC data are set to ‘100h’. Equation 1 calculates the actual output current.

$$Iout(mA) = I_{OLCMax}(mA) \times (CCR/511d \text{ or } CCG/511d \text{ or } CCB/511d) \quad (1)$$

where

- I_{OLCMax} = the maximum channel current for each channel, determined by BC data and R_{IREF} (see Equation 2)
- CCR/G/B = the color brightness control value for each color group in the FC1 register (000h to 1FFh)

Table 1 shows the CC data versus the constant-current against I_{OLCMax}:

Device Functional Modes (continued)

Table 1. CC Data vs Current Ratio and Set Current Value

CC DATA (CCR or CCG or CCB)			RATIO OF OUTPUT CURRENT TO I_{OLCMax}(%, typical)	OUTPUT CURRENT (mA, R_{IREF} = 7.41 kΩ)	
BINARY	DECIMAL	HEX		BC = 7 h (I_{OLCMax} = 25 mA)	BC = 0 h (I_{OLCMax} = 3.2 mA)
0 0000 0000	0	00	0	0	0
0 0000 0001	1	01	0.2	0.05	0.006
0 0000 0010	2	02	0.4	0.10	0.013
---	---	---	---	---	---
1 0000 0000 (Default)	256 (Default)	100 (Default)	50.1	12.52	1.621
---	---	---	---	---	---
1 1111 1101	509	1FD	99.6	24.90	3.222
1 1111 1110	510	1FE	99.8	24.95	3.229
1 1111 1111	511	1FF	100.0	25	3.235

8.3.3 Select R_{IREF} For a Given BC

The maximum output current per channel, I_{OLCMax}, is determined by resistor R_{IREF}, placed between the IREF and IREFGND pins, and the BC code in FC1 register. The voltage on IREF is typically 1.209 V. R_{IREF} can be calculated by Equation 2.

$$R_{IREF}(k\Omega) = V_{IREF}(V) / I_{OLCMax}(mA) \times Gain \quad (2)$$

where

- V_{IREF} = the internal reference voltage on IREF (1.209 V, typical)
- I_{OLCMax} = the largest current for each output at CCR/G/B = 1FFh.
- Gain = the current gain at a selected BC code (See **Table 2**)

Table 2. Current Gain Versus BC Code

BC DATA		GAIN	RATIO OF GAIN / GAIN_MAX (AT MAX BC)
BINARY	HEX		
000 (recommend)	0 (recommend)	20.4	12.9%
001	1	40.3	25.6%
010	2	59.7	52.4%
011	3	82.4	12.9%
100 (default)	4 (default)	101.8	64.7%
101	5	115.4	73.3%
110	6	144.3	91.7%
111	7	157.4	100%
NOTE: Recommend using a smaller BC code for better performance. For noise immunity purposes, suggest R_{IREF} < 60 kΩ			

8.3.4 Choosing BC/CC For a Different Application

BC is mainly used for global brightness adjustment between day and night. Suggested BC is 4h, which is in the middle of the range, allowing flexible changes in brightness up and down.

CC can be used to fine tune the brightness in 512 steps, this is suitable for white balance adjustment between RGB color group. To get a pure white color, the general requirement for the luminous intensity ratio of R, G, B LED is 3:6:1. Depending on the characteristics of the LED (Electro-Optical conversion efficiency), the current ratio of R, G, B LED will be much different from this ratio. Usually, the Red LED needs the largest current. Choose 511d (the max value) CC code for the color group that needs the largest initial current, then choose proper CC code for the other two color groups according to the current ratio requirement of the LED used.

8.3.4.1 Example 1: Red LED Current is 20 mA, Green LED Needs 12 mA, Blue LED needs 8 mA

1. Red LED needs the largest current; choose 511d for CCR
2. 511 x 12 mA / 20 mA = 306.6; choose 307d for CCG. With same method, choose 204d for CCB.
3. According to the required red LED current, choose 7h for BC.
4. According to Equation 2, R_{IREF} = 1.209 V/20 mA x 157.4 = 9.5 kΩ

In this example, choose 7h for BC instead of using the default 4h. This is because the Red LED current is 20 mA, approaching the upper limit of current range. To prevent the constant output current from exceeding the upper limit in case a larger BC code is input accidently, choose the maximum BC code here.

8.3.4.2 Example 2: Red LED Current is 5 mA, Green LED Needs 2 mA, Blue LED Needs 1 mA.

1. Red LED needs the largest current; choose 511d for CCR.
2. 511 x 2 mA / 5 mA = 204.4; choose 204d for CCG. With same method, choose 102d for CCB.
3. According to the required blue LED current, choose 0h for BC.
4. According to Equation 2, R_{IREF} = 1.209 V / 5 mA x 20.4 = 4.93 kΩ

In this example, choose 0h for BC, instead of using the default 4h. This is because the Blue LED current is 1 mA, is approaching the lower limit of current range. To prevent the constant output current from exceeding the lower limit in case a lower BC code is input accidently, choose the minimum BC code here. In general, if LED current is in the middle of the range (i.e, 10 mA), use the default 4h as BC code.

