

## 24-Channel, 12-Bit PWM LED Driver with Internal Oscillator

### FEATURES

- 24 Channels, Constant Current Sink Output
- 30-mA Capability (Constant Current Sink)
- 12-Bit (4096 Steps) PWM Grayscale Control
- LED Power-Supply Voltage up to 30 V
- $V_{CC} = 3.0\text{ V to }5.5\text{ V}$
- Constant Current Accuracy:
  - Channel-to-Channel =  $\pm 2\%$  (typ)
  - Device-to-Device =  $\pm 2\%$  (typ)
- CMOS Logic Level I/O
- 30-MHz Data Transfer Rate (Standalone)
- 15-MHz Data Transfer Rate (Cascaded Devices, SCLK Duty = 50%)
- Shift Out Data Changes With Falling Edge to Avoid Data Shift Errors
- Auto Display Repeat
- 4-MHz Internal Oscillator
- Thermal Shutdown (TSD):
  - Automatic shutdown at over temperature conditions
  - Restart under normal temperature

### Noise Reduction:

- 4-channel grouped delay to prevent inrush current

- Operating Temperature:  $-40^{\circ}\text{C to }+85^{\circ}\text{C}$

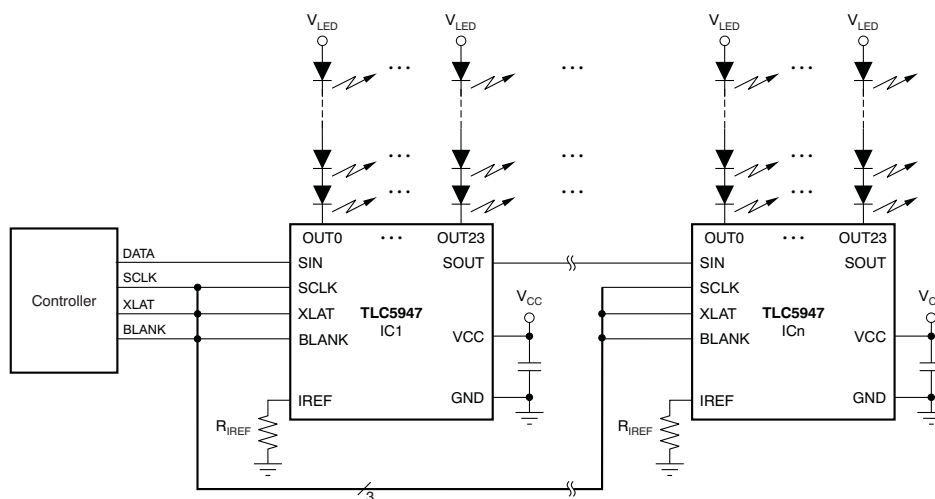
### APPLICATIONS

- Static LED Displays
- Message Boards
- Amusement Illumination
- TV Backlighting

### DESCRIPTION

The TLC5947 is a 24-channel, constant current sink LED driver. Each channel is individually adjustable with 4096 pulse-width modulated (PWM) steps. PWM control is repeated automatically with the programmed grayscale (GS) data. GS data are written via a serial interface port. The current value of all 24 channels is set by a single external resistor.

The TLC5947 has a thermal shutdown (TSD) function that turns off all output drivers during an over-temperature condition. All of the output drivers automatically restart when the temperature returns to normal conditions.



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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### PACKAGE/ORDERING INFORMATION<sup>(1)</sup>

| PRODUCT | PACKAGE-LEAD        | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|---------|---------------------|-----------------|---------------------------|
| TLC5947 | HTSSOP-32 PowerPAD™ | TLC5947DAPR     | Tape and Reel, 2000       |
|         |                     | TLC5947DAP      | Tube, 46                  |
| TLC5947 | 5-mm × 5-mm QFN-32  | TLC5947RHBR     | Tape and Reel, 3000       |
|         |                     | TLC5947RHB      | Tape and Reel, 250        |

- (1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).

### ABSOLUTE MAXIMUM RATINGS<sup>(1)(2)</sup>

Over operating free-air temperature range, unless otherwise noted.

| PARAMETER           |                                 |                        | TLC5947                       | UNIT |
|---------------------|---------------------------------|------------------------|-------------------------------|------|
| V <sub>CC</sub>     | Supply voltage: V <sub>CC</sub> |                        | –0.3 to +6.0                  | V    |
| I <sub>O</sub>      | Output current (dc)             | OUT0 to OUT23          | 38                            | mA   |
| V <sub>I</sub>      | Input voltage range             | SIN, SCLK, XLAT, BLANK | –0.3 to V <sub>CC</sub> + 0.3 | V    |
| V <sub>O</sub>      | Output voltage range            | SOUT                   | –0.3 to V <sub>CC</sub> + 0.3 | V    |
|                     |                                 | OUT0 to OUT23          | –0.3 to +33                   | V    |
| T <sub>J(MAX)</sub> | Operating junction temperature  |                        | +150                          | °C   |
| T <sub>STG</sub>    | Storage temperature range       |                        | –55 to +150                   | °C   |
| ESD rating          | Human body model (HBM)          |                        | 2                             | kV   |
|                     | Charged device model (CDM)      |                        | 500                           | V    |

- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.
- (2) All voltage values are with respect to network ground terminal.

### DISSIPATION RATINGS

| PACKAGE                                                | OPERATING FACTOR<br>ABOVE T <sub>A</sub> = +25°C | T <sub>A</sub> < +25°C<br>POWER RATING | T <sub>A</sub> = +70°C<br>POWER RATING | T <sub>A</sub> = +85°C<br>POWER RATING |
|--------------------------------------------------------|--------------------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| HTSSOP-32 with<br>PowerPAD soldered <sup>(1)</sup>     | 42.54 mW/°C                                      | 5318 mW                                | 3403 mW                                | 2765 mW                                |
| HTSSOP-32 with<br>PowerPAD not soldered <sup>(2)</sup> | 22.56 mW/°C                                      | 2820 mW                                | 1805 mW                                | 1466 mW                                |
| QFN-32 <sup>(3)</sup>                                  | 27.86 mW/°C                                      | 3482 mW                                | 2228 mW                                | 1811 mW                                |

- (1) With PowerPAD soldered onto copper area on printed circuit board (PCB); 2 oz. copper. For more information, see [SLMA002](#) (available for download at [www.ti.com](http://www.ti.com)).
- (2) With PowerPAD not soldered onto copper area on PCB.
- (3) The package thermal impedance is calculated in accordance with JESD51-5.

## RECOMMENDED OPERATING CONDITIONS

At  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ , unless otherwise noted.

| PARAMETER                                          |                                      | TEST CONDITIONS                    | TLC5947               |     |                       | UNIT |
|----------------------------------------------------|--------------------------------------|------------------------------------|-----------------------|-----|-----------------------|------|
|                                                    |                                      |                                    | MIN                   | NOM | MAX                   |      |
| DC Characteristics: V <sub>CC</sub> = 3 V to 5.5 V |                                      |                                    |                       |     |                       |      |
| V <sub>CC</sub>                                    | Supply voltage                       |                                    | 3.0                   |     | 5.5                   | V    |
| V <sub>O</sub>                                     | Voltage applied to output            | OUT0 to OUT23                      |                       |     | 30                    | V    |
| V <sub>IH</sub>                                    | High-level input voltage             |                                    | 0.7 × V <sub>CC</sub> |     | V <sub>CC</sub>       | V    |
| V <sub>IL</sub>                                    | Low-level input voltage              |                                    | GND                   |     | 0.3 × V <sub>CC</sub> | V    |
| I <sub>OH</sub>                                    | High-level output current            | SOUT                               |                       |     | −3                    | mA   |
| I <sub>OL</sub>                                    | Low-level output current             | SOUT                               |                       |     | 3                     | mA   |
| I <sub>OLC</sub>                                   | Constant output sink current         | OUT0 to OUT23                      | 2                     |     | 30                    | mA   |
| T <sub>A</sub>                                     | Operating free-air temperature range |                                    | −40                   |     | +85                   | °C   |
| T <sub>J</sub>                                     | Operating junction temperature       |                                    | −40                   |     | +125                  | °C   |
| AC Characteristics: V <sub>CC</sub> = 3 V to 5.5 V |                                      |                                    |                       |     |                       |      |
| f <sub>SCLK</sub>                                  | Data shift clock frequency           | SCLK, Standalone operation         |                       |     | 30                    | MHz  |
|                                                    |                                      | SCLK, Duty 50%, cascade operation  |                       |     | 15                    | MHz  |
| T <sub>WH0</sub>                                   | Pulse duration                       | SCLK = High-level pulse width      | 12                    |     |                       | ns   |
| T <sub>WL0</sub>                                   |                                      | SCLK = Low-level pulse width       | 10                    |     |                       | ns   |
| T <sub>WH1</sub>                                   |                                      | XLAT, BLANK High-level pulse width | 30                    |     |                       | ns   |
| T <sub>SU0</sub>                                   | Setup time                           | SIN−SCLK↑                          | 5                     |     |                       | ns   |
| T <sub>SU1</sub>                                   |                                      | XLAT↑−SCLK↑                        | 100                   |     |                       | ns   |
| T <sub>SU2</sub>                                   |                                      | XLAT↑−BLANK↓                       | 30                    |     |                       | ns   |
| T <sub>H0</sub>                                    | Hold time                            | SIN−SCLK↑                          | 3                     |     |                       | ns   |
| T <sub>H1</sub>                                    |                                      | XLAT↑−SCLK↑                        | 10                    |     |                       | ns   |

## ELECTRICAL CHARACTERISTICS

At  $V_{CC} = 3.0\text{ V}$  to  $5.5\text{ V}$  and  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ . Typical values at  $V_{CC} = 3.3\text{ V}$  and  $T_A = +25^\circ\text{C}$ , unless otherwise noted.

