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**TEXAS  
INSTRUMENTS**

**OPA140, OPA2140, OPA4140**

SBOS498B –JULY 2010–REVISED NOVEMBER 2015

## High-Precision, Low-Noise, Rail-to-Rail Output, 11-MHz JFET Op Amp

### 1 Features

- Very Low Offset Drift: 1  $\mu\text{V}/^\circ\text{C}$  Maximum
- Very Low Offset: 120  $\mu\text{V}$
- Low Input Bias Current: 10 pA Maximum
- Very Low 1/f Noise: 250 nV<sub>PP</sub>, 0.1 Hz to 10 Hz
- Low Noise: 5.1 nV/ $\sqrt{\text{Hz}}$
- Slew Rate: 20 V/ $\mu\text{s}$
- Low Supply Current: 2 mA Maximum
- Input Voltage Range Includes V<sub>−</sub> Supply
- Single-Supply Operation: 4.5 V to 36 V
- Dual-Supply Operation:  $\pm 2.25$  V to  $\pm 18$  V
- No Phase Reversal
- Industry-Standard SOIC Packages
- VSSOP, TSSOP, and SOT-23 Packages

### 2 Applications

- Battery-Powered Instruments
- Industrial Controls
- Medical Instrumentation
- Photodiode Amplifiers
- Active Filters
- Data Acquisition Systems
- Automatic Test Systems

### 3 Description

The OPA140, OPA2140, and OPA4140 operational amplifier (op amp) family is a series of low-power JFET input amplifiers that features good drift and low input bias current. The rail-to-rail output swing and input range that includes V<sub>−</sub> allow designers to take advantage of the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).

The OPA140 achieves 11-MHz unity-gain bandwidth and 20-V/ $\mu\text{s}$  slew rate while consuming only 1.8 mA (typical) of quiescent current. It runs on a single 4.5-V to 36-V supply or dual  $\pm 2.25$ -V to  $\pm 18$ -V supplies.

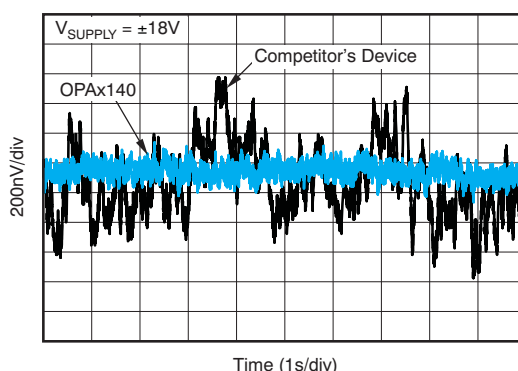
All versions are fully specified from  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for use in the most challenging environments. The OPA140 (single) is available in the 5-pin SOT-23, 8-pin VSSOP, and 8-pin SOIC packages; the OPA2140 (dual) is available in both 8-pin VSSOP and 8-pin SOIC packages; and the OPA4140 (quad) is available in the 14-pin SOIC and 14-pin TSSOP packages.

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

| PART NUMBER | PACKAGE    | BODY SIZE (NOM)   |
|-------------|------------|-------------------|
| OPA140      | SOIC (8)   | 4.90 mm × 3.90 mm |
|             | SOT23 (5)  | 2.90 mm × 1.60 mm |
|             | VSSOP (8)  | 3.00 mm × 3.00 mm |
| OPA2140     | SOIC (8)   | 4.90 mm × 3.90 mm |
|             | VSSOP (8)  | 3.00 mm × 3.00 mm |
| OPA4140     | SOIC (14)  | 8.65 mm × 3.90 mm |
|             | TSSOP (14) | 5.00 mm × 4.40 mm |

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

#### 0.1-Hz to 10-Hz Noise



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

## OPA140, OPA2140, OPA4140

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## 4 Revision History

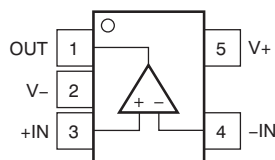
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision A (August 2010) to Revision B                                                                                                                                                                                                                                   | Page      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| • 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>  |
| • Changed title of <a href="#">Table 1</a> from Characteristic Performance Measurements to Table of Graphs .....                                                                                                                                                                      | <b>8</b>  |
| • Changed title for Power Dissipation and Thermal Protection section to Thermal Protection .....                                                                                                                                                                                      | <b>19</b> |

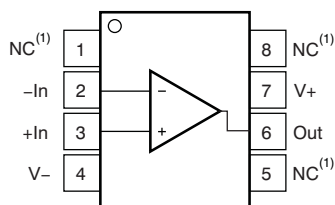
| Changes from Original (July 2010) to Revision A               | Page     |
|---------------------------------------------------------------|----------|
| • Moved device and data sheet to production data status ..... | <b>1</b> |
| • Added SOIC (8) (MSOP) packages .....                        | <b>3</b> |

## 5 Pin Configuration and Functions

**DBV Package: OPA140**  
**5-Pin SOT-23**  
**Top View**



**D and DGK Packages: OPA140**  
**8-Pin SOIC and VSSOP**  
**Top View**



(1) NC denotes no internal connection.

**Pin Functions: OPA140**

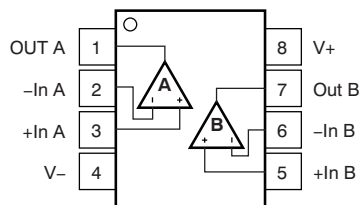
| NAME | PIN                      |           | I/O | DESCRIPTION                                   |
|------|--------------------------|-----------|-----|-----------------------------------------------|
|      | D (SOIC),<br>DGK (VSSOP) | DBV (SOT) |     |                                               |
| +IN  | 3                        | 3         | I   | Noninverting input                            |
| -IN  | 2                        | 4         | I   | Inverting input                               |
| NC   | 1, 5, 8                  | —         | —   | No internal connection (can be left floating) |
| OUT  | 6                        | 1         | O   | Output                                        |
| V+   | 7                        | 5         | —   | Positive (highest) power supply               |
| V-   | 4                        | 2         | —   | Negative (lowest) power supply                |

**OPA140, OPA2140, OPA4140**

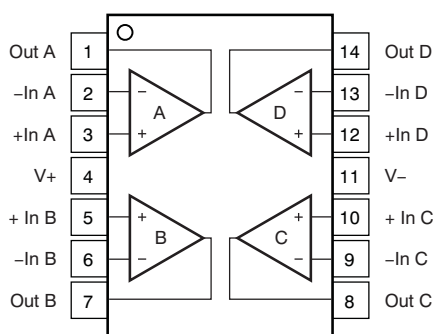
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**D and DGK Packages: OPA2140  
8-Pin SOIC and VSSOP  
Top View**



**D and PW Packages: OPA4140  
14-Pin SOIC and TSSOP  
Top View**



**Pin Functions: OPA2140 and OPA4140**

| NAME  | PIN                                 |                                    | I/O | DESCRIPTION                     |
|-------|-------------------------------------|------------------------------------|-----|---------------------------------|
|       | OPA2140<br>D (SOIC),<br>DGK (VSSOP) | OPA4140<br>D (SOIC),<br>PW (TSSOP) |     |                                 |
| +IN A | 3                                   | 3                                  | I   | Noninverting input, channel A   |
| +IN B | 5                                   | 5                                  | I   | Noninverting input, channel B   |
| +IN C | —                                   | 10                                 | I   | Noninverting input, channel C   |
| +IN D | —                                   | 12                                 | I   | Noninverting input, channel D   |
| –IN A | 2                                   | 2                                  | I   | Inverting input, channel A      |
| –IN B | 6                                   | 6                                  | I   | Inverting input, channel B      |
| –IN C | —                                   | 9                                  | I   | Inverting input, channel C      |
| –IN D | —                                   | 13                                 | I   | Inverting input, channel D      |
| OUT A | 1                                   | 1                                  | O   | Output, channel A               |
| OUT B | 7                                   | 7                                  | O   | Output, channel B               |
| OUT C | —                                   | 8                                  | O   | Output, channel C               |
| OUT D | —                                   | 14                                 | O   | Output, channel D               |
| V+    | 8                                   | 4                                  | —   | Positive (highest) power supply |
| V–    | 4                                   | 11                                 | —   | Negative (lowest) power supply  |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

|                                     |                        | MIN          | MAX          | UNIT |
|-------------------------------------|------------------------|--------------|--------------|------|
| Supply voltage, $V_S = (V+) - (V-)$ |                        |              | 40           | V    |
| Signal input pins                   | Voltage <sup>(2)</sup> | $(V-) - 0.5$ | $(V+) + 0.5$ | V    |
|                                     | Current <sup>(2)</sup> | -10          | 10           | mA   |
| Output short circuit <sup>(3)</sup> |                        | Continuous   |              |      |
| Temperature                         | Operating              | -55          | 150          | °C   |
|                                     | Junction               |              | 150          |      |
|                                     | Storage, $T_{stg}$     | -65          | 150          |      |

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

(2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5 V beyond the supply rails should be current-limited to 10 mA or less.

(3) Short-circuit to  $V_S/2$  (ground in symmetrical dual-supply setups), one amplifier per package.

### 6.2 ESD Ratings

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

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

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

### 6.3 Recommended Operating Conditions

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

|                       | MIN   | NOM | MAX | UNIT |
|-----------------------|-------|-----|-----|------|
| Supply voltage        | ±2.25 |     | ±18 | V    |
| Specified temperature | -40   |     | 125 | °C   |

## OPA140, OPA2140, OPA4140

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### 6.4 Thermal Information: OPA140

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA140   |           |             | UNIT |
|-------------------------------|----------------------------------------------|----------|-----------|-------------|------|
|                               |                                              | D (SOIC) | DBV (SOT) | DGK (VSSOP) |      |
|                               |                                              | 8 PINS   | 5 PINS    | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 160      | 210       | 180         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 75       | 200       | 55          | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 60       | 110       | 130         | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 9        | 40        | N/A         | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 50       | 105       | 120         | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | N/A      | N/A       | N/A         | °C/W |

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

### 6.5 Thermal Information: OPA2140

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA2140  |             | UNIT |
|-------------------------------|----------------------------------------------|----------|-------------|------|
|                               |                                              | D (SOIC) | DGK (VSSOP) |      |
|                               |                                              | 8 PINS   | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 160      | 180         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 75       | 55          | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 60       | 130         | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 9        | N/A         | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 50       | 120         | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | N/A      | N/A         | °C/W |

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

### 6.6 Thermal Information: OPA4140

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA4140  |            | UNIT |
|-------------------------------|----------------------------------------------|----------|------------|------|
|                               |                                              | D (SOIC) | PW (TSSOP) |      |
|                               |                                              | 14 PINS  | 14 PINS    |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 97       | 135        | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 56       | 45         | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 53       | 66         | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 19       | N/A        | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 46       | 60         | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | N/A      | N/A        | °C/W |

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

## 6.7 Electrical Characteristics: $V_S = 4.5\text{ V to }36\text{ V}$ ; $\pm 2.25\text{ V to } \pm 18\text{ V}$

at  $T_A = 25^\circ\text{C}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply, and  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.

| PARAMETER            |                                   | TEST CONDITIONS                                                         |                                 | MIN                         | TYP                    | MAX         | UNIT              |
|----------------------|-----------------------------------|-------------------------------------------------------------------------|---------------------------------|-----------------------------|------------------------|-------------|-------------------|
| OFFSET VOLTAGE       |                                   |                                                                         |                                 |                             |                        |             |                   |
| V <sub>OS</sub>      | Input offset voltage              |                                                                         |                                 |                             | 30                     | 120         | μV                |
|                      |                                   | V <sub>S</sub> = ±18 V, T <sub>A</sub> = −40°C to 125°C                 |                                 |                             |                        | 220         |                   |
|                      |                                   | V <sub>S</sub> = ±2.25 V to ±18 V, T <sub>A</sub> = −40°C to 125°C      |                                 |                             |                        |             | ±4                |
| dV <sub>OS</sub> /dT | Input offset voltage drift        | V <sub>S</sub> = ±18 V, T <sub>A</sub> = −40°C to 125°C                 |                                 |                             | ±0.35                  | 1           | μV/°C             |
| PSRR                 | Power-supply rejection ratio      | V <sub>S</sub> = ±2.25 V to ±18 V, T <sub>A</sub> = −40°C to 125°C      |                                 |                             | ±0.1                   | ±0.5        | μV/V              |
| INPUT BIAS CURRENT   |                                   |                                                                         |                                 |                             |                        |             |                   |
| I <sub>B</sub>       | Input bias current                |                                                                         |                                 |                             | ±0.5                   | ±10         | pA                |
|                      |                                   | T <sub>A</sub> = −40°C to 125°C                                         |                                 |                             |                        |             | ±3                |
| I <sub>OS</sub>      | Input offset current              |                                                                         |                                 |                             | ±0.5                   | ±10         | pA                |
|                      |                                   | T <sub>A</sub> = −40°C to 125°C                                         |                                 |                             |                        |             | ±1                |
| NOISE                |                                   |                                                                         |                                 |                             |                        |             |                   |
| E <sub>n</sub>       | Input voltage noise               | f = 0.1 Hz to 10 Hz                                                     |                                 |                             | 250                    |             | μV <sub>PP</sub>  |
|                      |                                   | f = 0.1 Hz to 10 Hz                                                     |                                 |                             | 42                     |             | μV <sub>RMS</sub> |
| e <sub>n</sub>       | Input voltage noise density       | f = 10 Hz                                                               |                                 |                             | 8                      |             | nV/√Hz            |
|                      |                                   | f = 100 Hz                                                              |                                 |                             | 5.8                    |             |                   |
|                      |                                   | f = 1 kHz                                                               |                                 |                             | 5.1                    |             |                   |
| i <sub>n</sub>       | Input current noise density       | f = 1 kHz                                                               |                                 |                             | 0.8                    |             | fA/√Hz            |
| INPUT VOLTAGE        |                                   |                                                                         |                                 |                             |                        |             |                   |
| V <sub>CM</sub>      | Common-mode voltage               | T <sub>A</sub> = −40°C to 125°C                                         |                                 | (V−) − 0.1                  |                        | (V+) − 3.5  | V                 |
| CMRR                 | Common-mode rejection ratio       | V <sub>S</sub> = ±18 V, V <sub>CM</sub> = (V−) − 0.1 V to (V+) − 3.5 V  |                                 | 126                         | 140                    |             | dB                |
|                      |                                   |                                                                         | T <sub>A</sub> = −40°C to 125°C | 120                         |                        |             |                   |
| INPUT IMPEDANCE      |                                   |                                                                         |                                 |                             |                        |             |                   |
| Z <sub>ID</sub>      | Differential                      |                                                                         |                                 |                             | 10 <sup>13</sup>    10 |             | Ω    pF           |
| Z <sub>IC</sub>      | Common-mode                       | V <sub>CM</sub> = (V−) − 0.1 V to (V+) − 3.5 V                          |                                 |                             | 10 <sup>13</sup>    7  |             | Ω    pF           |
| OPEN-LOOP GAIN       |                                   |                                                                         |                                 |                             |                        |             |                   |
| A <sub>OL</sub>      | Open-loop voltage gain            | V <sub>O</sub> = (V−) + 0.35 V to (V+) − 0.35 V, R <sub>L</sub> = 10 kΩ |                                 | 120                         | 126                    |             | dB                |
|                      |                                   |                                                                         |                                 | 114                         | 126                    |             |                   |
|                      |                                   | V <sub>O</sub> = (V−) + 0.35 V to (V+) − 0.35 V, R <sub>L</sub> = 2 kΩ  | T <sub>A</sub> = −40°C to 125°C | 108                         |                        |             |                   |
| FREQUENCY RESPONSE   |                                   |                                                                         |                                 |                             |                        |             |                   |
| BW                   | Gain bandwidth product            |                                                                         |                                 |                             | 11                     |             | MHz               |
| SR                   | Slew rate                         |                                                                         |                                 |                             | 20                     |             | V/μs              |
| t <sub>s</sub>       | Settling time                     | 12-bit                                                                  |                                 |                             | 880                    |             | ns                |
|                      |                                   | 16-bit                                                                  |                                 |                             | 1.6                    |             | μs                |
| t <sub>OR</sub>      | Overload recovery time            |                                                                         |                                 |                             | 600                    |             | ns                |
| THD+N                | Total harmonic distortion + noise | 1 kHz, G = 1, V <sub>O</sub> = 3.5 V <sub>RMS</sub>                     |                                 |                             | 0.00005%               |             |                   |
| OUTPUT               |                                   |                                                                         |                                 |                             |                        |             |                   |
| V <sub>O</sub>       | Voltage output                    | R <sub>LOAD</sub> = 10 kΩ, A <sub>OL</sub> ≥ 108 dB                     |                                 | (V−) + 0.2                  |                        | (V+) − 0.2  | V                 |
|                      |                                   | R <sub>LOAD</sub> = 2 kΩ, A <sub>OL</sub> ≥ 108 dB                      |                                 | (V−) + 0.35                 |                        | (V+) − 0.35 |                   |
| I <sub>SC</sub>      | Short-circuit current             | Source                                                                  |                                 |                             | 36                     |             | mA                |
|                      |                                   | Sink                                                                    |                                 |                             | −30                    |             |                   |
| C <sub>LOAD</sub>    | Capacitive load drive             |                                                                         |                                 | See Figure 19 and Figure 20 |                        |             |                   |
| Z <sub>O</sub>       | Open-loop output impedance        | f = 1 MHz, I <sub>O</sub> = 0 A (See Figure 18)                         |                                 |                             | 16                     |             | Ω                 |



