



# TPA6139A2 DirectPath™ 25-mW Headphone Amplifier With Programmable-Fixed Gain

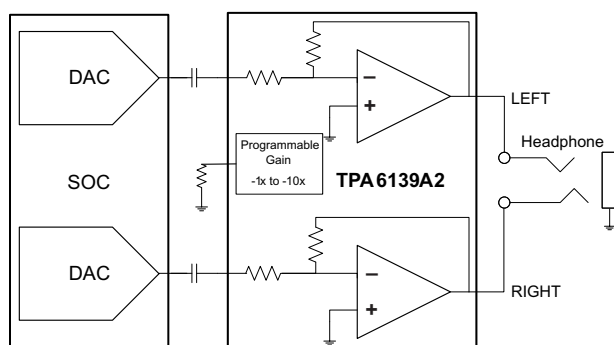
## 1 Features

- DirectPath™
  - Eliminates Pops and Clicks
  - Eliminates Output DC-Blocking Capacitors
  - 3-V to 3.6-V Supply Voltage
- Low Noise and THD
  - SNR > 105 dB at –1x Gain
  - Typical  $V_n < 15 \mu\text{Vms}$  20 to 20 kHz at –1x Gain
  - THD+N < 0.003% at 10-k $\Omega$  Load and –1x Gain
- 25 mW into 32- $\Omega$  Load
- 2-Vrms Output Voltage into 600- $\Omega$  Load
- Single-Ended Input and Output
- Programmable Gain Select Reduces Component Count
  - 13x Gain Values
- Active Mute With More Than 80-dB Attenuation
- Short-Circuit and Thermal Protection
- $\pm 8\text{-kV}$  HBM ESD Protected Outputs

## 2 Applications

- PDP and LCD TVs
- Blu-ray Discs™, DVD Players
- Mini and Micro Combo Systems
- Soundcards

**Functional Block Diagram**



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## 3 Description

The TPA6139A2 is a 25-mW, pop-free stereo headphone driver designed to reduce component count, board space and cost. It is ideal for single-supply electronics where size and cost are critical design parameters.

The TPA6139A2 device does not require a power supply greater than 3.3 V to generate its 25 mW, nor does it require a split rail power supply.

The TPA6139A2 device was designed using TI's patented DirectPath™ technology, which integrates a charge pump to generate a negative supply rail that provides a clean, pop-free ground biased output. The TPA6139A2 is capable of driving 25 mW into a 32- $\Omega$  load and 2 Vrms into a 600- $\Omega$  load. DirectPath also allows the removal of the costly output DC-blocking capacitors.

The device has fixed gain single-ended inputs with a gain select pin. Using a single resistor on this pin, the designer can choose from 13 internal programmable gain settings to match the line driver with the CODEC output level. It also reduces the component count and board space.

Headphone outputs have  $\pm 8\text{-kV}$  HBM ESD protection enabling a simple ESD protection circuit. The TPA6139A2 has built-in active mute control with more than 80-dB attenuation for pop-free mute ON and OFF control.

The TPA6139A2 device is available in a 14-pin TSSOP and a 16-pin QFN. For a pin-compatible, 2-Vrms line driver see [DRV612](#).

**Device Information<sup>(1)</sup>**

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)   |
|-------------|------------|-------------------|
| TPA6139A2   | TSSOP (14) | 5.00 mm × 4.40 mm |
|             | VQFN (16)  | 3.00 mm × 3.00 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.



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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

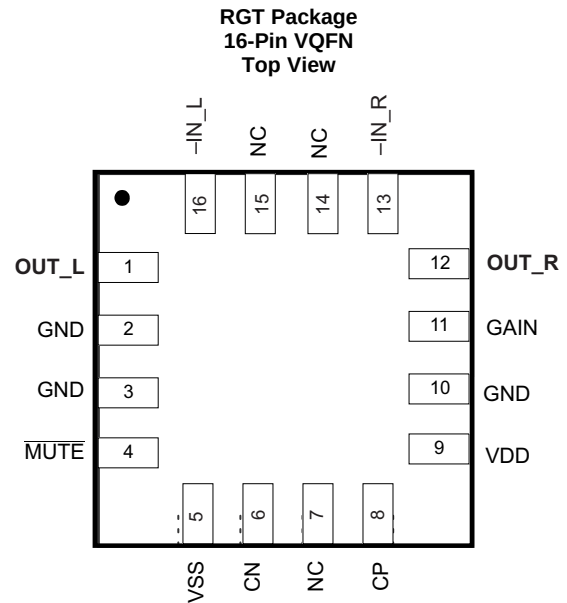
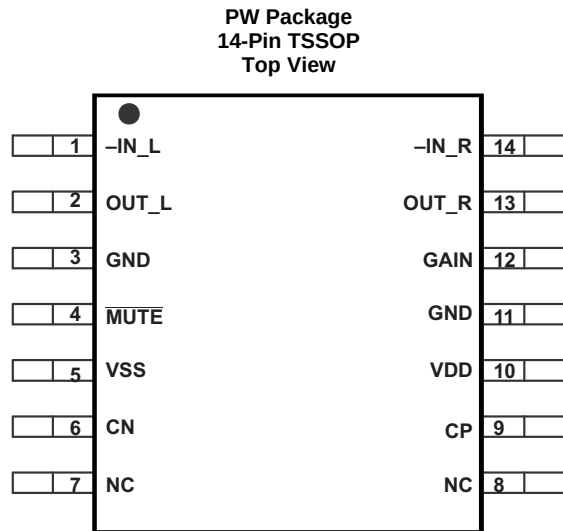
| Changes from Revision A (May 2011) to Revision C                                                                                                                                                                                                                                            | Page     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| • Added ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. .... | <b>1</b> |
| • Removed Ordering Information table .....                                                                                                                                                                                                                                                  | <b>1</b> |
| • Changed 600-Ω Load value to 32-Ω Load in Features .....                                                                                                                                                                                                                                   | <b>1</b> |
| • Changed 5-kΩ Load value to 600-Ω Load in Features .....                                                                                                                                                                                                                                   | <b>1</b> |
| • Changed 2 V <sub>ms</sub> to 2 V <sub>rms</sub> in Description .....                                                                                                                                                                                                                      | <b>1</b> |
| • Added R <sub>L</sub> valuse for the MIN and MAX columns and changed the TYP value from 5 to 32 in the Recommended Operating Conditions .....                                                                                                                                              | <b>4</b> |
| • Changed Line Driver Amplifiers subsection title to DirectPath Headphone Driver .....                                                                                                                                                                                                      | <b>9</b> |

| Changes from Original (January 2011) to Revision A                                                                                                | Page     |
|---------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| • Changed "2.5-mW" to "25-mW" in Title line and added revision A - May 2011 pub date to Header information .....                                  | <b>1</b> |
| • Changed conditions statement from "R <sub>IN</sub> = 10 kΩ, R <sub>fb</sub> = 20 kΩ" to "Step = –2V/V" for TYP CHARA, LINE DRIVER section ..... | <b>7</b> |

## 5 Device Comparison Table

|                      | TPA6132A2   | TPA6136A2    | TPA6139A2                 | TPA6141A2    |
|----------------------|-------------|--------------|---------------------------|--------------|
| Headphone Channels   | Stereo      | Stereo       | Stereo                    | Stereo       |
| Output Power (W)     | 0.025       | 0.025        | 0.025                     | 0.025        |
| Supply Voltage Range | 2.3 to 5.5  | 2.3 to 5.5   | 3 to 3.6                  | 2.5 to 5.5   |
| PSRR (dB)            | 100         | 100          | 80                        | 105          |
| Pin and Package      | 16-pin WQFN | 16-pin DSBGA | 16-pin VQFN, 14-pin TSSOP | 16-pin DSBGA |

## 6 Pin Configuration and Functions



### Pin Functions

| PIN   |       |           | TYPE <sup>(1)</sup> | DESCRIPTION                                                                                                         |
|-------|-------|-----------|---------------------|---------------------------------------------------------------------------------------------------------------------|
| NAME  | TSSOP | VQFN      |                     |                                                                                                                     |
| CN    | 6     | 6         | I/O                 | Charge Pump flying capacitor negative connection                                                                    |
| CP    | 9     | 8         | I/O                 | Charge Pump flying capacitor positive connection                                                                    |
| GAIN  | 12    | 11        | I                   | Gain set programming pin; connect a resistor to ground. See <a href="#">Table 2</a> for recommended resistor values |
| GND   | 3, 11 | 2, 3, 10  | P                   | Ground                                                                                                              |
| -IN_L | 1     | 16        | I                   | Negative input, left channel                                                                                        |
| -IN_R | 14    | 13        | I                   | Negative input, right channel                                                                                       |
| MUTE  | 4     | 4         | I                   | MUTE, active low                                                                                                    |
| NC    | 7, 8  | 7, 14, 15 | —                   | No internal connection                                                                                              |
| OUT_L | 2     | 1         | O                   | Output, left channel                                                                                                |
| OUT_R | 13    | 12        | O                   | Output, right channel                                                                                               |
| VDD   | 10    | 9         | P                   | Supply voltage, connect to positive supply                                                                          |
| VSS   | 5     | 5         | O                   | Change Pump negative supply voltage                                                                                 |

(1) I = input, O = output, P = power

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                                               | MIN       | MAX       | UNIT |
|-----------------------------------------------|-----------|-----------|------|
| VDD to GND                                    | −0.3      | 4         | V    |
| Input voltage, $V_I$                          | VSS − 0.3 | VDD + 0.3 | V    |
| MUTE to GND                                   | −0.3      | VDD + 0.3 | V    |
| Maximum operating junction temperature, $T_J$ | −40       | 150       | °C   |
| Lead temperature                              |           | 260       | °C   |
| Storage temperature, $T_{stg}$                | −40       | 150       | °C   |

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

### 7.2 ESD Ratings

|                          |                         |                                                                                |                          | VALUE | UNIT |
|--------------------------|-------------------------|--------------------------------------------------------------------------------|--------------------------|-------|------|
| TPA6139A2 IN PW PACKAGE  |                         |                                                                                |                          |       |      |
| V <sub>(ESD)</sub>       | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | All pins except 2 and 13 | ±4000 | V    |
|                          |                         |                                                                                | Pins 2 and 13            | ±8000 |      |
|                          |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> |                          | ±1500 |      |
| TPA6139A2 IN RGT PACKAGE |                         |                                                                                |                          |       |      |
| V <sub>(ESD)</sub>       | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | All pins except 1 and 12 | ±4000 | V    |
|                          |                         |                                                                                | Pins 1 and 12            | ±8000 |      |
|                          |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> |                          | ±1500 |      |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 7.3 Recommended Operating Conditions

over operating free-air temperature range unless otherwise noted

|                                   | MIN | NOM | MAX   | UNIT  |
|-----------------------------------|-----|-----|-------|-------|
| VDD Supply voltage                | 3   | 3.3 | 3.6   | V     |
| $R_L$ Load resistance             | 16  | 32  | 10000 | Ω     |
| $V_{IL}$ Low-level input voltage  | 38  | 40  | 43    | %PVDD |
| $V_{IH}$ High-level input voltage | 57  | 60  | 66    | %PVDD |
| $T_A$ Free-air temperature        | −40 | 25  | 85    | °C    |

