

## OPA2356-EP 200MHz、CMOS オペアンプ

### 1 特長

- ユニティ・ゲイン帯域幅: 450MHz
- 広い帯域幅: 200MHz GBW
- 高いスルーレート: 360V/ $\mu$ s
- 低ノイズ: 5.8nV/ $\sqrt{\text{Hz}}$
- 非常に優れたビデオ性能
  - 差動ゲイン: 0.02%
  - 差動位相: 0.05°
  - 0.1dB のゲイン・フラットネス: 75MHz
- 入力範囲にグラウンドを含む
- レール・ツー・レール出力 (100mV 以内)
- 低い入力バイアス電流: 3pA
- サーマル・シャットダウン
- 単一電源電圧範囲: 2.5V~5.5V
- Microsize パッケージ
- 防衛、航空宇宙、および医療アプリケーションをサポート
  - 管理されたベースライン
  - 軍用温度範囲 (-55°C~125°C) で利用可能
  - 長期にわたる製品ライフ・サイクル
  - 製品変更通知の延長
  - 製品のトレーサビリティ

### 2 アプリケーション

- ビデオ処理
- 光ネットワーク、調節可能なレーザー
- フォトダイオード・トランスインピーダンス・アンプ
- アクティブ・フィルタ
- 高速積分器
- A/Dコンバータ (ADC) の入力バッファ
- D/Aコンバータ (DAC) の出力アンプ
- 通信

### 3 概要

OPA2356-EP 高速、電圧帰還型 CMOS オペアンプは、ビデオや、広い帯域幅を必要とする他のアプリケーション用に設計されています。OPA2356-EP はユニティ・ゲイン安定で、大きな出力電流を駆動できます。差動ゲインは 0.02%、差動位相は 0.05°です。静止電流は、チャンネルごとにわずか 8.3mA です。

OPA2356-EP は、最低 2.5V ( $\pm 1.25$ V)、最高 5.5V ( $\pm 2.75$ V) のシングルまたはデュアル電源で動作するように最適化されています。OPA2356-EP の同相入力範囲はグラウンドの 100mV 下から、V+ の 1.5V 上まで伸びています。出力スイングはレールから 100mV 以内で、広いダイナミック・レンジに対応しています。

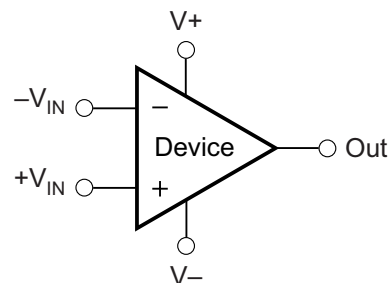
OPA2356-EP は、デュアル (VSSOP-8) バージョンで供給されます。これらのバージョンは、完全に独立した回路によりクロストークを最小化し、干渉の発生を防止しています。OPA2356-EP は、-55°C~125°C の拡張温度範囲で動作が規定されています。

#### 製品情報<sup>(1)</sup>

| 型番             | パッケージ     | 本体サイズ(公称)     |
|----------------|-----------|---------------|
| OPA2356MDGKREP | VSSOP (8) | 3.00mm×3.00mm |
| OPA2356MDGKTEP |           |               |

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

#### 概略回路図



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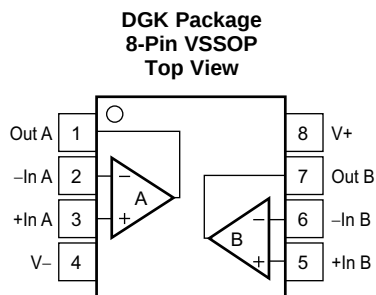
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## 4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

| 日付         | リビジョン | 注  |
|------------|-------|----|
| 2019 年 2 月 | *     | 初版 |

## 5 Pin Configuration and Functions



NOTE: NC means no internal connection.

### Pin Functions

| PIN   |     | I/O | DESCRIPTION                        |
|-------|-----|-----|------------------------------------|
| NAME  | NO. |     |                                    |
| –In A | 2   | I   | Inverting input pin, channel A.    |
| –In B | 6   | I   | Inverting input pin, channel B.    |
| +In A | 3   | I   | Noninverting input pin, channel A. |
| +In B | 5   | I   | Noninverting input pin, channel B. |
| Out A | 1   | O   | Output pin, channel A.             |
| Out B | 7   | O   | Output pin, channel B.             |
| V–    | 4   | —   | Negative power supply.             |
| V+    | 8   | —   | Positive power supply.             |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

|                  |                                           | MIN        | MAX        | UNIT |
|------------------|-------------------------------------------|------------|------------|------|
| V <sub>S</sub>   | Supply voltage, V+ to V–                  |            | 7.5        | V    |
|                  | Signal input pins, voltage <sup>(2)</sup> | (V–) – 0.5 | (V+) + 0.5 | V    |
|                  | Signal input pins, current <sup>(2)</sup> |            | 10         | mA   |
|                  | Output short-circuit <sup>(3)</sup>       |            | Continuous |      |
| T <sub>A</sub>   | Operating temperature                     | –55        | 150        | °C   |
| T <sub>J</sub>   | Junction temperature                      |            | 160        | °C   |
| T <sub>stg</sub> | Storage temperature                       | –65        | 150        | °C   |

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

### 6.2 ESD Ratings

|                    |                         | VALUE                                                   | UNIT  |
|--------------------|-------------------------|---------------------------------------------------------|-------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per AEC Q100-002 <sup>(1)</sup> | ±2000 |
|                    |                         | Charged-device model (CDM), per AEC Q100-011            | ±1500 |

- (1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

### 6.3 Recommended Operating Conditions

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

|                |                                | MIN | MAX | UNIT |
|----------------|--------------------------------|-----|-----|------|
| V <sub>S</sub> | Supply voltage, V– to V+       | 2.7 | 5.5 | V    |
| T <sub>A</sub> | Operating free-air temperature | –55 | 125 | °C   |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA2356-EP  | UNIT |
|-------------------------------|----------------------------------------------|-------------|------|
|                               |                                              | DGK (VSSOP) |      |
|                               |                                              | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 171.4       | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 60.2        | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 92.5        | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 7.3         | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 90.9        | °C/W |

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

## 6.5 Electrical Characteristics

at  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)