| PARAMETER         |                                                            | TEST CONDITIONS                                                                                                                                       | TLC5947        |         |          | UNIT             |
|-------------------|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|---------|----------|------------------|
|                   |                                                            |                                                                                                                                                       | MIN            | TYP     | MAX      |                  |
| $V_{OH}$          | High-level output voltage                                  | $I_{OH} = -3\text{ mA}$ at SOUT                                                                                                                       | $V_{CC} - 0.4$ |         | $V_{CC}$ | V                |
| $V_{OL}$          | Low-level output voltage                                   | $I_{OL} = 3\text{ mA}$ at SOUT                                                                                                                        |                |         | 0.4      | V                |
| $I_{IN}$          | Input current                                              | $V_{IN} = V_{CC}$ or GND at SIN, XLAT, and BLANK                                                                                                      | -1             |         | 1        | $\mu\text{A}$    |
| $I_{CC1}$         | Supply current ( $V_{CC}$ )                                | SIN/SCLK/XLAT = low, BLANK = high, $V_{OUTn} = 1\text{ V}$ , $R_{IREF} = 24\text{ k}\Omega$                                                           |                | 0.5     | 3        | mA               |
| $I_{CC2}$         |                                                            | SIN/SCLK/XLAT = low, BLANK = high, $V_{OUTn} = 1\text{ V}$ , $R_{IREF} = 3.3\text{ k}\Omega$                                                          |                | 1       | 6        | mA               |
| $I_{CC3}$         |                                                            | SIN/SCLK/XLAT = low, BLANK = low, $V_{OUTn} = 1\text{ V}$ , $R_{IREF} = 3.3\text{ k}\Omega$ , $GSn = \text{FFFh}$                                     |                | 15      | 45       | mA               |
| $I_{CC4}$         |                                                            | SIN/SCLK/XLAT = low, BLANK = low, $V_{OUTn} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$ , $GSn = \text{FFFh}$                                     |                | 30      | 90       | mA               |
| $I_{OLC}$         | Constant output current                                    | All $OUTn = \text{ON}$ , $V_{OUTn} = 1\text{ V}$ , $V_{OUTfix} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$                                        | 27.7           | 30.75   | 33.8     | mA               |
| $I_{OLK}$         | Output leakage current                                     | BLANK = high, $V_{OUTn} = 30\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$ , At $OUT0$ to $OUT23$                                                       |                |         | 0.1      | $\mu\text{A}$    |
| $\Delta I_{OLC}$  | Constant current error (channel-to-channel) <sup>(1)</sup> | All $OUTn = \text{ON}$ , $V_{OUTn} = 1\text{ V}$ , $V_{OUTfix} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$ , At $OUT0$ to $OUT23$                 |                | $\pm 2$ | $\pm 4$  | %                |
| $\Delta I_{OLC1}$ | Constant current error (device-to-device) <sup>(2)</sup>   | All $OUTn = \text{ON}$ , $V_{OUTn} = 1\text{ V}$ , $V_{OUTfix} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$                                        |                | $\pm 2$ | $\pm 7$  | %                |
| $\Delta I_{OLC2}$ | Line regulation <sup>(3)</sup>                             | All $OUTn = \text{ON}$ , $V_{OUTn} = 1\text{ V}$ , $V_{OUTfix} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$ , At $OUT0$ to $OUT23$                 |                | $\pm 1$ | $\pm 3$  | %/V              |
| $\Delta I_{OLC3}$ | Load regulation <sup>(4)</sup>                             | All $OUTn = \text{ON}$ , $V_{OUTn} = 1\text{ V}$ to $3\text{ V}$ , $V_{OUTfix} = 1\text{ V}$ , $R_{IREF} = 1.6\text{ k}\Omega$ , At $OUT0$ to $OUT23$ |                | $\pm 2$ | $\pm 6$  | %/V              |
| $T_{DOWN}$        | Thermal shutdown threshold                                 | Junction temperature <sup>(5)</sup>                                                                                                                   | +150           | +162    | +175     | $^\circ\text{C}$ |
| $T_{HYS}$         | Thermal error hysteresis                                   | Junction temperature <sup>(5)</sup>                                                                                                                   | +5             | +10     | +20      | $^\circ\text{C}$ |
| $V_{IREF}$        | Reference voltage output                                   | $R_{IREF} = 1.6\text{ k}\Omega$                                                                                                                       | 1.16           | 1.20    | 1.24     | V                |

- (1) The deviation of each output from the average of  $OUT0$ – $OUT23$  constant current. Deviation is calculated by the formula:

$$\Delta (\%) = \left[ \frac{I_{OUTn}}{\frac{(I_{OUT0} + I_{OUT1} + \dots + I_{OUT22} + I_{OUT23})}{24}} - 1 \right] \times 100$$

- (2) The deviation of the  $OUT0$ – $OUT23$  constant current average from the ideal constant current value. Deviation is calculated by the following formula:

$$\Delta (\%) = \left[ \frac{\frac{(I_{OUT0} + I_{OUT1} + \dots + I_{OUT22} + I_{OUT23})}{24} - (\text{Ideal Output Current})}{\text{Ideal Output Current}} \right] \times 100$$

Ideal current is calculated by the formula:

$$I_{OUT(\text{IDEAL})} = 41 \times \left[ \frac{1.20}{R_{IREF}} \right]$$

- (3) Line regulation is calculated by this equation:

$$\Delta (\%/V) = \left[ \frac{(I_{OUTn} \text{ at } V_{CC} = 5.5\text{ V}) - (I_{OUTn} \text{ at } V_{CC} = 3.0\text{ V})}{(I_{OUTn} \text{ at } V_{CC} = 3.0\text{ V})} \right] \times \frac{100}{5.5\text{ V} - 3.0\text{ V}}$$

- (4) Load regulation is calculated by the equation:

$$\Delta (\%/V) = \left[ \frac{(I_{OUTn} \text{ at } V_{OUTn} = 3\text{ V}) - (I_{OUTn} \text{ at } V_{OUTn} = 1\text{ V})}{(I_{OUTn} \text{ at } V_{OUTn} = 1\text{ V})} \right] \times \frac{100}{3\text{ V} - 1\text{ V}}$$

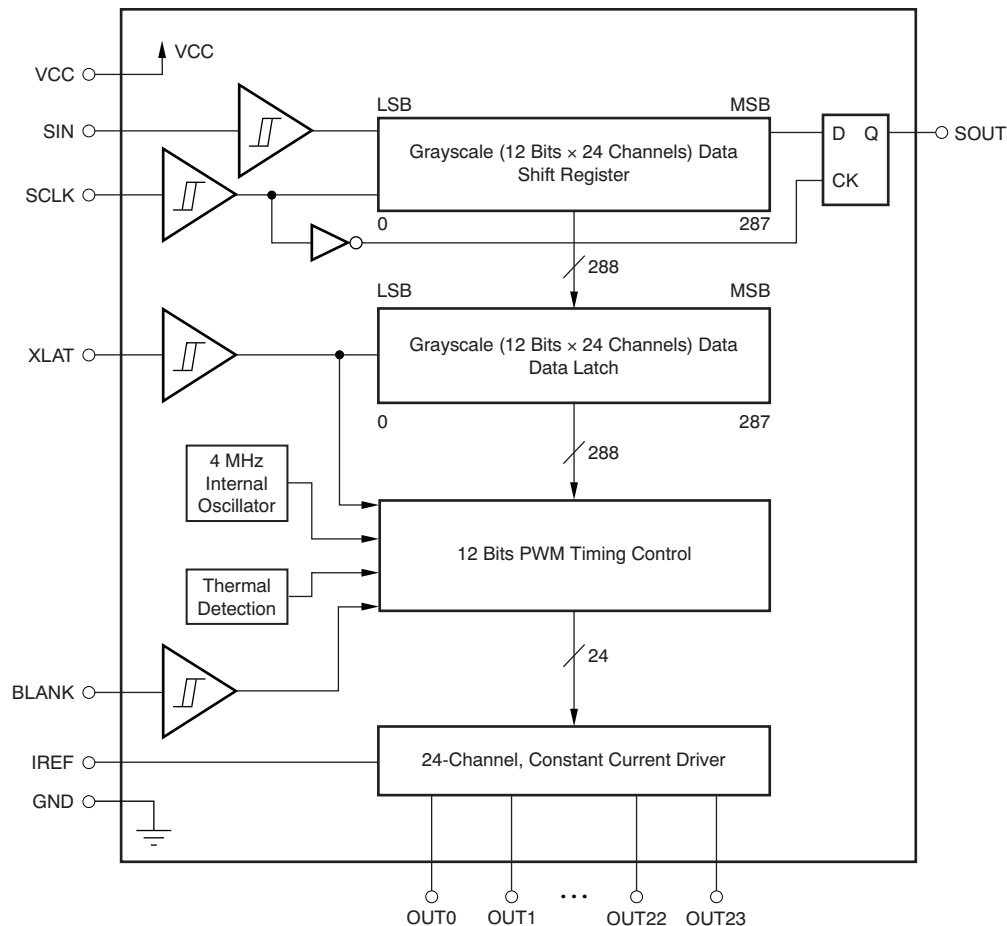
- (5) Not tested. Specified by design.

## SWITCHING CHARACTERISTICS

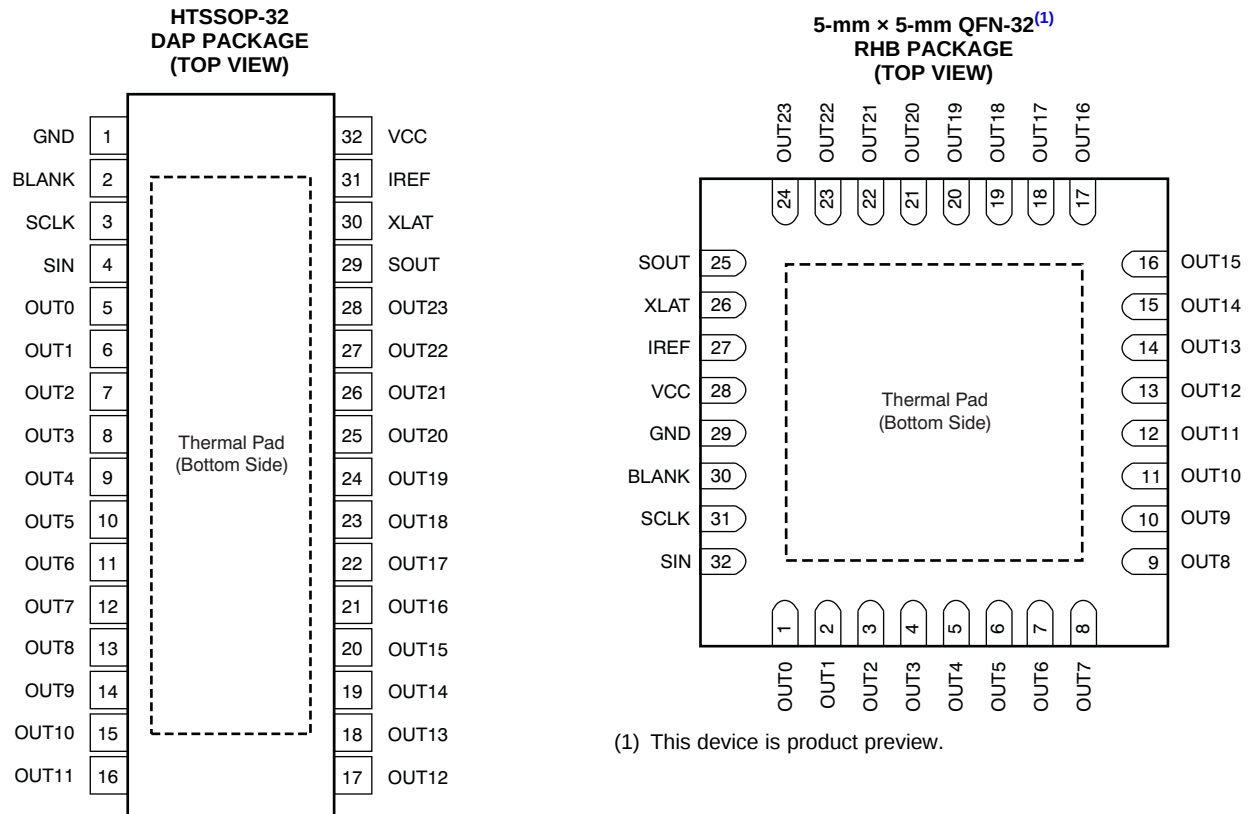
At  $V_{CC} = 3.0\text{ V}$  to  $5.5\text{ V}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $C_L = 15\text{ pF}$ ,  $R_L = 150\ \Omega$ ,  $R_{IREF} = 1.6\text{ k}\Omega$ , and  $V_{LED} = 5.5\text{ V}$ . Typical values at  $V_{CC} = 3.3\text{ V}$  and  $T_A = +25^\circ\text{C}$ , unless otherwise noted.