## OPA140, OPA2140, OPA4140

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### Electrical Characteristics: $V_S = 4.5\text{ V to }36\text{ V}$ ; $\pm 2.25\text{ V to } \pm 18\text{ V}$ (continued)

at  $T_A = 25^\circ\text{C}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply, and  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.

| PARAMETER          |                                 | TEST CONDITIONS                 |      | MIN         | TYP  | MAX     | UNIT |
|--------------------|---------------------------------|---------------------------------|------|-------------|------|---------|------|
| POWER SUPPLY       |                                 |                                 |      |             |      |         |      |
| V <sub>S</sub>     | Power-supply voltage            |                                 |      | 4.5 (±2.25) |      | 9 (±18) | V    |
| I <sub>Q</sub>     | Quiescent current per amplifier | I <sub>O</sub> = 0 A            |      | 1.8         |      | 2       | mA   |
|                    |                                 | T <sub>A</sub> = −40°C to 125°C |      | 2.7         |      |         |      |
| CHANNEL SEPARATION |                                 |                                 |      |             |      |         |      |
| Channel separation | At dc                           |                                 | 0.02 |             | μV/V |         |      |
|                    | At 100 kHz                      |                                 | 10   |             |      |         |      |

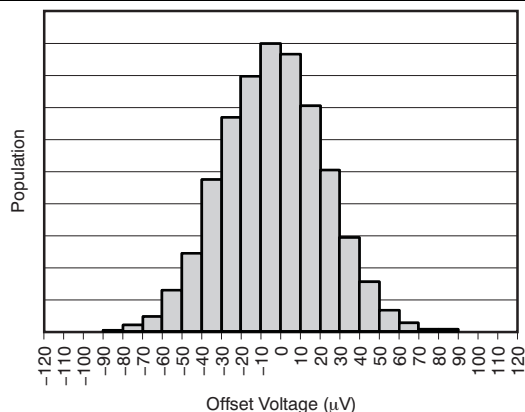
## 6.8 Typical Characteristics

Table 1. Table of Graphs

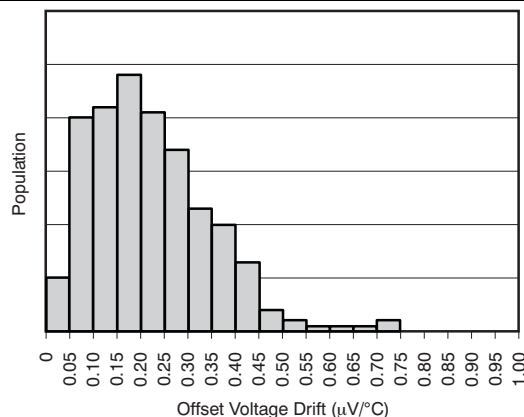
| DESCRIPTION                                            | FIGURE               |
|--------------------------------------------------------|----------------------|
| Offset Voltage Production Distribution                 | Figure 1             |
| Offset Voltage Drift Distribution                      | Figure 2             |
| Offset Voltage vs Common-Mode Voltage (Maximum Supply) | Figure 3             |
| $I_B$ vs Common-Mode Voltage                           | Figure 5             |
| Input Offset Voltage vs Temperature                    | Figure 4             |
| Output Voltage Swing vs Output Current                 | Figure 6             |
| CMRR and PSRR vs Frequency (RTI)                       | Figure 7             |
| Common-Mode Rejection Ratio vs Temperature             | Figure 8             |
| 0.1-Hz to 10-Hz Noise                                  | Figure 9             |
| Input Voltage Noise Density vs Frequency               | Figure 10            |
| THD+N Ratio vs Frequency (80-kHz AP Bandwidth)         | Figure 11            |
| THD+N Ratio vs Output Amplitude                        | Figure 12            |
| Quiescent Current vs Temperature                       | Figure 13            |
| Quiescent Current vs Supply Voltage                    | Figure 14            |
| Gain and Phase vs Frequency                            | Figure 15            |
| Closed-Loop Gain vs Frequency                          | Figure 16            |
| Open-Loop Gain vs Temperature                          | Figure 17            |
| Open-Loop Output Impedance vs Frequency                | Figure 18            |
| Small-Signal Overshoot vs Capacitive Load ( $G = 1$ )  | Figure 19            |
| Small-Signal Overshoot vs Capacitive Load ( $G = -1$ ) | Figure 20            |
| No Phase Reversal                                      | Figure 21            |
| Positive Overload Recovery                             | Figure 23            |
| Negative Overload Recovery                             | Figure 24            |
| Large-Signal Positive and Negative Settling Time       | Figure 25, Figure 26 |
| Small-Signal Step Response ( $G = 1$ )                 | Figure 27            |
| Small-Signal Step Response ( $G = -1$ )                | Figure 28            |
| Large-Signal Step Response ( $G = 1$ )                 | Figure 29            |
| Large-Signal Step Response ( $G = -1$ )                | Figure 30            |
| Short-Circuit Current vs Temperature                   | Figure 31            |
| Maximum Output Voltage vs Frequency                    | Figure 22            |
| Channel Separation vs Frequency                        | Figure 32            |

## 6.9 Typical Characteristics

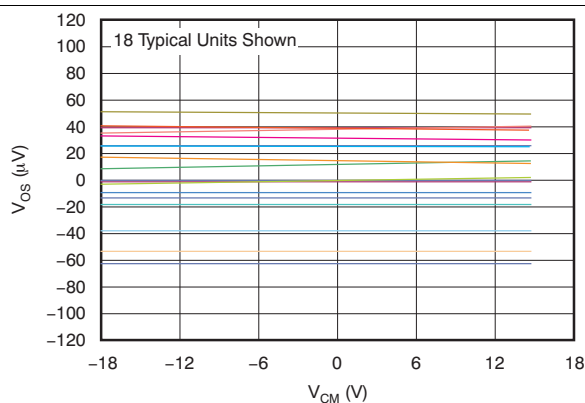
at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.



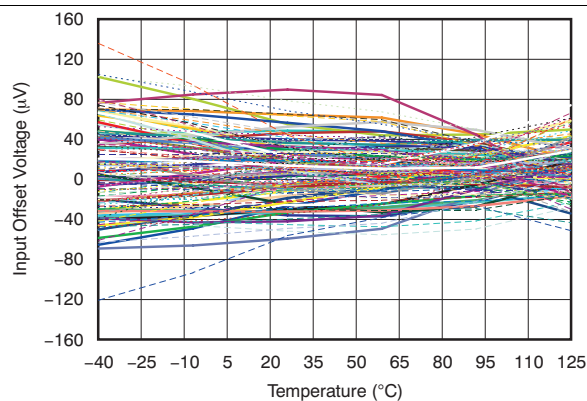
**Figure 1. Offset Voltage Production Distribution**



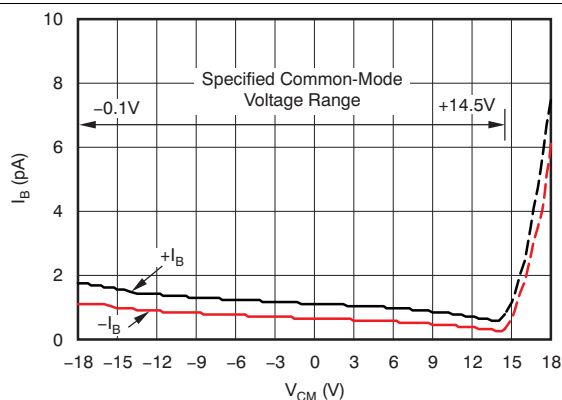
**Figure 2. Offset Voltage Drift Distribution**



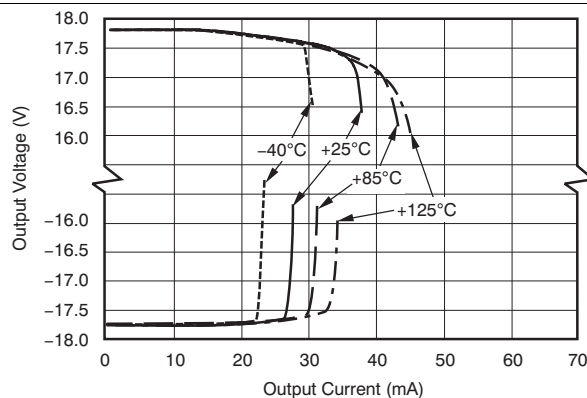
**Figure 3. Offset Voltage vs Common-Mode Voltage**



**Figure 4. Input Offset Voltage vs Temperature (144 Amplifiers)**



**Figure 5.  $I_B$  vs Common-Mode Voltage**



**Figure 6. Output Voltage Swing vs Output Current (Maximum Supply)**

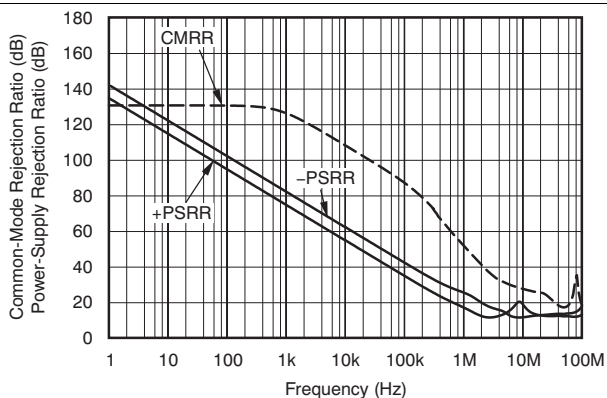
# OPA140, OPA2140, OPA4140

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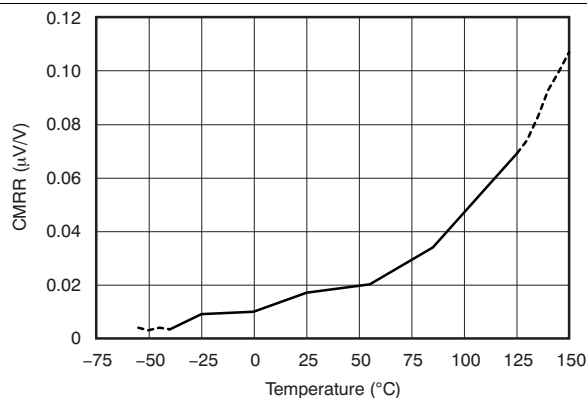
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## Typical Characteristics (continued)

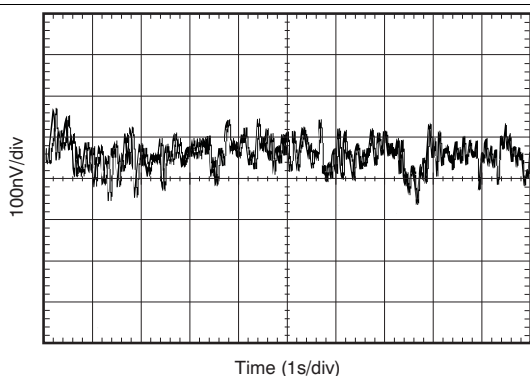
at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.



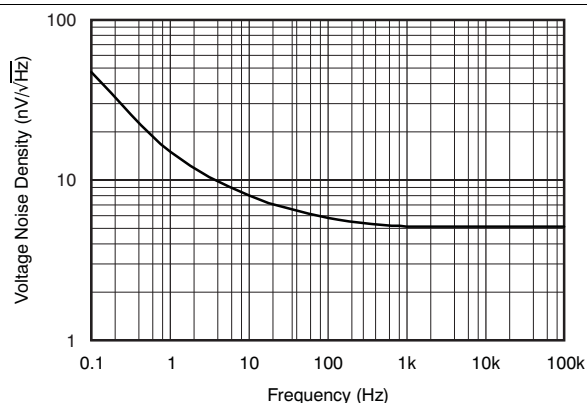
**Figure 7. CMRR and PSRR vs Frequency (Referred to Input)**



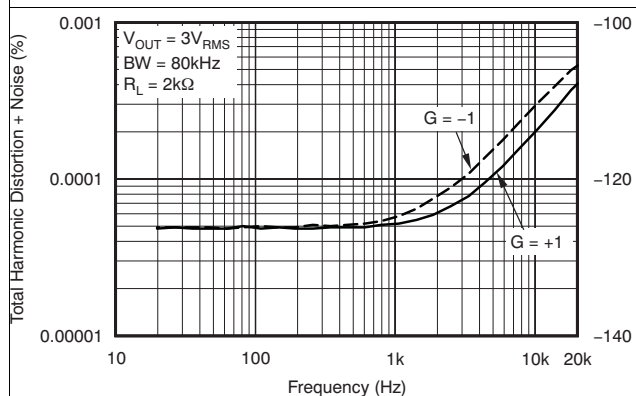
**Figure 8. Common-Mode Rejection Ratio vs Temperature**



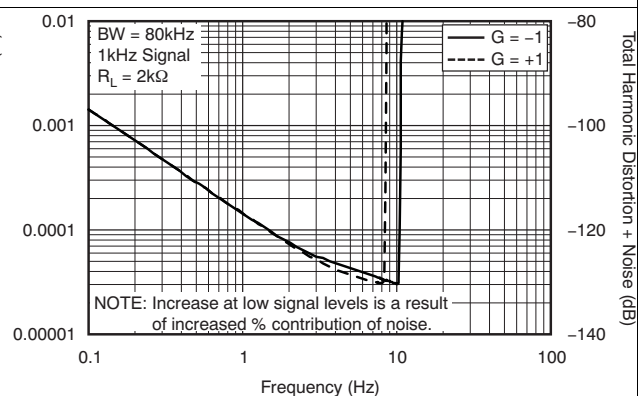
**Figure 9. 0.1-Hz to 10-Hz Noise**



**Figure 10. Input Voltage Noise Density vs Frequency**



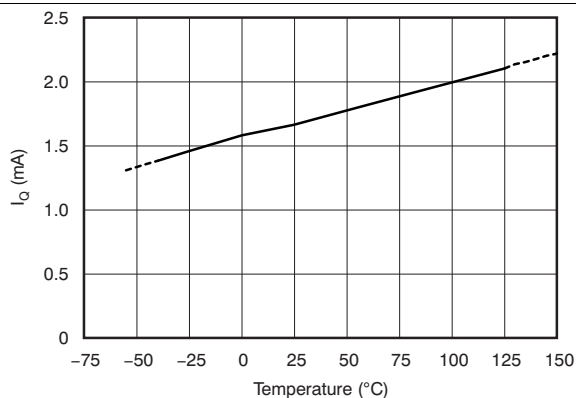
**Figure 11. THD+N Ratio vs Frequency**



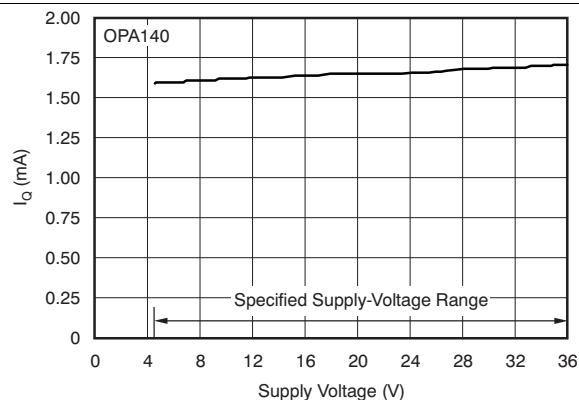
**Figure 12. THD+N Ratio vs Output Amplitude**

## Typical Characteristics (continued)

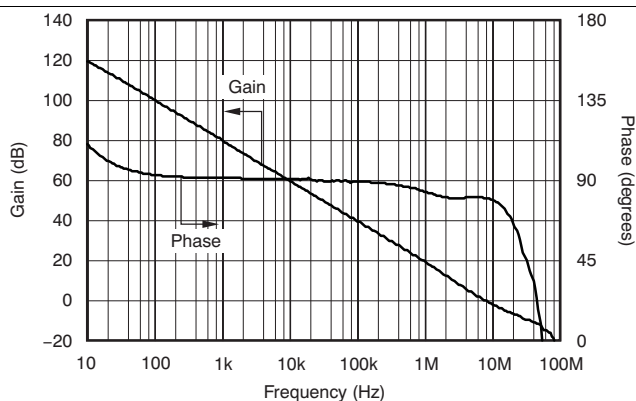
at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.