### 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | TPA6139A2  |            | UNIT |
|-------------------------------|----------------------------------------------|------------|------------|------|
|                               |                                              | PW (TSSOP) | RGT (VQFN) |      |
|                               |                                              | 14 PINS    | 16 PINS    |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 130        | 52         | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 49         | 71         | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 63         | 26         | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 3.6        | 3          | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 62         | 26         | °C/W |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | —          | 9.8        | °C/W |

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

## 7.5 Electrical Characteristics

VDD = 3.3 V, R<sub>Load</sub> = 32 Ω, T<sub>A</sub> = 25°C, Charge pump: C<sub>CP</sub> = 1 μF (unless otherwise noted)

| PARAMETER                   | TEST CONDITIONS                                    | MIN                                                                   | TYP    | MAX   | UNIT             |
|-----------------------------|----------------------------------------------------|-----------------------------------------------------------------------|--------|-------|------------------|
| V <sub>OS</sub>             | Output offset voltage                              |                                                                       | 0.5    | 1     | mV               |
| PSRR                        | Power-supply rejection ratio                       | 70                                                                    | 80     |       | dB               |
| V <sub>OH</sub>             | High-level output voltage                          | VDD = 3.3 V                                                           | 3.1    |       | V                |
| V <sub>OL</sub>             | Low-level output voltage                           | VDD = 3.3 V                                                           |        | –3.05 | V                |
| V <sub>uvp_on</sub>         | PVDD, under voltage detection                      |                                                                       |        | 2.8   | V                |
| V <sub>uvp_hysteresis</sub> | PVDD, under voltage detection, hysteresis          |                                                                       | 200    |       | mV               |
| F <sub>cp</sub>             | Charge pump switching frequency                    |                                                                       | 350    |       | kHz              |
| I <sub>IH</sub>             | High-level input current, $\overline{\text{MUTE}}$ | VDD = 3.3 V, V <sub>IH</sub> = VDD                                    |        | 1     | μA               |
| I <sub>IL</sub>             | Low-level input current, $\overline{\text{MUTE}}$  | VDD = 3.3 V, V <sub>IL</sub> = 0 V                                    |        | 1     | μA               |
| I (VDD)                     | Supply current, no load                            | VDD, $\overline{\text{MUTE}}$ = 3.3 V                                 | 25     |       | mA               |
|                             | Supply current, MUTED                              | VDD = 3.3 V, $\overline{\text{MUTE}}$ = GND                           | 25     |       | mA               |
| T <sub>sd</sub>             | Thermal shutdown                                   |                                                                       | 150    |       | °C               |
|                             | Thermal shutdown hysteresis                        |                                                                       | 15     |       | °C               |
| P <sub>O</sub>              | Output Power, outputs in phase                     | THD+N = 1%, f = 1 kHz, 32-Ω load                                      | 25     |       | mW               |
| V <sub>O</sub>              | Output Voltage, outputs in phase                   | THD+N = 1%, f = 1 kHz, 32-Ω load                                      | 0.9    |       | V <sub>rms</sub> |
|                             |                                                    | THD+N = 1%, f = 1 kHz, 600-Ω load                                     | 2      |       |                  |
| THD+N                       | Total Harmonic distortion plus noise               | f = 1 kHz, 32-Ω load, P <sub>O</sub> = 25 mW, –1x gain                | 0.03%  |       |                  |
| THD+N                       | Total Harmonic distortion plus noise               | f = 1 kHz, 10-kΩ load, V <sub>O</sub> = 2 V <sub>rms</sub> , –1x gain | 0.005% |       |                  |
| ΔA <sub>v</sub>             | Gain matching                                      | Between left and right channels                                       | 0.25   |       | dB               |
| Z <sub>O</sub>              | Output impedance when muted                        | $\overline{\text{MUTE}}$ = GND                                        |        | 1     | Ω                |
|                             | Input to output attenuation when muted             | $\overline{\text{MUTE}}$ = GND                                        | 80     |       | dB               |
| SNR                         | Signal to noise ratio                              | A-weighted, AES17 filter, 1-V <sub>rms</sub> ref 32-Ω load, –1x gain  | 99     |       | dB               |
|                             | Signal to noise ratio                              | A-weighted, AES17 filter, 2-V <sub>rms</sub> ref 600-Ω load, –1x gain | 105    |       | dB               |
| V <sub>n</sub>              | Noise voltage                                      | A-weighted, AES17 filter, Gain = –2x                                  | 12     |       | μV               |
|                             | Slew rate                                          |                                                                       | 4.5    |       | V/μs             |
| G <sub>bw</sub>             | Unity gain bandwidth                               |                                                                       | 8      |       | MHz              |
| Crosstalk                   | Channel to channel                                 | f = 1 kHz, R <sub>load</sub> = 32 Ω, P <sub>O</sub> = 25 mW           | –85    |       | dB               |
| V <sub>incm_pos</sub>       | Positive common-mode input voltage                 |                                                                       | +2     |       | V                |
| V <sub>incm_neg</sub>       | Negative common-mode input voltage                 |                                                                       | –2     |       | V                |
| I <sub>lim</sub>            | Output current limit                               |                                                                       | 60     |       | mA               |

**TPA6139A2**

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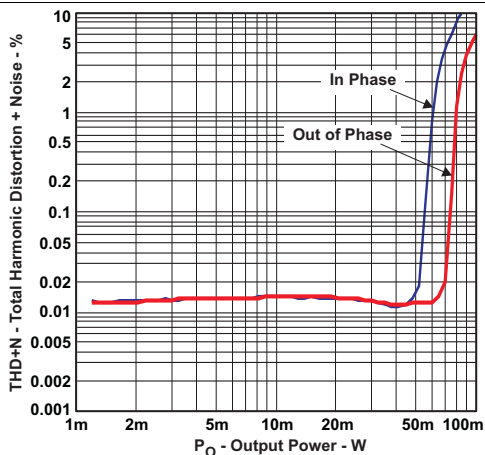
[www.ti.com](http://www.ti.com)
**7.6 Programmable Gain Settings**
 $V_{DD} = 3.3\text{ V}$ ,  $R_{load} = 32\text{ k}\Omega$ ,  $T_A = 25^\circ\text{C}$ , Charge pump:=  $C_{CP} 1\text{ }\mu\text{F}$ ,  $C_{IN} = 1\text{ }\mu\text{F}$ , 1x gain select (unless otherwise noted)<sup>(1)</sup>

| PARAMETER       |                                     | TEST CONDITIONS                 |  | MIN | TYP  | MAX | UNIT       |
|-----------------|-------------------------------------|---------------------------------|--|-----|------|-----|------------|
| R_Tol           | Gain programming resistor tolerance |                                 |  |     |      | 2%  |            |
| $\Delta A_V$    | Gain matching                       | Between left and right channels |  |     | 0.25 |     | dB         |
|                 | Gain step tolerance                 |                                 |  |     | 0.1  |     | dB         |
| Gain steps      | Gain resistor 2% tolerance          | 249k or higher                  |  |     | –2   |     | V/V        |
|                 |                                     | 82k0                            |  |     | –1   |     |            |
|                 |                                     | 49k2                            |  |     | –1.5 |     |            |
|                 |                                     | 35k1                            |  |     | –2.3 |     |            |
|                 |                                     | 27k3                            |  |     | –2.5 |     |            |
|                 |                                     | 20k5                            |  |     | –3   |     |            |
|                 |                                     | 15k4                            |  |     | –3.5 |     |            |
|                 |                                     | 11k5                            |  |     | –4   |     |            |
|                 |                                     | 9k09                            |  |     | –5   |     |            |
|                 |                                     | 7k50                            |  |     | –5.6 |     |            |
|                 |                                     | 6k19                            |  |     | –6.4 |     |            |
|                 |                                     | 5k11                            |  |     | –8.3 |     |            |
|                 |                                     | 3k90                            |  |     | –10  |     |            |
| Input impedance | Gain resistor 2% tolerance          | 249k or higher                  |  |     | 37   |     | k $\Omega$ |
|                 |                                     | 82k0                            |  |     | 55   |     |            |
|                 |                                     | 49k2                            |  |     | 44   |     |            |
|                 |                                     | 35k1                            |  |     | 33   |     |            |
|                 |                                     | 27k3                            |  |     | 31   |     |            |
|                 |                                     | 20k5                            |  |     | 28   |     |            |
|                 |                                     | 15k4                            |  |     | 24   |     |            |
|                 |                                     | 11k5                            |  |     | 22   |     |            |
|                 |                                     | 9k09                            |  |     | 18   |     |            |
|                 |                                     | 7k50                            |  |     | 17   |     |            |
|                 |                                     | 6k19                            |  |     | 15   |     |            |
|                 |                                     | 5k11                            |  |     | 12   |     |            |
|                 |                                     | 3k90                            |  |     | 10   |     |            |

- (1) If pin 12, GAIN, is left floating an internal pullup sets the gain to –2x.  
Gain setting is latched during power up.