8.3.5 LED Open Detection (LOD)

The LOD function detects faults caused by an open circuit in any LED string; or, a short from OUTXn to ground with low impedance. It does this by comparing the OUTXn voltage to the LOD detection threshold voltage level set by LODVLT in the FC1 register. If the OUTXn voltage is lower than the programmed voltage, the corresponding output LOD bit is set to '1' to indicate an open LED. Otherwise, the output of that LOD bit is '0'. LOD data output by the detection circuit are valid only during the ‘on’ period of that OUTXn output channel. The LOD data are always ‘0’ for outputs that are turned off.

8.3.6 Internal Circuit for Caterpillar Removal

Caterpillar effect is a common issue for the LED panel. It is usually caused by LED lamp open, LED lamp leakage or LED lamp short. The TLC59581 device implements an internal circuit that can eliminate the caterpillar issue caused by LED open. The caterpillar removal function is enabled by setting LOD_MMC_EN (bit4 of FC1 register) to ‘1’. When powered on, the default value of this bit is ‘0’. When this function is enabled, the IC automatically detects the open LED lamp, and the lamp does not turn on until IC reset.

8.3.7 Power Save Mode (PSM)

The power-save mode (PSM) is enabled by setting PSAVE_ENA (bit5 of FC2 register) to ‘1’. At power on, this bit default is ‘0’.

When this function is enabled, if the GS data received for the next frame is all ‘0’, the IC enters power-save mode immediately.

When the IC is in power-save mode, it resumes normal mode when it detects non-zero GS data input. In power-save mode all analog circuits such as constant current output and the LOD circuit are not operational; the device total current consumption, I_{CC}, is below 1 mA.

8.3.8 Internal Pre-Charge FET

The internal pre-charge FET can prevent ghosting of multiplexed LED modules. One cause of this phenomenon is the charging current for parasitic capacitance of the OUTXn through the LED when the supply voltage switches from one common line to the next common line.

To prevent this unwanted charging current, the TLC59581 device uses an internal FET to pull OUTXn up to VCC –1.4 V during the common line switching period. As a result, no charging current flows through LED and ghosting is eliminated.

8.3.9 Thermal Shutdown (TSD)

The thermal shutdown (TSD) function turns off all IC constant-current outputs when the junction temperature (T_J) exceeds 170°C (typical). It resumes normal operation when T_J falls below 160°C (typical).

8.3.10 IREF Resistor Short Protection (ISP)

The IREF resistor short protection (ISP) function prevents unwanted large currents from flowing though the constant-current output when the IREF resistor is shorted accidently. The TLC59581 device turns off all output channels when the IREF pin voltage is lower than 0.19 V (typical). When the IREF pin voltage goes higher than 0.325 V (typical), the TLC59581 device resumes normal operation.

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.

See application note: *Build High Density, High Refresh Rate, Multiplexing LED Panel with TLC59581,* SLVA744 available on ti.com

10 Power Supply Recommendations

Decouple the V_{CC} power supply voltage by placing a 0.1-µF ceramic capacitor close to VCC pin and GND plane. Depending on panel size, several electrolytic capacitors must be placed on the board equally distributed to get a well regulated LED supply voltage (VLED). VLED voltage ripple must be less than 5% of its nominal value. Furthermore, set the VLED voltage as calculated by equation:

VLED > Vf + 0.4 V (10 mA constant current example)

where

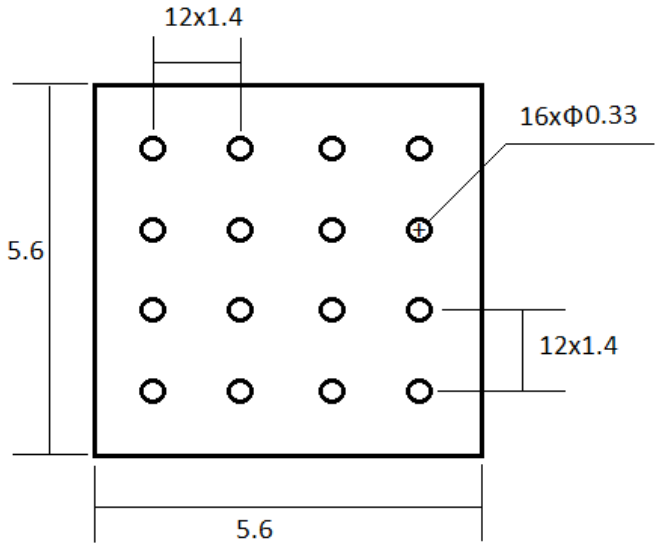
- Vf = maximum forward voltage of LED (3)

