

# OPAx837 低消費電力、高精度、105MHz電圧帰還型オペアンプ

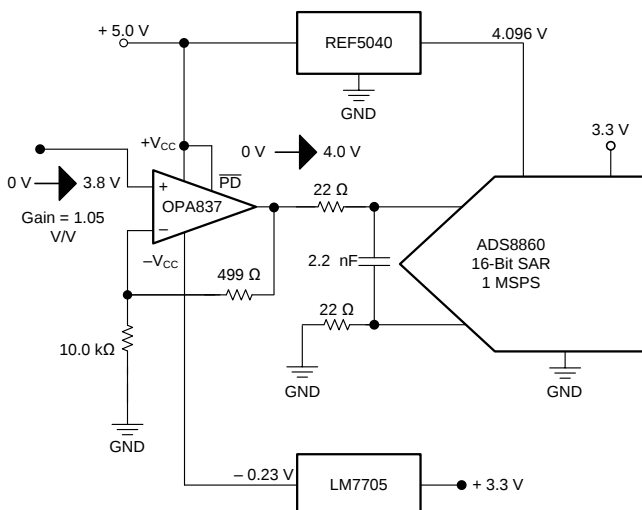
## 1 特長

- ・ 帯域幅: 105MHz ( $A_V = 1V/V$ )
- ・ 非常に低い(トリムされた)消費電流: 600 $\mu$ A
- ・ ゲイン帯域幅積: 50MHz
- ・ スルーレート: 105V/ $\mu$ s
- ・ 負レール入力、レール・ツー・レール出力
- ・ 単一電源動作電圧範囲: 2.7V~5.4V
- ・ 25°Cでの入力オフセット:  $\pm 130\mu$ V (最大値)
- ・ 入力オフセット電圧ドリフト(DCKパッケージ):  $< \pm 1.6\mu$ V/ $^{\circ}$ C(最大値)
- ・ 入力電圧ノイズ: 4.7nV/ $\sqrt{\text{Hz}}$  ( $> 100\text{Hz}$ )
- ・ HD2: 2V<sub>PP</sub>、100kHzにおいて-120dBc
- ・ HD3: 2V<sub>PP</sub>、100kHzにおいて-145dBc
- ・ セトリング時間(0.1%) : 35ns (0.5Vステップ)
- ・ シャットダウン電流: 5 $\mu$ A、  
パワー・スケーリング・アプリケーションで  
シャットダウンから高速でリカバリ

## 2 アプリケーション

- ・ 12ビット~16ビットの低消費電力SARドライバ
- ・ 高精度ADCリファレンス・バッファ
- ・ 超低消費電力アクティブ・フィルタ
- ・ 低消費電力トランスインピーダンス・アンプ
- ・ センサ信号コンディショニング
- ・ ウェアラブル・デバイス
- ・ ローサイド電流センシング

真のグランド入力および出力範囲を備えた低消費電力、低ノイズ、高精度、シングルエンドSAR ADCドライバ



## 3 概要

OPA837およびOPA2837はシングルおよびデュアル・チャンネルのユニティ・ゲイン安定、電圧帰還型アンプで、高精度オペアンプとして最高の電力対帯域幅比(MHz/mW)を実現しています。5Vの単一電源でチャンネルごとの消費電流を600 $\mu$ Aに抑えたこれらの3.0mWデバイスは、1V/Vのゲインで105MHzの帯域幅を提供します。 $\pm 0.4\mu$ V/ $^{\circ}$ Cの標準( $\pm 1\sigma$ )ドリフトで、 $\pm 130\mu$ V (最大値)という非常に低い値のトリムされたオフセット電圧を実現します。