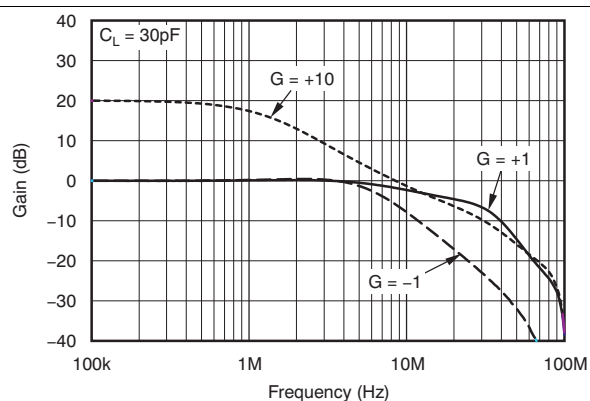
**Figure 13. Quiescent Current vs Temperature**



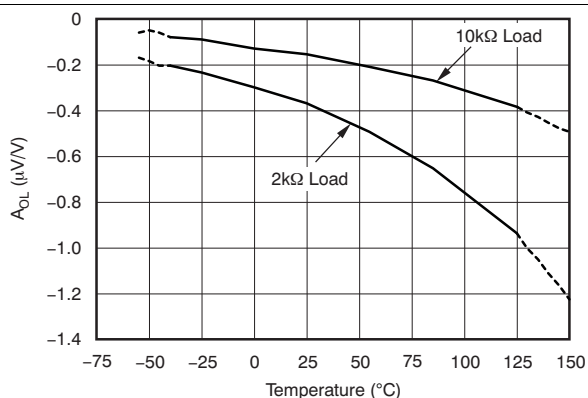
**Figure 14. Quiescent Current vs Supply Voltage**



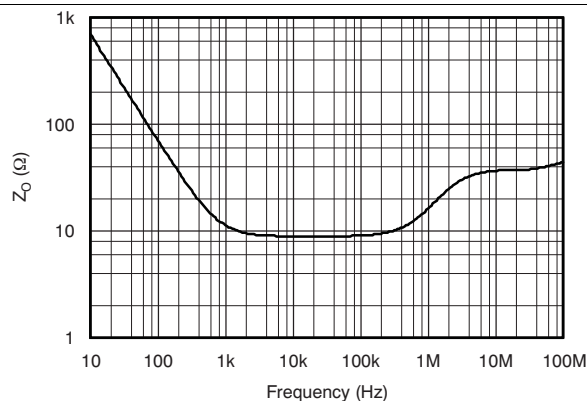
**Figure 15. Gain and Phase vs Frequency**



**Figure 16. Closed-Loop Gain vs Frequency**



**Figure 17. Open-Loop Gain vs Temperature**



**Figure 18. Open-Loop Output Impedance vs Frequency**

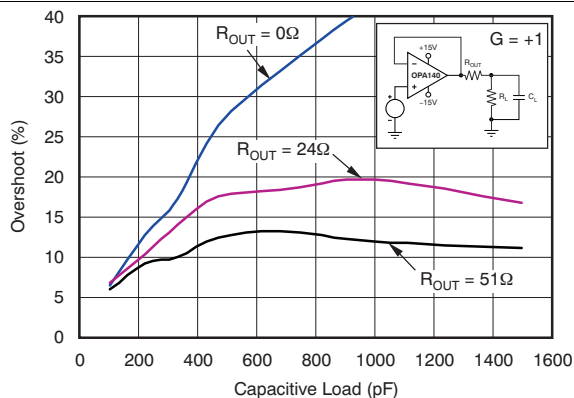
## OPA140, OPA2140, OPA4140

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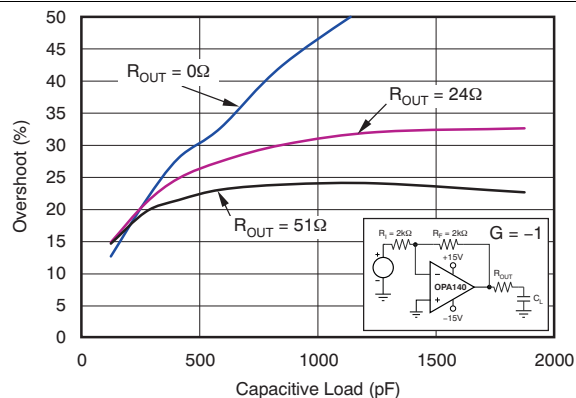
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### Typical Characteristics (continued)

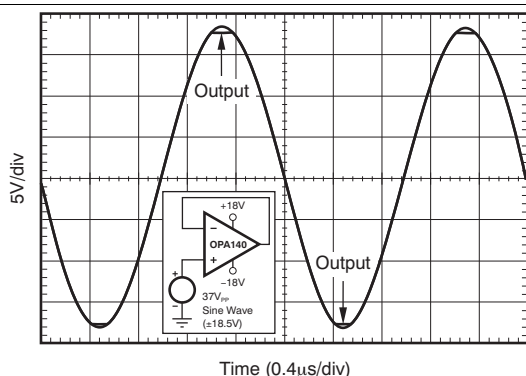
at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.



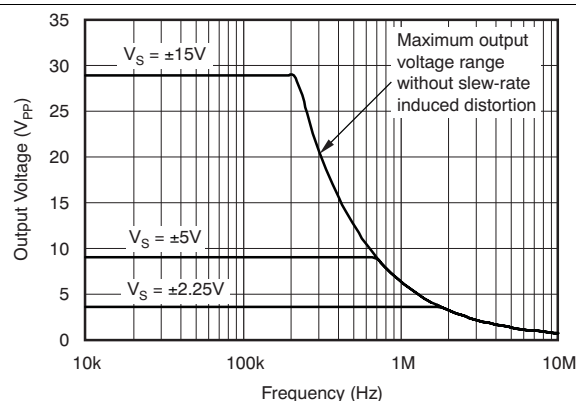
**Figure 19. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**



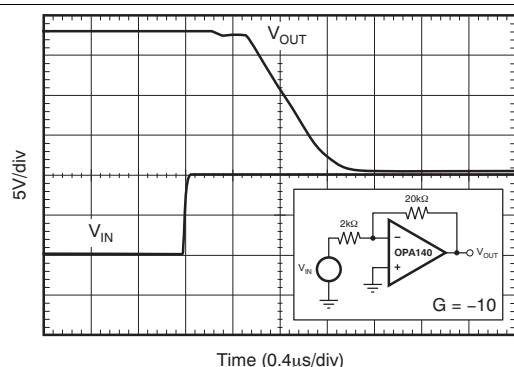
**Figure 20. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)**



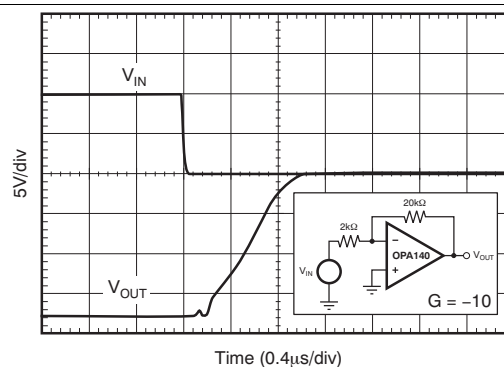
**Figure 21. No Phase Reversal**



**Figure 22. Maximum Output Voltage vs Frequency**



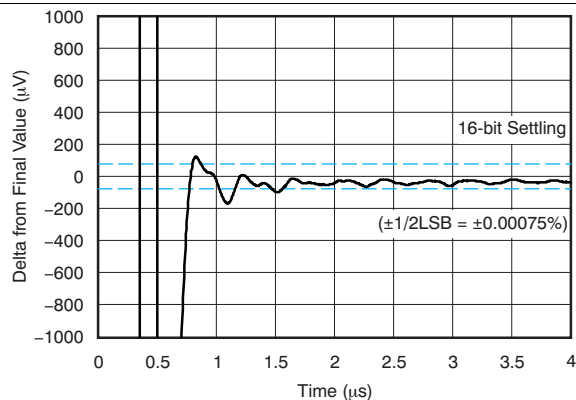
**Figure 23. Positive Overload Recovery**



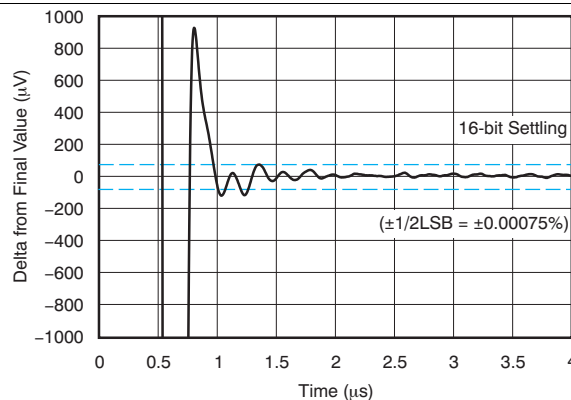
**Figure 24. Negative Overload Recovery**

## Typical Characteristics (continued)

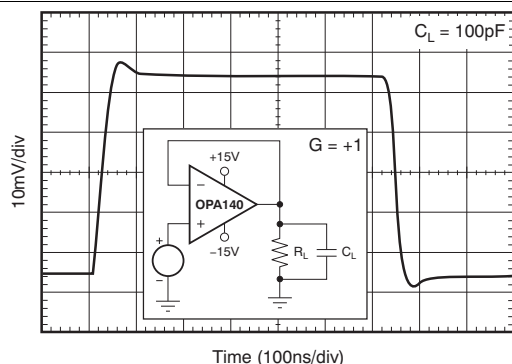
at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.



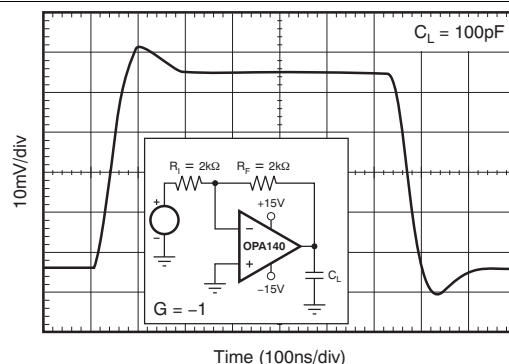
**Figure 25. Large-Signal Positive Settling Time (10-V Step)**



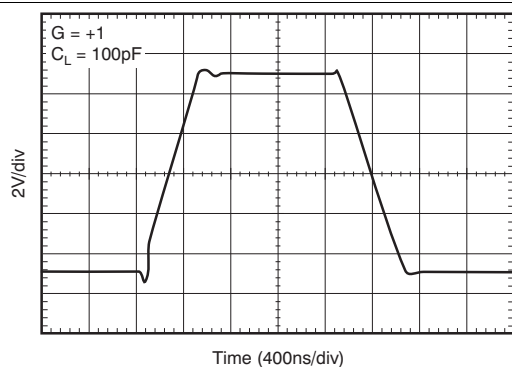
**Figure 26. Large-Signal Negative Settling Time (10-V Step)**



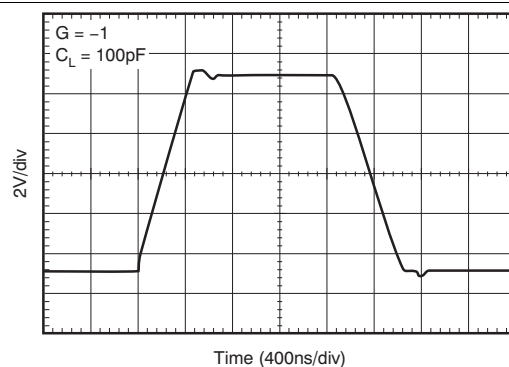
**Figure 27. Small-Signal Step Response (100 mV)**



**Figure 28. Small-Signal Step Response (100 mV)**



**Figure 29. Large-Signal Step Response**



**Figure 30. Large-Signal Step Response**

## OPA140, OPA2140, OPA4140

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### Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 18\text{ V}$ ,  $R_L = 2\text{ k}\Omega$  connected to midsupply,  $V_{CM} = V_{OUT} = \text{midsupply}$ , unless otherwise noted.

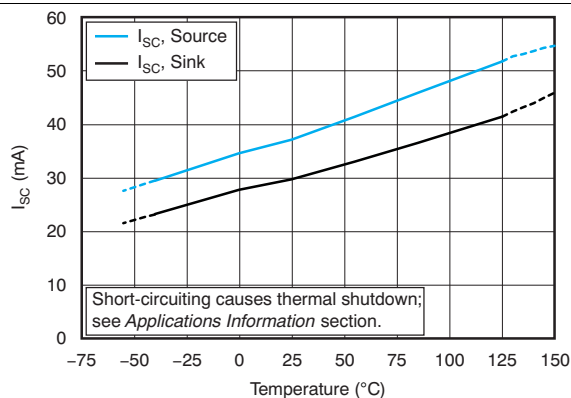


Figure 31. Short Circuit Current vs Temperature

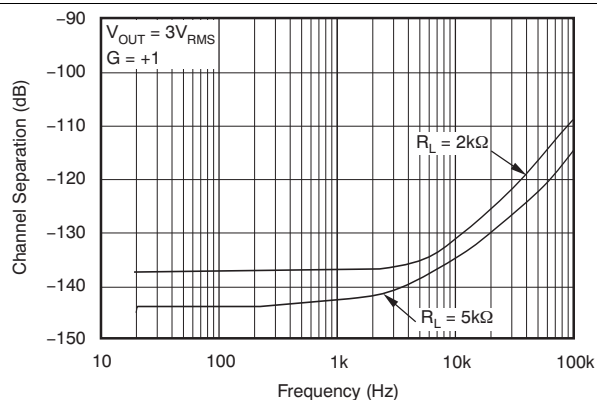


Figure 32. Channel Separation vs Frequency

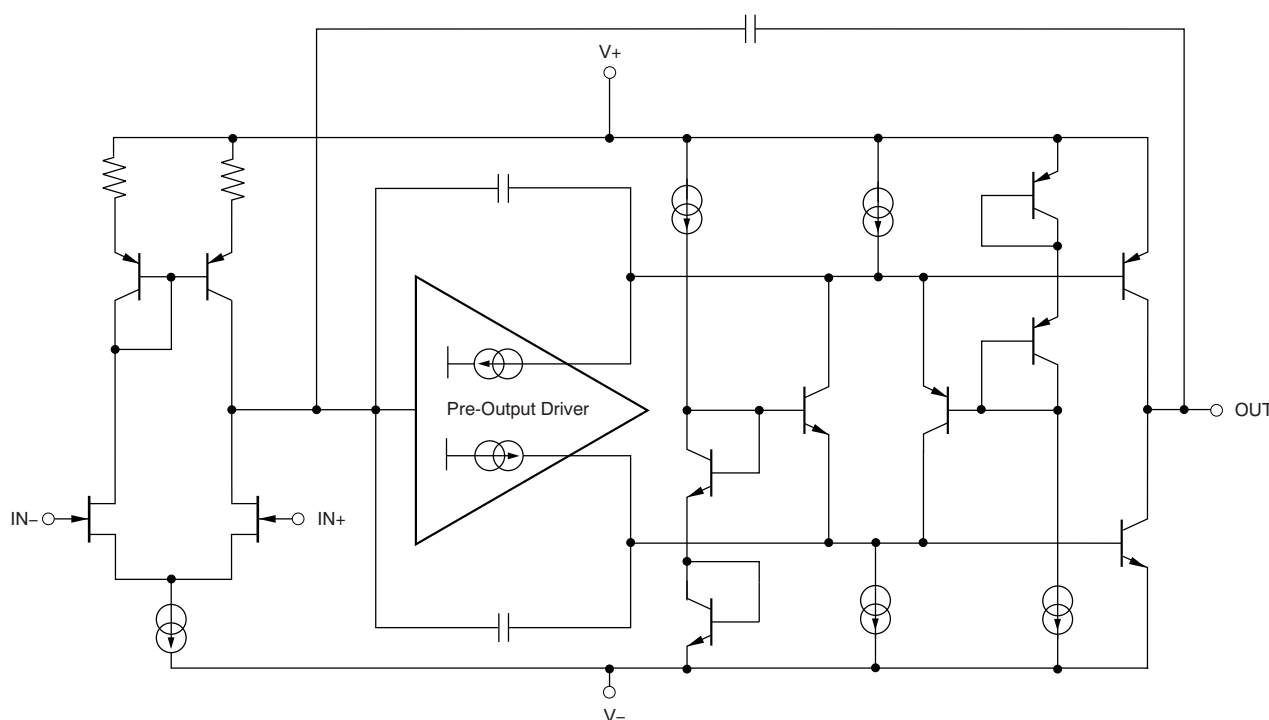
## 7 Detailed Description

### 7.1 Overview

The OPAx140 family of operational amplifiers is a series of low-power JFET input amplifiers that feature superior drift performance and low input bias current. The rail-to-rail output swing and input range that includes  $V^-$  allow designers to use the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). The OPAx140 series achieves 11-MHz unity-gain bandwidth and 20-V/ $\mu$ s slew rate, and consumes only 1.8 mA (typical) of quiescent current. These devices operate on a single 4.5-V to 36-V supply or dual  $\pm 2.25$ -V to  $\pm 18$ -V supplies.