11 Layout

11.1 Layout Guidelines

1. Place the decoupling capacitor near the VCC pin and GND plane.
2. Place the current programming resistor R_{IREF} close to IREF pin and IREFGND pin.
3. Route the GND pattern as widely as possible for large GND currents. Maximum GND current is approximately 1.2 A.
4. Routing between the LED cathode side and the device OUTXn pin should be as short and straight as possible to reduce wire inductance.
5. The PowerPAD™ must be connected to GND plane because the pad is used as power ground pin internally, there will be large current flow through this pad when all channels turn on. Furthermore, this pad should be connected to a heat sink layer by thermal via to reduce device temperature. One suggested thermal via pattern is shown as below. For more information about suggested thermal via pattern and via size, see *PowerPAD Thermally Enhanced Package*, SLMA002G.
6. MOSFETS must be placed in the in the middle of the board, which should be laid out as symmetrically as possible.

11.2 Layout Example



12 器件和文档支持

12.1 社区资源

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

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.2 相关链接

1. *应用报告《PowerPAD 耐热增强型封装》*，SLMA002G
2. *应用报告《半导体和 IC 封装热指标》*，SPRA953
3. *应用报告《使用 TLC59581 构建高密度、高刷新率多路复用 LED 面板》*，SLVA744

12.3 商标

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12.4 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。

12.5 Glossary

SLYZ022 — *TI Glossary*.

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

13 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

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只有那些 TI 特别注明属于军用等级或"增强型塑料"的 TI 组件才是设计或专门用于军事/航空应用或环境的。购买者认可并同 意，对并非指定面向军事或航空航天用途的 TI 组件进行军事或航空航天方面的应用，其风险由客户单独承担，并且由客户独 力负责满足与此类使用相关的所有法律和法规要求。

TI 已明确指定符合 ISO/TS16949 要求的产品，这些产品主要用于汽车。在任何情况下，因使用非指定产品而无法达到 ISO/TS16949 要求，TI不承担任何责任。

	产品		应用
数字音频	www.ti.com.cn/audio	通信与电信	www.ti.com.cn/telecom
放大器和线性器件	www.ti.com.cn/amplifiers	计算机及周边	www.ti.com.cn/computer
数据转换器	www.ti.com.cn/dataconverters	消费电子	www.ti.com/consumer-apps
DLP® 产品	www.dlp.com	能源	www.ti.com/energy
DSP - 数字信号处理器	www.ti.com.cn/dsp	工业应用	www.ti.com.cn/industrial
时钟和计时器	www.ti.com.cn/clockandtimers	医疗电子	www.ti.com.cn/medical
接口	www.ti.com.cn/interface	安防应用	www.ti.com.cn/security
逻辑	www.ti.com.cn/logic	汽车电子	www.ti.com.cn/automotive
电源管理	www.ti.com.cn/power	视频和影像	www.ti.com.cn/video
微控制器 (MCU)	www.ti.com.cn/microcontrollers		
RFID 系统	www.ti.com.cn/rfidsys		
OMAP应用处理器	www.ti.com/omap		
无线连通性	www.ti.com.cn/wirelessconnectivity	德州仪器在线技术支持社区	www.deyisupport.com

邮寄地址： 上海市浦东新区世纪大道1568 号，中建大厦32 楼邮政编码： 200122

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
TLC59581RTQR	ACTIVE	QFN	RTQ	56	2000	RoHS & Green	NIPDAU | NIPDAUAG	Level-3-260C-168 HR	-40 to 85	TLC59581AB	Samples
TLC59581RTQT	ACTIVE	QFN	RTQ	56	250	RoHS & Green	NIPDAU | NIPDAUAG	Level-3-260C-168 HR	-40 to 85	TLC59581AB	Samples

(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.