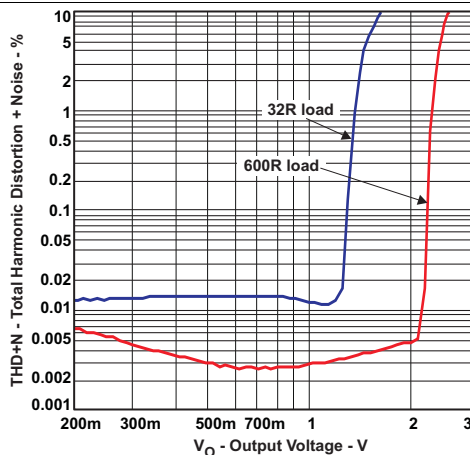
## 7.7 Typical Characteristics, Line Driver

$V_{DD} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 2.5\text{ k}\Omega$ ,  $C_{PUMP} = C_{VSS} = 10\text{ }\mu\text{F}$ , Gain Step =  $-2\text{ V/V}$  (unless otherwise noted)



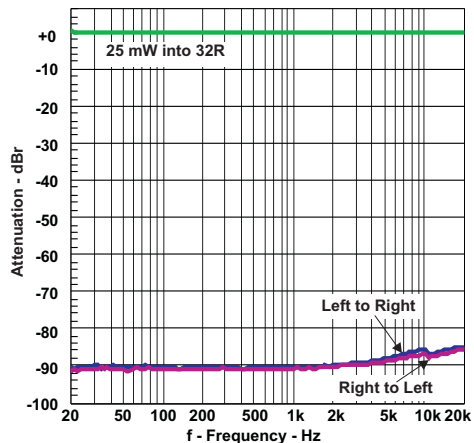
3.3 V, 100 k $\Omega$ , 1 kHz

**Figure 1. THD+N vs Output Voltage**



3.3 V, 600- $\Omega$  load, 1 kHz

**Figure 2. THD+N vs Output Voltage**



3.3 V, 5-k $\Omega$  load, 2 Vrms, Blue L to R, Red R to L

**Figure 3. Channel Separation**

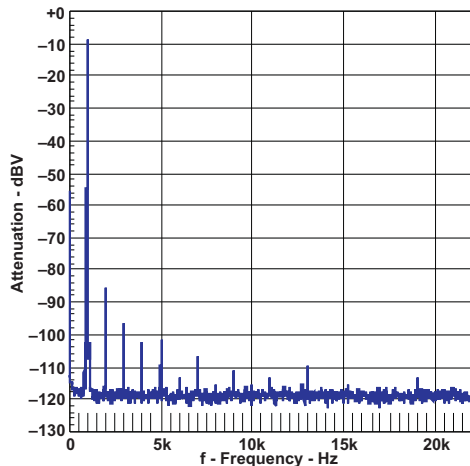


**Figure 4. FFT**

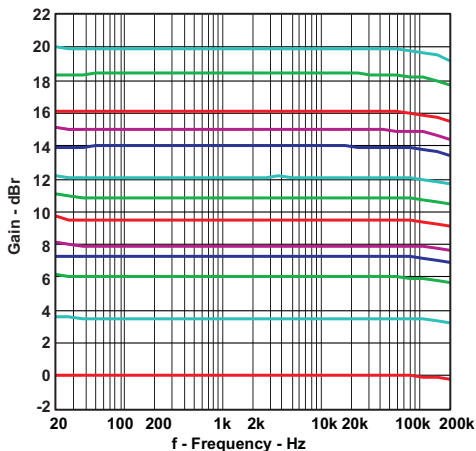


**Figure 5. Gain vs Frequency**

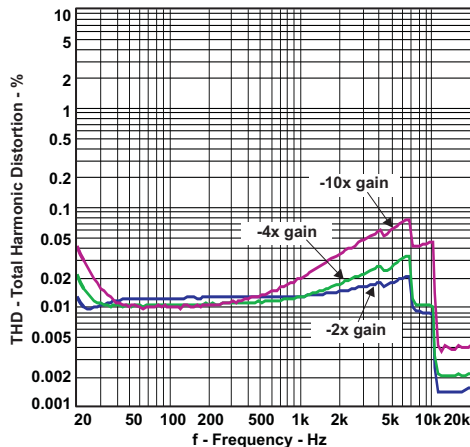
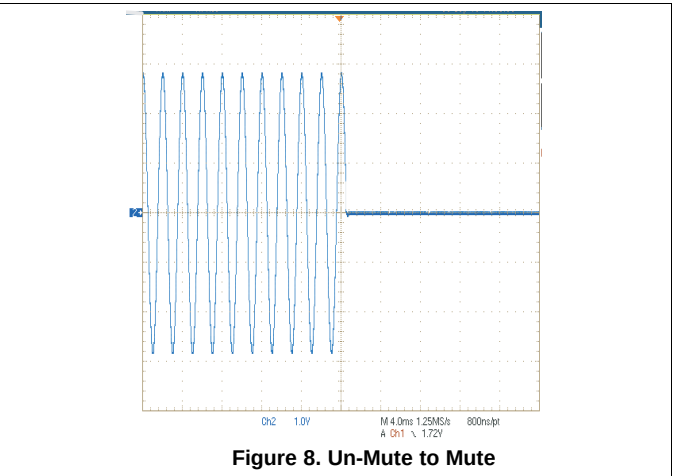
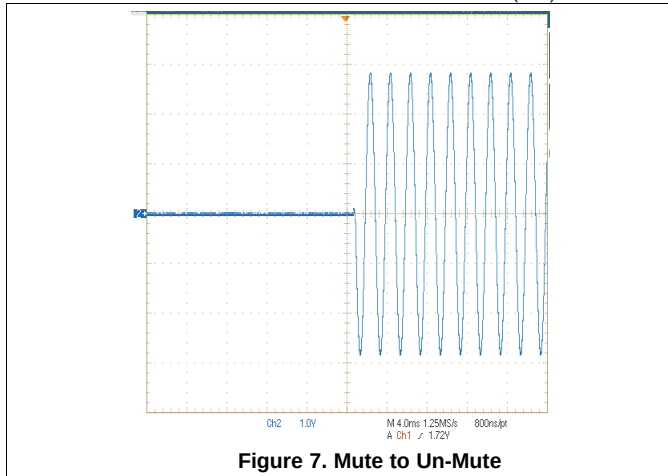


**Figure 6. Total Harmonic Distortion vs Frequency**

## Typical Characteristics, Line Driver (continued)

$V_{DD} = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 2.5\text{ k}\Omega$ ,  $C_{PUMP} = C_{(VSS)} = 10\text{ }\mu\text{F}$ , Gain Step =  $-2\text{ V/V}$  (unless otherwise noted)



## 8 Parameter Measurement Information

All parameters are measured according to the conditions described in the [Specifications](#) section.

## 9 Detailed Description

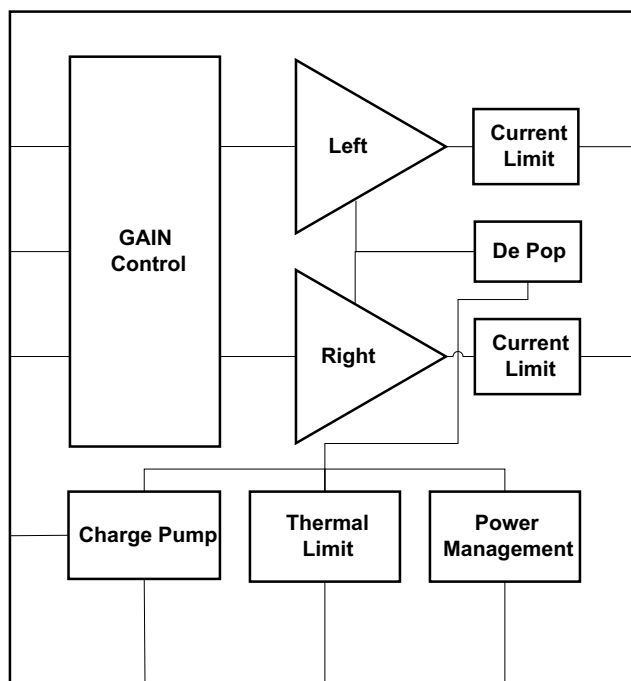
### 9.1 Overview

The TPA6139A2 is a DirectPath stereo headphone amplifier that requires no output DC-blocking capacitors and is capable of delivering 25 mW into a 32-Ω load. The device has built-in pop suppression circuitry to completely eliminate pop noise during turnon and turnoff. The amplifier outputs have short-circuit protection.

The TPA6139A2 gain is controlled by external resistors  $R_{in}$  and  $R_{fb}$ , see [Gain Setting](#) for recommended values.

The TPA6139A2 operates from a single 3-V to 3.6-V supply, as it uses a built-in charge pump to generate a negative voltage supply for the headphone amplifiers.

### 9.2 Functional Block Diagram



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### 9.3 Feature Description

#### 9.3.1 DirectPath Headphone Driver

Single-supply line-driver amplifiers typically require DC-blocking capacitors. The top drawing in [Figure 9](#) illustrates the conventional line-driver amplifier connection to the load and output signal.

DC-blocking capacitors are often large in value, and a mute circuit is needed during power up to minimize click and pop. The output capacitor and mute circuit consume PCB area and increase cost of assembly, and can reduce the fidelity of the audio output signal.

## Feature Description (continued)

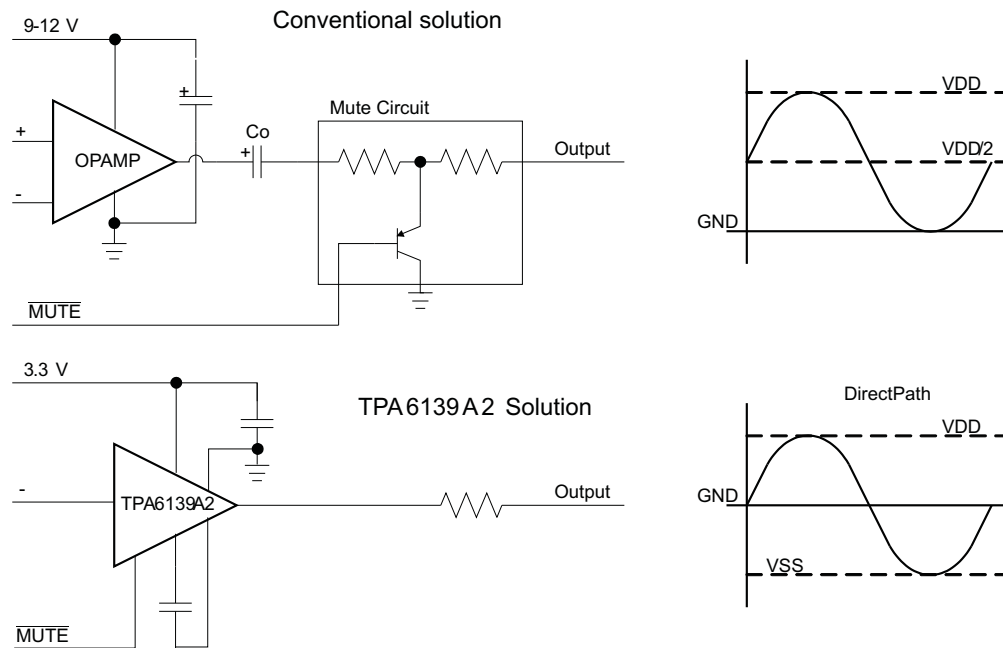


**Figure 9. Conventional and DirectPath Line Driver**

The DirectPath amplifier architecture operates from a single supply but makes use of an internal charge pump to provide a negative voltage rail.

Combining the user-provided positive rail and the negative rail generated by the IC, the device operates in what is effectively a split supply mode.

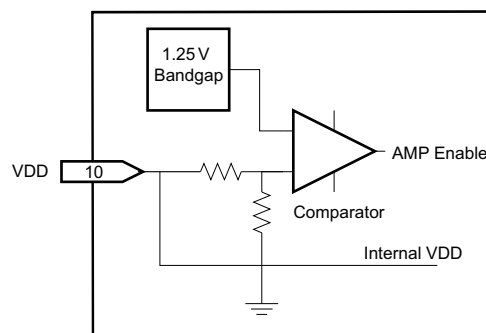
The output voltages are now centered at zero volts with the capability to swing to the positive rail or negative rail. Combining this with the built-in click and pop reduction circuit, the DirectPath amplifier requires no output DC-blocking capacitors.