| PARAMETER |                               | TEST CONDITIONS                                  | TLC5947 |     |     | UNIT |
|-----------|-------------------------------|--------------------------------------------------|---------|-----|-----|------|
|           |                               |                                                  | MIN     | TYP | MAX |      |
| $t_{R0}$  | Rise time                     | SOUT                                             |         | 10  | 15  | ns   |
| $t_{R1}$  |                               | OUTn                                             |         | 15  | 40  | ns   |
| $t_{F0}$  | Fall time                     | SOUT                                             |         | 10  | 15  | ns   |
| $t_{F1}$  |                               | OUTn                                             |         | 100 | 300 | ns   |
| $f_{OSC}$ | Internal oscillator frequency |                                                  | 2.4     | 4   | 5.6 | MHz  |
| $t_{D0}$  | Propagation delay time        | SCLK↓ to SOUT                                    |         | 15  | 25  | ns   |
| $t_{D1}$  |                               | BLANK↑ to OUT0 sink current off                  |         | 20  | 40  | ns   |
| $t_{D2}$  |                               | OUT0 current on to OUT1/5/9/13/17/21 current on  | 15      | 24  | 33  | ns   |
| $t_{D3}$  |                               | OUT0 current on to OUT2/6/10/14/18/22 current on | 30      | 48  | 66  | ns   |
| $t_{D4}$  |                               | OUT0 current on to OUT3/7/11/15/19/23 current on | 45      | 72  | 99  | ns   |

## FUNCTIONAL BLOCK DIAGRAM



## DEVICE INFORMATION



NOTE: Thermal pad is not connected to GND internally. The thermal pad must be connected to GND via the PCB pattern.

## TERMINAL FUNCTIONS

| TERMINAL |     |     | I/O | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                     |
|----------|-----|-----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME     | DAP | RHB |     |                                                                                                                                                                                                                                                                                                                                                                                 |
| SIN      | 4   | 32  | I   | Serial input for grayscale data                                                                                                                                                                                                                                                                                                                                                 |
| SCLK     | 3   | 31  | I   | Serial data shift clock. Schmitt buffer input. Data present on the SIN pin are shifted into the shift register with the rising edge of the SCLK pin. Data are shifted to the MSB side by 1-bit synchronizing of the rising edge of SCLK. The MSB data appears on SOUT at the falling edge of SCLK. A rising edge on the SCLK input is allowed 100 ns after an XLAT rising edge. |
| XLAT     | 30  | 26  | I   | The data in the grayscale shift register are moved to the grayscale data latch with a low-to-high transition on this pin. When the XLAT rising edge is input, all constant current outputs are forced off until the next grayscale display period. The grayscale counter is not reset to zero with a rising edge of XLAT.                                                       |
| BLANK    | 2   | 30  | I   | Blank (all constant current outputs off). When BLANK is high, all constant current outputs (OUT0 through OUT23) are forced off, the grayscale PWM timing controller initializes, and the grayscale counter resets to '0'. When BLANK is low, all constant current outputs are controlled by the grayscale PWM timing controller.                                                |
| IREF     | 31  | 27  | I/O | This pin sets the constant current value. OUT0 through OUT23 constant sink current is set to the desired value by connecting an external resistor between IREF and GND.                                                                                                                                                                                                         |
| SOUT     | 29  | 25  | O   | Serial data output. This output is connected to the shift register placed after the MSB of the grayscale shift register. Therefore, the MSB data of the grayscale shift register appears at the falling edge of SCLK. This function reduces the data shifting errors caused by small timing margins between SIN and SCLK.                                                       |
| OUT0     | 5   | 1   | O   | Constant current output. Multiple outputs can be tied together to increase the constant current capability. Different voltages can be applied to each output.                                                                                                                                                                                                                   |
| OUT1     | 6   | 2   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT2     | 7   | 3   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT3     | 8   | 4   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT4     | 9   | 5   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT5     | 10  | 6   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT6     | 11  | 7   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT7     | 12  | 8   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT8     | 13  | 9   | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT9     | 14  | 10  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT10    | 15  | 11  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT11    | 16  | 12  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT12    | 17  | 13  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT13    | 18  | 14  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT14    | 19  | 15  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT15    | 20  | 16  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT16    | 21  | 17  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT17    | 22  | 18  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT18    | 23  | 19  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT19    | 24  | 20  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT20    | 25  | 21  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT21    | 26  | 22  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT22    | 27  | 23  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| OUT23    | 28  | 24  | O   | Constant current output                                                                                                                                                                                                                                                                                                                                                         |
| VCC      | 32  | 28  | —   | Power-supply voltage                                                                                                                                                                                                                                                                                                                                                            |
| GND      | 1   | 29  | —   | Power ground                                                                                                                                                                                                                                                                                                                                                                    |

## PARAMETER MEASUREMENT INFORMATION

### PIN EQUIVALENT INPUT AND OUTPUT SCHEMATIC DIAGRAMS

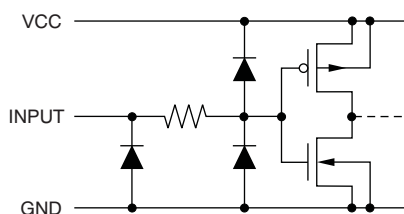


Figure 1. SIN, SCLK, XLAT, BLANK

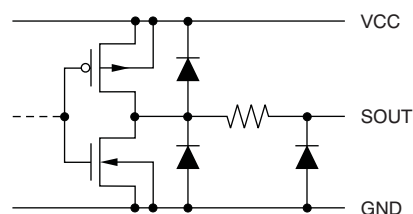


Figure 2. SOUT

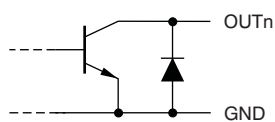


Figure 3. OUT0 Through OUT23

### TEST CIRCUITS

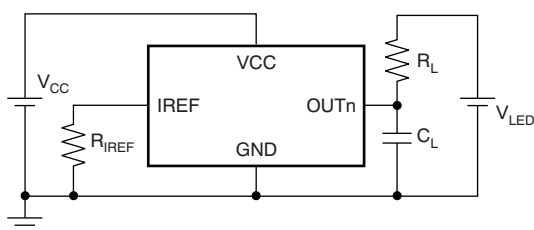


Figure 4. Rise Time and Fall Time Test Circuit for OUTn

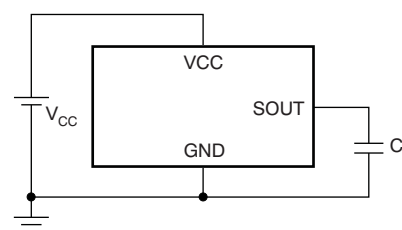


Figure 5. Rise Time and Fall Time Test Circuit for SOUT

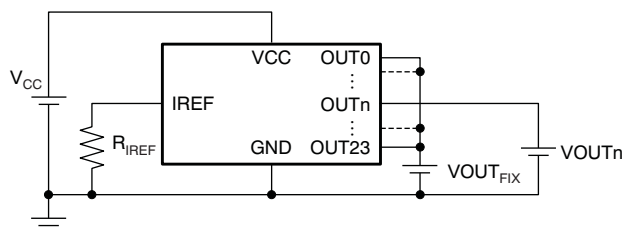
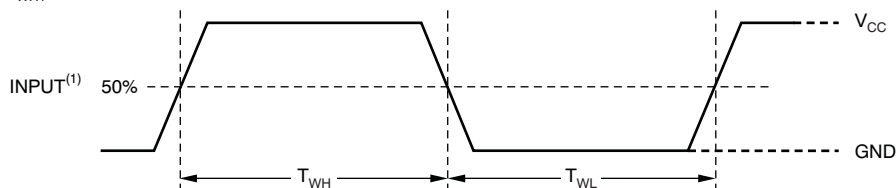
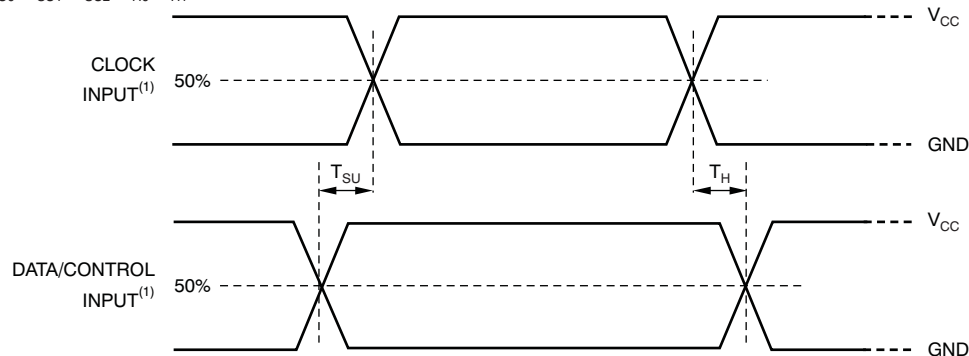


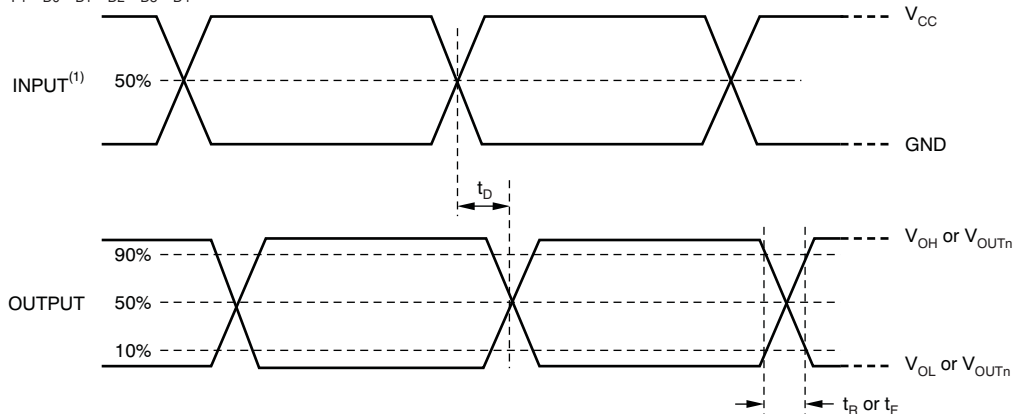
Figure 6. Constant Current Test Circuit for OUTn