| PARAMETER                    |                                       | TEST CONDITIONS                                                                       | MIN        | TYP                     | MAX        | UNIT    |
|------------------------------|---------------------------------------|---------------------------------------------------------------------------------------|------------|-------------------------|------------|---------|
| OFFSET VOLTAGE               |                                       |                                                                                       |            |                         |            |         |
| V <sub>OS</sub>              | Input offset voltage                  | V <sub>S</sub> = 5 V                                                                  |            | ±2                      | ±9         | mV      |
|                              |                                       | T <sub>A</sub> = −55°C to 125°C                                                       |            |                         | ±15        |         |
| ΔV <sub>OS</sub> /ΔT         | Offset voltage drift over temperature | T <sub>A</sub> = −55°C to 125°C                                                       |            | ±7                      |            | μV/°C   |
| PSRR                         | Offset voltage drift vs power supply  | V <sub>S</sub> = 2.7 V to 5.5 V,<br>V <sub>CM</sub> = V <sub>S</sub> / 2 − 0.15 V     |            | ±80                     | ±350       | μV/V    |
| INPUT BIAS CURRENT           |                                       |                                                                                       |            |                         |            |         |
| I <sub>B</sub>               | Input bias current                    |                                                                                       |            | 3                       | ±50        | pA      |
| I <sub>OS</sub>              | Input offset current                  |                                                                                       |            | ±1                      | ±50        | pA      |
| NOISE                        |                                       |                                                                                       |            |                         |            |         |
| V <sub>n</sub>               | Input voltage noise density           | f = 1 MHz                                                                             |            | 5.8                     |            | nV/√Hz  |
| I <sub>n</sub>               | Current noise density                 | f = 1 MHz                                                                             |            | 50                      |            | fA/√Hz  |
| INPUT VOLTAGE RANGE          |                                       |                                                                                       |            |                         |            |         |
| V <sub>CM</sub>              | Input common-mode voltage range       |                                                                                       | (V−) − 0.1 |                         | (V+) − 1.5 | V       |
| CMRR                         | Input common-mode rejection ratio     | V <sub>S</sub> = 5.5 V, −0.1 V < V <sub>CM</sub> < 4 V                                | 66         | 80                      |            | dB      |
|                              |                                       | T <sub>A</sub> = −55°C to 125°C                                                       | 66         |                         |            |         |
| INPUT IMPEDANCE              |                                       |                                                                                       |            |                         |            |         |
| Differential input impedance |                                       |                                                                                       |            | 10 <sup>13</sup>    1.5 |            | Ω    pF |
| Common-mode input impedance  |                                       |                                                                                       |            | 10 <sup>13</sup>    1.5 |            | Ω    pF |
| OPEN-LOOP GAIN               |                                       |                                                                                       |            |                         |            |         |
| Open-loop gain               |                                       | V <sub>S</sub> = 5 V, 0.4 V < V <sub>O</sub> < 4.6 V, T <sub>A</sub> = −55°C to 125°C | 80         |                         |            | dB      |
| FREQUENCY RESPONSE           |                                       |                                                                                       |            |                         |            |         |
| f <sub>−3dB</sub>            | Small-signal bandwidth                | G = 1, V <sub>O</sub> = 100 mVp-p, R <sub>F</sub> = 0 Ω                               |            | 450                     |            | MHz     |
|                              |                                       | G = 2, V <sub>O</sub> = 100 mVp-p, R <sub>L</sub> = 50 Ω                              |            | 100                     |            |         |
|                              |                                       | G = 2, V <sub>O</sub> = 100 mVp-p, R <sub>L</sub> = 150 Ω                             |            | 170                     |            |         |
|                              |                                       | G = 2, V <sub>O</sub> = 100 mVp-p, R <sub>L</sub> = 1 kΩ                              |            | 200                     |            |         |
| GBW                          | Gain-bandwidth product                | G = 10, R <sub>L</sub> = 1 kΩ                                                         |            | 200                     |            | MHz     |
| f <sub>0.1dB</sub>           | Bandwidth for 0.1-dB gain flatness    | G = 2, V <sub>O</sub> = 100 mVp-p, R <sub>F</sub> = 560 Ω                             |            | 75                      |            | MHz     |
| SR                           | Slew rate                             | V <sub>S</sub> = 5 V, G = 2, 4-V output step                                          |            | 300                     |            | V/μs    |
|                              |                                       |                                                                                       |            | −360                    |            |         |
|                              | Rise and fall times                   | G = 2, V <sub>O</sub> = 200 mVp-p, 10% to 90%                                         |            | 2.4                     |            | ns      |
|                              |                                       | G = 2, V <sub>O</sub> = 2 Vp-p, 10% to 90%                                            |            | 8                       |            |         |
| Settling time                | 0.1%                                  | V <sub>S</sub> = 5 V, G = 2, 2-V output step                                          |            | 30                      |            | ns      |
|                              | 0.01%                                 |                                                                                       |            | 120                     |            |         |
| Overload recovery time       |                                       | V <sub>IN</sub> × Gain = V <sub>S</sub>                                               |            | 8                       |            | ns      |
| Harmonic distortion          | Second harmonic                       | G = 2, f = 1 MHz, V <sub>O</sub> = 2 Vp-p, R <sub>L</sub> = 200 Ω                     |            | −81                     |            | dBc     |
|                              | Third harmonic                        |                                                                                       |            | −93                     |            |         |
| Differential gain error      |                                       | NTSC, R <sub>L</sub> = 150 Ω                                                          |            | 0.02%                   |            |         |
| Differential phase error     |                                       | NTSC, R <sub>L</sub> = 150 Ω                                                          |            | 0.05                    |            | °       |
| Channel-to-channel crosstalk |                                       | f = 5 MHz                                                                             |            | −90                     |            | dB      |

## Electrical Characteristics (continued)

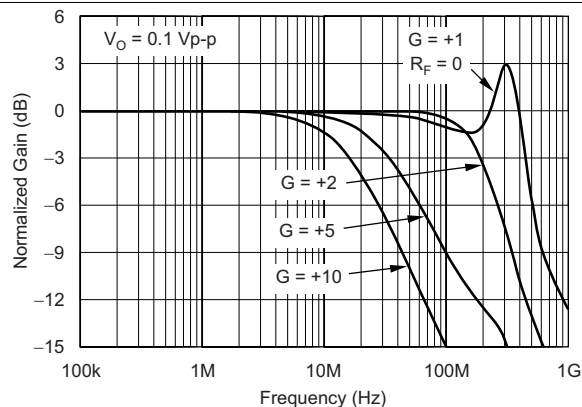
 at  $T_A = -55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)

| PARAMETER                      |                                                                       | TEST CONDITIONS | MIN                                                     | TYP | MAX | UNIT |
|--------------------------------|-----------------------------------------------------------------------|-----------------|---------------------------------------------------------|-----|-----|------|
| OUTPUT                         |                                                                       |                 |                                                         |     |     |      |
| Voltage output swing from rail | V <sub>S</sub> = 5 V, R <sub>L</sub> = 150 Ω, A <sub>OL</sub> > 84 dB |                 |                                                         | 0.2 | 0.3 | V    |
|                                | V <sub>S</sub> = 5 V, R <sub>L</sub> = 1 kΩ                           |                 |                                                         | 0.1 |     |      |
|                                | I <sub>O</sub> = ±100 mA                                              |                 |                                                         | 0.8 | 1   |      |
| I <sub>O</sub>                 | Continuous output current <sup>(1)</sup>                              |                 | ±60                                                     |     |     | mA   |
| I <sub>O</sub>                 | Peak output current <sup>(1)</sup>                                    |                 | V <sub>S</sub> = 5 V<br>±100                            |     |     | mA   |
|                                |                                                                       |                 | V <sub>S</sub> = 3 V<br>±80                             |     |     |      |
|                                | Short-circuit current                                                 |                 | 250<br>–200                                             |     |     | mA   |
|                                |                                                                       |                 |                                                         |     |     |      |
|                                | Closed-loop output impedance                                          |                 | 0.02                                                    |     |     | Ω    |
| POWER SUPPLY                   |                                                                       |                 |                                                         |     |     |      |
| I <sub>Q</sub>                 | Quiescent current (per amplifier)                                     |                 | V <sub>S</sub> = 5 V, I <sub>O</sub> = 0 V<br>8.3<br>11 |     |     | mA   |
|                                |                                                                       |                 | T <sub>A</sub> = –55°C to 125°C<br>14                   |     |     |      |
| THERMAL SHUTDOWN               |                                                                       |                 |                                                         |     |     |      |
| Junction temperature           | Shutdown                                                              |                 | 160                                                     |     |     | °C   |
|                                | Reset from shutdown                                                   |                 | 140                                                     |     |     |      |

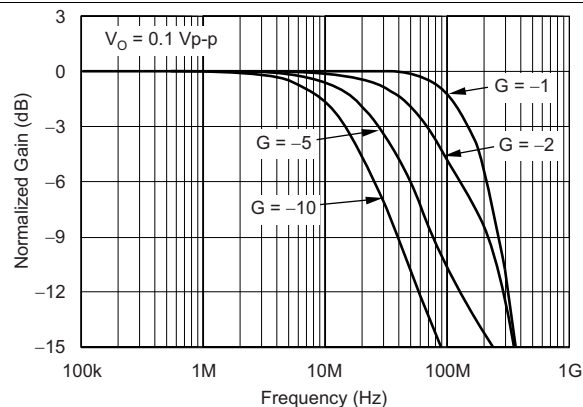
 (1) See [Figure 20](#).