The bottom block diagram and waveform of [Figure 9](#) illustrate the ground-referenced line-driver architecture.

## 9.4 Device Functional Modes

### 9.4.1 Internal Undervoltage Detection

The TPA6139A2 contains an internal precision band-gap reference voltage and a comparator used to monitor the supply voltage, VDD. The internal VDD monitor is set at 2.8 V with 200-mV hysteresis.



## Device Functional Modes (continued)

### 9.4.2 Pop-Free Power Up

Pop-free power up is ensured by keeping the  $\overline{\text{MUTE}}$  low during power-supply ramp-up and ramp-down. The pin must be kept low until the input AC-coupling capacitors are fully charged before asserting the  $\overline{\text{MUTE}}$  pin high to precharge the AC-coupling; and, pop-less power up is achieved. [Figure 10](#) illustrates the preferred sequence.

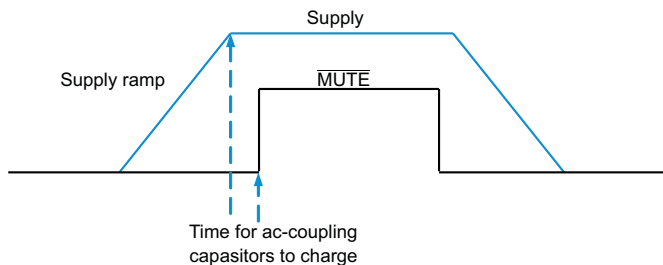


**Figure 10. Power-Up Sequence**

## 10 Application and Implementation

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### 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.

---

### 10.1 Application Information

The TPA6139A2 device starts its operation by asserting the MUTE pin to logic 1. The device enters in mute mode when pulling the MUTE pin low. The charge pump generates a negative supply voltage. The charge pump flying capacitor connected between CP and CN transfers charge to generate the negative supply voltage. The output voltages are capable of positive and negative voltage swings and are centered close to 0 V, eliminating the need for output capacitors. Input coupling capacitors block any DC bias from the audio source and ensure maximum dynamic range.

This typical connection diagram highlights the required external components and system level connections for proper operation of the device in popular use case. Any design variation can be supported by TI through schematic and layout reviews. Visit <https://e2e.ti.com> for design assistance and join the audio amplifier discussion forum for additional information.

#### 10.1.1 Capacitive Load

The TPA6139A2 has the ability to drive a high capacitive load up to 220 pF directly. Higher capacitive loads can be accepted by adding a series resistor of 47  $\Omega$  or larger for the line driver output.

## 10.2 Typical Application

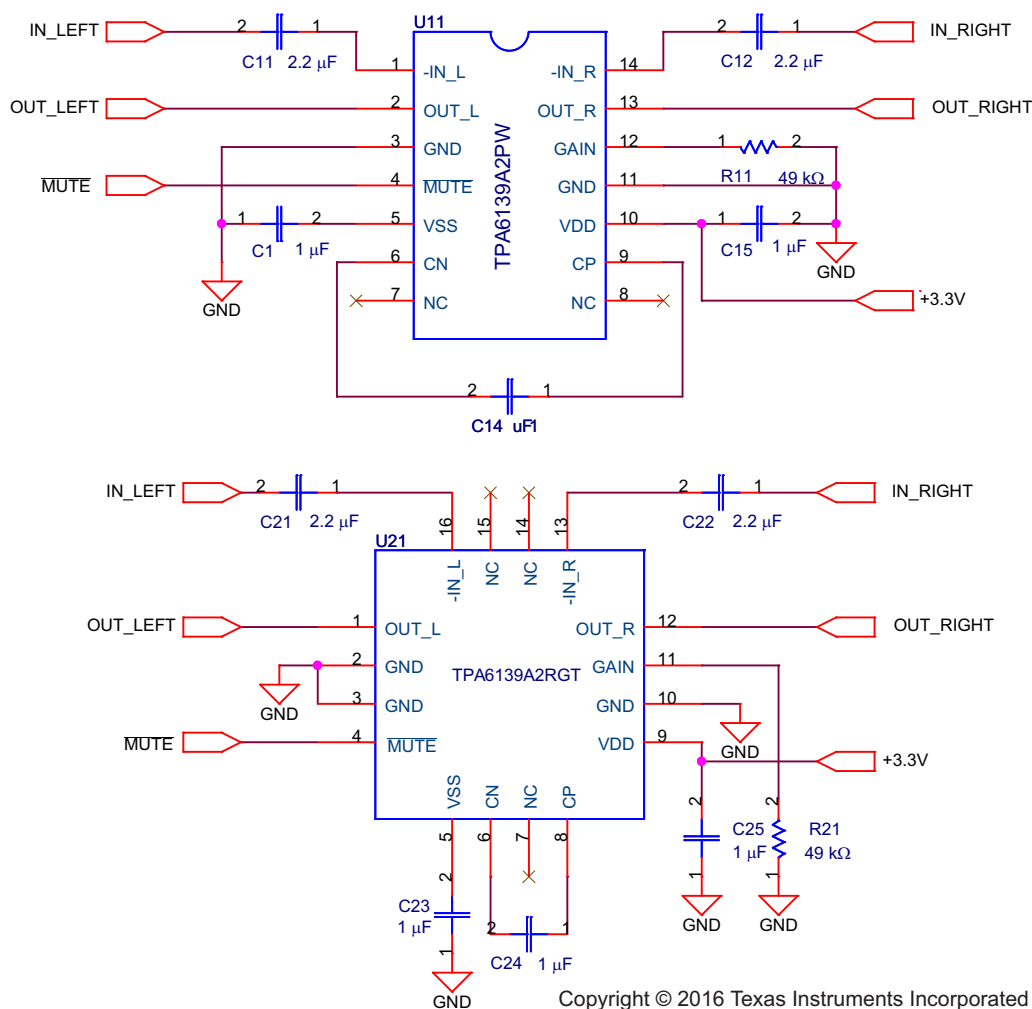


Figure 11. Single-Ended Input and Output, Gain Set to  $-1.5\times$

### 10.2.1 Design Requirements

Table 1 lists the design parameters of this example.

Table 1. Design Parameters

| DESIGN PARAMETER           | EXAMPLE VALUE |
|----------------------------|---------------|
| Input voltage supply range | 3 V to 3.6 V  |
| Current                    | 130 mA        |
| Load impedance             | 32 $\Omega$   |

### 10.2.2 Detailed Design Procedure

#### 10.2.2.1 Component Selection

##### 10.2.2.1.1 Charge Pump

The charge pump flying capacitor serves to transfer charge during the generation of the negative supply voltage. The VSS capacitor must be at least equal to the charge pump capacitor in order to allow maximum charge transfer. Low ESR capacitors are an ideal selection, and a value of 1  $\mu\text{F}$  is typical. Capacitor values that are smaller than 1  $\mu\text{F}$  cannot be recommended as it limits the negative voltage swing in low impedance loads.

### 10.2.2.1.2 Decoupling Capacitors

The TPA6139A2 is a DirectPath amplifier that requires adequate power-supply decoupling to ensure that the noise and total harmonic distortion (THD) are low. A good low equivalent-series-resistance (ESR) ceramic capacitor, typically 1  $\mu$ F, placed as close as possible to the device VDD leads works best. Placing this decoupling capacitor close to the TPA6139A2 is important for the performance of the amplifier. For filtering lower frequency noise signals, a 10- $\mu$ F or greater capacitor placed near the audio power amplifier also helps, but it is not required in most applications because of the high PSRR of this device.

### 10.2.2.1.3 Gain Setting

The gain setting is programmed with the GAIN pin individually for line driver and headphone section. Gain setting is latched when the MUTE pin is set high. [Table 2](#) lists the gain settings. The default gain with the gain-set pin left open is  $-2\times$ .

**Table 2. Gain Settings**

| Gain_set RESISTOR | GAIN         | GAIN (dB) | INPUT RESISTANCE |
|-------------------|--------------|-----------|------------------|
| No connect        | $-2\times$   | 6         | 37k              |
| 82k0              | $-1\times$   | 0         | 55k              |
| 49k2              | $-1.5\times$ | 3.5       | 44k              |
| 35k1              | $-2.3\times$ | 7.2       | 33k              |
| 27k3              | $-2.5\times$ | 8         | 31k              |
| 20k5              | $-3\times$   | 9.5       | 28k              |
| 15k4              | $-3.5\times$ | 10.9      | 24k              |
| 11k5              | $-4\times$   | 12        | 22k              |
| 9k09              | $-5\times$   | 14        | 18k              |
| 7k50              | $-5.6\times$ | 15        | 17k              |
| 6k19              | $-6.4\times$ | 16.1      | 15k              |
| 5k11              | $-8.3\times$ | 18.4      | 12k              |
| 3k90              | $-10\times$  | 20        | 10k              |

### 10.2.2.1.4 Input-Blocking Capacitors

DC input-blocking capacitors are required to be added in series with the audio signal into the input pins of the TPA6139A2. These capacitors block the DC portion of the audio source and allow the TPA6139A2 inputs to be properly biased to provide maximum performance. The input blocking capacitors also limit the DC gain to 1, limiting the DC-offset voltage at the output.

These capacitors form a high-pass filter with the input resistor,  $R_{IN}$ . The cutoff frequency is calculated using [Equation 1](#). For this calculation, the capacitance used is the input-blocking capacitor and the resistance is the input resistor chosen from [Table 2](#). Then the frequency or capacitance can be determined when one of the two values is given, as shown in [Equation 1](#).

$$f_{C_{IN}} = \frac{1}{2\pi R_{IN} C_{IN}} \text{ or } C_{IN} = \frac{1}{2\pi f_{C_{IN}} R_{IN}} \quad (1)$$

For a fixed cutoff frequency of 2 Hz, the size of the input capacitance is shown [Table 3](#) with the capacitors rounded up to the nearest E6 values. For 20-Hz cutoff, simply divide the capacitor values with 10; for example, for 1x gain, 150 nF is needed.