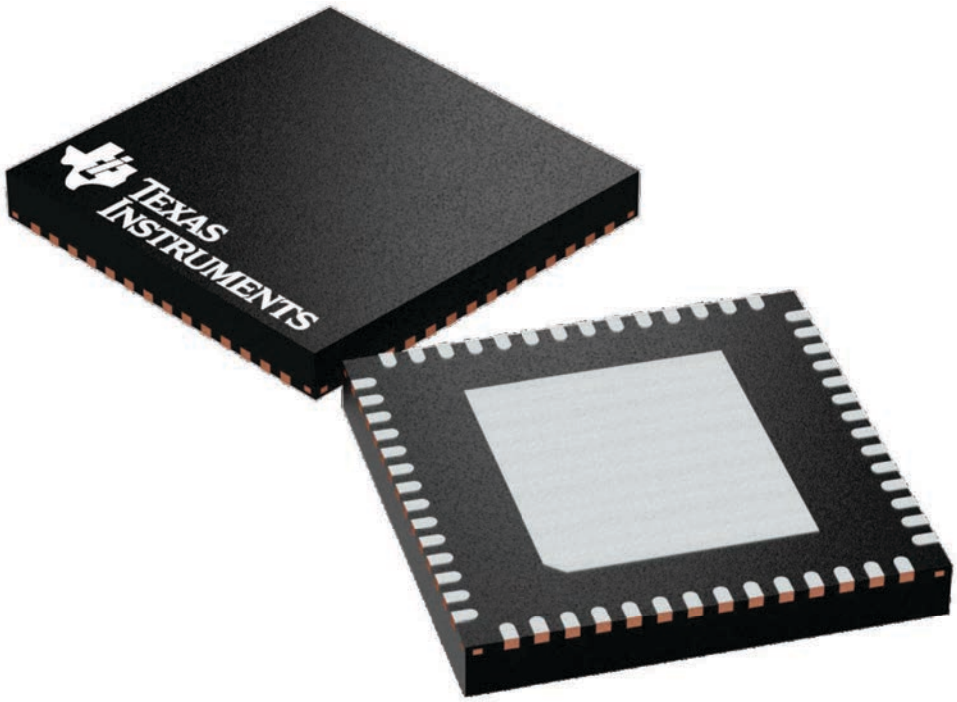
GENERIC PACKAGE VIEW

RTQ 56

VQFN - 1 mm max height

8 x 8, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

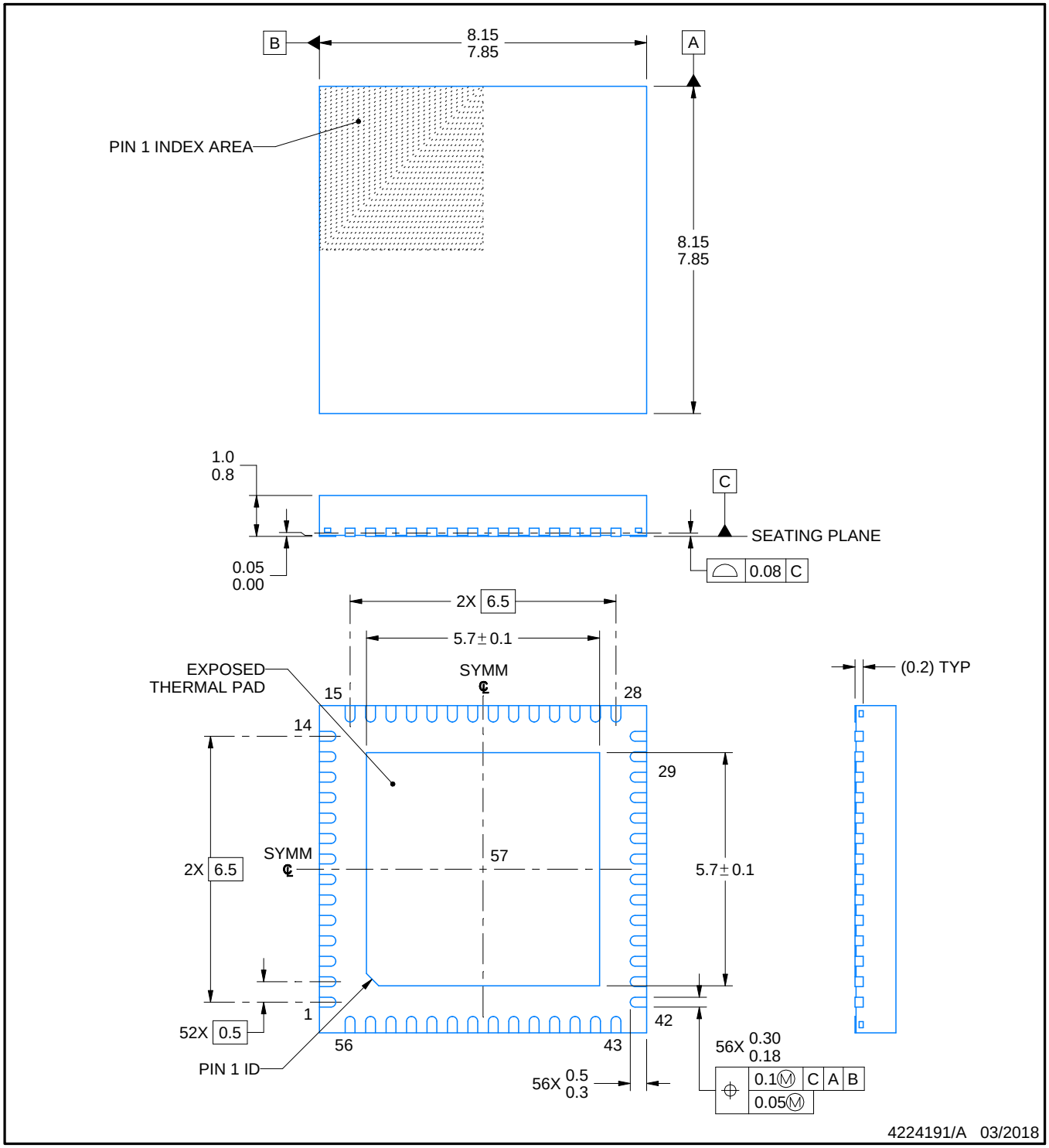