## 6.6 Typical Characteristics

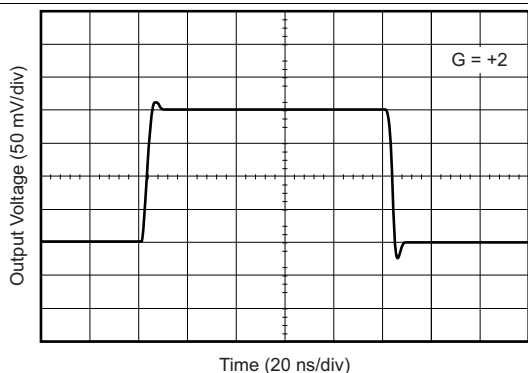
at  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $G = 2$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)



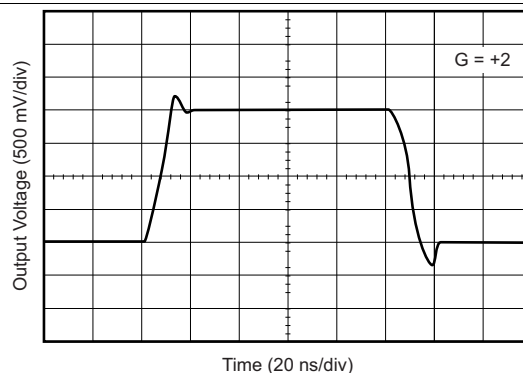
**Figure 1. Noninverting Small-Signal Frequency Response**



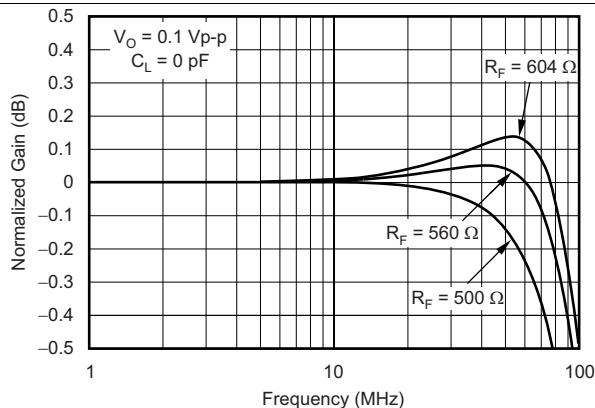
**Figure 2. Inverting Small-Signal Frequency Response**



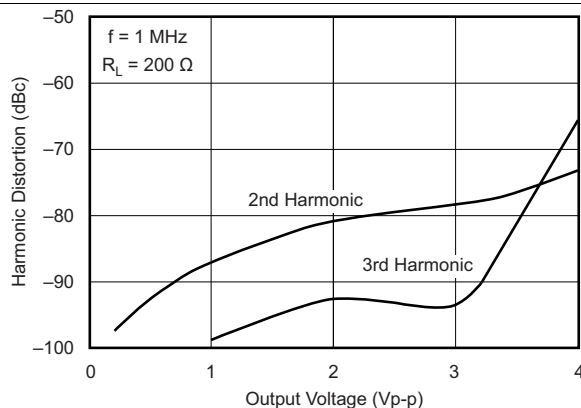
**Figure 3. Noninverting Small-Signal Step Response**



**Figure 4. Noninverting Large-Signal Step Response**



**Figure 5. 0.1-dB Gain Flatness for Various  $R_F$**



**Figure 6. Harmonic Distortion vs Output Voltage**

## Typical Characteristics (continued)

at  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $G = 2$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)

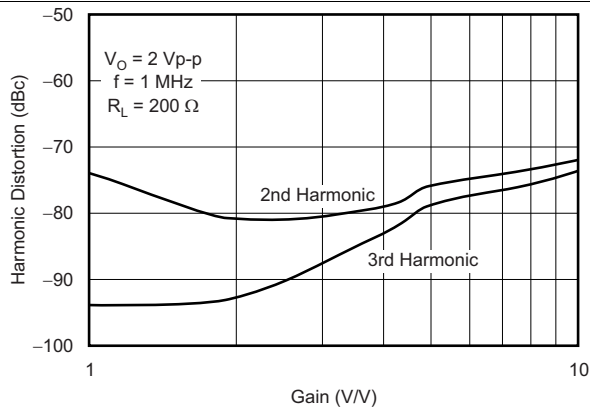


Figure 7. Harmonic Distortion vs Noninverting Gain

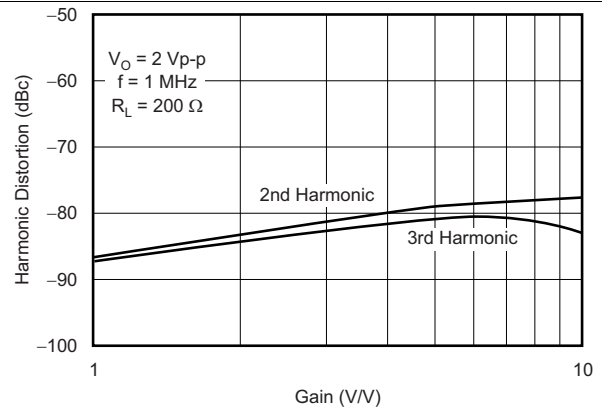


Figure 8. Harmonic Distortion vs Inverting Gain

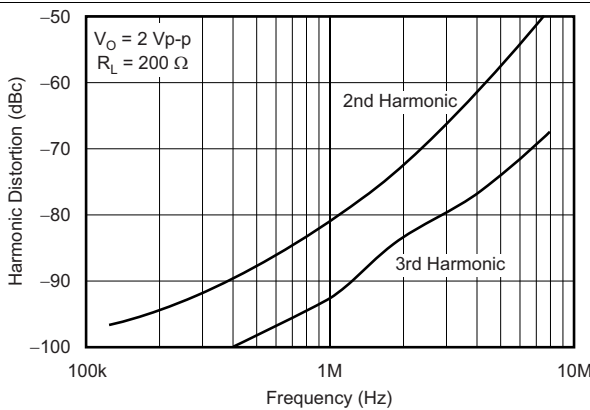


Figure 9. Harmonic Distortion vs Frequency

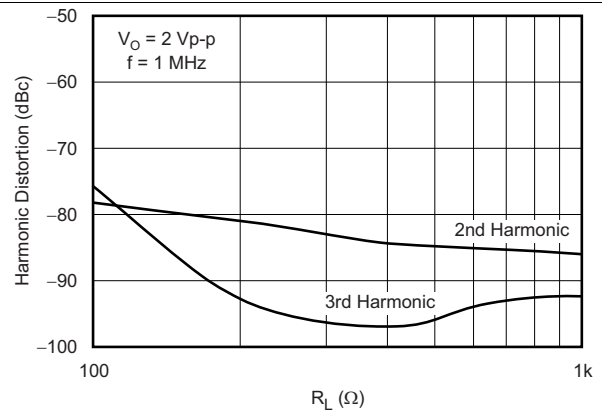


Figure 10. Harmonic Distortion vs Load Resistance

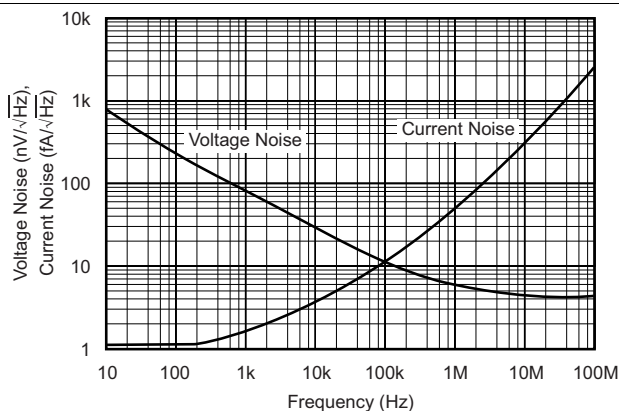


Figure 11. Input Voltage and Current Noise Spectral Density vs Frequency

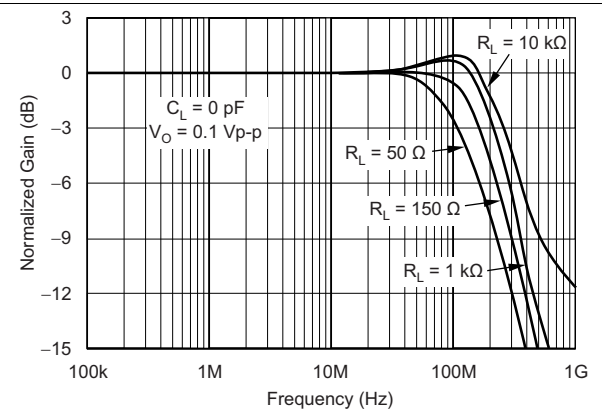


Figure 12. Frequency Response for Various  $R_L$

## Typical Characteristics (continued)

at  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $G = 2$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)