## TIMING DIAGRAMS

 $T_{WH0}, T_{WL0}, T_{WH1}:$ 

 $T_{SU0}, T_{SU1}, T_{SU2}, T_{H0}, T_{H1}:$ 


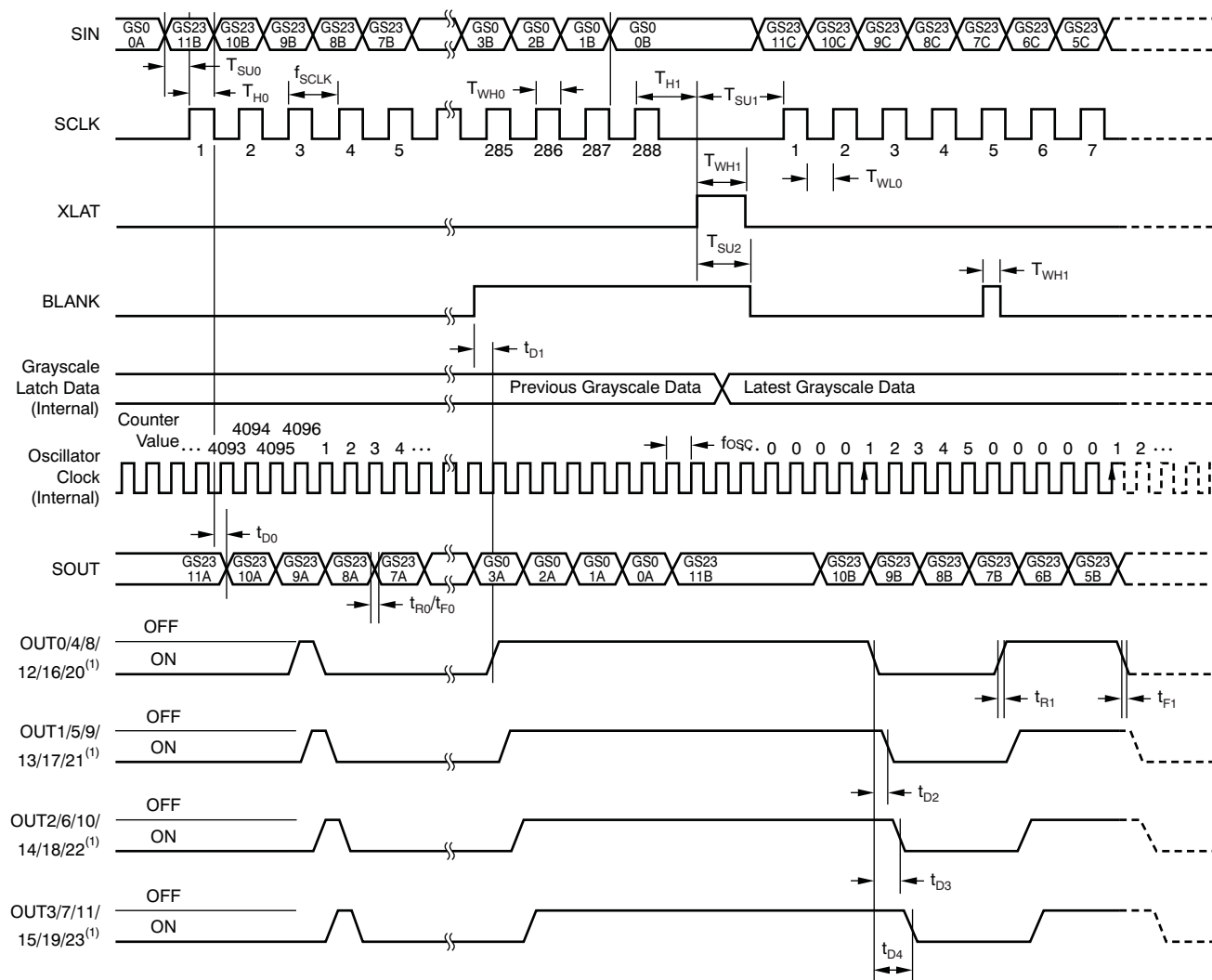
(1) Input pulse rise and fall time is 1 ns to 3 ns.

**Figure 7. Input Timing**

 $t_{R0}, t_{R1}, t_{F0}, t_{F1}, t_{D0}, t_{D1}, t_{D2}, t_{D3}, t_{D4}:$ 


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

**Figure 8. Output Timing**



(1) GS data = FFFh.

**Figure 9. Grayscale Data Write and OUTn Operation Timing**

## TYPICAL CHARACTERISTICS

At  $V_{CC} = 3.3\text{ V}$  and  $T_A = +25^\circ\text{C}$ , unless otherwise noted.

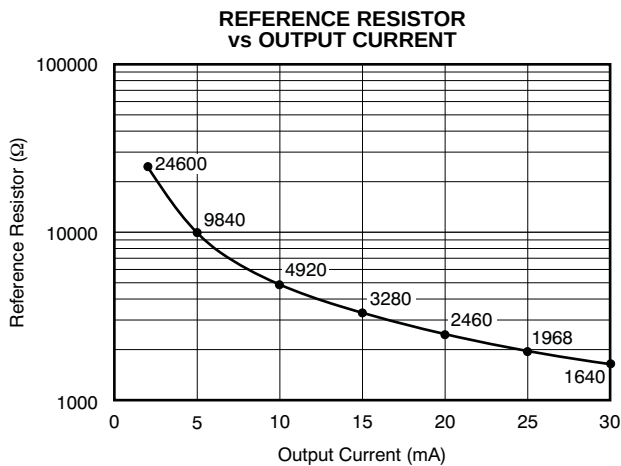


Figure 10.

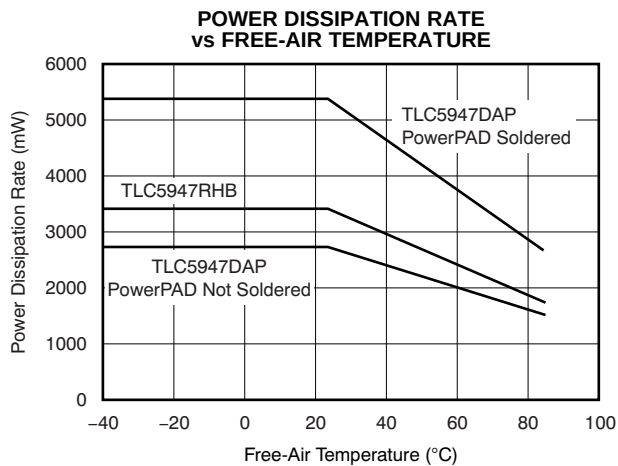


Figure 11.

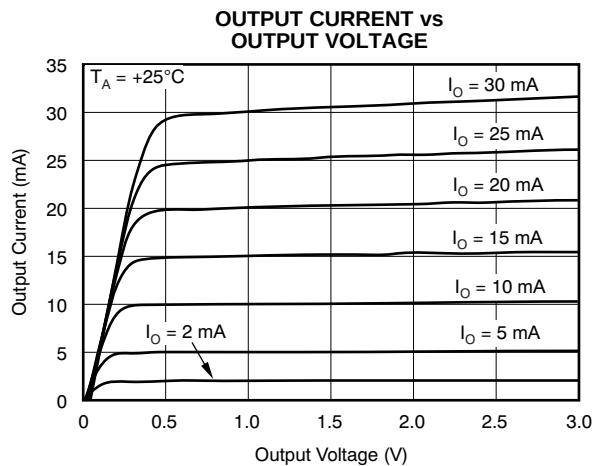


Figure 12.

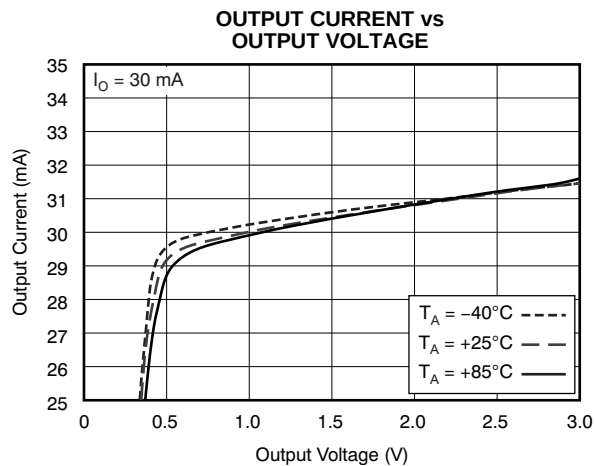


Figure 13.

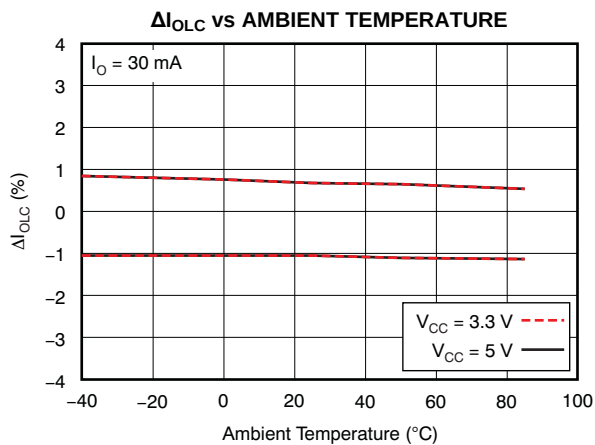


Figure 14.

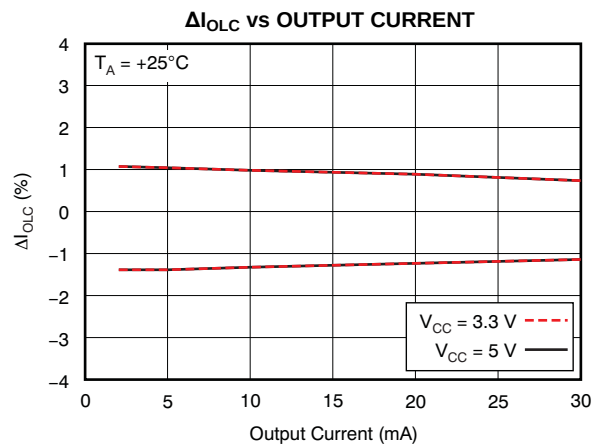
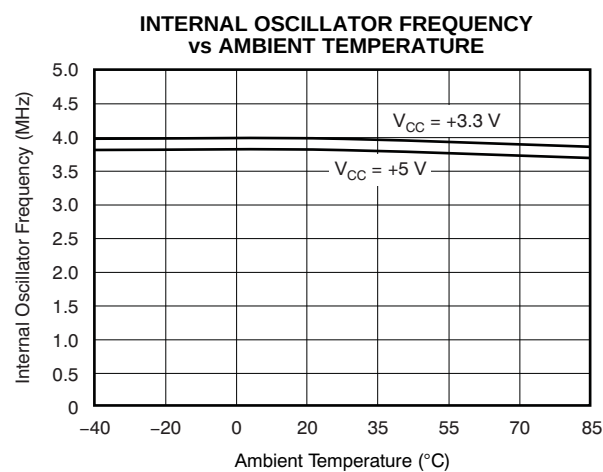


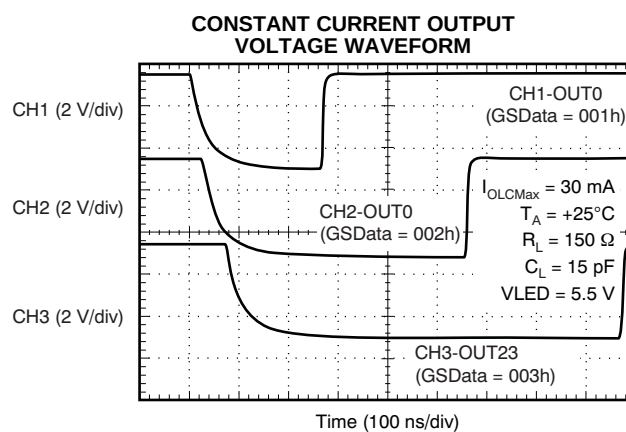
Figure 15.