The [Functional Block Diagram](#) section shows the simplified diagram of the OPAx140.

### 7.2 Functional Block Diagram





## OPA140, OPA2140, OPA4140

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### 7.3 Feature Description

#### 7.3.1 Operating Voltage

The OPA140, OPA2140, and OPA4140 series of op amps can be used with single or dual supplies from an operating range of  $V_S = 4.5\text{ V}$  ( $\pm 2.25\text{ V}$ ) and up to  $V_S = 36\text{ V}$  ( $\pm 18\text{ V}$ ). These devices do not require symmetrical supplies; they only require a minimum supply voltage of  $4.5\text{ V}$  ( $\pm 2.25\text{ V}$ ). For  $V_S$  less than  $\pm 3.5\text{ V}$ , the common-mode input range does not include midsupply. Supply voltages higher than  $40\text{ V}$  can permanently damage the device; see the [Absolute Maximum Ratings](#) table. Key parameters are specified over the operating temperature range,  $T_A = -40^\circ\text{C}$  to  $125^\circ\text{C}$ . Key parameters that vary over the supply voltage or temperature range are shown in the [Typical Characteristics](#) section of this data sheet.

#### 7.3.2 Capacitive Load and Stability

The dynamic characteristics of the OPAx140 have been optimized for commonly encountered gains, loads, and operating conditions. The combination of low closed-loop gain and high capacitive loads decreases the phase margin of the amplifier and can lead to gain peaking or oscillations. As a result, heavier capacitive loads must be isolated from the output. The simplest way to achieve this isolation is to add a small resistor ( $R_{OUT}$  equal to  $50\ \Omega$ , for example) in series with the output.

[Figure 19](#) and [Figure 20](#) illustrate graphs of *Small-Signal Overshoot vs Capacitive Load* for several values of  $R_{OUT}$ . Also, see the *application note, Feedback Plots Define Op Amp AC Performance* ([SBOA015](#), available for download from the [TI website](#)), for details of analysis techniques and application circuits.

#### 7.3.3 Output Current Limit

The output current of the OPAx140 series is limited by internal circuitry to  $36\text{ mA}/-30\text{ mA}$  (sourcing/sinking), to protect the device if the output is accidentally shorted. This short circuit current depends on temperature, as shown in [Figure 31](#).

#### 7.3.4 Noise Performance

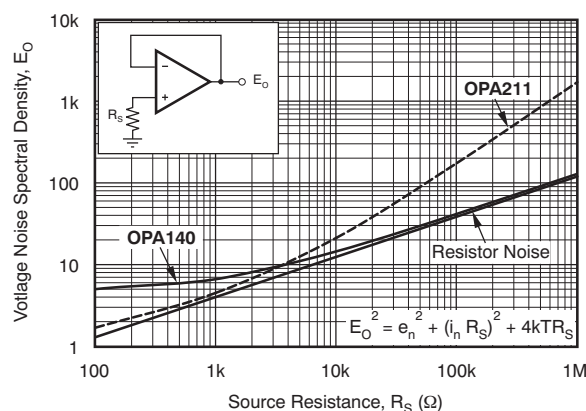
[Figure 33](#) shows the total circuit noise for varying source impedances with the operational amplifier in a unity-gain configuration (with no feedback resistor network and therefore no additional noise contributions). The OPA140 and OPA211 are shown with total circuit noise calculated. The op amp itself contributes both a voltage noise component and a current noise component. The voltage noise is commonly modeled as a time-varying component of the offset voltage. The current noise is modeled as the time-varying component of the input bias current and reacts with the source resistance to create a voltage component of noise. Therefore, the lowest noise op amp for a given application depends on the source impedance. For low source impedance, current noise is negligible, and voltage noise generally dominates. The OPA140, OPA2140, and OPA4140 family has both low voltage noise and extremely low current noise because of the FET input of the op amp. As a result, the current noise contribution of the OPAx140 series is negligible for any practical source impedance, which makes it the better choice for applications with high source impedance.

The equation in [Figure 33](#) shows the calculation of the total circuit noise, with these parameters:

- $e_n$  = voltage noise
- $I_n$  = current noise
- $R_S$  = source impedance
- $k$  = Boltzmann's constant =  $1.38 \times 10^{-23}\text{ J/K}$
- $T$  = temperature in degrees Kelvin (K)

For more details on calculating noise, see [Basic Noise Calculations](#).

## Feature Description (continued)



**Figure 33. Noise Performance of the OPA140 and OPA211 in Unity-Gain Buffer Configuration**

### 7.3.5 Basic Noise Calculations

Low-noise circuit design requires careful analysis of all noise sources. External noise sources can dominate in many cases; consider the effect of source resistance on overall op amp noise performance. Total noise of the circuit is the root-sum-square combination of all noise components.

The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. This function is plotted in Figure 33. The source impedance is usually fixed; consequently, select the op amp and the feedback resistors to minimize the respective contributions to the total noise.

Figure 34 illustrates both noninverting (A) and inverting (B) op amp circuit configurations with gain. In circuit configurations with gain, the feedback network resistors also contribute noise. In general, the current noise of the op amp reacts with the feedback resistors to create additional noise components. However, the extremely low current noise of the OPAx140 means that its current noise contribution can be neglected.

The feedback resistor values can generally be chosen to make these noise sources negligible. Low impedance feedback resistors load the output of the amplifier. The equations for total noise are shown for both configurations.

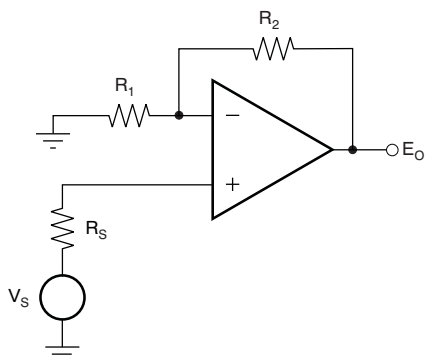
**OPA140, OPA2140, OPA4140**

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**Feature Description (continued)**

**A) Noise in Noninverting Gain Configuration**



Noise at the output:

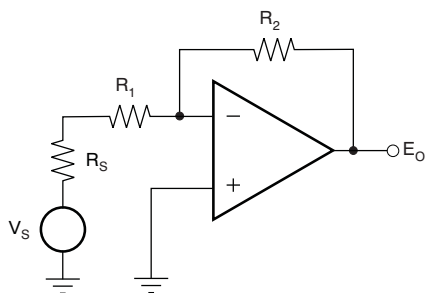
$$E_o^2 = \left(1 + \frac{R_2}{R_1}\right)^2 e_n^2 + \left(\frac{R_2}{R_1}\right)^2 e_1^2 + e_2^2 + \left(1 + \frac{R_2}{R_1}\right)^2 e_s^2$$

Where  $e_s = \sqrt{4kTR_s}$  = thermal noise of  $R_s$

$e_1 = \sqrt{4kTR_1}$  = thermal noise of  $R_1$

$e_2 = \sqrt{4kTR_2}$  = thermal noise of  $R_2$

**B) Noise in Inverting Gain Configuration**



Noise at the output:

$$E_o^2 = \left(1 + \frac{R_2}{R_1 + R_s}\right)^2 e_n^2 + \left(\frac{R_2}{R_1 + R_s}\right)^2 e_1^2 + e_2^2 + \left(\frac{R_2}{R_1 + R_s}\right)^2 e_s^2$$

Where  $e_s = \sqrt{4kTR_s}$  = thermal noise of  $R_s$

$e_1 = \sqrt{4kTR_1}$  = thermal noise of  $R_1$

$e_2 = \sqrt{4kTR_2}$  = thermal noise of  $R_2$

For the OPAx140 series of operational amplifiers at 1 kHz,  $e_n = 5.1 \text{ nV}/\sqrt{\text{Hz}}$ .

**Figure 34. Noise Calculation in Gain Configurations**

## Feature Description (continued)

### 7.3.6 Phase-Reversal Protection

The OPA140, OPA2140, and OPA4140 family has internal phase-reversal protection. Many FET- and bipolar-input op amps exhibit a phase reversal when the input is driven beyond its linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input circuitry of the OPA140, OPA2140, and OPA4140 prevents phase reversal with excessive common-mode voltage; instead, the output limits into the appropriate rail (see [Figure 21](#)).

### 7.3.7 Thermal Protection

The OPAx140 series of op amps are capable of driving 2-k $\Omega$  loads with power-supply voltages of up to  $\pm 18$  V over the specified temperature range. In a single-supply configuration, where the load is connected to the negative supply voltage, the minimum load resistance is 2.8 k $\Omega$  at a supply voltage of 36 V. For lower supply voltages (either single-supply or symmetrical supplies), a lower load resistance may be used, as long as the output current does not exceed 13 mA; otherwise, the device short circuit current protection circuit may activate.

Internal power dissipation increases when operating at high supply voltages. Copper leadframe construction used in the OPA140, OPA2140, and OPA4140 series devices improves heat dissipation compared to conventional materials. Printed-circuit-board (PCB) layout can also help reduce a possible increase in junction temperature. Wide copper traces help dissipate the heat by acting as an additional heatsink. Temperature rise can be further minimized by soldering the devices directly to the PCB rather than using a socket.

Although the output current is limited by internal protection circuitry, accidental shorting of one or more output channels of a device can result in excessive heating. For instance, when an output is shorted to mid-supply, the typical short-circuit current of 36 mA leads to an internal power dissipation of over 600 mW at a supply of  $\pm 18$  V.

In the case of a dual OPA2140 in an 8-pin VSSOP package (thermal resistance  $\theta_{JA} = 180^{\circ}\text{C/W}$ ), such power dissipation would lead the die temperature to be  $220^{\circ}\text{C}$  above ambient temperature, when both channels are shorted. This temperature increase significantly decreases the operating life of the device.

To prevent excessive heating, the OPAx140 series has an internal thermal shutdown circuit, which shuts down the device if the die temperature exceeds approximately  $180^{\circ}\text{C}$ . When this thermal shutdown circuit activates, a built-in hysteresis of  $15^{\circ}\text{C}$  ensures that the die temperature must drop to approximately  $165^{\circ}\text{C}$  before the device switches on again.

Additional consideration should be given to the combination of maximum operating voltage, maximum operating temperature, load, and package type. [Figure 35](#) and [Figure 36](#) show several practical considerations when evaluating the OPA2140 (dual version) and the OPA4140 (quad version).

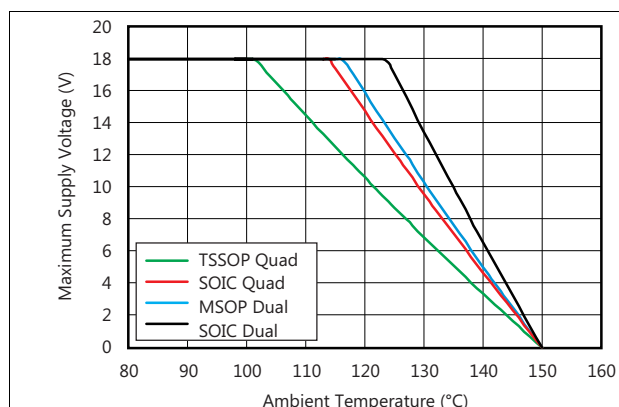
As an example, the OPA4140 has a maximum total quiescent current of 10.8 mA (2.7 mA/channel) over temperature. The 14-pin TSSOP package has a typical thermal resistance of  $135^{\circ}\text{C/W}$ . This parameter means that because the junction temperature should not exceed  $150^{\circ}\text{C}$  to ensure reliable operation, either the supply voltage must be reduced, or the ambient temperature should remain low enough so that the junction temperature does not exceed  $150^{\circ}\text{C}$ . This condition is illustrated in [Figure 35](#) for various package types. Moreover, resistive loading of the output causes additional power dissipation and thus self-heating, which also must be considered when establishing the maximum supply voltage or operating temperature. To this end, [Figure 36](#) shows the maximum supply voltage versus temperature for a worst-case dc load resistance of 2 k $\Omega$ .

## OPA140, OPA2140, OPA4140

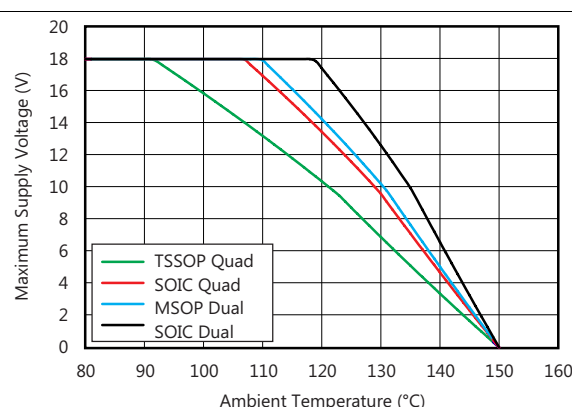
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### Feature Description (continued)



**Figure 35. Maximum Supply Voltage vs Temperature (OPA2140 and OPA4140), Quiescent Condition**



**Figure 36. Maximum Supply Voltage vs Temperature (OPA2140 and OPA4140), Maximum DC Load**

### 7.3.8 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but may involve the supply voltage pins or even the output pin. Each of these different pin functions have electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect them from accidental ESD events both before and during product assembly.

It is helpful to have a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event. See [Figure 37](#) for an illustration of the ESD circuits contained in the OPAx140 series (indicated by the dashed line area). The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power-supply lines, where they meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

An ESD event produces a short duration, high-voltage pulse that is transformed into a short duration, high-current pulse as it discharges through a semiconductor device. The ESD protection circuits are designed to provide a current path around the operational amplifier core to prevent it from being damaged. The energy absorbed by the protection circuitry is then dissipated as heat.

When an ESD voltage develops across two or more of the amplifier device pins, current flows through one or more of the steering diodes. Depending on the path that the current takes, the absorption device may activate. The absorption device has a trigger, or threshold voltage, that is above the normal operating voltage of the OPAx140 but below the device breakdown voltage level. Once this threshold is exceeded, the absorption device quickly activates and clamps the voltage across the supply rails to a safe level.