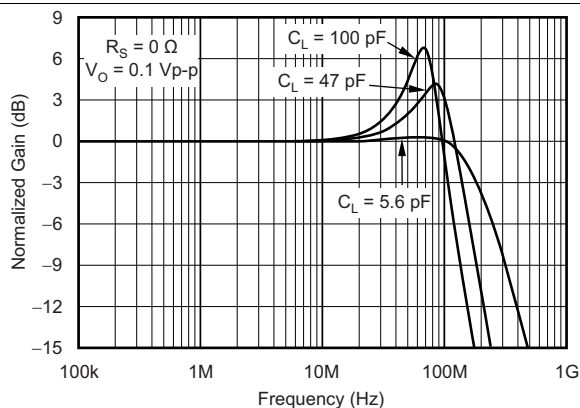


Figure 13. Frequency Response for Various  $C_L$

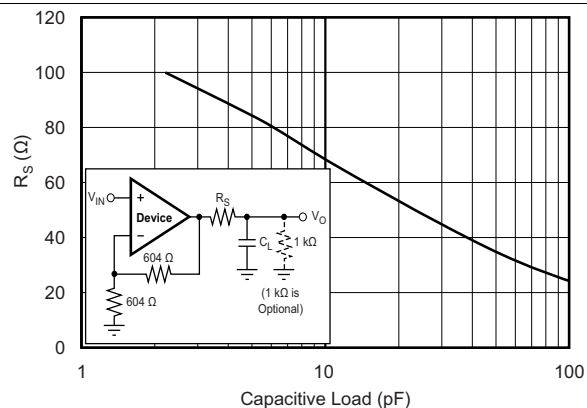


Figure 14. Recommended  $R_S$  vs Capacitive Load

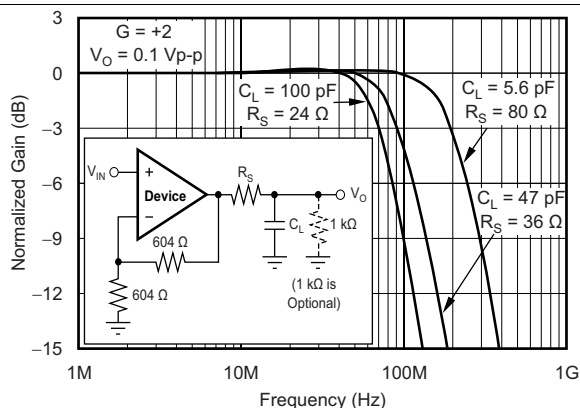


Figure 15. Frequency Response vs Capacitive Load

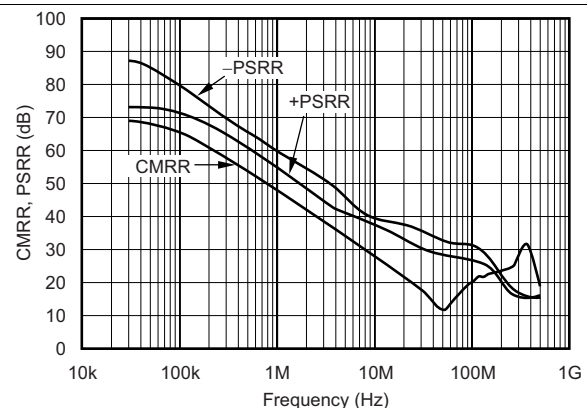


Figure 16. Common-Mode Rejection Ratio and Power-Supply Rejection Ratio vs Frequency

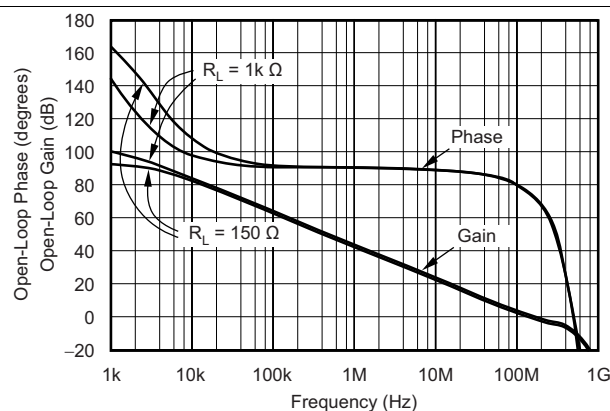


Figure 17. Open-Loop Gain and Phase

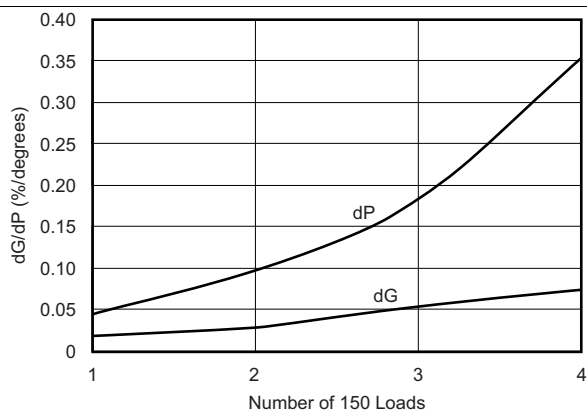


Figure 18. Composite Video Differential Gain and Phase

## Typical Characteristics (continued)

at  $T_A = -55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_S = 5\text{ V}$ ,  $G = 2$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)