## TYPICAL CHARACTERISTICS (continued)

At  $V_{CC} = 3.3\text{ V}$  and  $T_A = +25^\circ\text{C}$ , unless otherwise noted.



**Figure 16.**



**Figure 17.**

## DETAILED DESCRIPTION

### SETTING FOR THE CONSTANT SINK CURRENT VALUE

The constant current value for all channels is set by an external resistor ( $R_{IREF}$ ) placed between IREF and GND. The resistor ( $R_{IREF}$ ) value is calculated by [Equation 1](#).

$$R_{IREF} (\Omega) = 41 \times \frac{V_{IREF} (V)}{I_{OLC} (mA)} \quad (1)$$

Where:

$V_{IREF}$  = the internal reference voltage on the IREF pin (typically 1.20 V).

$I_{OLC}$  must be set in the range of 2 mA to 30 mA. The constant sink current characteristic for the external resistor value is shown in [Figure 10](#). [Table 1](#) describes the constant current output versus external resistor value.

**Table 1. Constant-Current Output versus External Resistor Value**

| $I_{OLC}$ (mA, Typical) | $R_{IREF}$ ( $\Omega$ ) |
|-------------------------|-------------------------|
| 30                      | 1640                    |
| 25                      | 1968                    |
| 20                      | 2460                    |
| 15                      | 3280                    |
| 10                      | 4920                    |
| 5                       | 9840                    |
| 2                       | 24600                   |

### GRAYSCALE (GS) CONTROL FUNCTION

Each constant current sink output OUT0–OUT23 (OUTn) turns on (starts to sink constant current) at the fifth rising edge of the grayscale internal oscillator clock after the BLANK signal transitions from high to low if the grayscale data latched into the grayscale data latch are not zero. After turn-on, the number of rising edges of the internal oscillator is counted by the 12-bit grayscale counter. Each OUTn output is turned off once its corresponding grayscale data values equal the grayscale counter or the counter reaches 4096d (FFFh). The PWM control operation is repeated as long as BLANK is low. OUTn is not turned on when BLANK is high. The timing is shown in [Figure 18](#). All outputs are turned off at the XLAT rising edge. After that, each output is controlled again from the first clock of the internal oscillator for the next display period, based on the latest grayscale data.

When the IC is powered on, the data in the grayscale data shift register and latch are not set to default values. Therefore, grayscale data must be written to the GS latch before turning on the constant current output. BLANK should be at a high level when powered on to keep the outputs off until valid grayscale data are written to the latch. This avoids the LED being randomly illuminated immediately after power-up. If having the outputs turn on at power-up is not a problem for the application, then BLANK does not need to be held high. The grayscale functions can be controlled directly by grayscale data writing, even though BLANK is connected to GND.

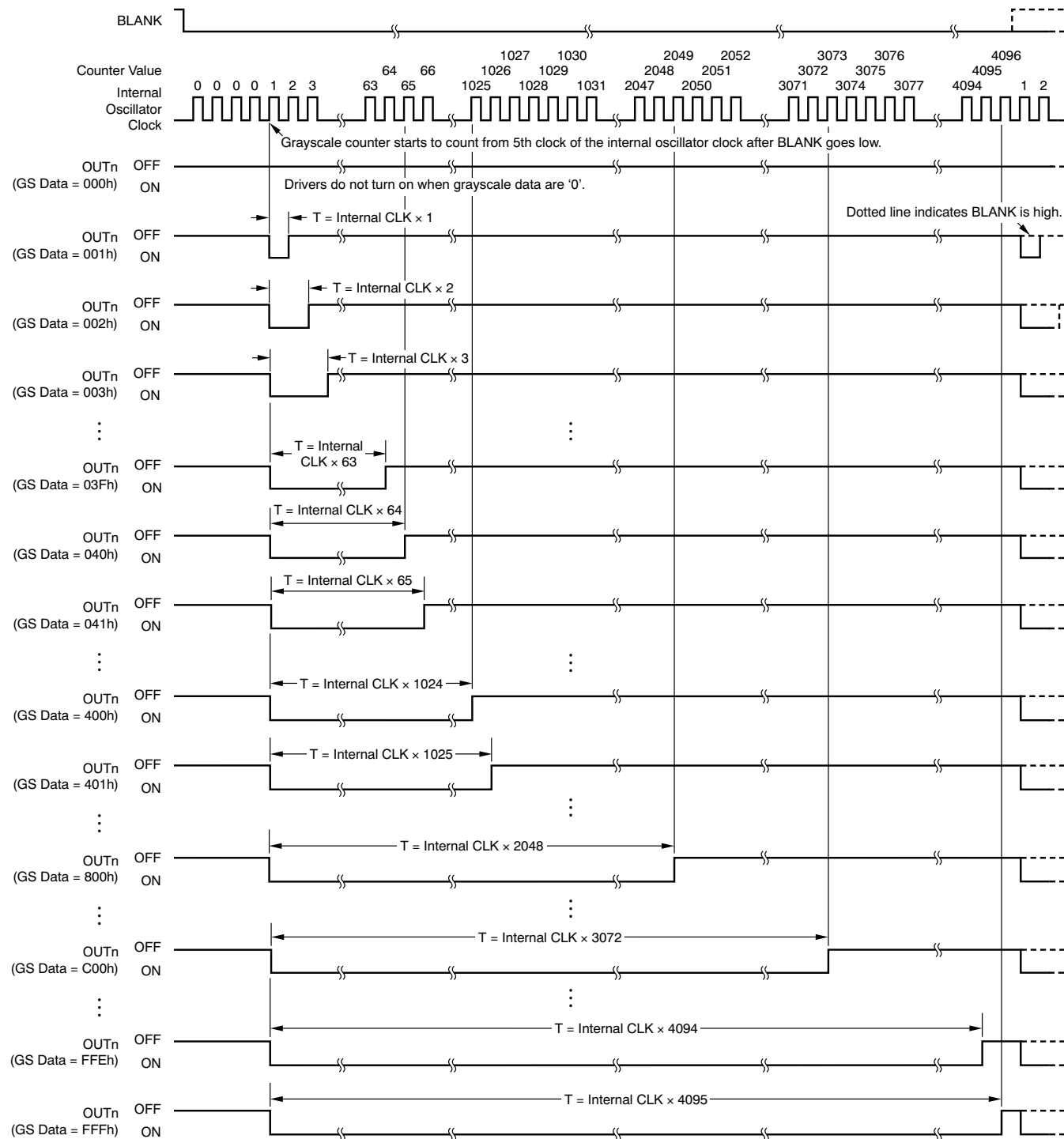
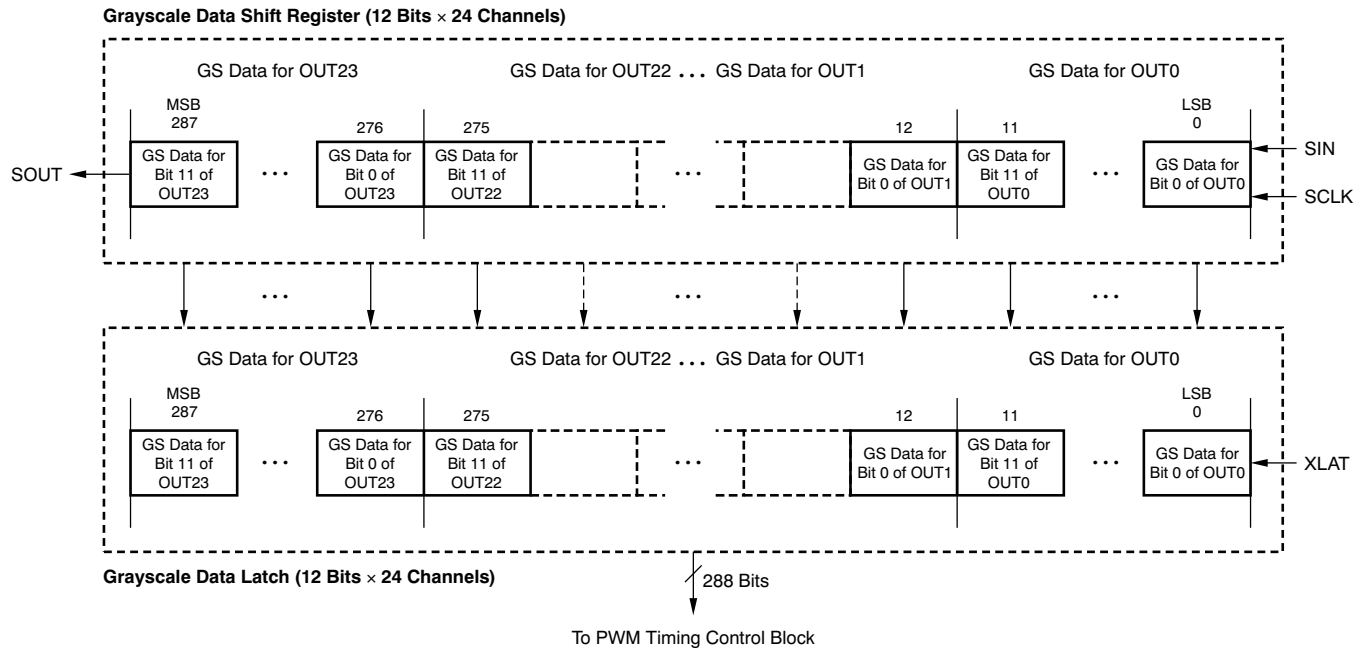


Figure 18. PWM Operation

## REGISTER CONFIGURATION

The TLC5947 has a grayscale (GS) data shift register and data latch. Both the GS data shift register and latch are 288 bits long and are used to set the PWM timing for the constant current driver. Table 2 shows the on duty cycle for each GS data. Figure 19 shows the shift register and data latch configuration. The data at the SIN pin are shifted to the LSB of the shift register at the rising edge of the SCLK pin; SOUT data are shifted out on the falling edge of SCLK. The timing diagram for data writing is shown in Figure 20. The driver on duty is controlled by the data in the GS data latch.