4224653/A

RTQ0056E

PACKAGE OUTLINE

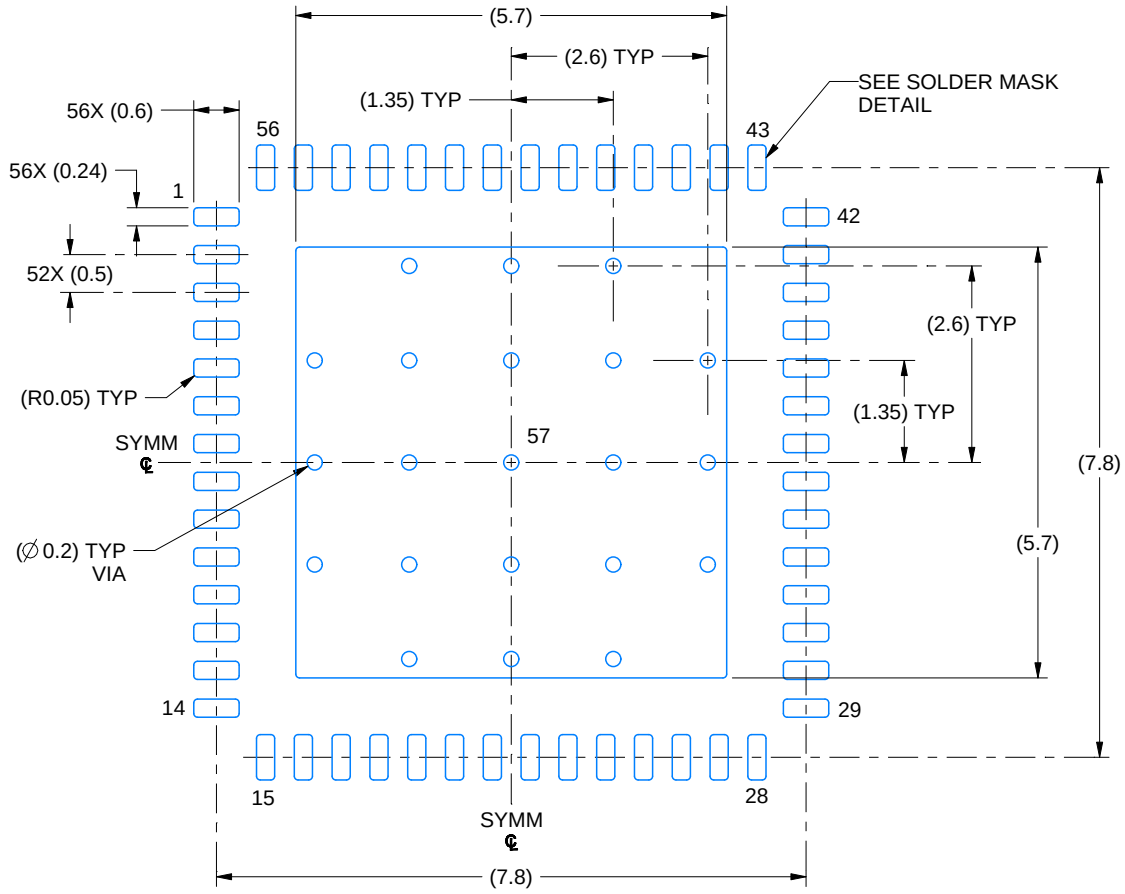
VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

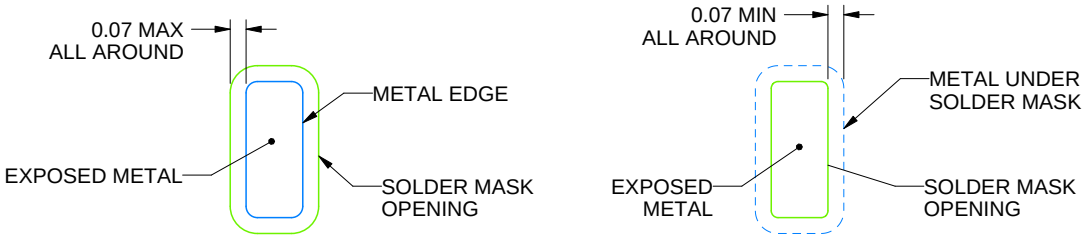


NOTES:

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



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

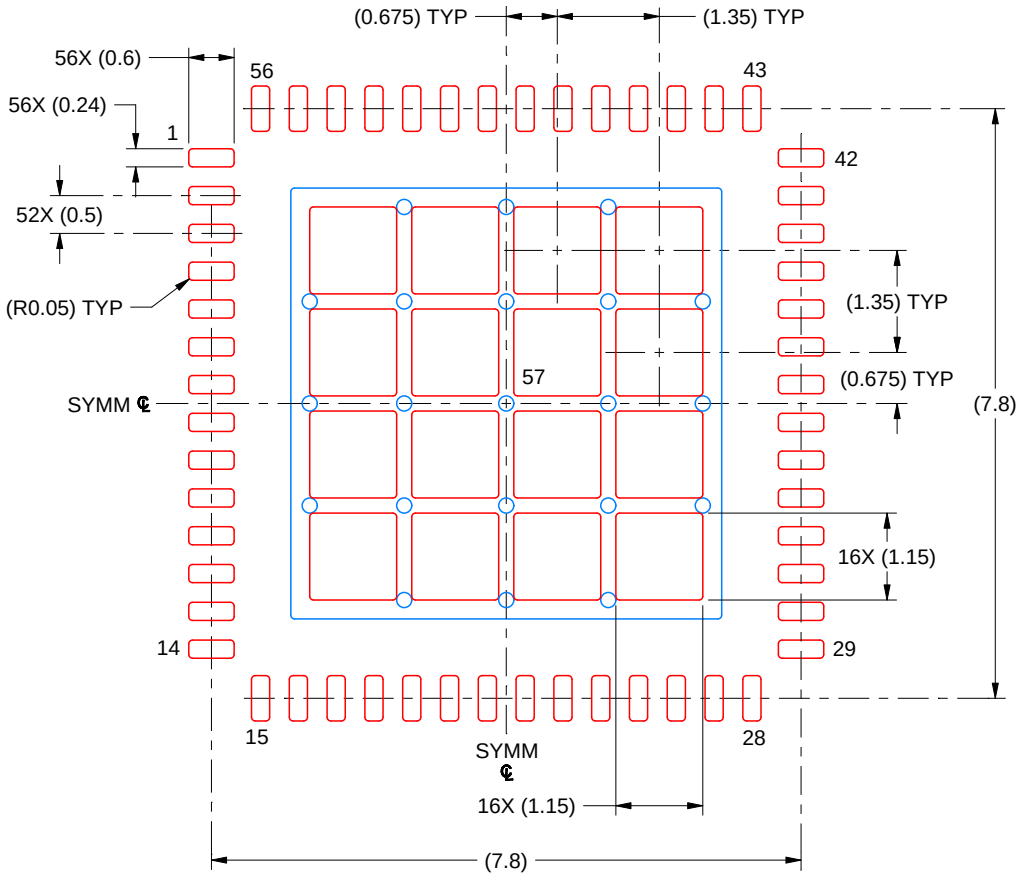


SOLDER MASK DETAILS

4224191/A 03/2018

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).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 10X

EXPOSED PAD 57
65% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

4224191/A 03/2018

NOTES: (continued)