When the operational amplifier connects into a circuit such as the one [Figure 37](#) shows, the ESD protection components are intended to remain inactive and not become involved in the application circuit operation. However, circumstances may arise where an applied voltage exceeds the operating voltage range of a given pin. Should this condition occur, there is a risk that some of the internal ESD protection circuits may be biased on, and conduct current. Any such current flow occurs through steering diode paths and rarely involves the absorption device.

[Figure 37](#) depicts a specific example where the input voltage,  $V_{IN}$ , exceeds the positive supply voltage ( $+V_S$ ) by 500 mV or more. Much of what happens in the circuit depends on the supply characteristics. If  $+V_S$  can sink the current, one of the upper input steering diodes conducts and directs current to  $+V_S$ . Excessively high current levels can flow with increasingly higher  $V_{IN}$ . As a result, the data sheet specifications recommend that applications limit the input current to 10 mA.

If the supply is not capable of sinking the current,  $V_{IN}$  may begin sourcing current to the operational amplifier, and then take over as the source of positive supply voltage. The danger in this case is that the voltage can rise to levels that exceed the operational amplifier absolute maximum ratings.

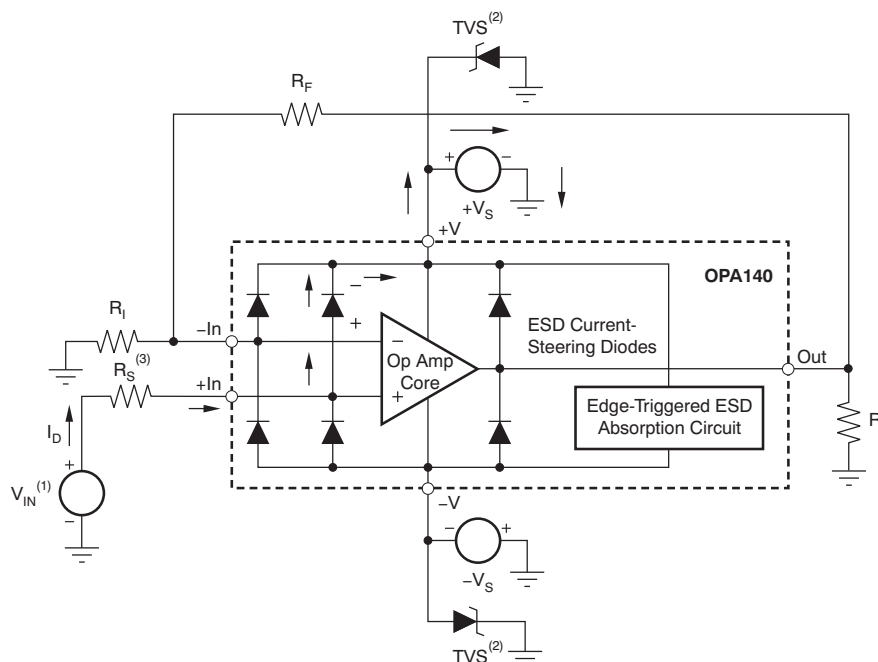
## Feature Description (continued)

Another common question involves what happens to the amplifier if an input signal is applied to the input while the power supplies  $+V_S$  or  $-V_S$  are at 0 V.

Again, it depends on the supply characteristic while at 0 V, or at a level below the input signal amplitude. If the supplies appear as high impedance, then the operational amplifier supply current may be supplied by the input source through the current steering diodes. This state is not a normal bias condition; the amplifier most likely will not operate normally. If the supplies are low impedance, then the current through the steering diodes can become quite high. The current level depends on the ability of the input source to deliver current, and any resistance in the input path.

If there is an uncertainty about the ability of the supply to absorb this current, external Zener diodes may be added to the supply pins as shown in Figure 37. The Zener voltage must be selected such that the diode does not turn on during normal operation.

However, its Zener voltage should be low enough so that the Zener diode conducts if the supply pin begins to rise above the safe operating supply voltage level.



- (1)  $V_{IN} = +V_S + 500 \text{ mV}$ .
- (2) TVS:  $+V_{S(max)} > V_{TVSBR (Min)} > +V_S$
- (3) Suggested value approximately 1 k $\Omega$ .

**Figure 37. Equivalent Internal ESD Circuitry and Its Relation to a Typical Circuit Application**

## OPA140, OPA2140, OPA4140

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### Feature Description (continued)

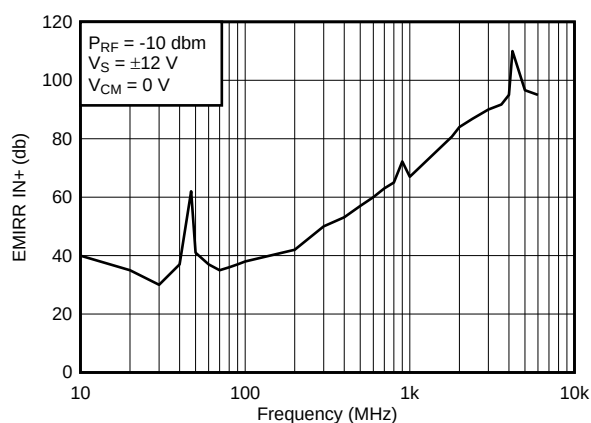
#### 7.3.9 EMI Rejection

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many op amps is a change in the offset voltage as a result of RF signal rectification. An op amp that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this section provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the op amp. In general, only the noninverting input is tested for EMIRR for the following three reasons:

- Op amp input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
- The noninverting and inverting op amp inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance
- EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input terminal can be isolated on a PCB. This isolation allows the RF signal to be applied directly to the noninverting input terminal with no complex interactions from other components or connecting PCB traces. [Figure 38](#)

The EMIRR IN+ of the OPA2140 is plotted versus frequency as shown in .If available, any dual and quad op amp device versions have nearly similar EMIRR IN+ performance. The OPA2140 unity-gain bandwidth is 11 MHz. EMIRR performance below this frequency denotes interfering signals that fall within the op amp bandwidth.

See the application report, *EMI Rejection Ratio of Operational Amplifiers* ([SBOA128](#)), available for download from [www.ti.com](http://www.ti.com).



**Figure 38. OPA2140 EMIRR**



## Feature Description (continued)

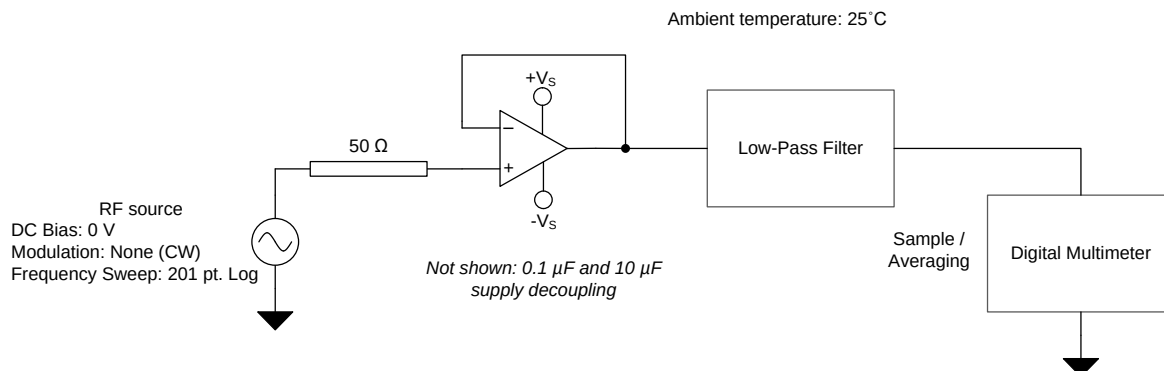
Table 2 lists the EMIRR IN+ values for the OPA2140 at particular frequencies commonly encountered in real-world applications. Applications listed in Table 2 may be centered on or operated near the particular frequency shown. This information may be of special interest to designers working with these types of applications, or working in other fields likely to encounter RF interference from broad sources, such as the industrial, scientific, and medical (ISM) radio band.

**Table 2. OPA2140 EMIRR IN+ for Frequencies of Interest**

| FREQUENCY | APPLICATION OR ALLOCATION                                                                                                                                                        | EMIRR IN+ |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 400 MHz   | Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications                                                                         | 53.1 dB   |
| 900 MHz   | Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications                        | 72.2 dB   |
| 1.8 GHz   | GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)                                                                                  | 80.7 dB   |
| 2.4 GHz   | 802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz) | 86.8 dB   |
| 3.6 GHz   | Radiolocation, aero communication and navigation, satellite, mobile, S-band                                                                                                      | 91.7 dB   |
| 5 GHz     | 802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)                                                | 96.6 dB   |

### 7.3.10 EMIRR +IN Test Configuration

Figure 39 shows the circuit configuration for testing the EMIRR IN+. An RF source is connected to the op amp noninverting input terminal using a transmission line. The op amp is configured in a unity gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM). A large impedance mismatch at the op amp input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. The resulting DC offset voltage is sampled and measured by the multimeter. The LPF isolates the multimeter from residual RF signals that may interfere with multimeter accuracy.



**Figure 39. EMIRR +IN Test Configuration**

## 7.4 Device Functional Modes

The OPAX140 has a single functional mode and is operational when the power-supply voltage is greater than 4.5 V (±2.25 V). The maximum power supply voltage for the OPAX140 is 36 V (±18 V).



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## 8 Application and Implementation

### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

The OPA140, OPA2140, and OPA4140 are unity-gain stable, operational amplifiers with very low noise, input bias current, and input offset voltage. Applications with noisy or high-impedance power supplies require decoupling capacitors placed close to the device pins. In most cases, 0.1-μF capacitors are adequate. Designers can easily use the rail-to-rail output swing and input range that includes V<sub>-</sub> to take advantage of the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision data converters.

### 8.2 Typical Application

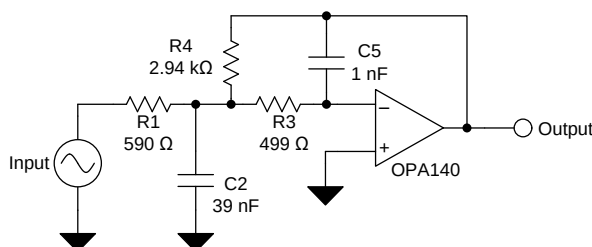


Figure 40. 25-kHz Low-pass Filter

#### 8.2.1 Design Requirements

Lowpass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The OPAX140 are ideally suited to construct high-speed, high-precision active filters. Figure 40 shows a second-order, low-pass filter commonly encountered in signal processing applications.

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order Chebyshev filter response with 3-dB gain peaking in the passband

#### 8.2.2 Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in. Use Equation 1 to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1 R_3 C_2 C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3 R_4 C_2 C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, the gain at DC and the lowpass cutoff frequency are calculated by Equation 2:

$$\text{Gain} = \frac{R_4}{R_1}$$

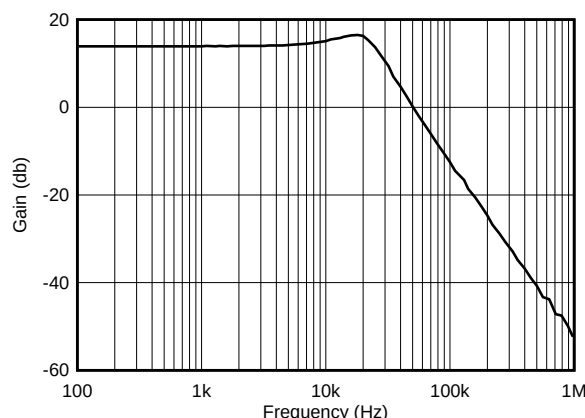
$$f_c = \frac{1}{2\pi} \sqrt{1/R_3 R_4 C_2 C_5} \quad (2)$$

## Typical Application (continued)

Software tools are readily available to simplify filter design. WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The [WEBENCH® Filter Designer](#) lets you create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

Available as a web based tool from the WEBENCH Design Center, WEBENCH Filter Designer allows you to design, optimize, and simulate complete multistage active filter solutions within minutes.

### 8.2.3 Application Curve



**Figure 41. OPAx140 Second-Order, 25-kHz, Chebyshev, Low-pass Filter**

## 9 Power Supply Recommendations

The OPAx140 is specified for operation from 4.5 V to 36 V ( $\pm 2.25$  V to  $\pm 18$  V); many specifications apply from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the [Typical Characteristics](#).

### CAUTION

Supply voltages larger than 40 V can permanently damage the device; see the [Absolute Maximum Ratings](#).

Place 0.1- $\mu\text{F}$  bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see the [Layout](#) section.

**OPA140, OPA2140, OPA4140**

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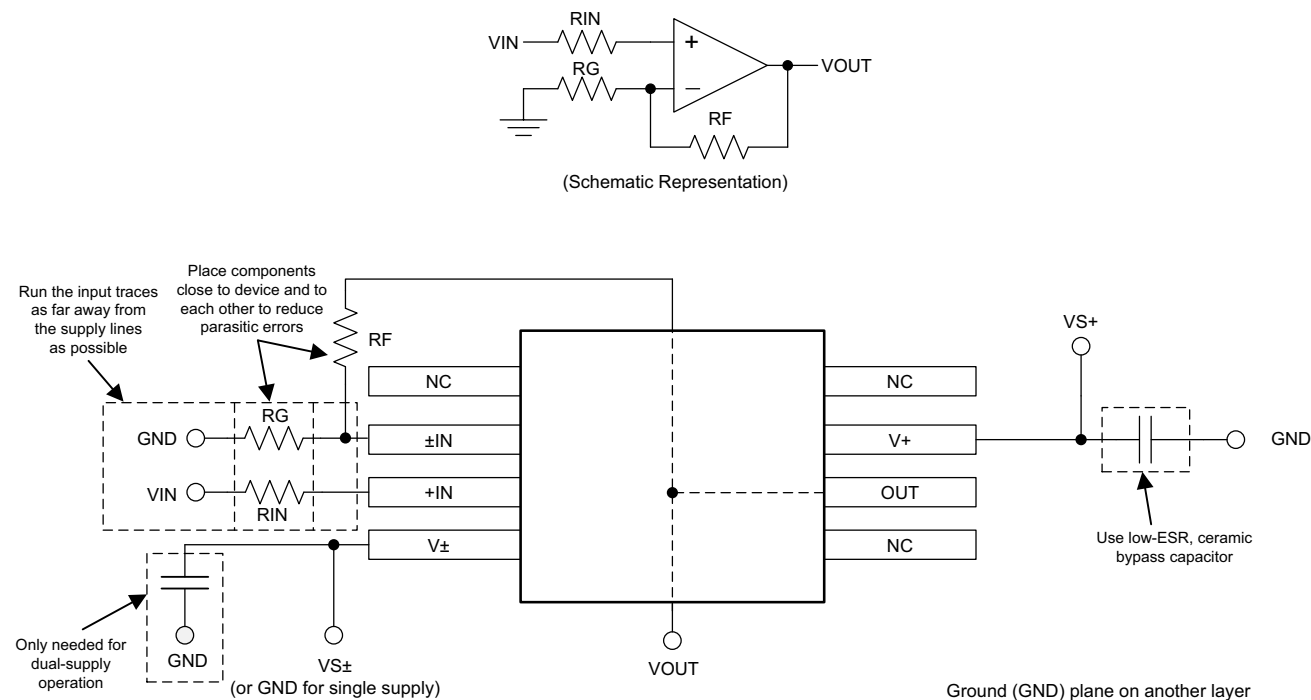
## 10 Layout

### 10.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu$ F ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current. For more detailed information, see *Circuit Board Layout Techniques* (SLOA089).
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. As illustrated in Figure 42, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- For best performance, TI recommends cleaning the PCB following board assembly.
- Any precision integrated circuit may experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, TI recommends baking the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

## 10.2 Layout Example



**Figure 42. Operational Amplifier Board Layout for Noninverting Configuration**

## OPA140, OPA2140, OPA4140

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## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Development Support

##### 11.1.1.1 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI is a free, fully-functional version of the TINA software, preloaded with a library of macro models in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a [free download](#) from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

#### NOTE

These files require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the [TINA-TI folder](#).