**Figure 19. Grayscale Data Shift Register and Latch Configuration**

**Table 2. GS Data versus On Duty**

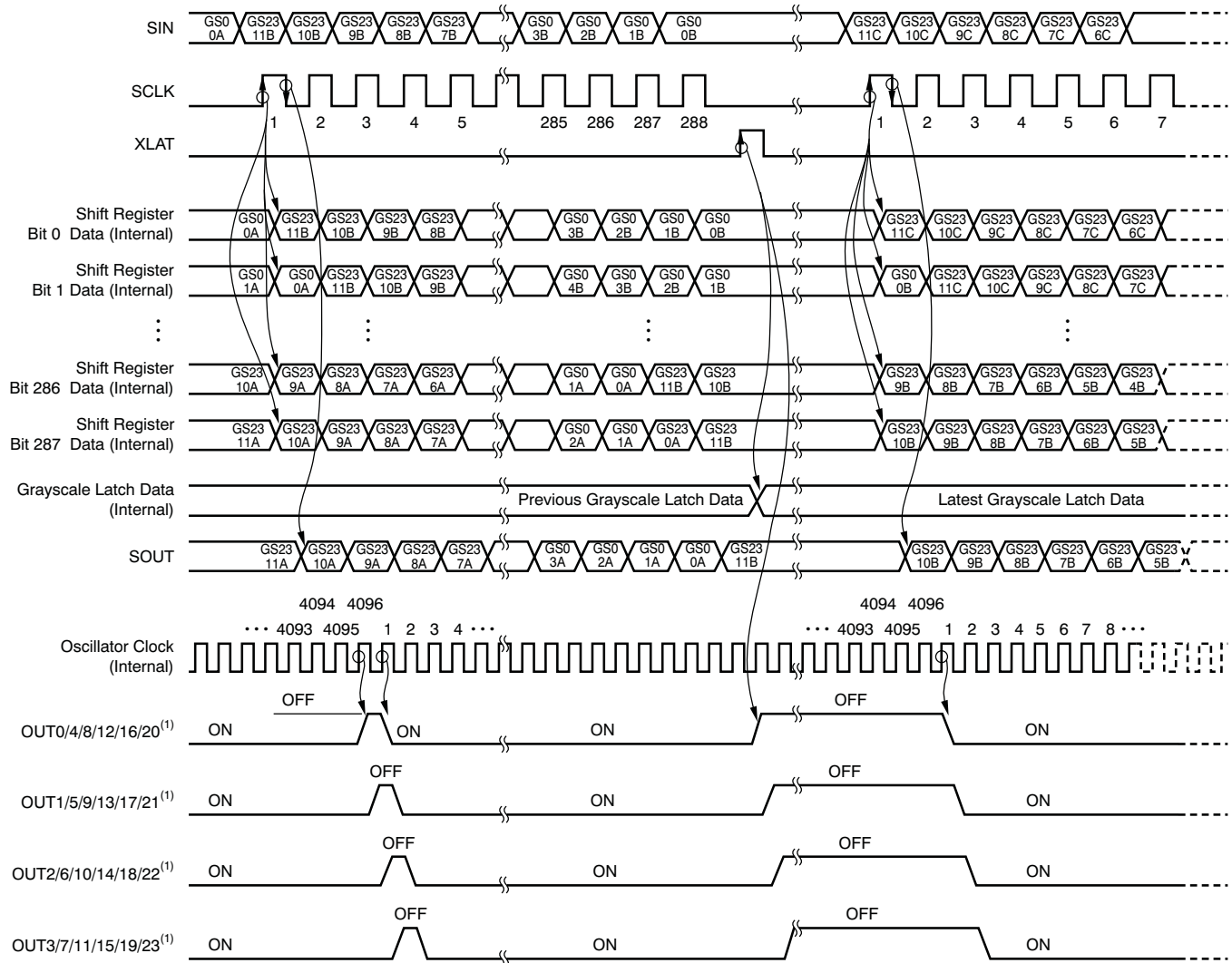
| GS DATA (Binary) | GS DATA (Decimal) | GS DATA (Hex) | DUTY OF DRIVER TURN-ON TIME (%) |
|------------------|-------------------|---------------|---------------------------------|
| 0000 0000 0000   | 0                 | 000           | 0.00                            |
| 0000 0000 0001   | 1                 | 001           | 0.02                            |
| 0000 0000 0010   | 2                 | 002           | 0.05                            |
| 0000 0000 0011   | 3                 | 003           | 0.07                            |
| —                | —                 | —             | —                               |
| 0111 1111 1111   | 2047              | 7FF           | 49.98                           |
| 1000 0000 0000   | 2048              | 800           | 50.00                           |
| 1000 0000 0001   | 2049              | 801           | 50.02                           |
| —                | —                 | —             | —                               |
| 1111 1111 1101   | 4093              | FFD           | 99.93                           |
| 1111 1111 1110   | 4094              | FFE           | 99.95                           |
| 1111 1111 1111   | 4095              | FFF           | 99.98                           |

GS data are transferred from the shift register to the latch by the rising edge of XLAT. When powered up, the data in the grayscale shift register and data latch are not set to default values. Therefore, grayscale data must be written to the GS latch before turning on the constant current output. BLANK should be at a high level when powered on to avoid falsely turning on the constant current outputs due to random values in the latch at power-up. All of the constant current outputs are forced off when BLANK is high. However, if the random values turning on at power-up is not a concern in the application, BLANK can be at any level. GS can be controlled correctly with the grayscale data writing functions, even if BLANK is connected to GND. Equation 2 determines each output on duty.

$$\text{On Duty (\%)} = \frac{\text{GSn}}{4096} \times 100 \quad (2)$$

where:

GSn = the programmed grayscale value for OUTn (GSn = 0 to 4095)

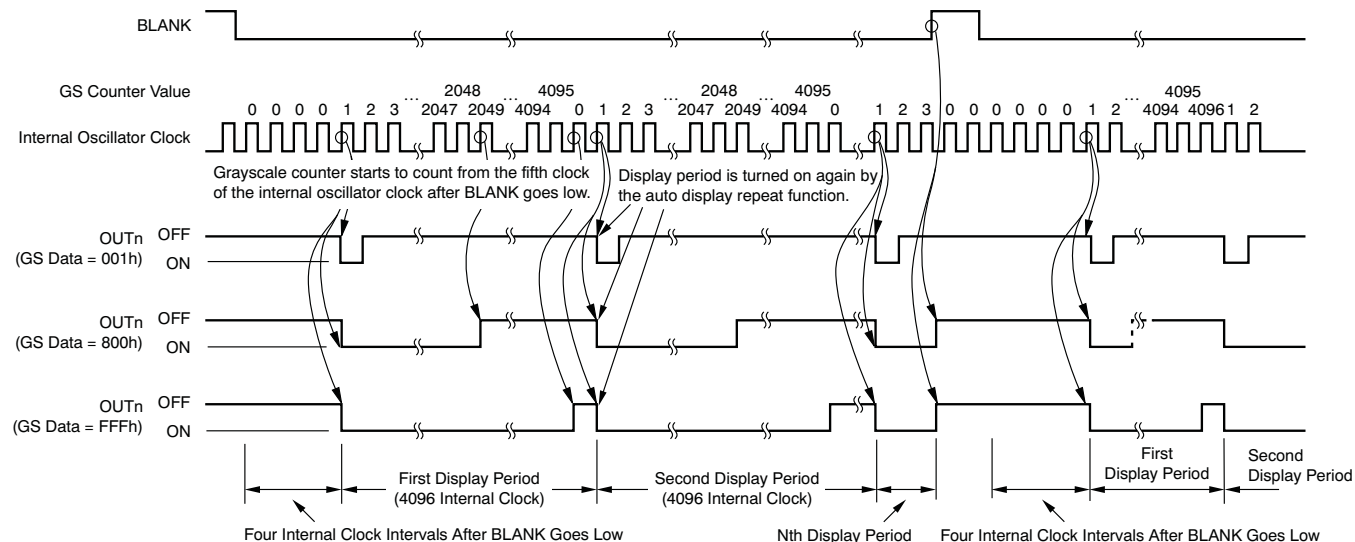


(1) GS data = FFFh.

**Figure 20. Grayscale Data Write Operation**

## AUTO DISPLAY REPEAT FUNCTION

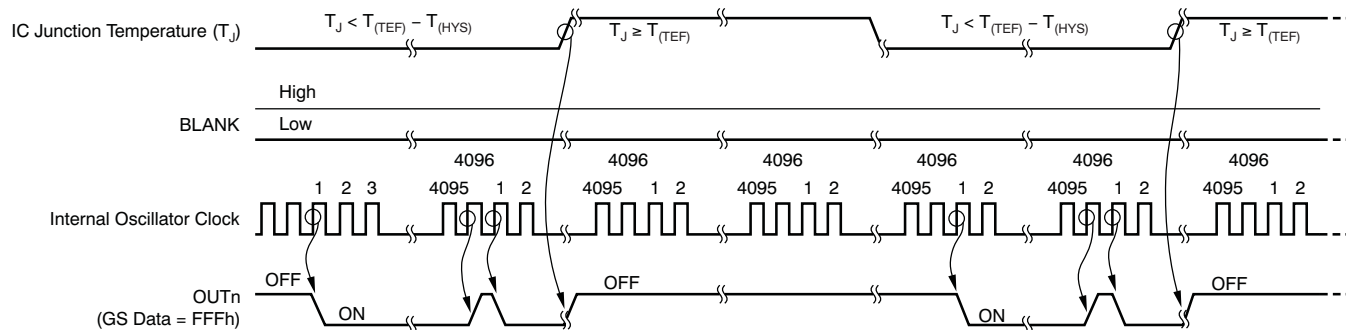
This function can repeat the total display period without any timing control signal, as shown in Figure 21.



**Figure 21. Auto Display Repeat Operation**

## THERMAL SHUTDOWN (TSD)

The thermal shutdown (TSD) function turns off all constant current outputs immediately when the IC junction temperature exceeds the high temperature threshold ( $T_{(TEF)} = +162^{\circ}\text{C}$ , typ). The outputs will remain disabled as long as the over-temperature condition exists. The outputs are turned on again at the first clock after the IC junction temperature falls below the temperature of  $T_{(TEF)} - T_{(HYS)}$ . Figure 22 shows the TSD operation.



**Figure 22. TSD Operation**

## NOISE REDUCTION

Large surge currents may flow through the IC and the board on which the device is mounted if all 24 LED channels turn on simultaneously at the start of each grayscale cycle. These large current surges could introduce detrimental noise and electromagnetic interference (EMI) into other circuits. The TLC5947 turns on the LED channels in a series delay, to provide a current soft-start feature. The output current sinks are grouped into four groups of six channels each. The first group is OUT0, 4, 8, 12, 16, 20; the second group is OUT1, 5, 9, 13, 17, 21; the third group is OUT2, 6, 10, 14, 18, 22; and the fourth group is OUT3, 7, 11, 15, 19, 23. Each group turns on sequentially with a small delay between groups; see [Figure 9](#). Both turn-on and turn-off are delayed.