OPAx837は、シングルエンドの逐次比較型(SAR)アナログ/デジタル・コンバータ(ADC)駆動アプリケーションに最適で、3mWの静止電力で4.7nV/ $\sqrt{\text{Hz}}$ という極めて低い入力スポット・ノイズ・レベルを実現します。50MHzの非常に高いゲイン帯域幅積により、SAR ADCドライバ・アプリケーションでの急速充電電流の供給に必要な高周波数に対して、低い出力インピーダンスを提供します。この低いダイナミック出力インピーダンスは、高精度ADCを搭載したリファレンス・バッファ・アプリケーションにも適しています。シングル・チャンネルのOPA837は6ピンのSOT-23パッケージ(電源シャットダウン機能が含まれます)と、5ピンのSC70パッケージで供給され、デュアル・チャンネルのOPA2837は8ピンのVSSOPパッケージと、10ピンのWQFNパッケージで供給されます。

OPAx837は、-40°C~+125°Cの広い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)     |
|---------|------------|---------------|
| OPA837  | SOT-23 (6) | 2.90mm×1.60mm |
|         | SC70 (5)   | 2.00mm×1.25mm |
| OPA2837 | VSSOP (8)  | 3.00mm×3.00mm |
|         | WQFN (10)  | 2.00mm×2.00mm |

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にあるパッケージ・オプションについての付録を参照してください。

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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。

| Revision C (August 2018) から Revision D に変更                                                                                                                         | Page |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 「概要」セクションにWQFN (RUN)パッケージへの言及を追加                                                                                                                                   | 1    |
| Added OPA2837 RUN package thermal information to document.                                                                                                         | 6    |
| Changed values of maximum and minimum input-referred offset voltage at $25^\circ\text{C}$ and across temperature in 5 V and 3 V Electrical Characteristics tables. | 7    |
| Changed value of maximum input offset current drift for OPA2837 in 5 V and 3 V Electrical Characteristics tables.                                                  | 8    |
| Changed minimum value of CMRR in 5 V Electrical Characteristics table                                                                                              | 8    |
| 追加 reference to TIDA-01565 reference design in <i>Power-Down Operation</i> section                                                                                 | 24   |
| 追加 reference to TIDA-01565 reference design in <i>1-Bit PGA Operation</i> section                                                                                  | 42   |

| Revision B (July 2018) から Revision C に変更 | Page |
|------------------------------------------|------|
| OPA2837 RUNパッケージをドキュメントに追加               | 1    |

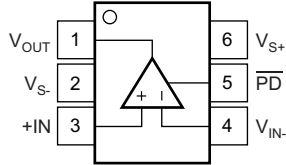
| Revision A (April 2018) から Revision B に変更                                          | Page |
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| Changed input common-mode impedance in 5V and 3V electrical characteristics tables | 8    |

| 2017年9月発行のものから更新                                                                                                       | Page |
|------------------------------------------------------------------------------------------------------------------------|------|
| ドキュメントにOPA2837を追加                                                                                                      | 1    |
| 「特長」の「単一電源動作電圧範囲」箇条書き項目を追加                                                                                             | 1    |
| 表紙の図で「1SPS」を「1MSPS」に変更                                                                                                 | 1    |
| Added footnote to <i>Pin Functions</i> table                                                                           | 4    |
| Changed footnote describing method of computation of slew rate in Electrical Characteristics: $V_S = 5\text{ V}$ table | 7    |
| Changed default test condition in Electrical Characteristics: $V_S = 3\text{ V}$ table                                 | 9    |