##### 11.1.1.2 WEBENCH Filter Designer Tool

[WEBENCH® Filter Designer](#) is a simple, powerful, and easy-to-use active filter design program. The WEBENCH Filter Designer lets you create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

##### 11.1.1.3 TI Precision Designs

TI Precision Designs are available online at <http://www.ti.com/ww/en/analog/precision-designs/>. TI Precision Designs are analog solutions created by TI's precision analog applications experts and offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits.

## 11.2 Documentation Support

### 11.2.1 Related Documentation

For related documentation see the following:

- *Circuit Board Layout Techniques*, [SLOA089](#).
- *Op Amps for Everyone*, [SLOD006](#).
- *OPA140, OPA2140, OPA4140 EMI Immunity Performance*, [SBOT035](#).
- *Compensate Transimpedance Amplifiers Intuitively*, [SBOA055](#).
- *Operational amplifier gain stability, Part 3: AC gain-error analysis*, [SLYT383](#).
- *Operational amplifier gain stability, Part 2: DC gain-error analysis*, [SLYT374](#).
- *Using infinite-gain, MFB filter topology in fully differential active filters*, [SLYT343](#).
- *Op Amp Performance Analysis*, [SBOS054](#).
- *Single-Supply Operation of Operational Amplifiers*, [SBOA059](#).
- *Tuning in Amplifiers*, [SBOA067](#).
- *Shelf-Life Evaluation of Lead-Free Component Finishes*, [SZZA046](#).
- *Feedback Plots Define Op Amp AC Performance*, [SBOA015](#).
- *EMI Rejection Ratio of Operational Amplifiers*, [SBOA128A](#).

## 11.3 Related Links

**Table 3** lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 3. Related Links**

| PARTS   | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|---------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| OPA140  | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| OPA2140 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| OPA4140 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

## 11.4 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.

## 11.5 Trademarks

E2E is a trademark of Texas Instruments.

TINA-TI is a trademark of Texas Instruments, Inc and DesignSoft, Inc.

WEBENCH is a registered trademark of Texas Instruments.

Bluetooth is a registered trademark of Bluetooth SIG, Inc.

TINA, DesignSoft are trademarks of DesignSoft, Inc.

All other trademarks are the property of their respective owners.

## 11.6 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.

## 11.7 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 12 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 Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| OPA140AID        | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | OPA140                  | <a href="#">Samples</a> |
| OPA140AIDBVR     | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O140                    | <a href="#">Samples</a> |
| OPA140AIDBVT     | ACTIVE        | SOT-23       | DBV                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O140                    | <a href="#">Samples</a> |
| OPA140AIDGKR     | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU   Call TI     | Level-2-260C-1 YEAR  | -40 to 125   | (140 – O140)            | <a href="#">Samples</a> |
| OPA140AIDGKT     | ACTIVE        | VSSOP        | DGK                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU   Call TI     | Level-2-260C-1 YEAR  | -40 to 125   | 140                     | <a href="#">Samples</a> |
| OPA140AIDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | OPA140                  | <a href="#">Samples</a> |
| OPA2140AID       | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O2140A                  | <a href="#">Samples</a> |
| OPA2140AIDGKR    | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | 2140                    | <a href="#">Samples</a> |
| OPA2140AIDGKT    | ACTIVE        | VSSOP        | DGK                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | 2140                    | <a href="#">Samples</a> |
| OPA2140AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O2140A                  | <a href="#">Samples</a> |
| OPA4140AID       | ACTIVE        | SOIC         | D                  | 14   | 50             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 125   | O4140A                  | <a href="#">Samples</a> |
| OPA4140AIDR      | ACTIVE        | SOIC         | D                  | 14   | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-3-260C-168 HR  | -40 to 125   | O4140A                  | <a href="#">Samples</a> |
| OPA4140AIPW      | ACTIVE        | TSSOP        | PW                 | 14   | 90             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O4140A                  | <a href="#">Samples</a> |
| OPA4140AIPWR     | ACTIVE        | TSSOP        | PW                 | 14   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | O4140A                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**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.

<sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

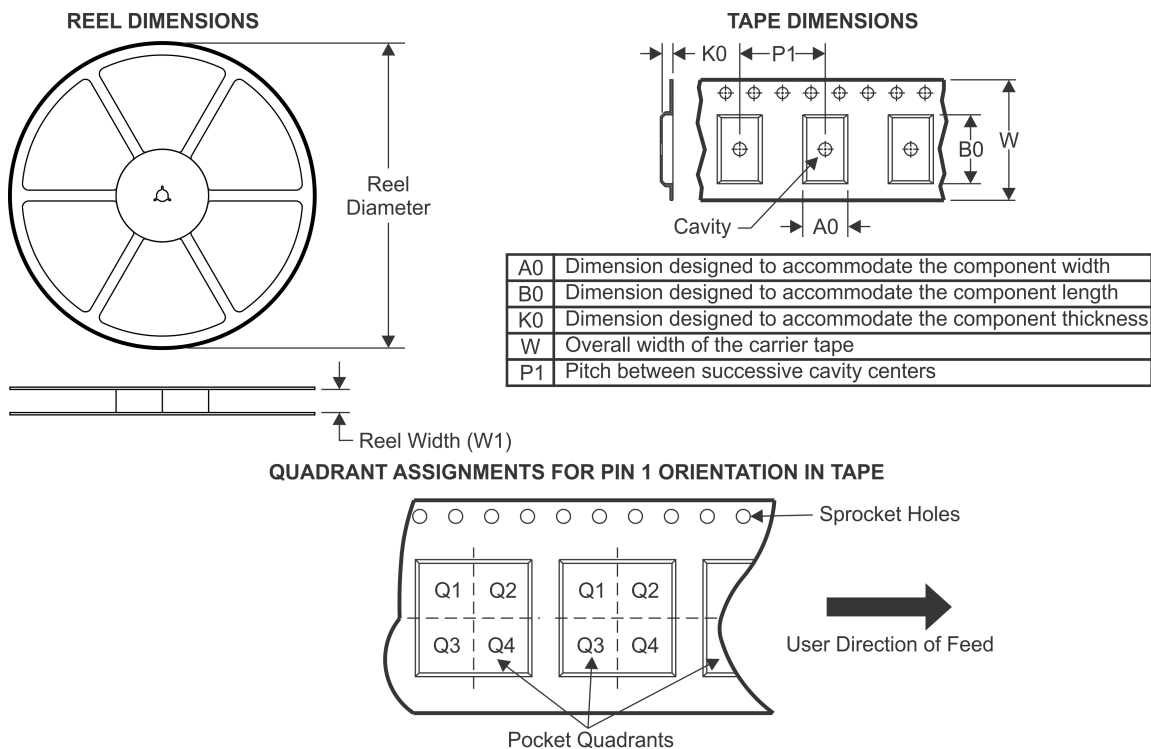
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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



## PACKAGE MATERIALS INFORMATION

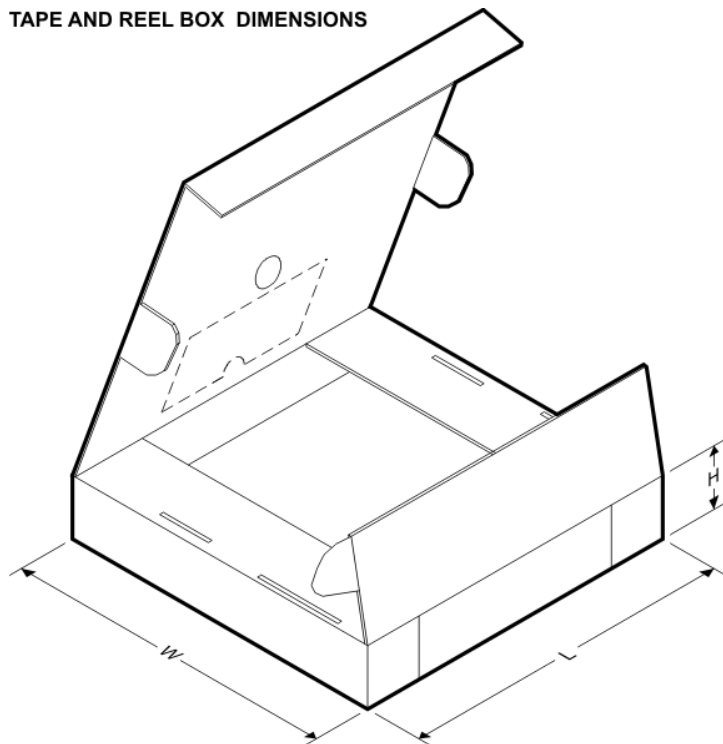
### TAPE AND REEL INFORMATION



\*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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| OPA140AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 180.0              | 8.4                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA140AIDBVT  | SOT-23       | DBV             | 5    | 250  | 180.0              | 8.4                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA140AIDGKR  | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA140AIDGKT  | VSSOP        | DGK             | 8    | 250  | 180.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA140AIDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| OPA2140AIDGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2140AIDGKT | VSSOP        | DGK             | 8    | 250  | 180.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2140AIDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| OPA4140AIDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| OPA4140AIPWR  | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

**TAPE AND REEL BOX DIMENSIONS**



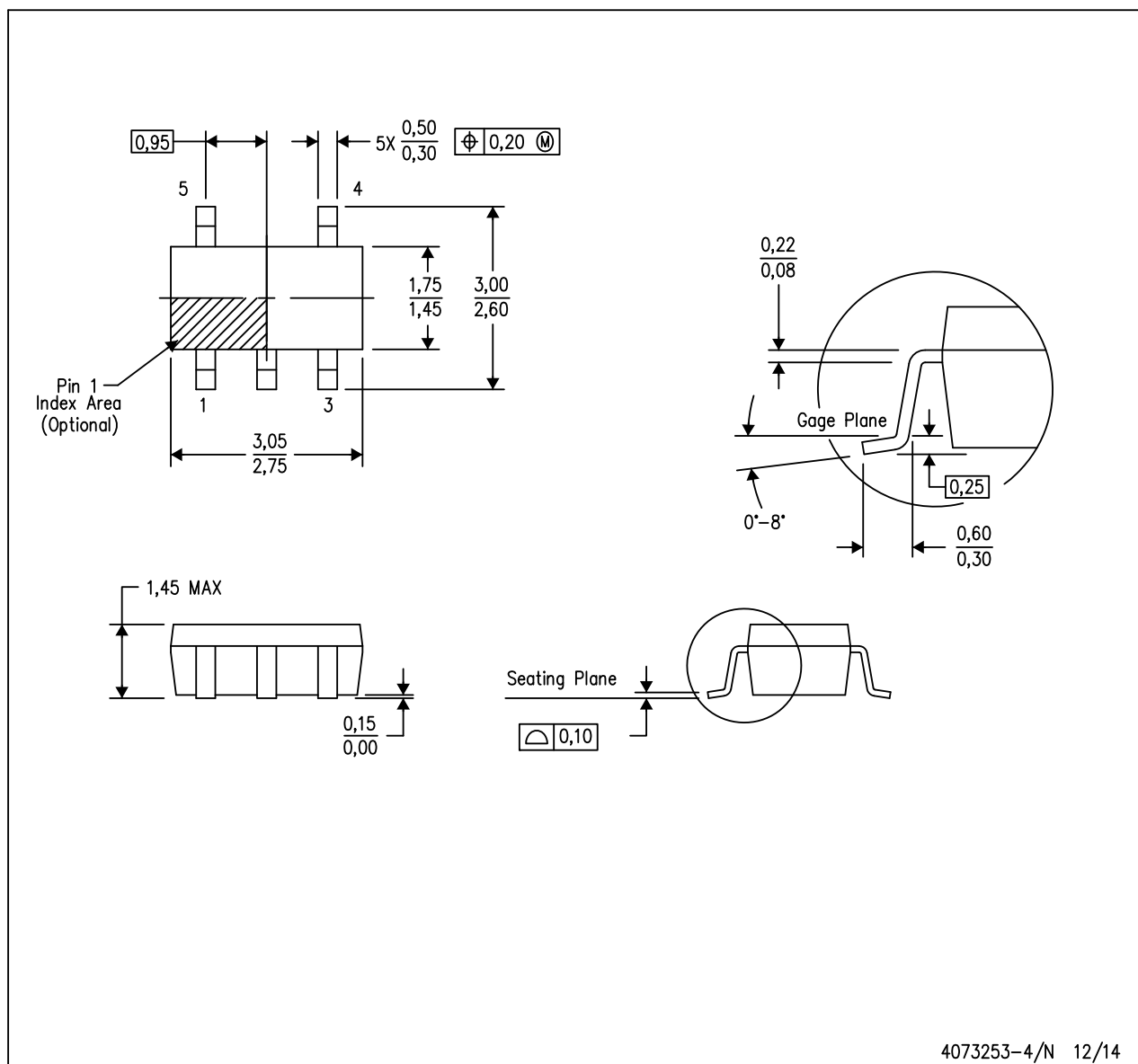
\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| OPA140AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 202.0       | 201.0      | 28.0        |
| OPA140AIDBVT  | SOT-23       | DBV             | 5    | 250  | 202.0       | 201.0      | 28.0        |
| OPA140AIDGKR  | VSSOP        | DGK             | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA140AIDGKT  | VSSOP        | DGK             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| OPA140AIDR    | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA2140AIDGKR | VSSOP        | DGK             | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA2140AIDGKT | VSSOP        | DGK             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| OPA2140AIDR   | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA4140AIDR   | SOIC         | D               | 14   | 2500 | 367.0       | 367.0      | 38.0        |
| OPA4140AIPWR  | TSSOP        | PW              | 14   | 2000 | 367.0       | 367.0      | 35.0        |

## MECHANICAL DATA

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE

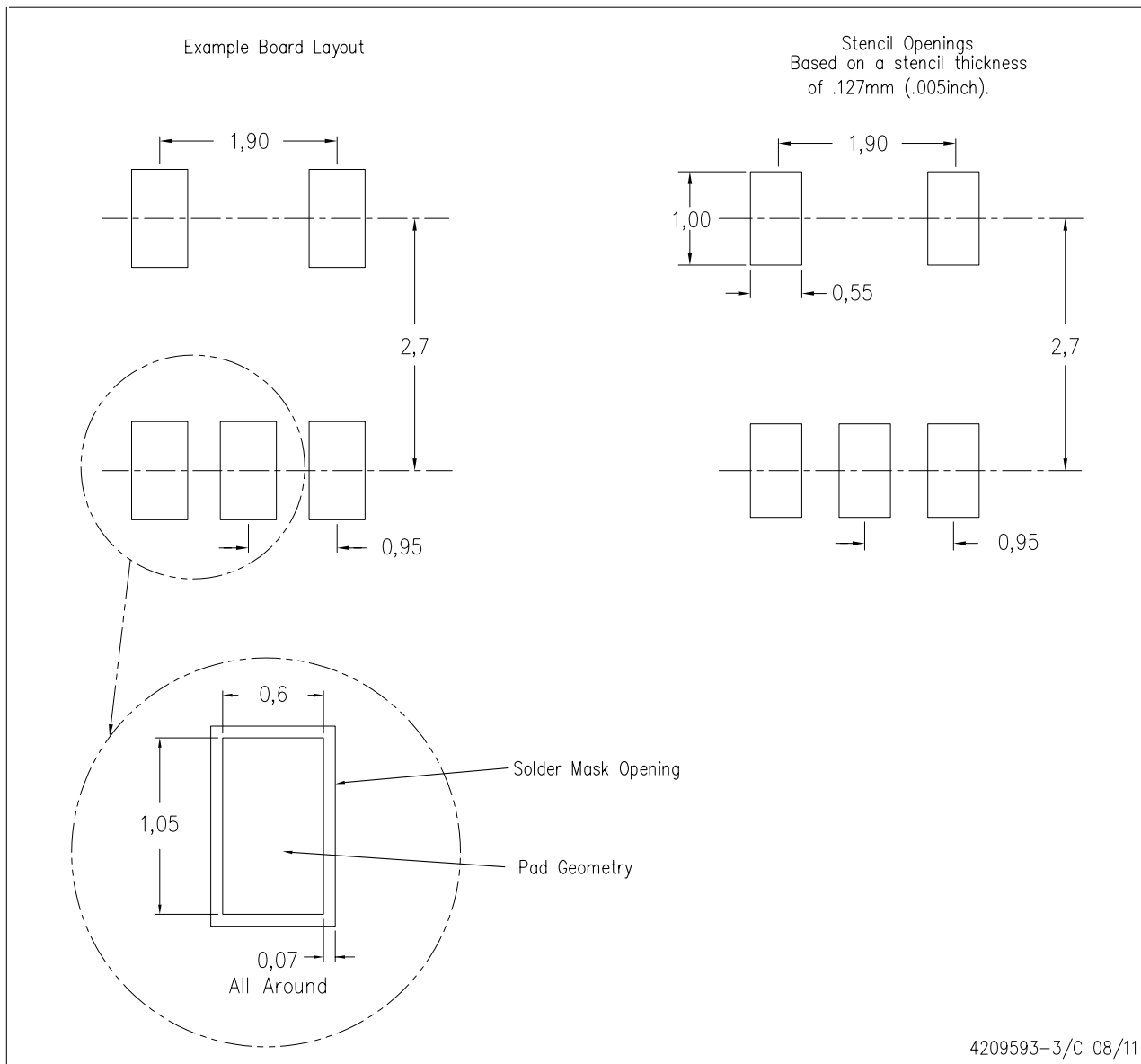


- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-178 Variation AA.