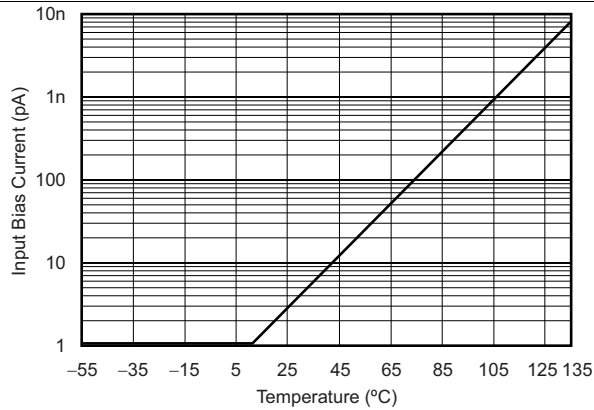


Figure 19. Input Bias Current vs Temperature

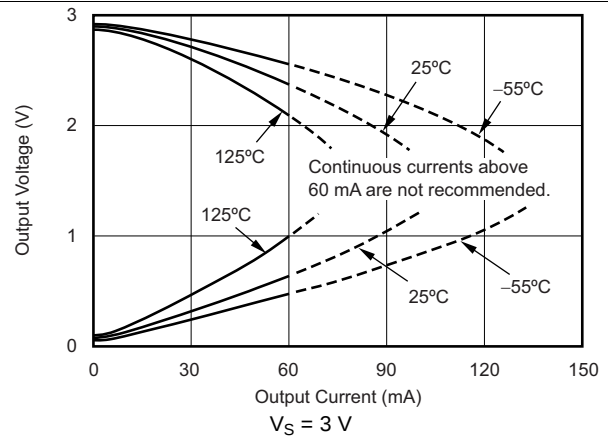


Figure 20. Output Voltage Swing vs Output Current

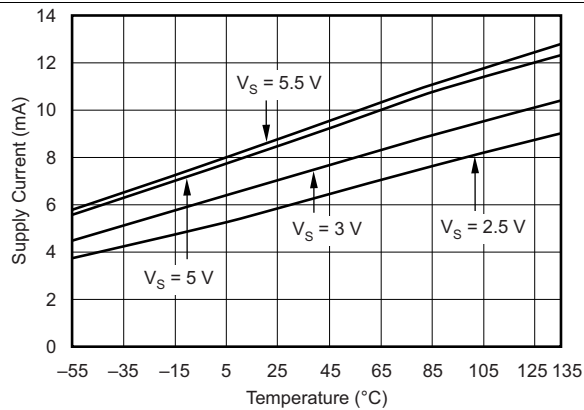


Figure 21. Supply Current vs Temperature

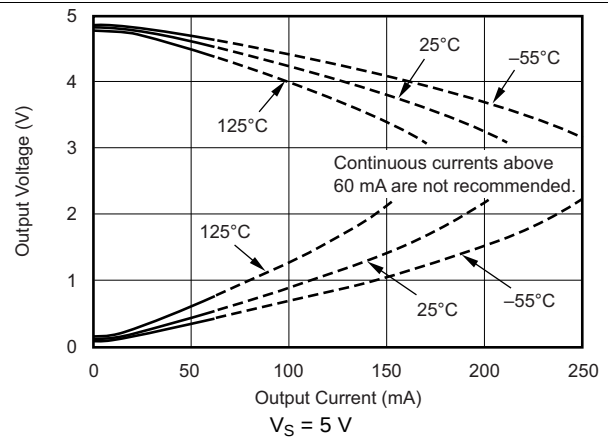


Figure 22. Output Voltage Swing vs Output Current

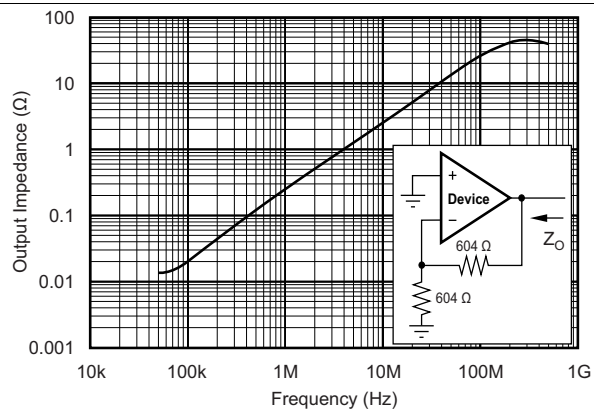


Figure 23. Closed-Loop Output Impedance vs Frequency

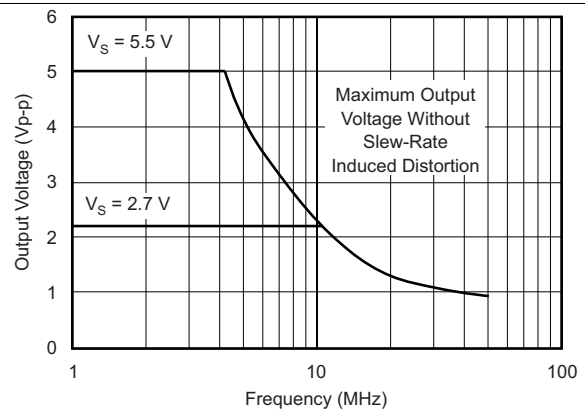
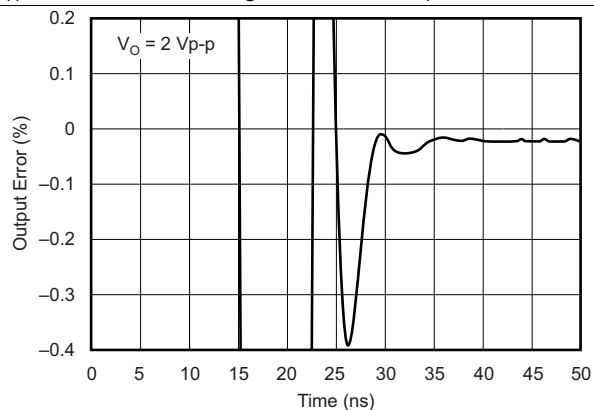


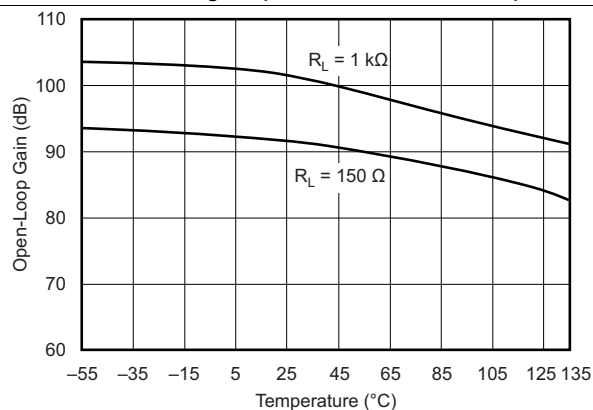
Figure 24. Maximum Output Voltage vs Frequency

## Typical Characteristics (continued)

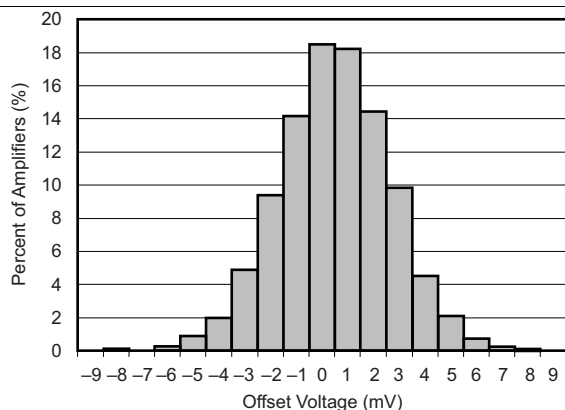
at  $T_A = -55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_S = 5\text{ V}$ ,  $G = 2$ ,  $R_F = 604\ \Omega$ , and  $R_L = 150\ \Omega$  connected to  $V_S / 2$  (unless otherwise noted)



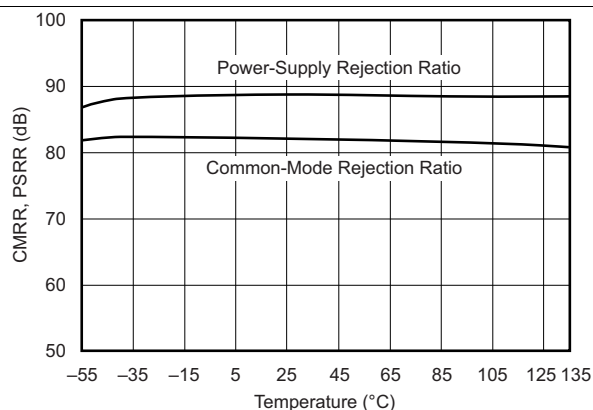
**Figure 25. Output Settling Time to 0.1%**



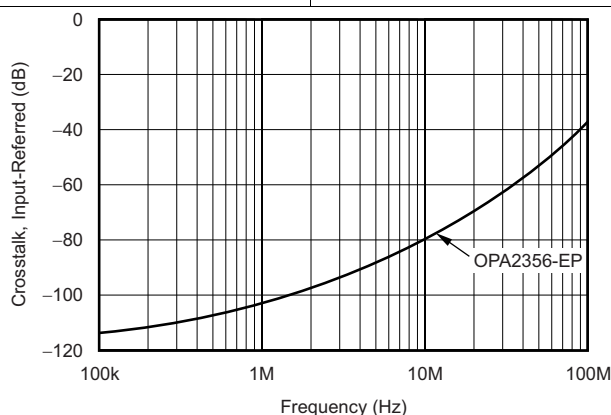
**Figure 26. Open-Loop Gain vs Temperature**



**Figure 27. Offset Voltage Production Distribution**



**Figure 28. Common-Mode Rejection Ratio and Power-Supply Rejection Ratio vs Temperature**



**Figure 29. Channel-to-Channel Crosstalk**



## 7.3 Feature Description

### 7.3.1 Operating Voltage

The OPA2356-EP is specified over a power-supply range of 2.7 V to 5.5 V ( $\pm 1.35$  V to  $\pm 2.75$  V). However, the supply voltage may range from 2.5 V to 5.5 V ( $\pm 1.25$  V to  $\pm 2.75$  V). Supply voltages higher than 7.5 V (absolute maximum) can permanently damage the amplifier.

Parameters that vary significantly over supply voltage or temperature are shown in the [Typical Characteristics](#) section of this data sheet.

### 7.3.2 Output Drive

The output stage of the OPA2356-EP is capable of driving a standard back-terminated 75- $\Omega$  video cable. A back-terminated transmission line does not exhibit a capacitive load to its driver. A properly back-terminated 75- $\Omega$  cable does not appear as capacitance; the cable presents only a 150- $\Omega$  resistive load to the OPA2356-EP output.

The output stage can supply high short-circuit current (typically over 200 mA). Therefore, an on-chip thermal shutdown circuit is provided to protect the OPA2356-EP from dangerously high junction temperatures. At 160°C, the protection circuit shuts down the amplifier. Normal operation resumes when the junction temperature cools to below 140°C.

---

#### NOTE

TI does not recommend running a continuous dc current in excess of  $\pm 60$  mA. See [Figure 20](#) in the [Typical Characteristics](#) section.

---

## 7.4 Device Functional Modes

The OPA2356-EP is powered on when the supply is connected. The device can operate as a single-supply operational amplifier or dual-supply amplifier depending on the application. The device can also be used with asymmetrical supplies as long as the differential voltage ( $V_-$  to  $V_+$ ) is at least 1.8 V and no greater than 5.5 V (for example,  $V_-$  is set to  $-3.5$  V and  $V_+$  is set to 1.5 V).

## 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 OPA2356-EP is a CMOS, high-speed, voltage-feedback, operational amplifier (op amp) designed for general-purpose applications.

The amplifier features a 200-MHz gain bandwidth and 300-V/ $\mu$ s slew rate, but the device is unity-gain stable and operates as a 1-V/V voltage follower.