**Table 3. Input Capacitor for Different Gain and Cutoff**

| Gain_set RESISTOR | GAIN         | Gain (dB) | INPUT RESISTANCE | 2-Hz CUTOFF |
|-------------------|--------------|-----------|------------------|-------------|
| 249k              | $-2\times$   | 6         | 37k              | 2.2 $\mu$ F |
| 82k0              | $-1\times$   | 0         | 55k              | 1.5 $\mu$ F |
| 49k2              | $-1.5\times$ | 3.5       | 44k              | 2.2 $\mu$ F |
| 35k1              | $-2.3\times$ | 7.2       | 33k              | 3.3 $\mu$ F |
| 27k3              | $-2.5\times$ | 8         | 31k              | 3.3 $\mu$ F |

**Table 3. Input Capacitor for Different Gain and Cutoff (continued)**

| Gain_set<br>RESISTOR | GAIN  | Gain<br>(dB) | INPUT<br>RESISTANCE | 2-Hz<br>CUTOFF |
|----------------------|-------|--------------|---------------------|----------------|
| 20k5                 | –3x   | 9.5          | 28k                 | 3.3 $\mu$ F    |
| 15k4                 | –3.5x | 10.9         | 24k                 | 3.3 $\mu$ F    |
| 11k5                 | –4x   | 12           | 22k                 | 4.7 $\mu$ F    |
| 9k09                 | –5x   | 14           | 18k                 | 4.7 $\mu$ F    |
| 7k50                 | –5.6x | 15           | 17k                 | 4.7 $\mu$ F    |
| 6k19                 | –6.4x | 16.1         | 15k                 | 6.8 $\mu$ F    |
| 5k11                 | –8.3x | 18.4         | 12k                 | 6.8 $\mu$ F    |
| 3k90                 | –10x  | 20           | 10k                 | 10 $\mu$ F     |

### 10.2.3 Application Curves

The characteristics of this design are shown in [Typical Characteristics, Line Driver](#).

**Table 4. Table of Graphs**

|                                        | FIGURE                   |
|----------------------------------------|--------------------------|
| THD+N vs Output Voltage                | <a href="#">Figure 2</a> |
| Total Harmonic Distortion vs Frequency | <a href="#">Figure 6</a> |
| Mute to Un-Mute                        | <a href="#">Figure 7</a> |
| Un-Mute to mute                        | <a href="#">Figure 8</a> |

## 11 Power Supply Recommendations

The device is designed to operate from an input voltage supply from 3 V to 3.6 V. Therefore, the output voltage range of power supply should be within this range and well regulated. TI recommends placing decoupling capacitors in every voltage source pin. Place these decoupling capacitors as close as possible to the TPA6139A2.

## 12 Layout

### 12.1 Layout Guidelines

A proposed layout for the TPA6139A2 can be seen in the TPA6139A2EVM User's Guide ([SLOU308](#)), and the Gerber files can be downloaded from <http://focus.ti.com/docs/toolsw/folders/print/TPA6139A2evm.html>. To access this information, open the TPA6139A2 product folder and look in the Tools and Software folder.

TI recommends routing the ground traces as a star ground to minimize hum interference. VDD, VSS decoupling capacitors, and the charge pump capacitors should be connected with short traces.

The TPA6139A2 stereo headphone amplifier is pin-compatible with the DRV612. A single PCB layout can therefore be used with stuffing options for different board configurations.

## 12.2 Layout Example

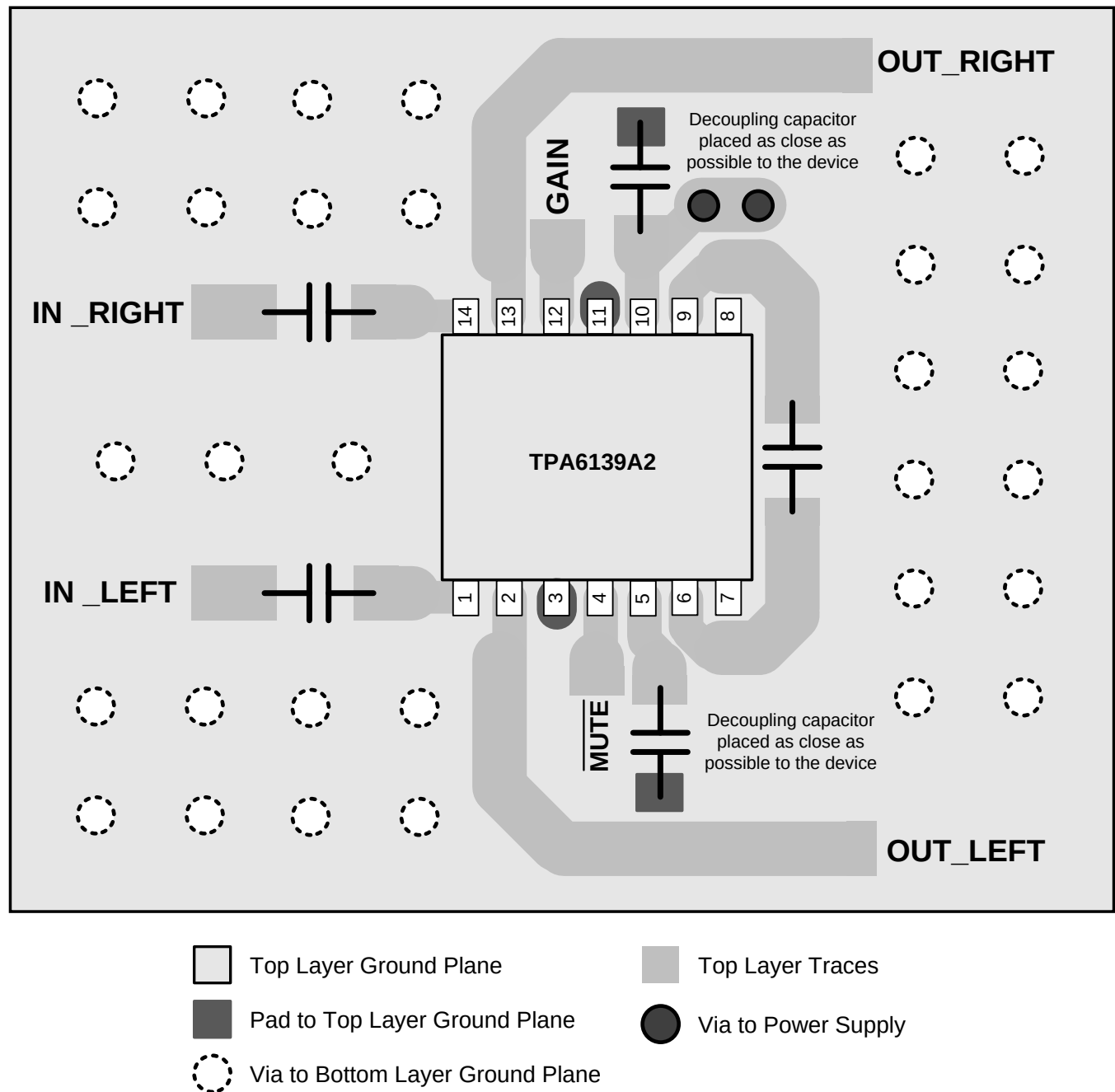


**Figure 12. Layout Example for the TSSOP Package**

## Layout Example (continued)

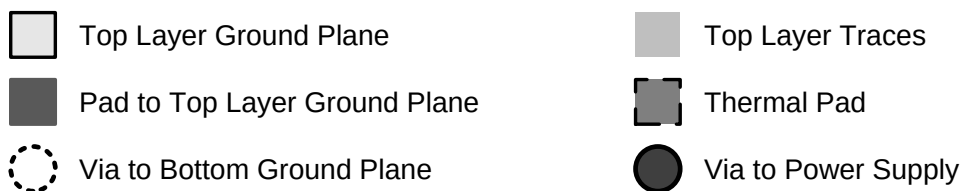
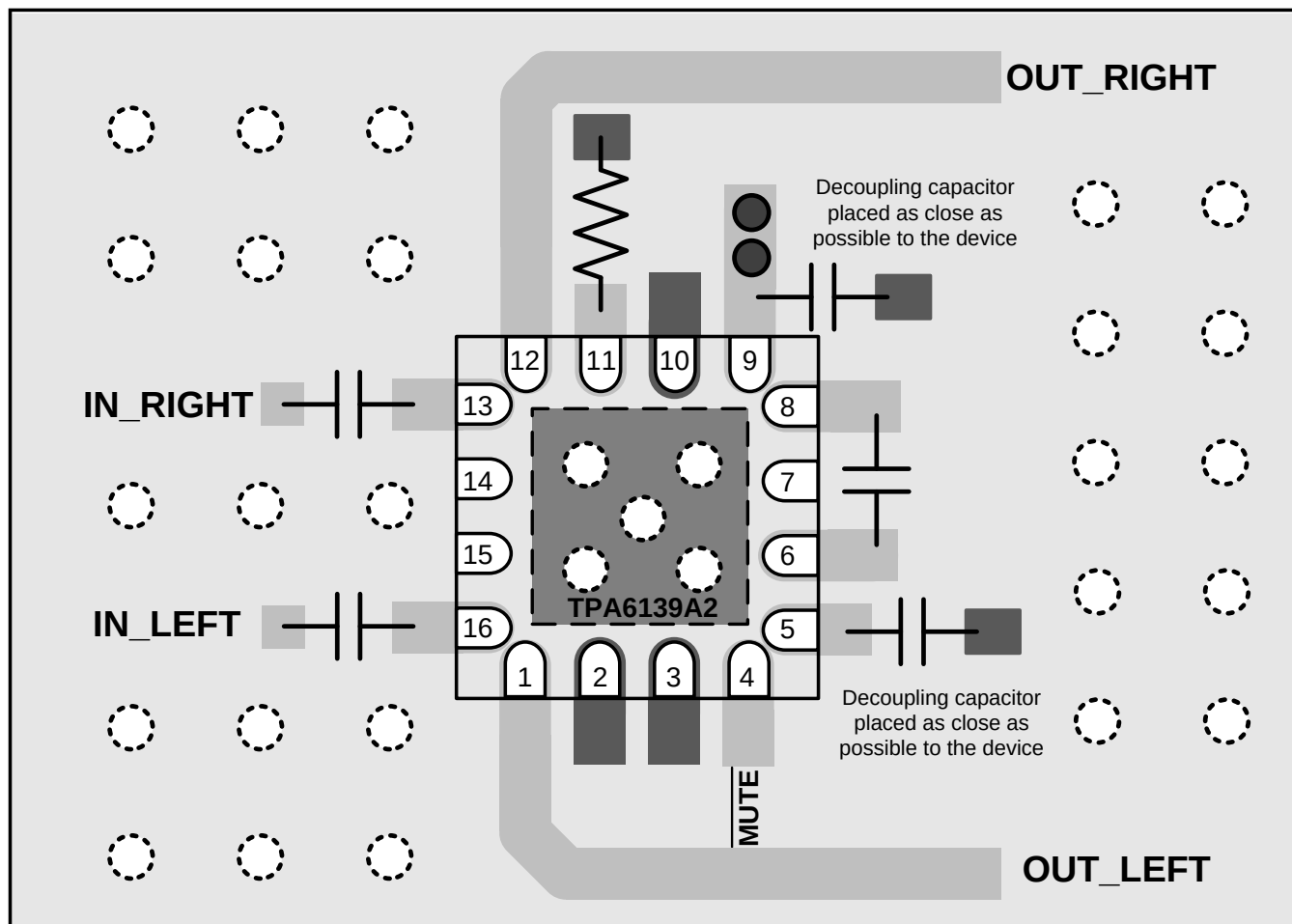


**Figure 13. Layout Example for the VQFN Package**

## 13 Device and Documentation Support

### 13.1 Device Support

For device support, see the following:

Gerber – <http://focus.ti.com/docs/toolsw/folders/print/TPA6139A2evm.html>

### 13.2 Documentation Support

For related documentation, see the following:

*TPA6139A2EVM User's Guide* (SLOU308)

### 13.3 Community Resources

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](http://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.