## POWER DISSIPATION CALCULATION

The device power dissipation must be below the power dissipation rate of the device package (illustrated in [Figure 11](#)) to ensure correct operation. [Equation 3](#) calculates the power dissipation of the device:

$$P_D = (V_{CC} \times I_{CC}) + (V_{OUT} \times I_{OLC} \times N \times d_{PWM}) \quad (3)$$

Where:

- $V_{CC}$  = device supply voltage
- $I_{CC}$  = device supply current
- $V_{OUT}$  = OUTn voltage when driving LED current
- $I_{OLC}$  = LED current adjusted by  $R_{IREF}$  resistor
- $N$  = number of OUTn driving LED at the same time
- $d_{PWM}$  = duty ratio defined by GS value

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TLC5947DAP       | ACTIVE                | HTSSOP       | DAP             | 32   | 46          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-260C-168 HR          |                             |
| TLC5947DAPG4     | ACTIVE                | HTSSOP       | DAP             | 32   | 46          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-260C-168 HR          |                             |
| TLC5947DAPR      | ACTIVE                | HTSSOP       | DAP             | 32   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-260C-168 HR          |                             |
| TLC5947DAPRG4    | ACTIVE                | HTSSOP       | DAP             | 32   | 2000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-260C-168 HR          |                             |
| TLC5947RHBR      | ACTIVE                | QFN          | RHB             | 32   | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TLC5947RHBRG4    | ACTIVE                | QFN          | RHB             | 32   | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TLC5947RHBT      | ACTIVE                | QFN          | RHB             | 32   | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TLC5947RHBTG4    | ACTIVE                | QFN          | RHB             | 32   | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**TAPE AND REEL INFORMATION**
**REEL DIMENSIONS**

**TAPE DIMENSIONS**


|    |                                                           |
|----|-----------------------------------------------------------|
| A0 | Dimension designed to accommodate the component width     |
| B0 | Dimension designed to accommodate the component length    |
| K0 | Dimension designed to accommodate the component thickness |
| W  | Overall width of the carrier tape                         |
| P1 | Pitch between successive cavity centers                   |

**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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC5947DAPR | HTSSOP       | DAP             | 32   | 2000 | 330.0              | 24.4               | 8.6     | 11.5    | 1.6     | 12.0    | 24.0   | Q1            |
| TLC5947RHBR | QFN          | RHB             | 32   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.5     | 8.0     | 12.0   | Q2            |
| TLC5947RHBT | QFN          | RHB             | 32   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.5     | 8.0     | 12.0   | Q2            |

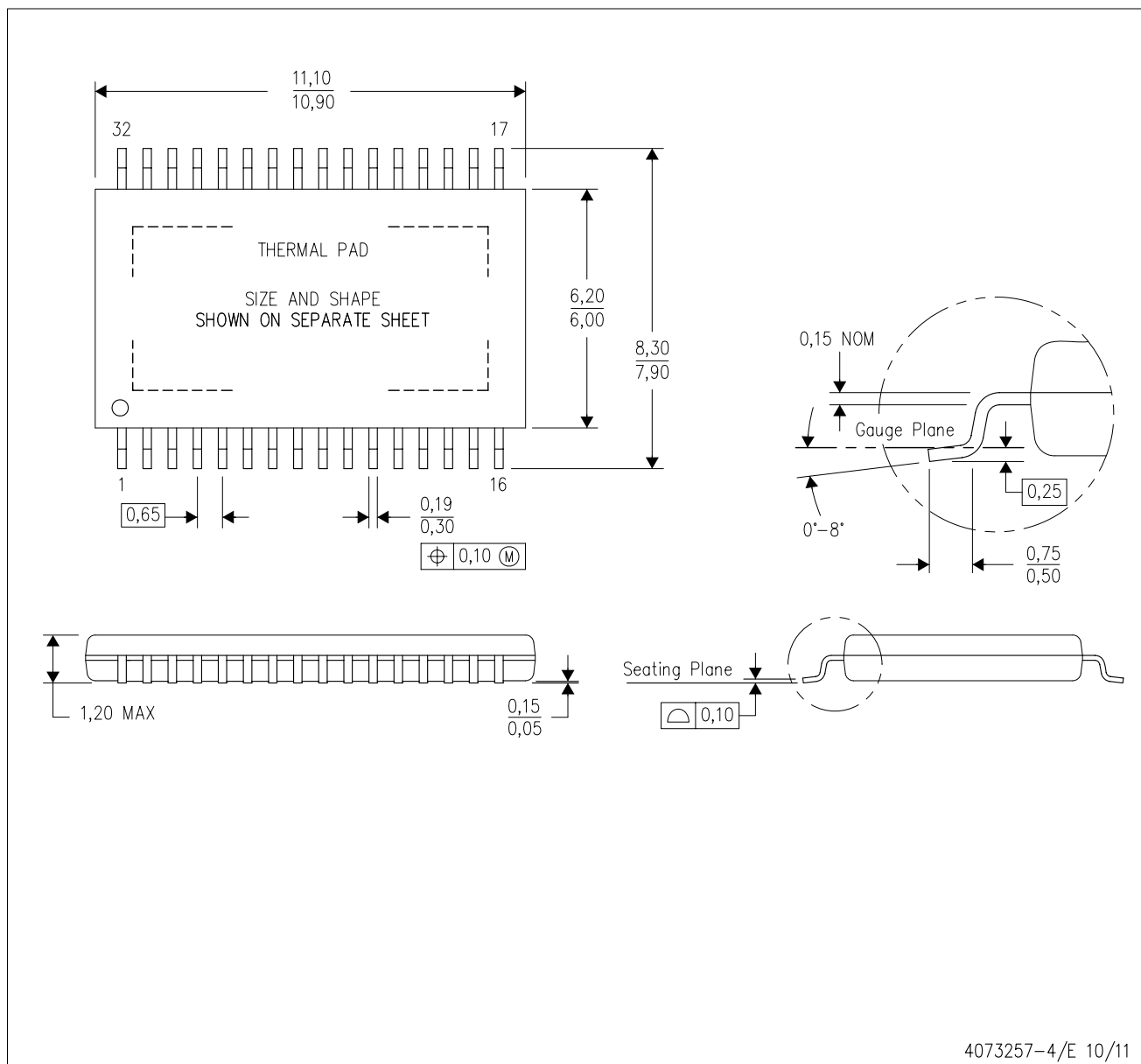
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC5947DAPR | HTSSOP       | DAP             | 32   | 2000 | 367.0       | 367.0      | 45.0        |
| TLC5947RHBR | QFN          | RHB             | 32   | 3000 | 367.0       | 367.0      | 35.0        |
| TLC5947RHBT | QFN          | RHB             | 32   | 250  | 210.0       | 185.0      | 35.0        |

## DAP (R-PDSO-G32) PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
-  Falls within JEDEC MO-153 Variation DCT.

DAP (R-PDSO-G32)

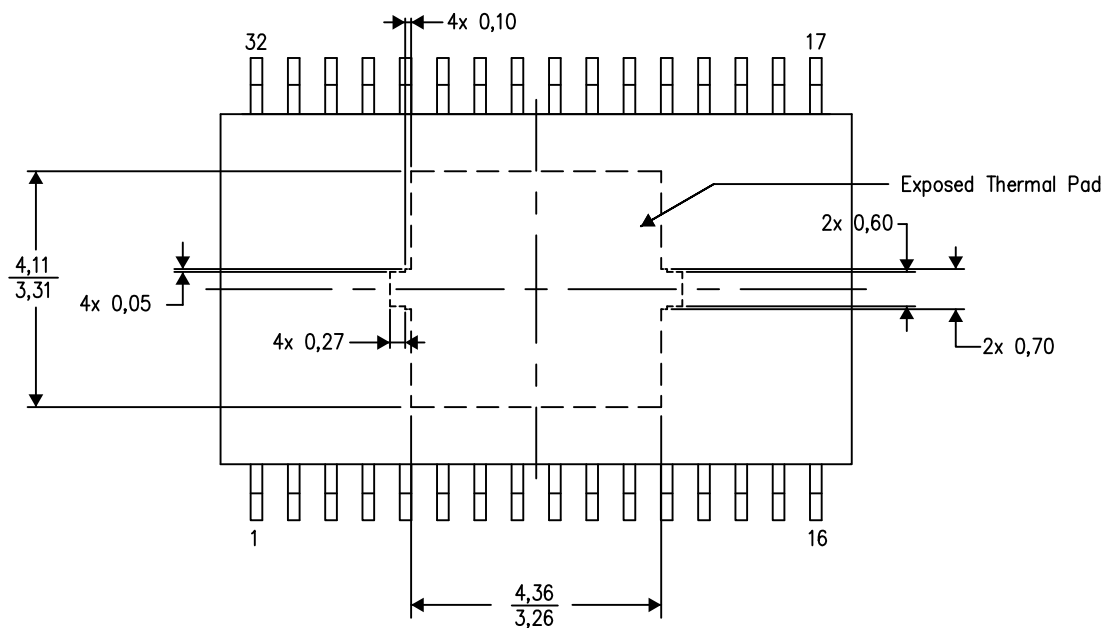
PowerPAD™ PLASTIC SMALL OUTLINE

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



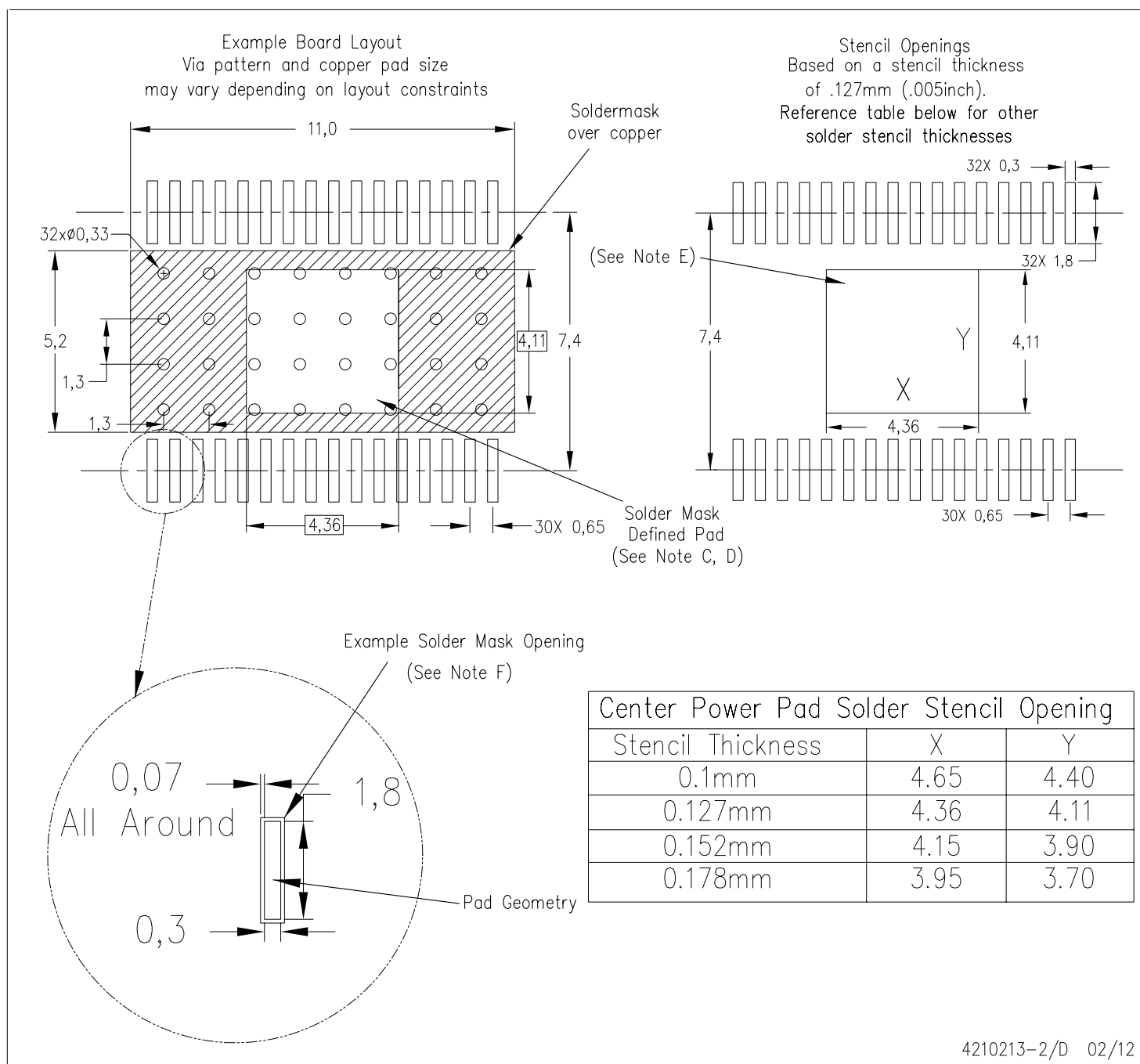
Top View  
Exposed Thermal Pad Dimensions

4206319-3/K 04/12

NOTE: All linear dimensions are in millimeters

PowerPAD is a trademark of Texas Instruments.