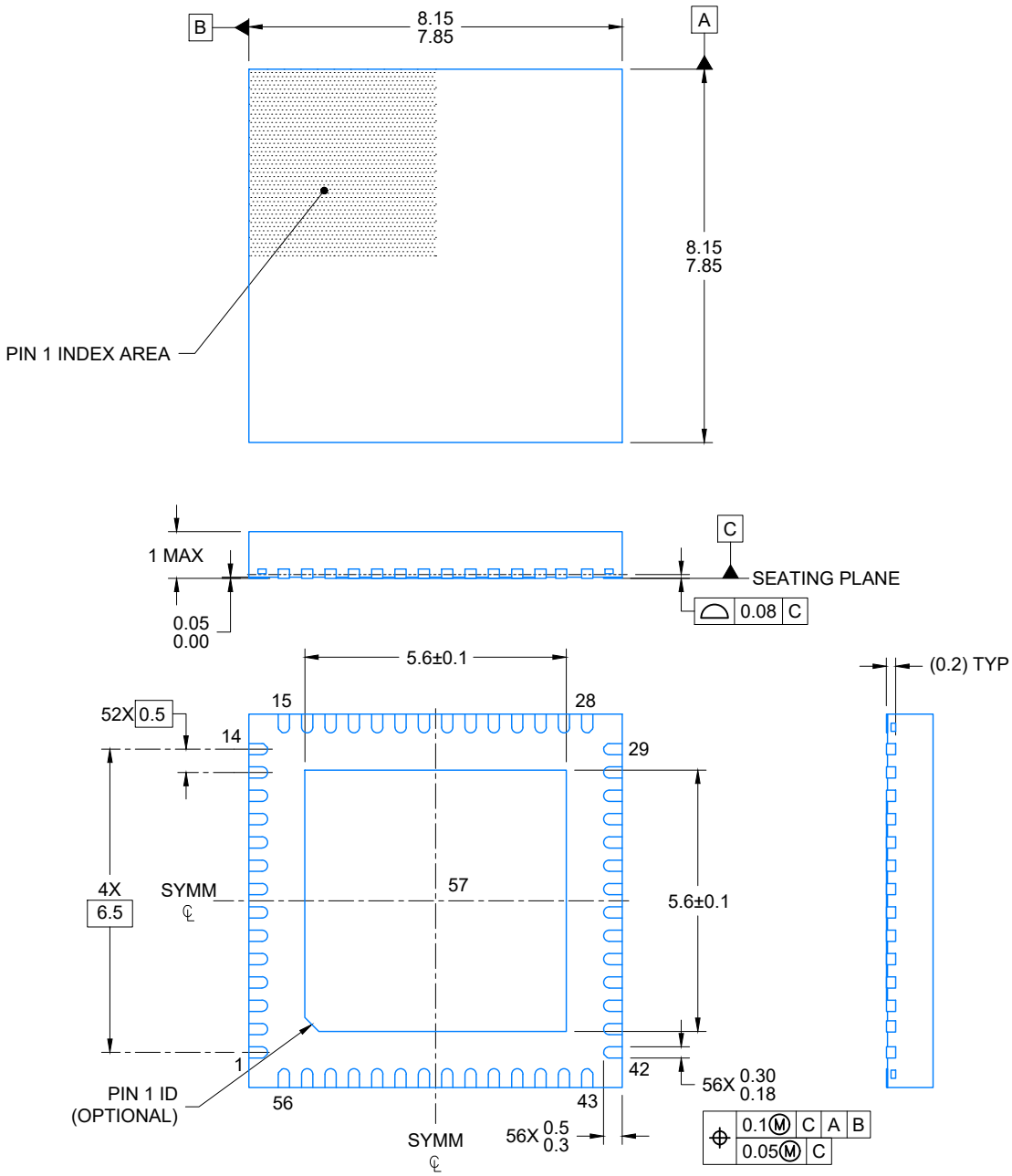
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