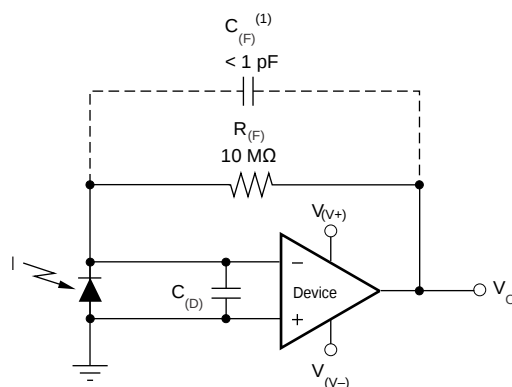
The input common-mode voltage range of the device includes ground, which allows the OPA2356-EP to be used in virtually any single-supply application up to a supply voltage of 5.5 V.

### 8.2 Typical Applications

#### 8.2.1 Transimpedance Amplifier

Wide gain bandwidth, low input bias current, low input voltage, and current noise make the OPA2356-EP a preferred wideband photodiode transimpedance amplifier. Low-voltage noise is important because photodiode capacitance causes the effective noise gain of the circuit to increase at high frequency.

The key elements to a transimpedance design, as shown in Figure 30, are the expected diode capacitance ( $C_{(D)}$ ), which must include the parasitic input common-mode and differential-mode input capacitance (4 pF + 5 pF), the desired transimpedance gain ( $R_{(FB)}$ ), and the gain-bandwidth (GBW) for the OPA2356-EP (20 MHz). With these three variables set, the feedback capacitor value ( $C_{(FB)}$ ) is set to control the frequency response.  $C_{(FB)}$  includes the stray capacitance of  $R_{(FB)}$ , which is 0.2 pF for a typical surface-mount resistor.



(1)  $C_{(FB)}$  is optional to prevent gain peaking.  $C_{(FB)}$  includes the stray capacitance of  $R_{(FB)}$ .

**Figure 30. Dual-Supply Transimpedance Amplifier**

#### 8.2.1.1 Design Requirements

| PARAMETER                 | VALUE  |
|---------------------------|--------|
| Supply voltage $V_{(V+)}$ | 2.5 V  |
| Supply voltage $V_{(V-)}$ | -2.5 V |

### 8.2.1.2 Detailed Design Procedure

#### 8.2.1.2.1 Custom Design With WEBENCH® Tools

Click [here](#) to create a custom design using the OPA2356 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ( $V_{IN}$ ), output voltage ( $V_{OUT}$ ), and output current ( $I_{OUT}$ ) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at [www.ti.com/WEBENCH](http://www.ti.com/WEBENCH).

#### 8.2.1.2.2 OPA2356-EP Design Procedure

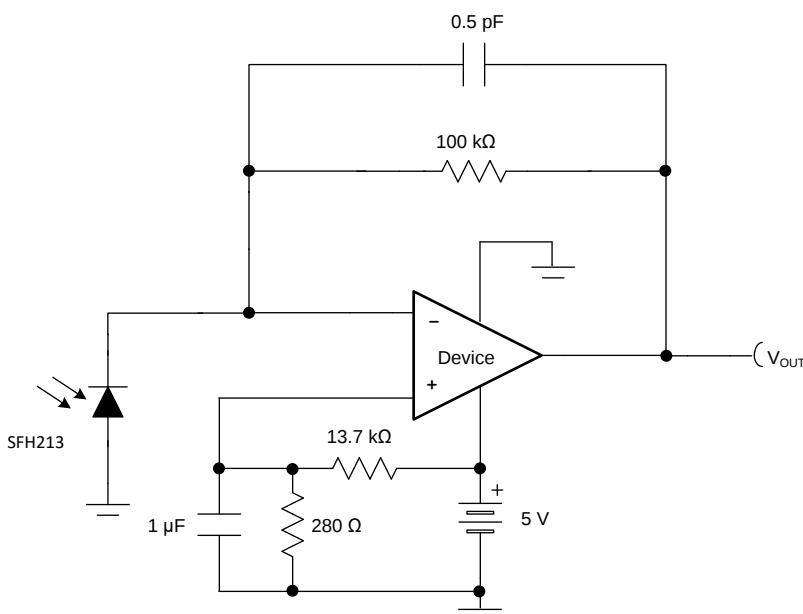
To achieve a maximally-flat, second-order Butterworth frequency response, the feedback pole must be set to:

$$\frac{1}{2 \times \pi \times R_{(FB)} \times C_{(FB)}} = \sqrt{\frac{GBW}{4 \times \pi \times R_{(FB)} \times C_{(D)}}} \quad (1)$$

Use Equation 2 to calculate the bandwidth.

$$f_{(-3 \text{ dB})} = \sqrt{\frac{GBW}{2 \times \pi \times R_{(FB)} \times C_{(D)}}} \quad (2)$$

For single-supply applications, the +INx input can be biased with a positive DC voltage to allow the output to reach true zero when the photodiode is not exposed to any light, and respond without the added delay that results from coming out of the negative rail; this configuration is shown in Figure 31. This bias voltage appears across the photodiode, providing a reverse bias for faster operation.



**Figure 31. Single-Supply Transimpedance Amplifier**

For additional information, see the [Compensate transimpedance amplifiers intuitively](#) application report.

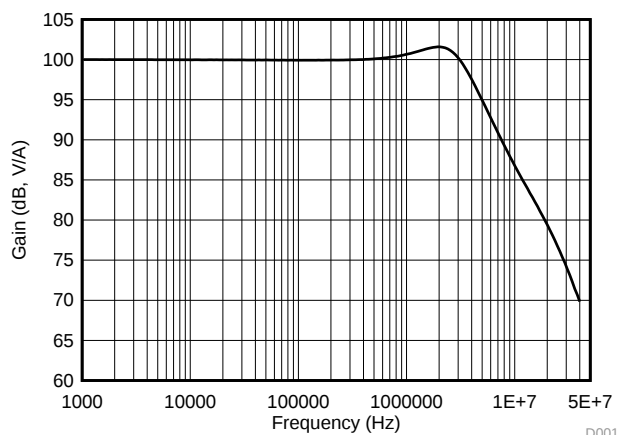
#### 8.2.1.2.2.1 Optimizing the Transimpedance Circuit

To achieve the best performance, select components according to the following guidelines:

1. For lowest noise, select  $R_{(FB)}$  to create the total required gain. Using a lower value for  $R_{(FB)}$  and adding gain after the transimpedance amplifier generally produces poorer noise performance. The noise produced by  $R_{(FB)}$  increases with the square-root of  $R_{(FB)}$ , whereas the signal increases linearly. Therefore, signal-to-noise ratio improves when all the required gain is placed in the transimpedance stage.
2. Minimize photodiode capacitance and stray capacitance at the summing junction (inverting input). This capacitance causes the voltage noise of the op amp to amplify (increasing amplification at high frequency). Using a low-noise voltage source to reverse-bias a photodiode can significantly reduce the capacitance. Smaller photodiodes have lower capacitance. Use optics to concentrate light on a small photodiode.
3. Noise increases with increased bandwidth. Limit the circuit bandwidth to only that required. Use a capacitor across the  $R_{(FB)}$  to limit bandwidth, even if not required for stability.
4. Circuit board leakage can degrade the performance of an otherwise well-designed amplifier. Clean the circuit board carefully. A circuit board guard trace that encircles the summing junction and is driven at the same voltage can help control leakage.

For additional information, see the [Noise analysis of FET transimpedance amplifiers](#) and [Noise analysis for high-speed op amps](#) application reports.

#### 8.2.1.3 Application Curve



–3-dB bandwidth is 4.56 MHz

**Figure 32. AC Transfer Function**

### 8.2.2 High-Impedance Sensor Interface

Many sensors have high source impedances that may range up to 10 M $\Omega$ , or even higher. The output signal of sensors often must be amplified or otherwise conditioned by means of an amplifier. The input bias current of this amplifier can load the sensor output and cause a voltage drop across the source resistance, as shown in [Figure 33](#), where  $(V_{(+INX)} = V_S - I_{(BIAS)} \times R_{(S)})$ . The last term,  $I_{(BIAS)} \times R_{(S)}$ , shows the voltage drop across  $R_{(S)}$ . To prevent errors introduced to the system as a result of this voltage, an op amp with very low input bias current must be used with high impedance sensors. This low current keeps the error contribution by  $I_{(BIAS)} \times R_{(S)}$  less than the input voltage noise of the amplifier, so that the input voltage noise does not become the dominant noise factor. The OPA2356-EP op amp features very low input bias current (typically 200 fA) and is therefore a preferred choice for such applications.