## LAND PATTERN DATA

DBV (R-PDSO-G5)

## PLASTIC SMALL OUTLINE



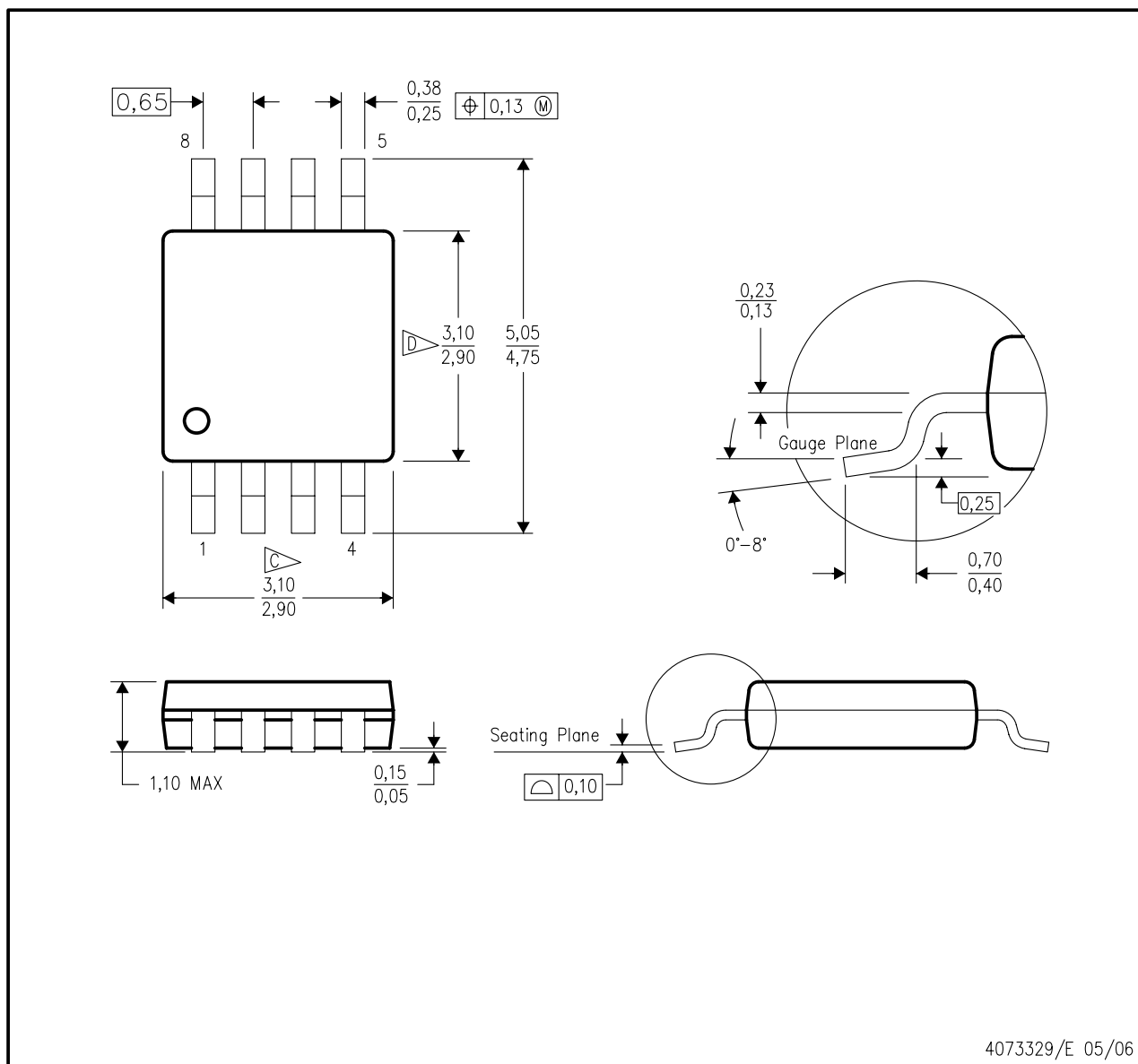
NOTES:

- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
- D. Publication IPC-7351 is recommended for alternate designs.
- E. 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.

## MECHANICAL DATA

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

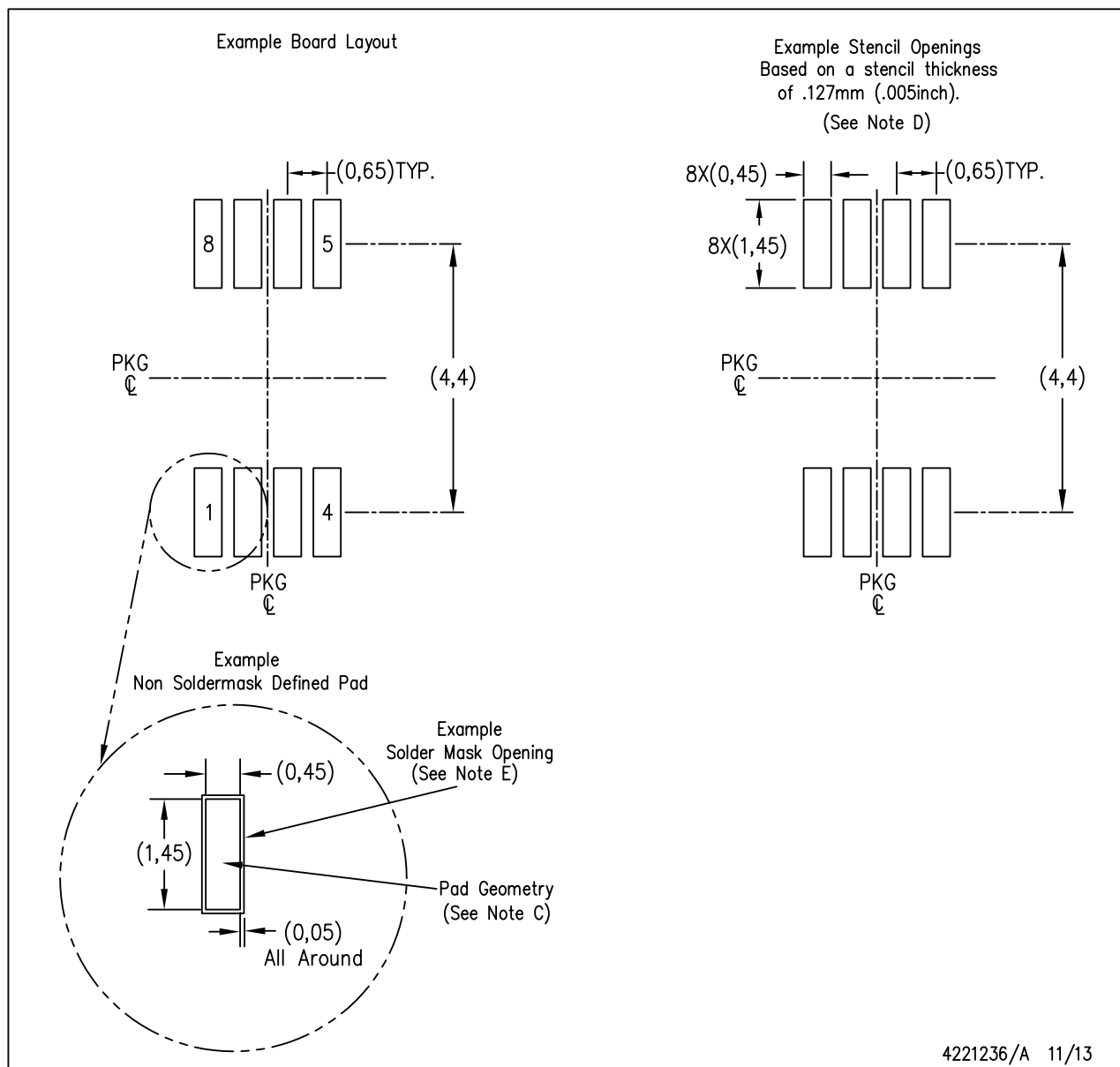


- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
  - E. Falls within JEDEC MO-187 variation AA, except interlead flash.

## LAND PATTERN DATA

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE

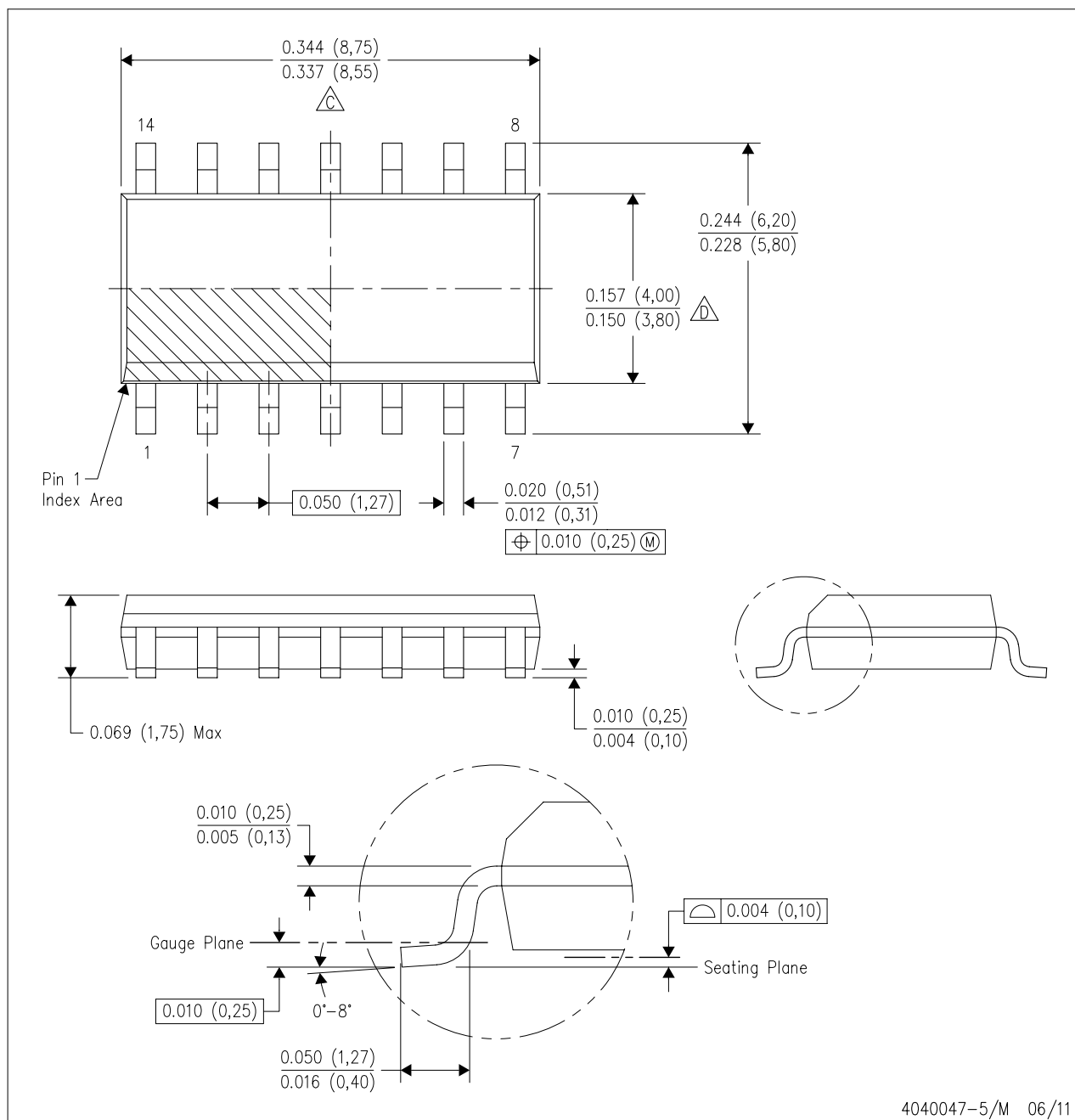


- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

## MECHANICAL DATA

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



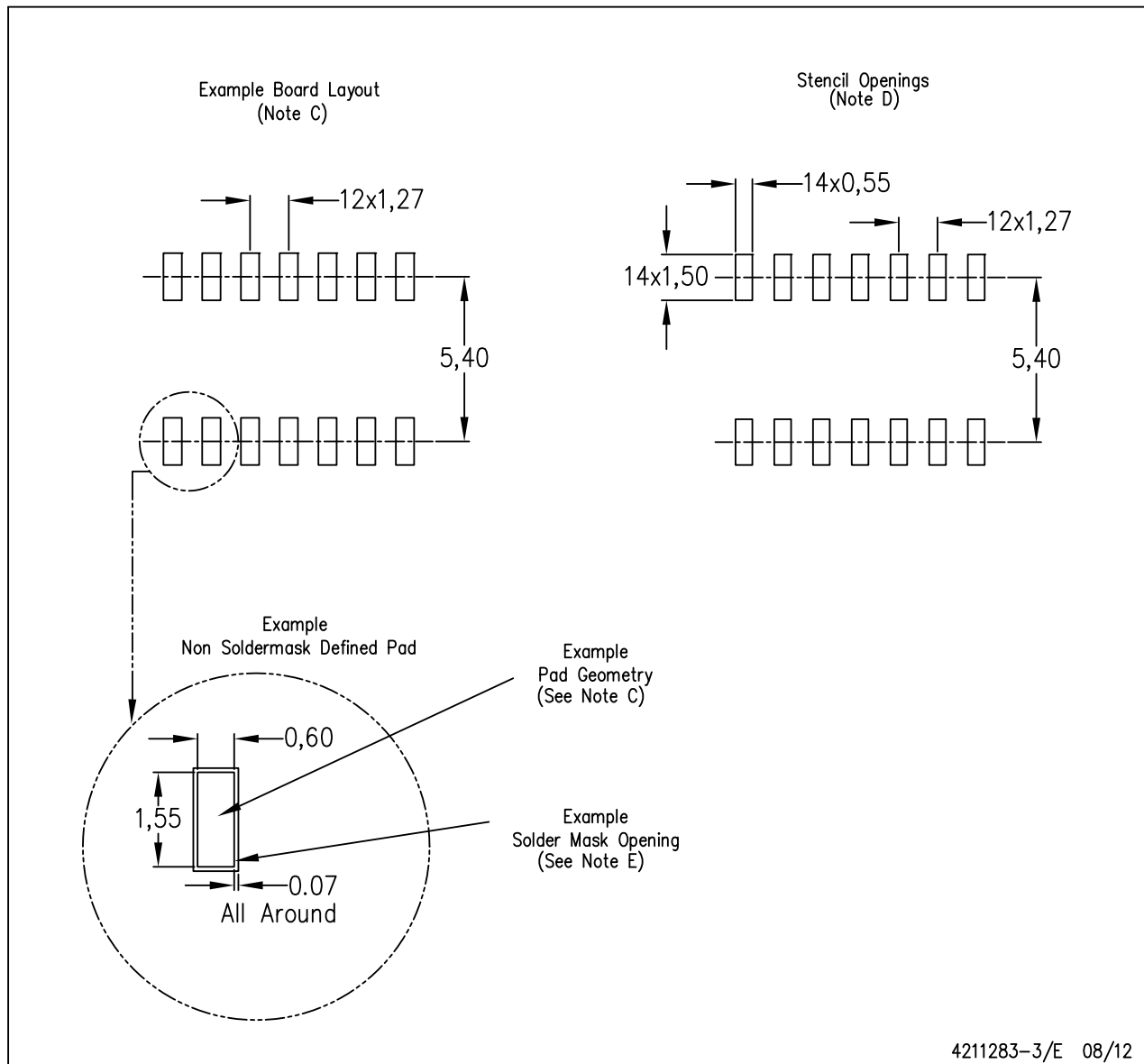
4040047-5/M 06/11

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AB.