### 13.4 Trademarks

DirectPath, E2E are trademarks of Texas Instruments.

Blu-ray Discs is a trademark of Blu-ray Disc Association.

All other trademarks are the property of their respective owners.

### 13.5 Electrostatic Discharge Caution



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

### 13.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number         | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TPA6139A2PW</a>   | Active        | Production           | TSSOP (PW)   14 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | TPA6139             |
| TPA6139A2PW.A                 | Active        | Production           | TSSOP (PW)   14 | 90   TUBE             | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | TPA6139             |
| <a href="#">TPA6139A2PWR</a>  | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | TPA6139             |
| TPA6139A2PWR.A                | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | TPA6139             |
| <a href="#">TPA6139A2RGTR</a> | Active        | Production           | VQFN (RGT)   16 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 150   | T6139               |
| TPA6139A2RGTR.A               | Active        | Production           | VQFN (RGT)   16 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 150   | T6139               |
| <a href="#">TPA6139A2RGTT</a> | Active        | Production           | VQFN (RGT)   16 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 150   | T6139               |
| TPA6139A2RGTT.A               | Active        | Production           | VQFN (RGT)   16 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 150   | T6139               |

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

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

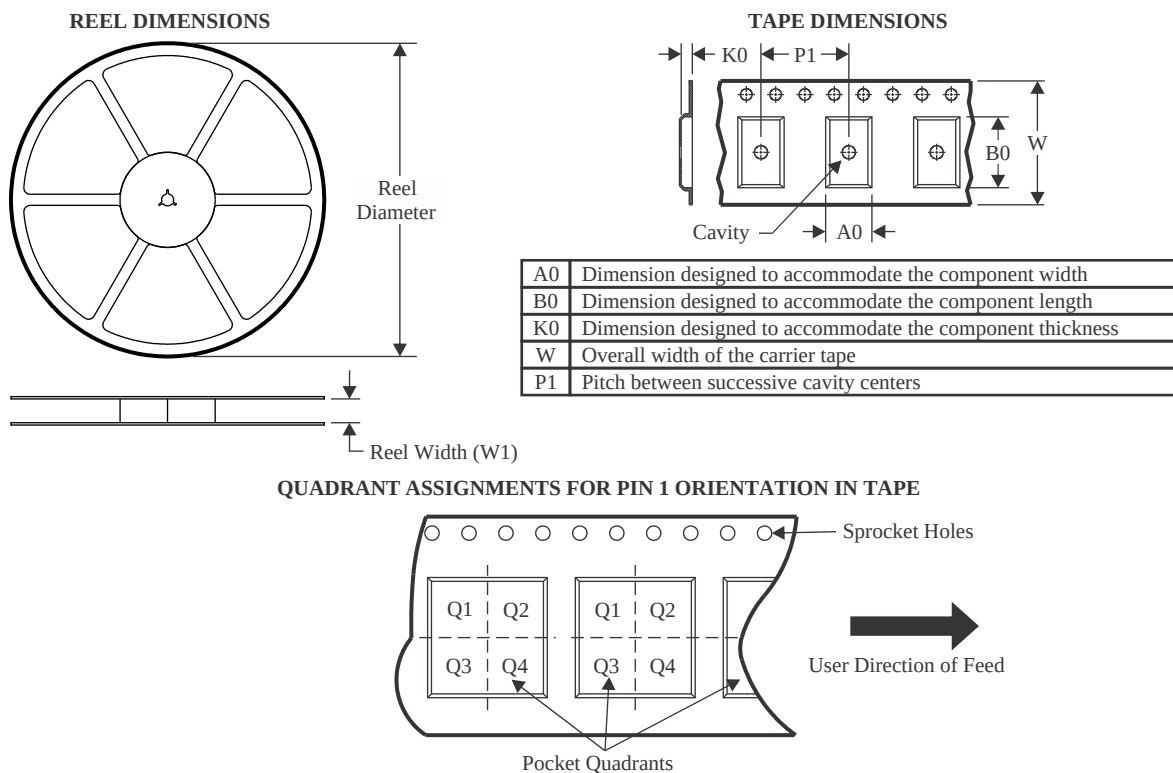
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

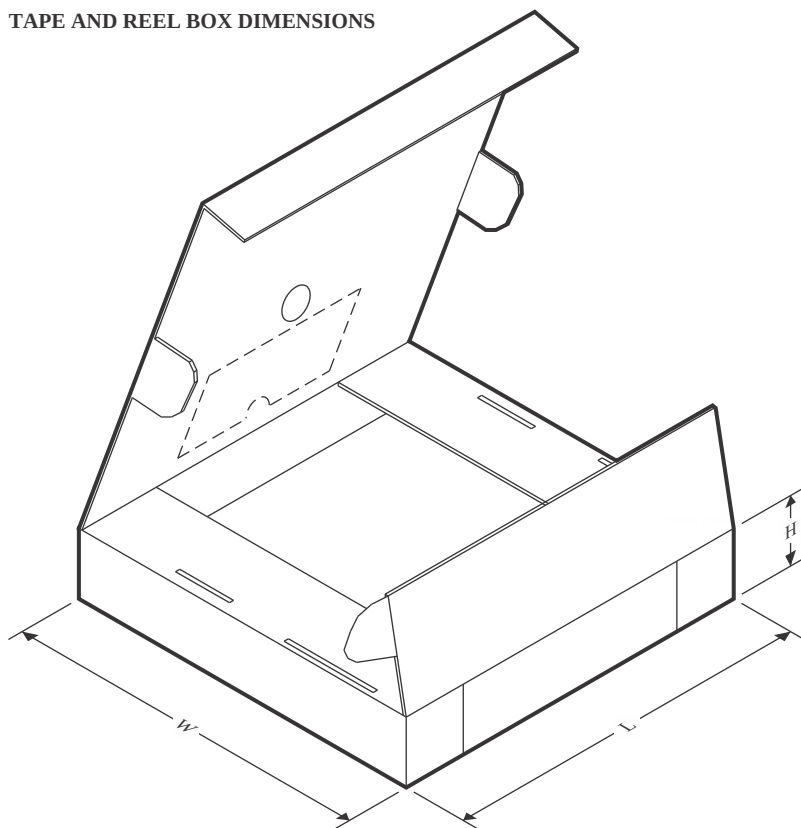
## TAPE AND REEL INFORMATION



\*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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPA6139A2PWR | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

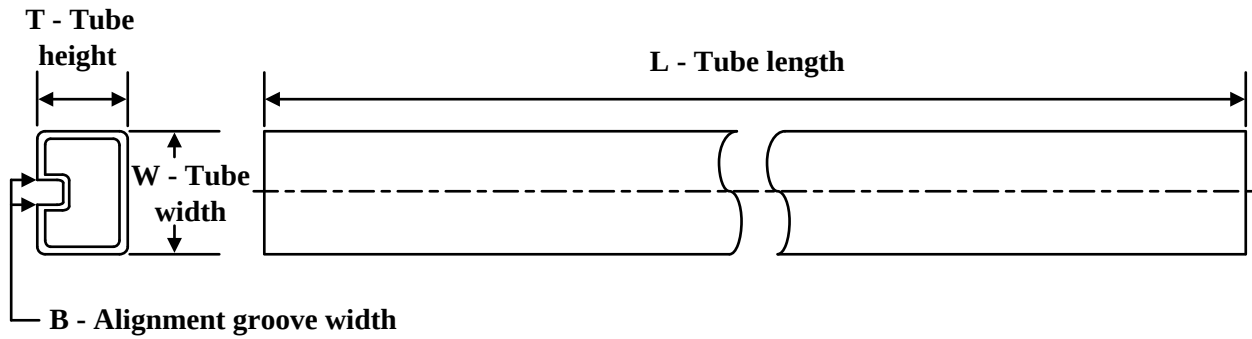
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPA6139A2PWR | TSSOP        | PW              | 14   | 2000 | 350.0       | 350.0      | 43.0        |

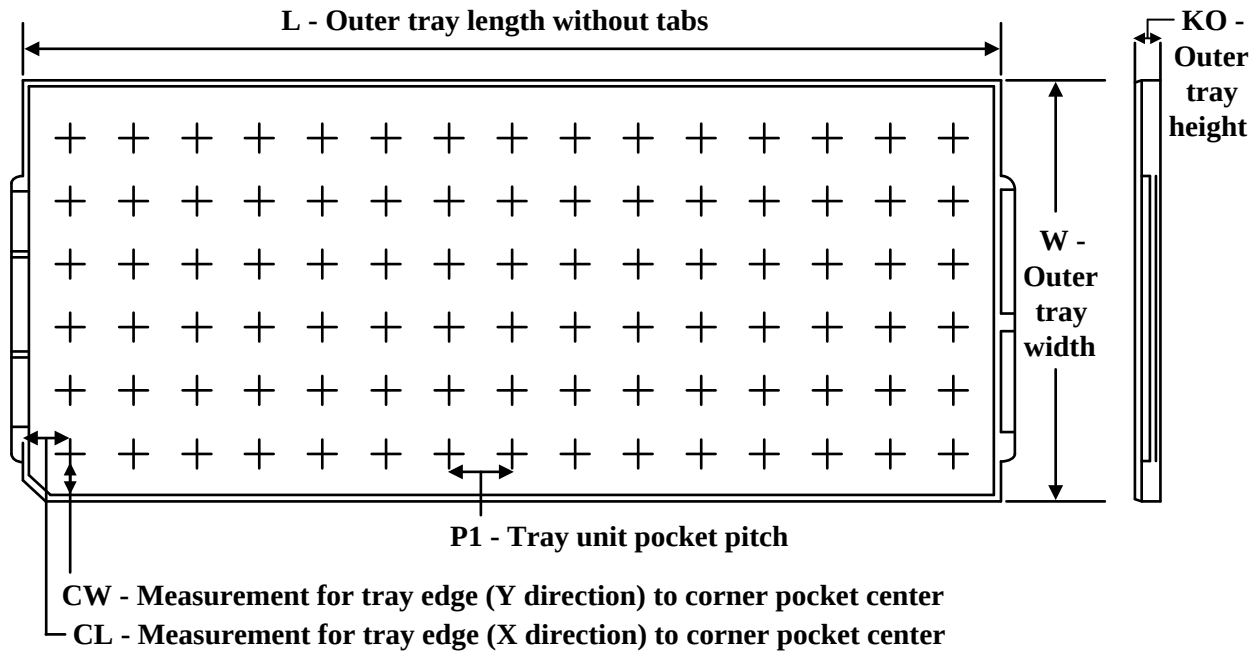
## TUBE



\*All dimensions are nominal

| Device        | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|---------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TPA6139A2PW   | PW           | TSSOP        | 14   | 90  | 530    | 10.2   | 3600   | 3.5    |
| TPA6139A2PW.A | PW           | TSSOP        | 14   | 90  | 530    | 10.2   | 3600   | 3.5    |

## TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

\*All dimensions are nominal

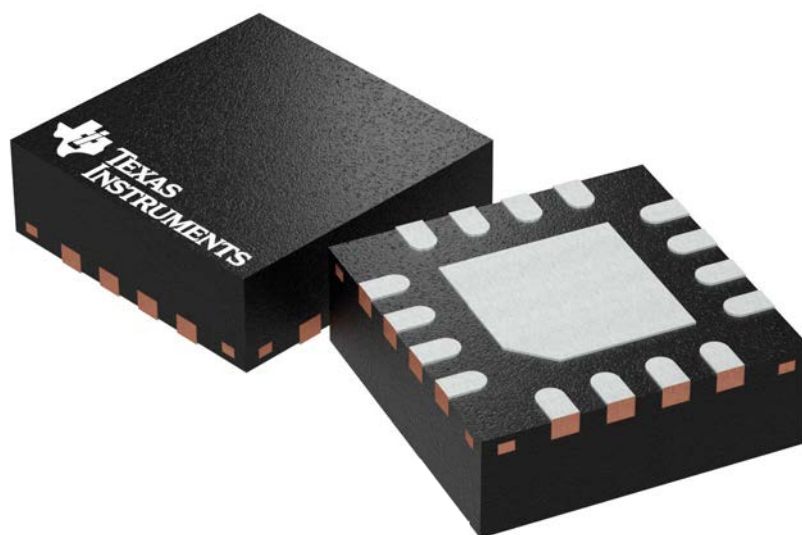
| Device          | Package Name | Package Type | Pins | SPQ  | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|-----------------|--------------|--------------|------|------|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| TPA6139A2RGTR   | RGT          | VQFN         | 16   | 3000 | 35 X 14           | 150                  | 315    | 135.9  | 7620    | 8.8     | 7.9     | 8.15    |
| TPA6139A2RGTR.A | RGT          | VQFN         | 16   | 3000 | 35 X 14           | 150                  | 315    | 135.9  | 7620    | 8.8     | 7.9     | 8.15    |
| TPA6139A2RGTT   | RGT          | VQFN         | 16   | 250  | 35 X 14           | 150                  | 315    | 135.9  | 7620    | 8.8     | 7.9     | 8.15    |
| TPA6139A2RGTT.A | RGT          | VQFN         | 16   | 250  | 35 X 14           | 150                  | 315    | 135.9  | 7620    | 8.8     | 7.9     | 8.15    |

**RGT 16**

**GENERIC PACKAGE VIEW**

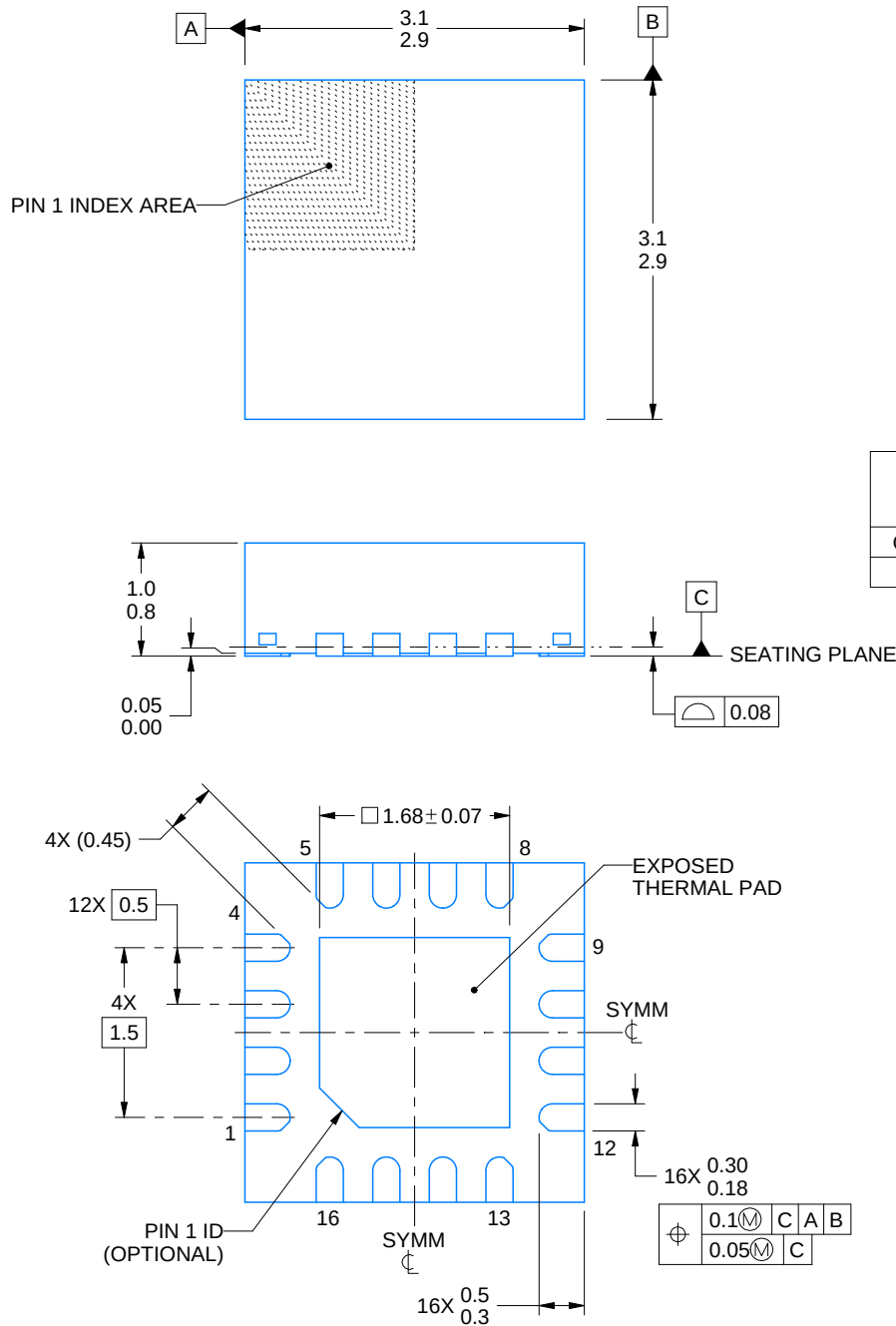
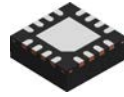
**VQFN - 1 mm max height**

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.

4203495/1



4222419/E 07/2025

## NOTES:

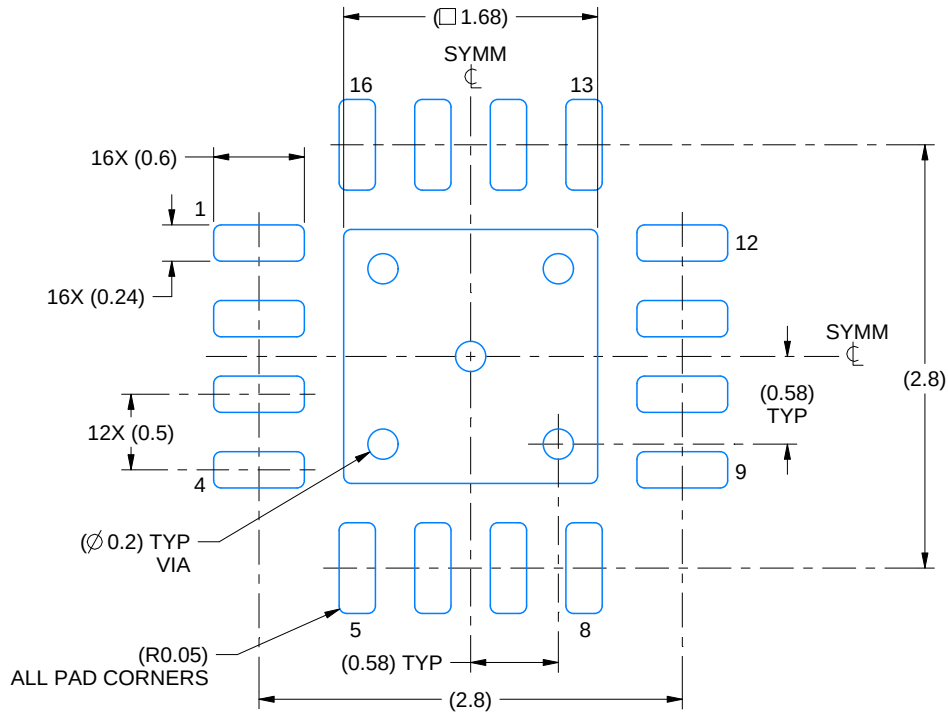
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

# EXAMPLE BOARD LAYOUT

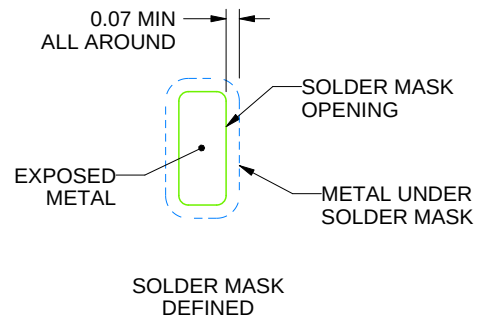
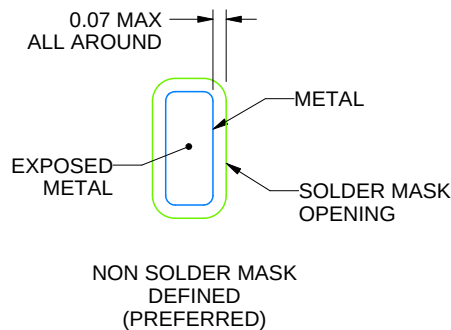
RGT0016C

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



SOLDER MASK DETAILS

4222419/E 07/2025

NOTES: (continued)