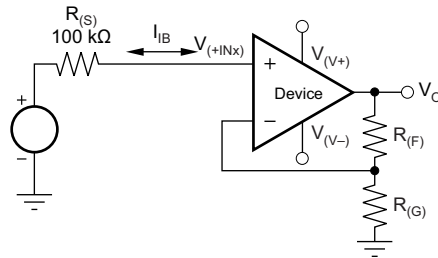
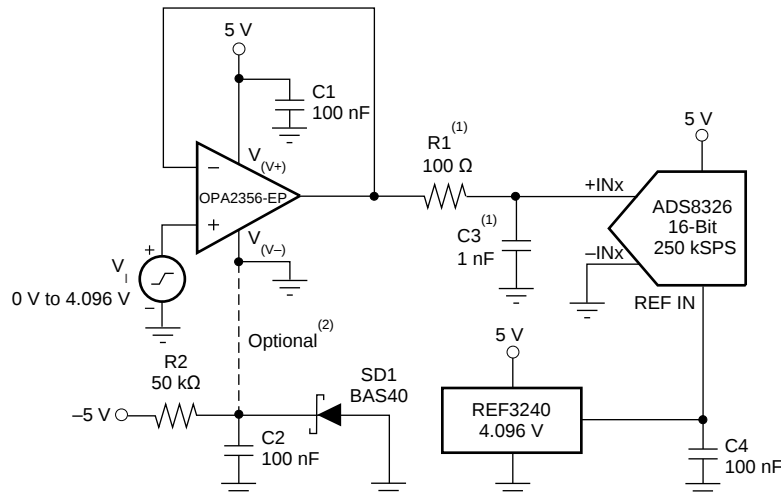


Figure 33. Noise as a Result of  $I_{BIAS}$

### 8.2.3 Driving ADCs

The OPA2356-EP op amps are designed for driving sampling analog-to-digital converters (ADCs) with sampling speeds up to 1 MSPS. The zero-crossover distortion input stage topology allows the OPA2356-EP to drive ADCs without degradation of differential linearity and THD.

The OPA2356-EP can be used to buffer the ADC switched input capacitance and resulting charge injection while providing signal gain. Figure 34 shows the OPA2356-EP configured to drive the ADS8326.



- (1) Suggested value; may require adjustment based on specific application.
- (2) Single-supply applications lose a small number of ADC codes near ground as a result of op amp output swing limitation. If a negative power supply is available, this simple circuit creates a  $-0.3\text{ V}$  supply to allow output swing to true ground potential.

Figure 34. Driving the ADS8326

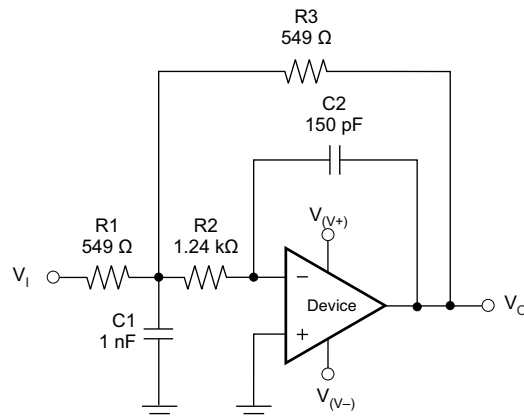
### 8.2.4 Active Filter

The OPA2356-EP is designed for active filter applications that require a wide bandwidth, fast slew rate, low-noise, single-supply operational amplifier. Figure 35 depicts a 500-kHz, second-order, low-pass filter using the multiple-feedback (MFB) topology. The components are selected to provide a maximally-flat Butterworth response. Beyond the cutoff frequency, roll-off is  $-40\text{ dB/dec}$ . The Butterworth response is preferred for applications requiring predictable gain characteristics, such as the anti-aliasing filter used in front of an ADC.

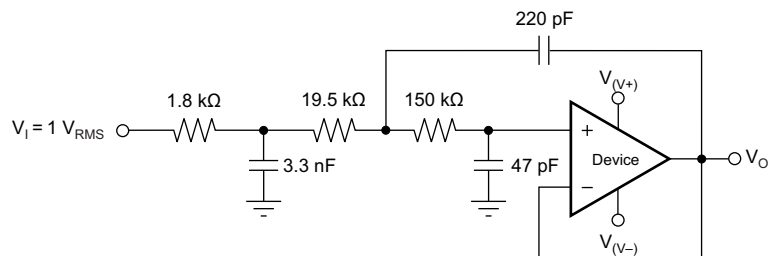
One point to observe when considering the MFB filter is that the output is inverted, relative to the input. If this inversion is not required, or not desired, a noninverting output can be achieved through one of the following options:

1. Adding an inverting amplifier,
2. Adding an additional second-order MFB stage,
3. Using a noninverting filter topology, such as the Sallen-Key (see Figure 36).

MFB and Sallen-Key, low-pass and high-pass filter synthesis is quickly accomplished using TI's *FilterPro™* program. This software is available as a free download at [www.ti.com](http://www.ti.com).



**Figure 35. Second-Order Butterworth 500-kHz Low-Pass Filter**



**Figure 36. OPA2356-EP Configured as a Three-Pole, 20-kHz, Sallen-Key Filter**

## 9 Power Supply Recommendations

The OPA2356-EP is specified for operation from 2.7 to 5.5 V ( $\pm 1.35$  to  $\pm 2.75$  V); many specifications apply from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Parameters that can exhibit significant variance with regard to operating voltage or temperature are shown in the [Typical Characteristics](#) section.

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 Guidelines](#) section.

Power dissipation depends on power-supply voltage, signal, and load conditions. With DC signals, power dissipation is equal to the product of output current times the voltage across the conducting output transistor,  $V_S - V_O$ . Minimize power dissipation by using the lowest possible power-supply voltage required to ensure the required output voltage swing.

For resistive loads, the maximum power dissipation occurs at a DC output voltage of one-half the power-supply voltage. Dissipation with AC signals is lower.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heat sink. For reliable operation, limit junction temperature to  $150^{\circ}\text{C}$  maximum. To estimate the margin of safety in a complete design, increase the ambient temperature to trigger the thermal protection at  $160^{\circ}\text{C}$ . The thermal protection must trigger more than  $35^{\circ}\text{C}$  above the maximum expected ambient condition of the application.

## 10 Layout

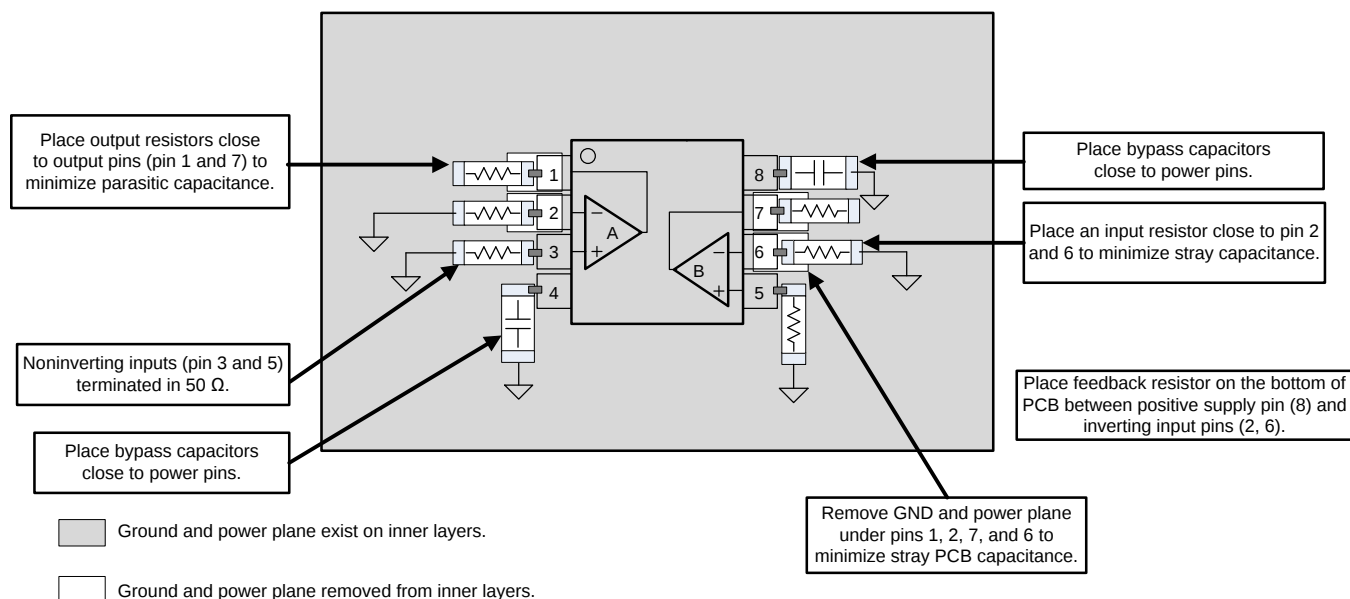
### 10.1 Layout Guidelines

Good high-frequency PC board layout techniques should be employed for the OPA2356-EP. Generous use of ground planes, short direct signal traces, and a suitable bypass capacitor located at the V+ pin assure clean, stable operation. Large areas of copper also provide a means of dissipating heat that is generated within the amplifier in normal operation.