## LAND PATTERN DATA

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



4211283-3/E 08/12

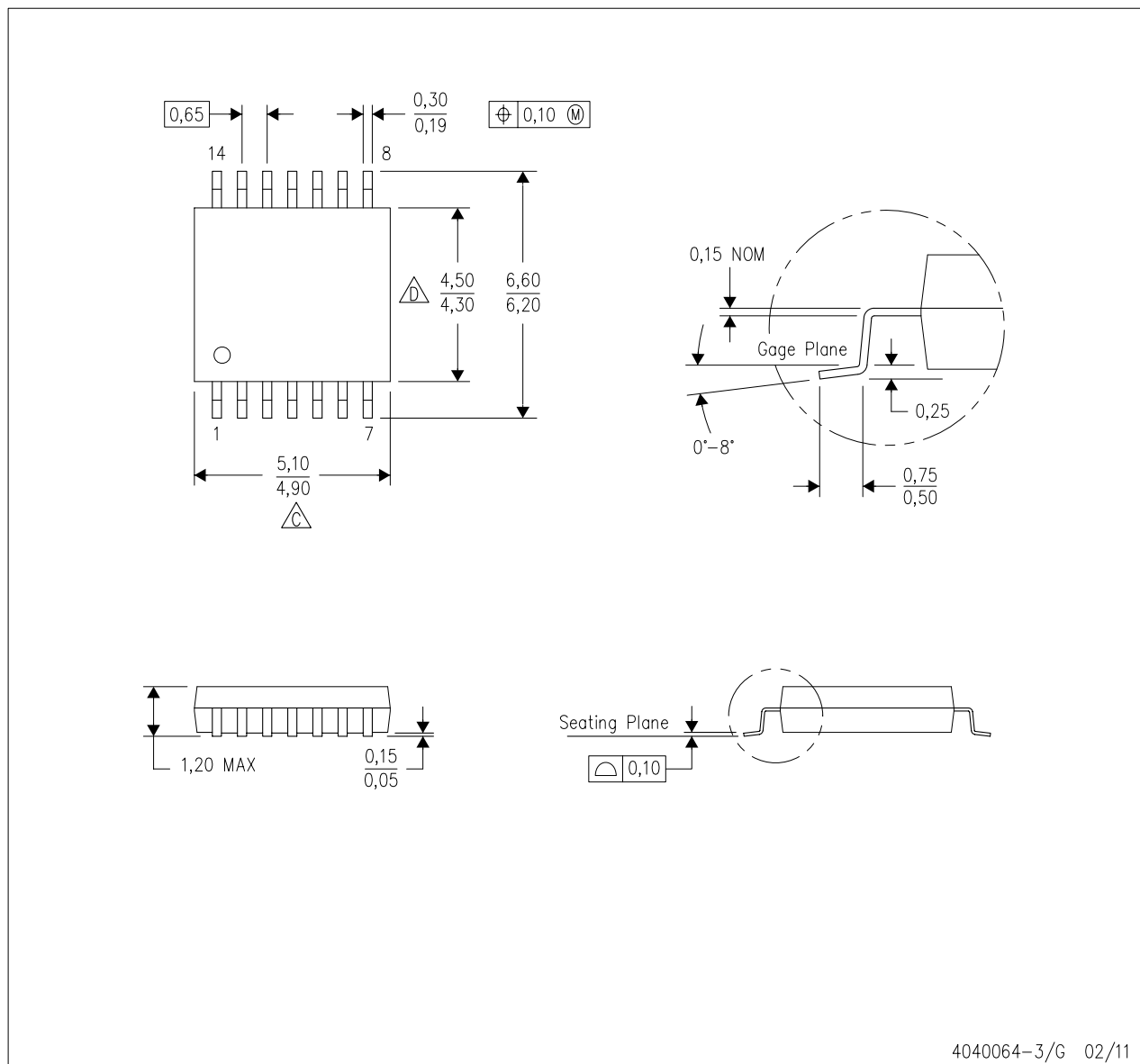
- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



## MECHANICAL DATA

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



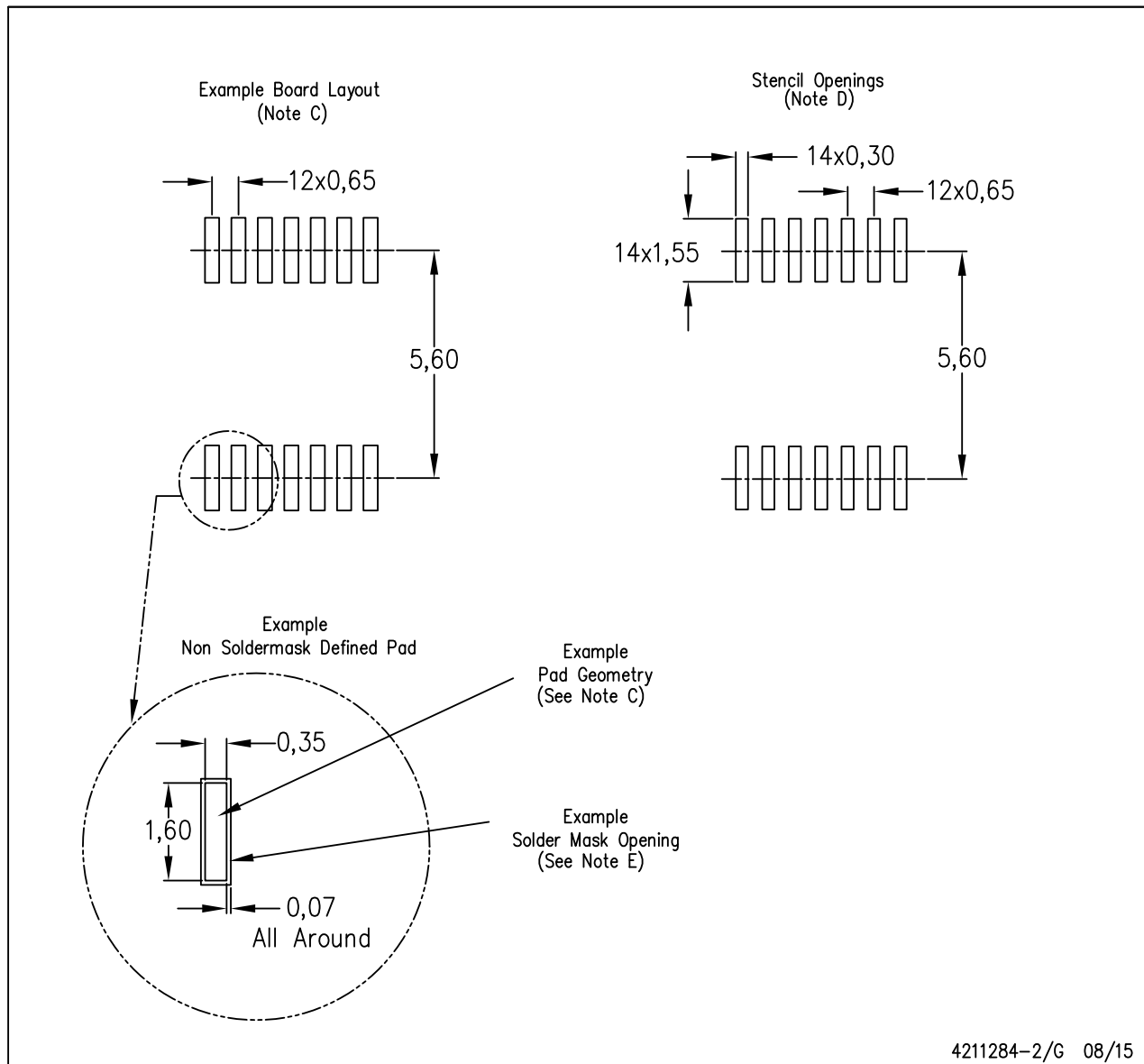
4040064-3/G 02/11

- 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. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

## LAND PATTERN DATA

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

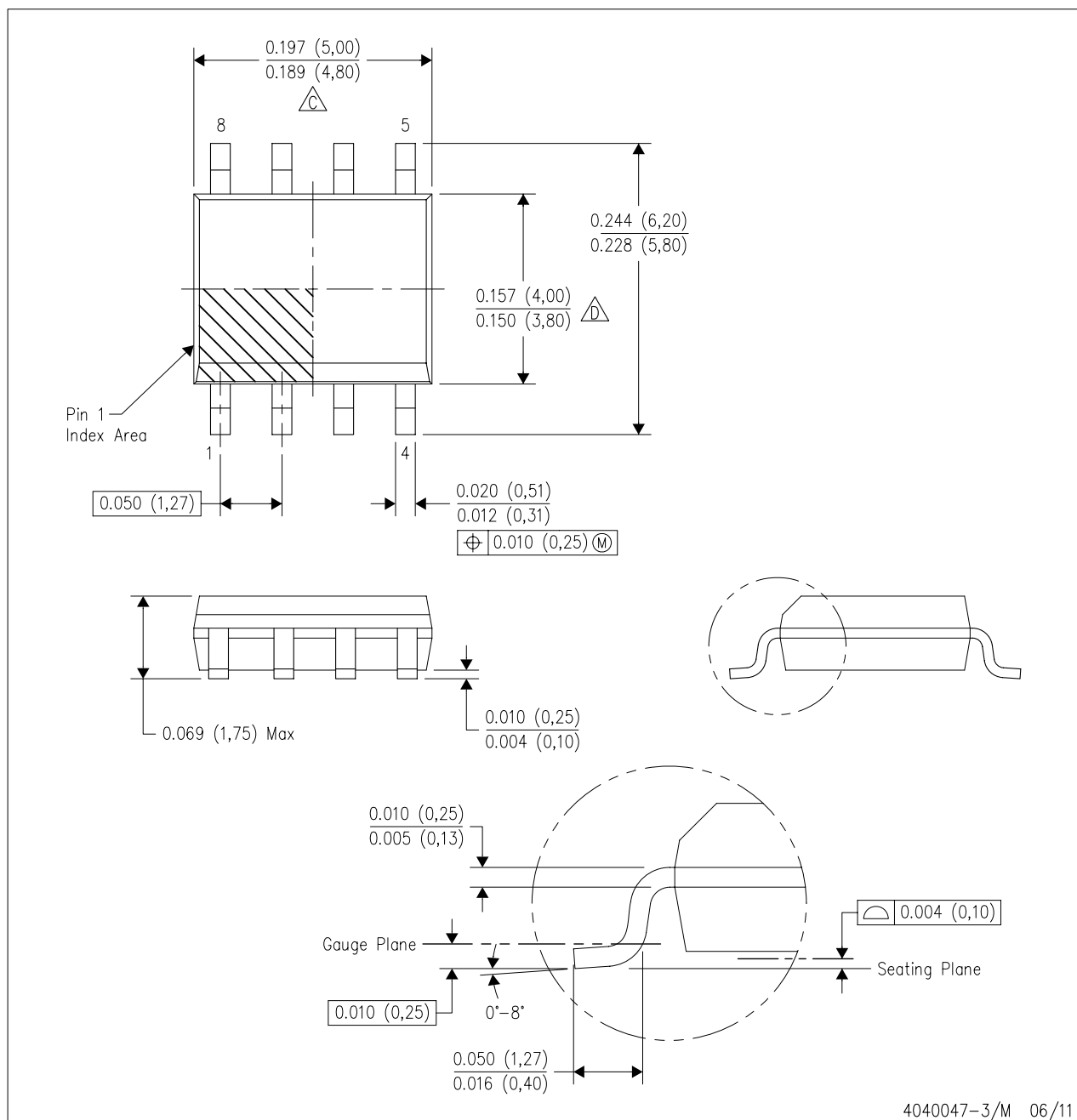


- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

## MECHANICAL DATA

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



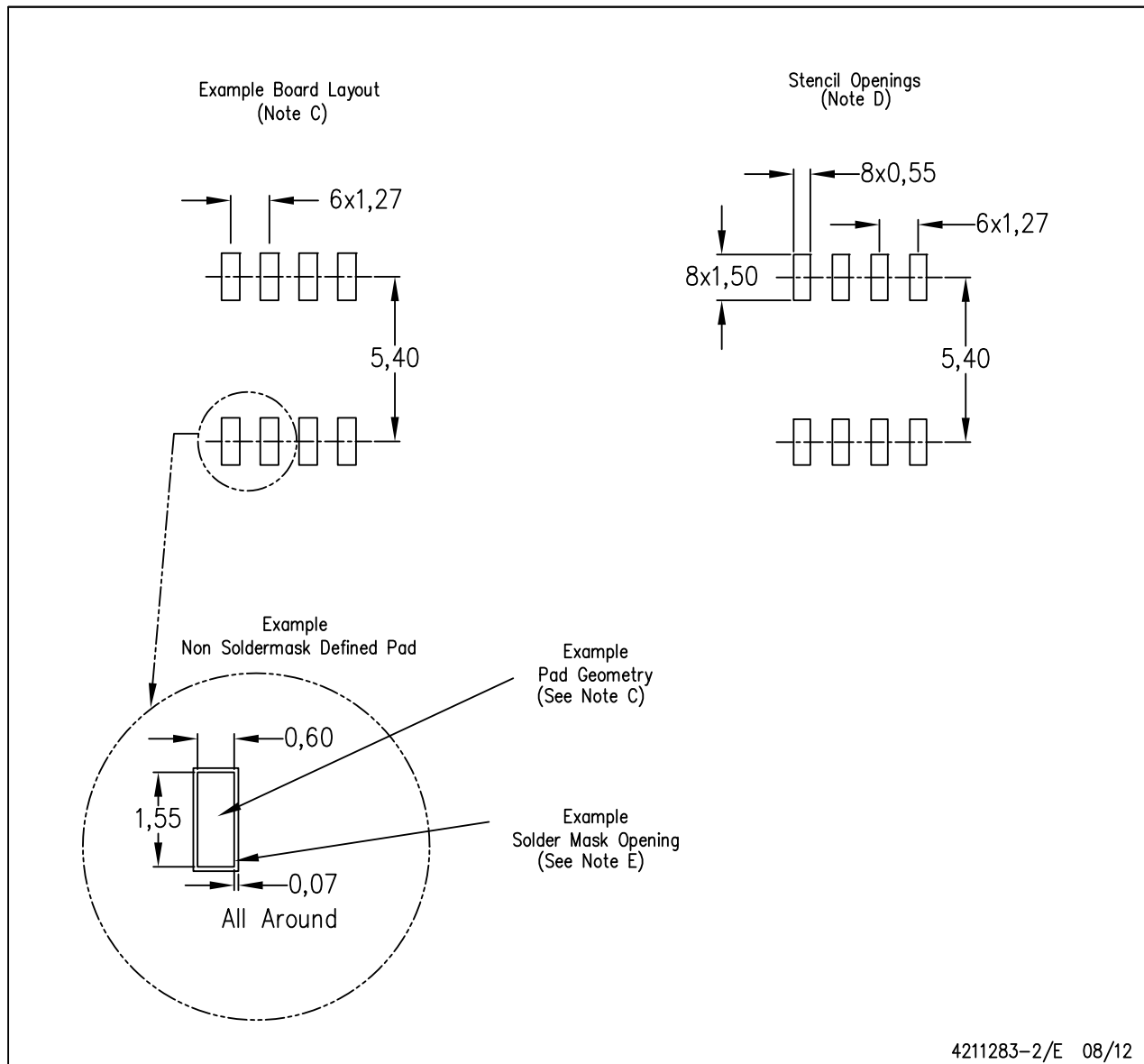
4040047-3/M 06/11

- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - Reference JEDEC MS-012 variation AA.

## LAND PATTERN DATA

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. 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 other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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