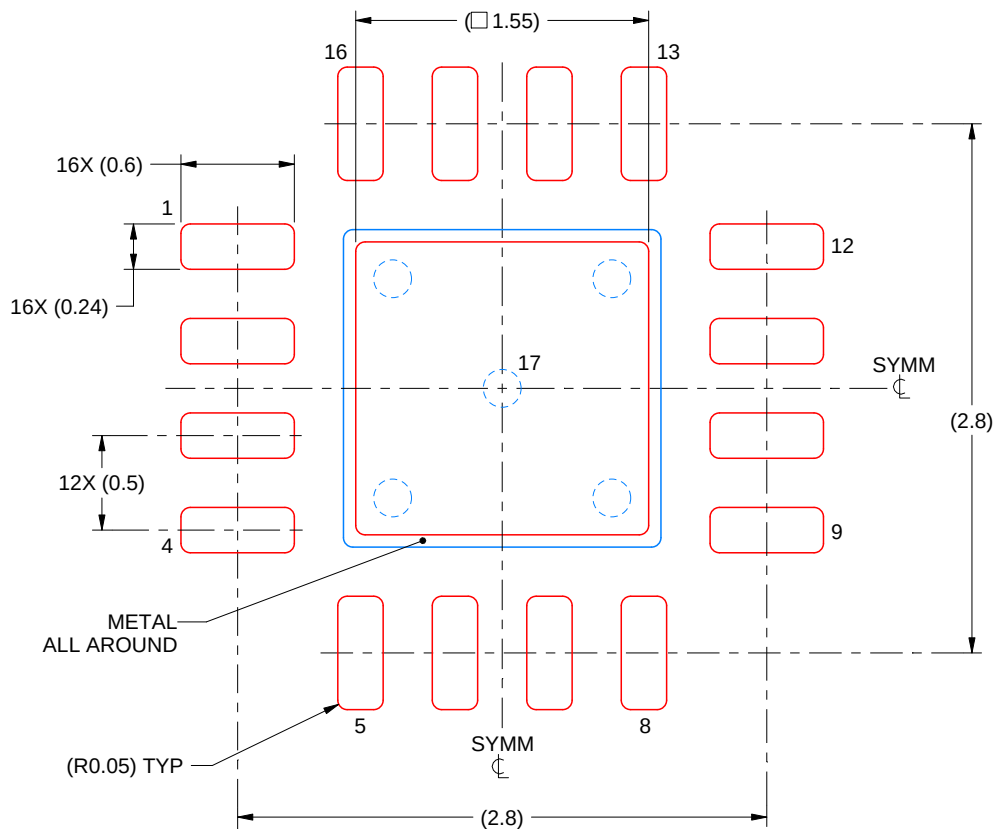
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

# EXAMPLE STENCIL DESIGN

RGT0016C

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



**SOLDER PASTE EXAMPLE**  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 17:  
85% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:25X

4222419/E 07/2025

NOTES: (continued)

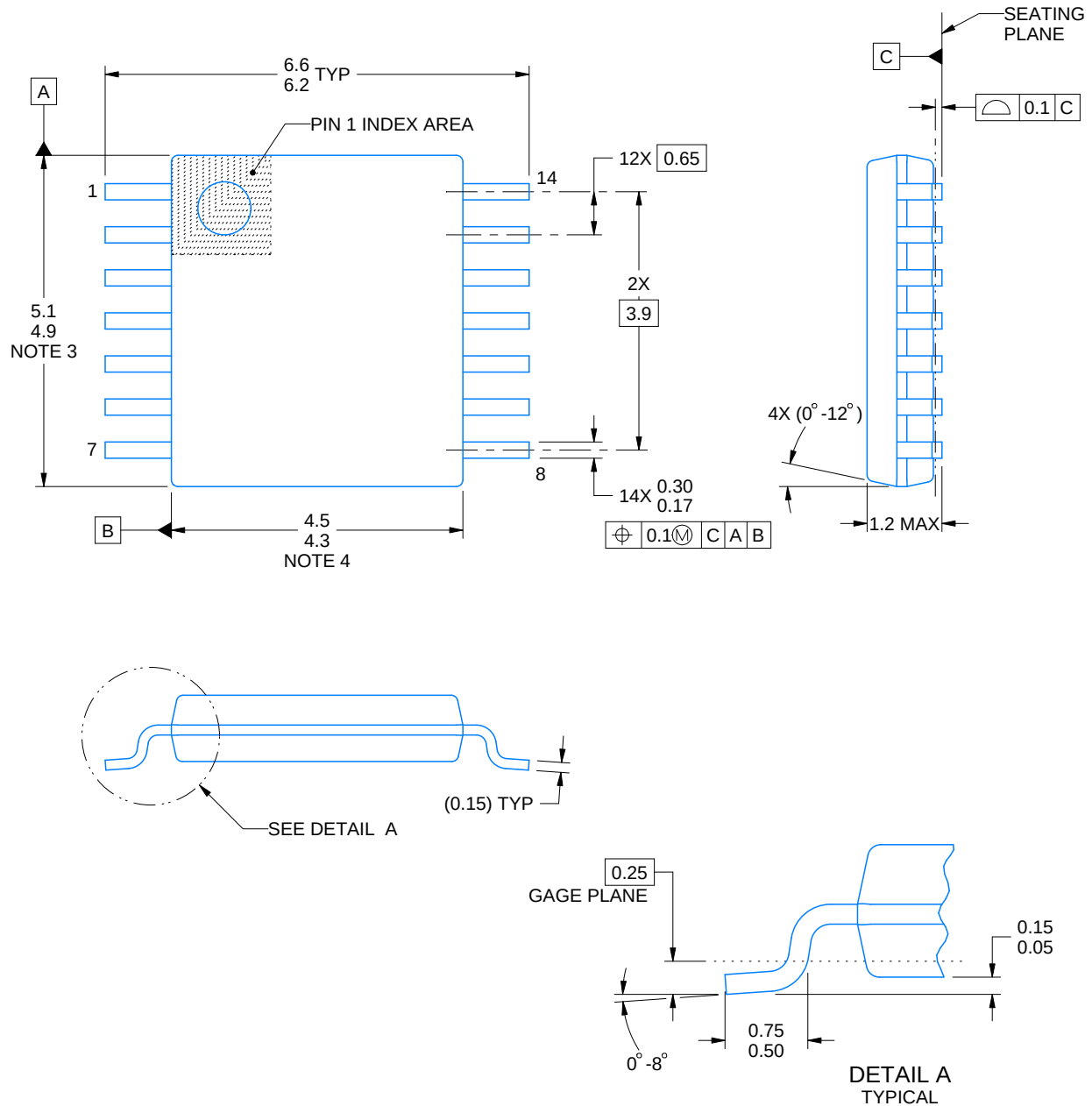
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

**PW0014A**

## PACKAGE OUTLINE

**TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



4220202/B 12/2023

NOTES:

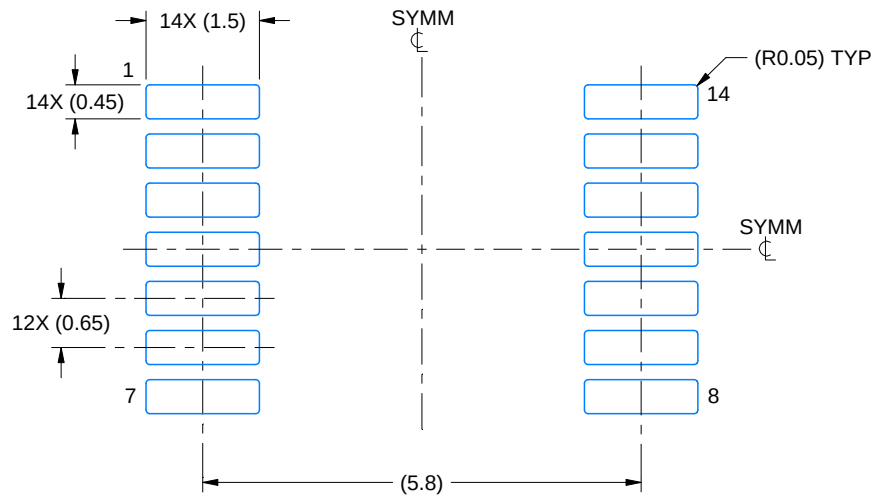
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

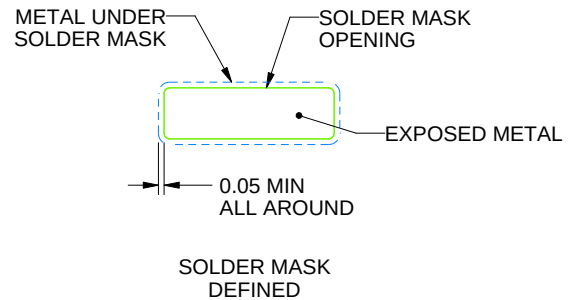
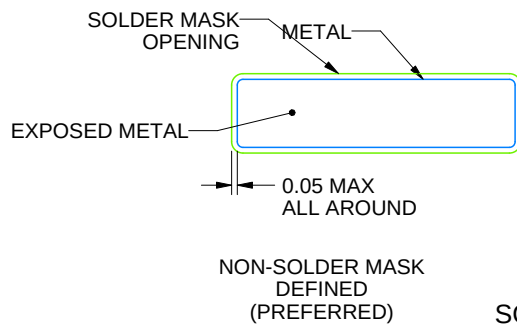
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

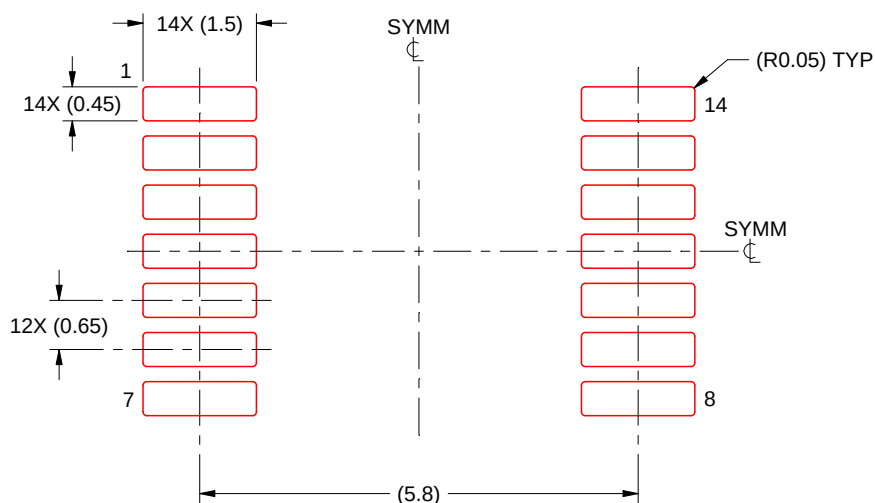
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

4220202/B 12/2023

NOTES: (continued)

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

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