## DAP (R-PDSO-G32) PowerPAD™ PLASTIC SMALL OUTLINE PACKAGE

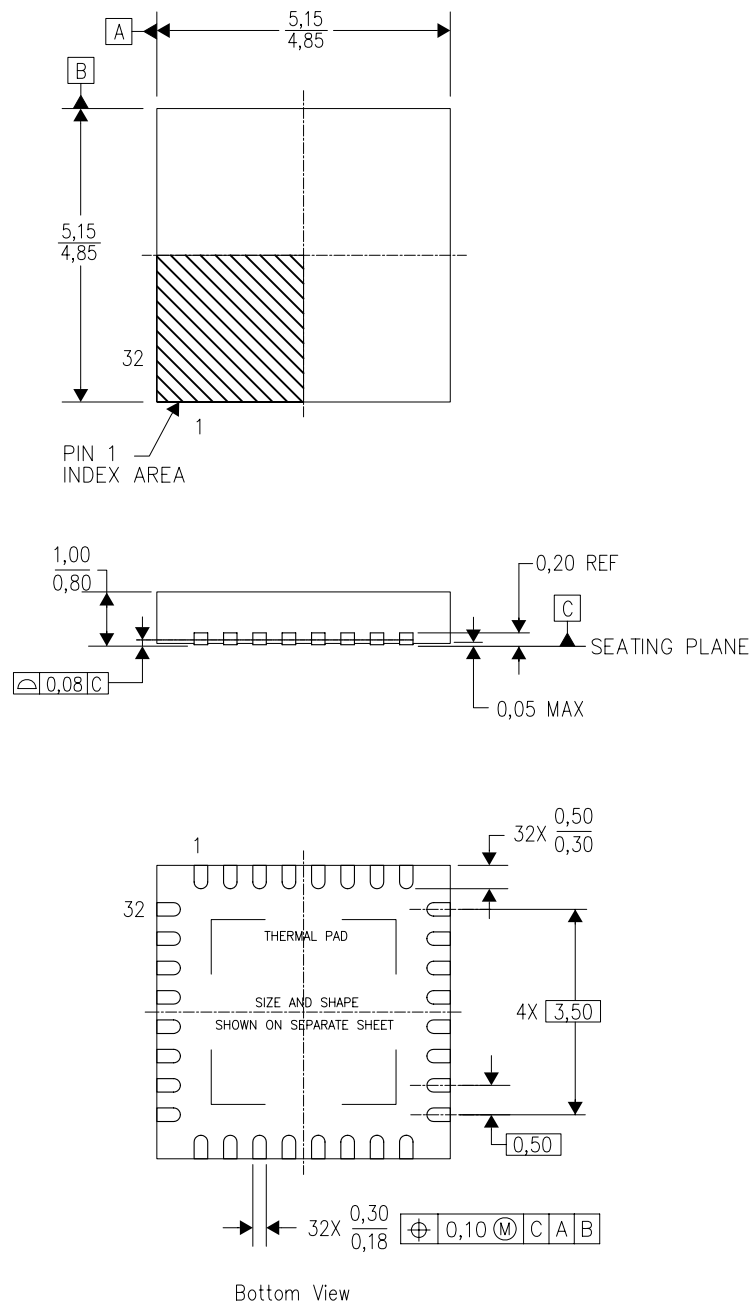


- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>. Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - Contact the board fabrication site for recommended soldermask tolerances.

PowerPAD is a trademark of Texas Instruments

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



4204326/D 06/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. QFN (Quad Flatpack No-Lead) Package configuration.
  - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - F. Falls within JEDEC MO-220.

RHB (S-PVQFN-N32)

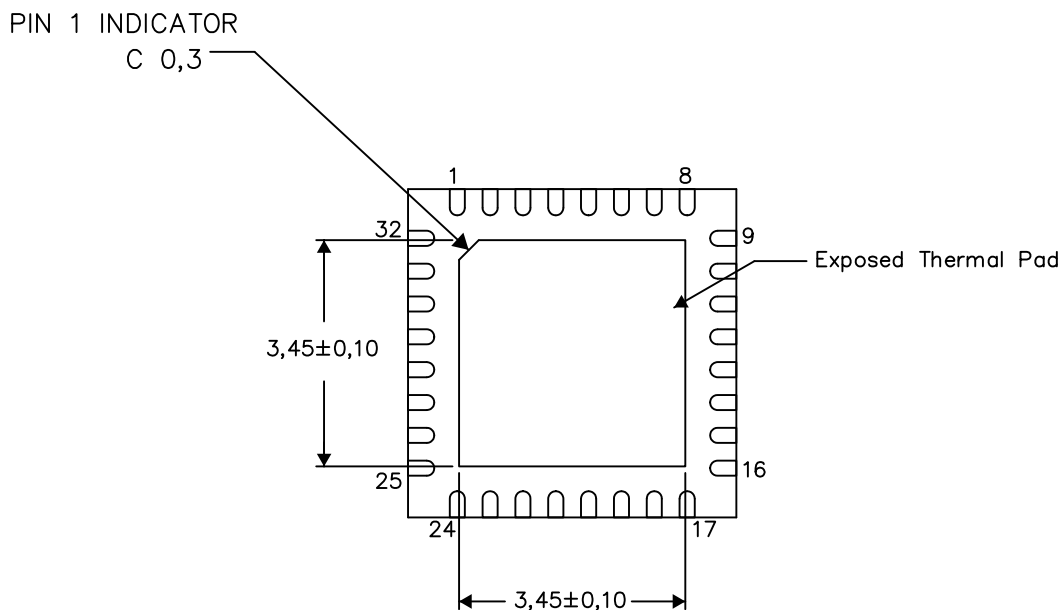
PLASTIC QUAD FLATPACK NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



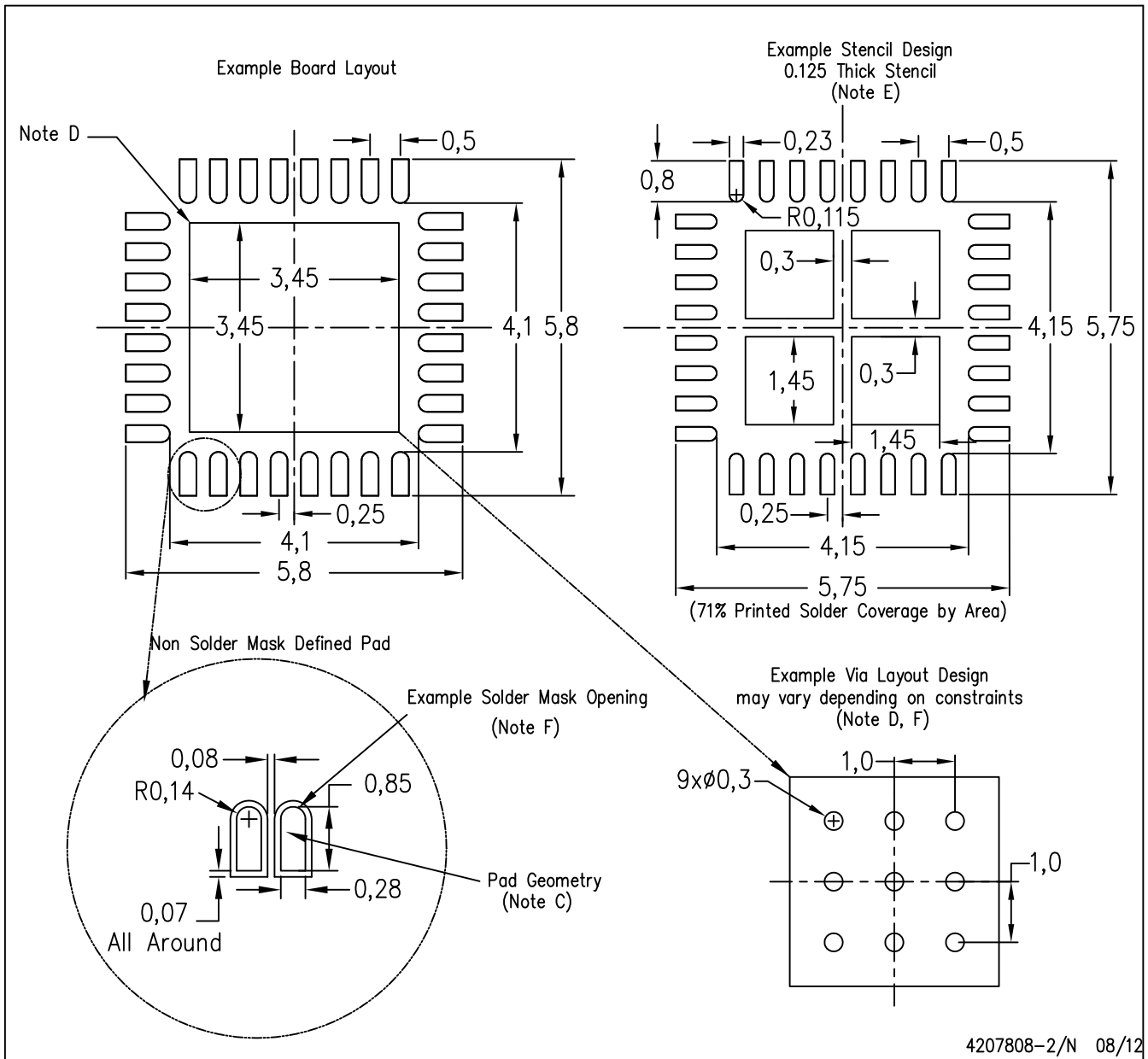
Exposed Thermal Pad Dimensions

4206356-2/W 09/12

NOTE: A. All linear dimensions are in millimeters

RHB (S-PVQFN-N32)

PLASTIC QUAD FLATPACK NO-LEAD



4207808-2/N 08/12

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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| Data Converters              | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>                       |
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