PACKAGE OUTLINE

RTQ0056G

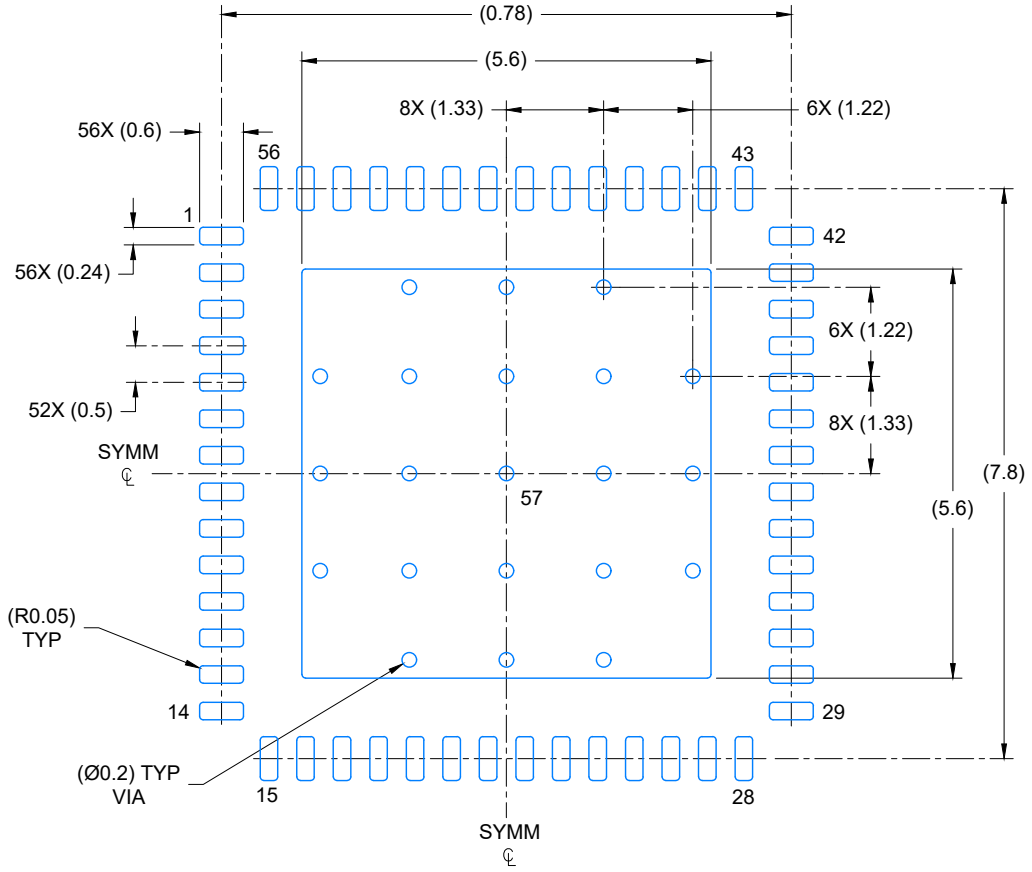
VQFN - 1 mm max height

PLASTIC QUAD FLATPACK-NO LEAD



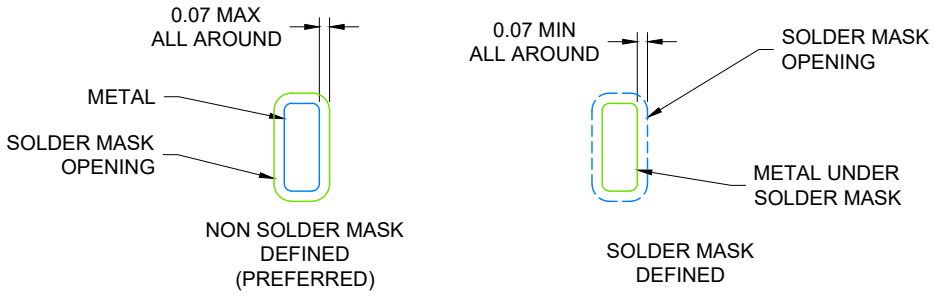
NOTES:

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



LAND PATTERN EXAMPLE

SCALE: 10X

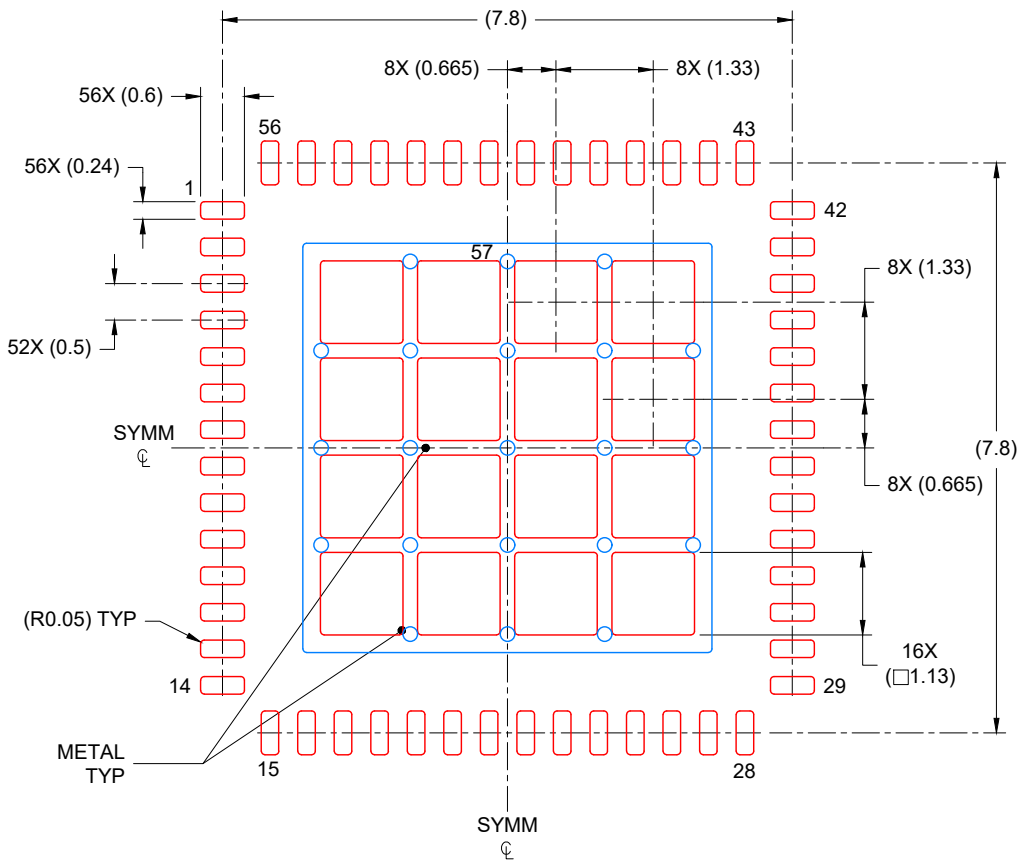


SOLDER MASK DETAILS

4225369 / A 10/2019

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).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. it is recommended thar vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
66% PRINTED COVERAGE BY AREA
SCALE: 10X

4225369 / A 10/2019

NOTES: (continued)

6. 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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