Sockets are not recommended for use with any high-speed amplifier.

A 10- $\mu$ F ceramic bypass capacitor is the minimum recommended value; adding a 1- $\mu$ F or larger tantalum capacitor in parallel can be beneficial when driving a low-resistance load. Providing adequate bypass capacitance is essential to achieving very low harmonic and intermodulation distortion.

### 10.2 Layout Example



**Figure 37. Example Layout**

## 11 デバイスおよびドキュメントのサポート

### 11.1 ドキュメントのサポート

#### 11.1.1 関連資料

関連資料については、以下を参照してください。

- テキサス・インスツルメンツ、[『Compensate transimpedance amplifiers intuitively』アプリケーション・レポート](#) (英語)
- テキサス・インスツルメンツ、[『Noise analysis of FET transimpedance amplifiers』アプリケーション・レポート](#) (英語)
- テキサス・インスツルメンツ、[『Noise analysis for high-speed op amps』アプリケーション・レポート](#) (英語)
- テキサス・インスツルメンツ、[『FilterPro™』ユーザー・ガイド](#) (英語)

#### 11.2 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[ti.com](http://ti.com)のデバイス製品フォルダを開いてください。右上の「アラートを受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

#### 11.3 コミュニティ・リソース

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.

#### 11.4 商標

E2E is a trademark of Texas Instruments.

FilterPro is a trademark of Texas Instruments Incorporated.

All other trademarks are the property of their respective owners.

#### 11.5 静電気放電に関する注意事項



すべての集積回路は、適切なESD保護方法を用いて、取扱いと保存を行うようにして下さい。

静電気放電はわずかな性能の低下から完全なデバイスの故障に至るまで、様々な損傷を与えます。高精度の集積回路は、損傷に対して敏感であり、極めてわずかなパラメータの変化により、デバイスに規定された仕様に適合しなくなる場合があります。

#### 11.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 12 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| OPA2356MDGKREP   | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | RoHS & Green    | NIPDAUAG                             | Level-3-260C-168 HR  | -55 to 125   | AYIH                    | <a href="#">Samples</a> |
| OPA2356MDGKTEP   | ACTIVE        | VSSOP        | DGK                | 8    | 250            | RoHS & Green    | NIPDAUAG                             | Level-3-260C-168 HR  | -55 to 125   | AYIH                    | <a href="#">Samples</a> |
| V62/18609-01XE   | ACTIVE        | VSSOP        | DGK                | 8    | 250            | RoHS & Green    | NIPDAUAG                             | Level-3-260C-168 HR  | -55 to 125   | AYIH                    | <a href="#">Samples</a> |
| V62/18609-01XE-R | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | RoHS & Green    | NIPDAUAG                             | Level-3-260C-168 HR  | -55 to 125   | AYIH                    | <a href="#">Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

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

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

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

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

**OBSELETE:** TI has discontinued the production of the device.

<sup>(2)</sup> **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| OPA2356MDGKREP | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2356MDGKTEP | VSSOP        | DGK             | 8    | 250  | 180.0              | 12.4               | 5.3     | 3.4     | 1.4     | 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) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| OPA2356MDGKREP | VSSOP        | DGK             | 8    | 2500 | 356.0       | 356.0      | 35.0        |
| OPA2356MDGKTEP | VSSOP        | DGK             | 8    | 250  | 210.0       | 185.0      | 35.0        |

## DGK (S-PDSO-G8)

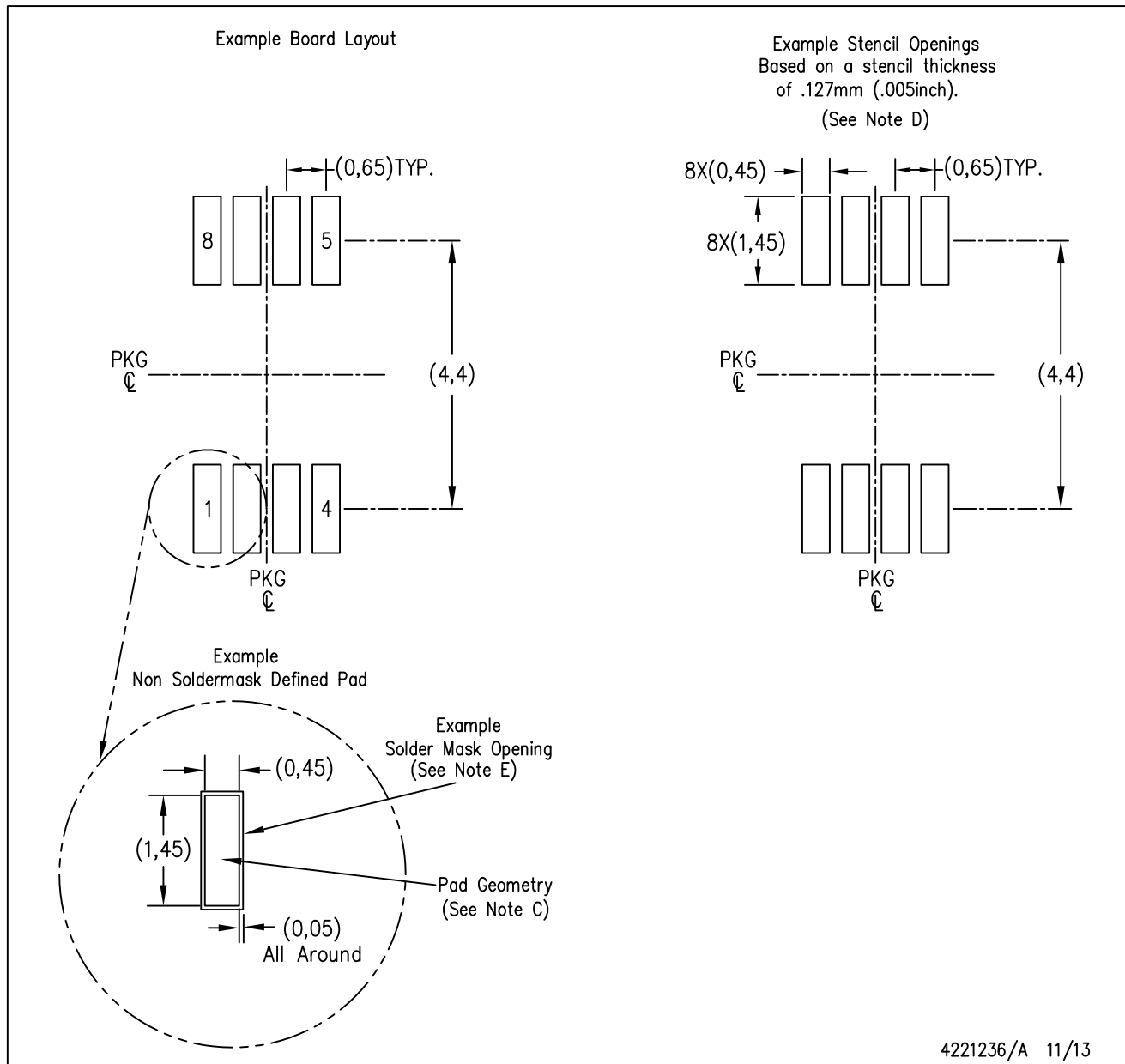
## PLASTIC SMALL-OUTLINE PACKAGE



- 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.

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



- 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.

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