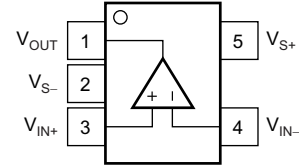
|                                                                                                                                                                                             |    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| • Changed footnote describing method of computation of slew rate in Electrical Characteristics: $V_S = 3\text{ V}$ table .....                                                              | 9  |
| • Changed values for common-mode input range, high in Electrical Characteristics: $V_S = 3\text{ V}$ table .....                                                                            | 10 |
| • Changed values for $V_{OH}$ in Electrical Characteristics: $V_S = 3\text{ V}$ table .....                                                                                                 | 10 |
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| • 変更 <i>gain</i> $-1\text{ V/V}$ to $-2\text{ V/V}$ , swapped legend colors in <i>Inverting Overdrive Recovery</i> figure .....                                                             | 12 |
| • 変更 $V_{OUT} = 2\text{ V}_{PP}$ to $V_{OUT} = 1\text{ V}_{PP}$ in conditions of <i>Typical Characteristics: <math>V_S = 3.0\text{ V}</math></i> section .....                              | 14 |
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| • 変更 $V_{OUT} = 2\text{ V}_{PP}$ to $V_{OUT} = 1\text{ V}_{PP}$ in <i>Harmonic Distortion vs Gain Magnitude</i> figure conditions .....                                                     | 16 |
| • 変更 y-axis caption in <i>Turn-On Time to Sinusoidal Input</i> and <i>Turn-Off Time to Sinusoidal Input</i> figures .....                                                                   | 19 |
| • 追加 OPA838 row to <i>Device Family Comparison</i> table .....                                                                                                                              | 23 |
| • 変更 EVM link in <i>Split-Supply Operation</i> section from OPA837DBV to OPA835DBV .....                                                                                                    | 26 |
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## 5 Pin Configuration and Functions

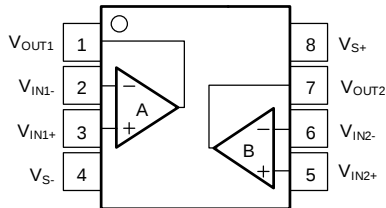
**OPA837 DBV Package**  
6-Pin SOT-23  
Top View



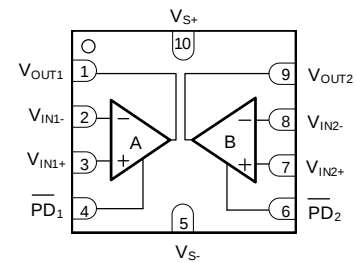
**OPA837 DCK Package**  
5-Pin SC70  
Top View



**OPA2837 DGK Package**  
8-Pin VSSOP  
Top View



**OPA2837 RUN Package**  
10-Pin WQFN  
Top View



### Pin Functions

| PIN                      |        |       |         |      | FUNCTION <sup>(1)</sup> | DESCRIPTION                                                                              |
|--------------------------|--------|-------|---------|------|-------------------------|------------------------------------------------------------------------------------------|
| NAME                     | OPA837 |       | OPA2837 |      |                         |                                                                                          |
|                          | SOT-23 | SC-70 | VSSOP   | WQFN |                         |                                                                                          |
| $\overline{\text{PD}}$   | 5      | —     | —       | —    | I                       | Amplifier power down.<br>Low = disabled, high = normal operation (pin must be driven).   |
| $\overline{\text{PD}}_1$ | —      | —     | —       | 4    | I                       | Amplifier 1 power down.<br>Low = disabled, high = normal operation (pin must be driven). |
| $\overline{\text{PD}}_2$ | —      | —     | —       | 6    | I                       | Amplifier 2 power down.<br>Low = disabled, high = normal operation (pin must be driven). |
| V <sub>IN−</sub>         | 4      | 4     | —       | —    | I                       | Inverting input pin                                                                      |
| V <sub>IN+</sub>         | 3      | 3     | —       | —    | I                       | Noninverting input pin                                                                   |
| V <sub>IN1−</sub>        | —      | —     | 2       | 2    | I                       | Amplifier 1 inverting input pin                                                          |
| V <sub>IN1+</sub>        | —      | —     | 3       | 3    | I                       | Amplifier 1 noninverting input pin                                                       |
| V <sub>IN2−</sub>        | —      | —     | 6       | 8    | I                       | Amplifier 2 inverting input pin                                                          |
| V <sub>IN2+</sub>        | —      | —     | 5       | 7    | I                       | Amplifier 2 noninverting input pin                                                       |
| V <sub>OUT</sub>         | 1      | 1     | —       | —    | O                       | Output pin                                                                               |
| V <sub>OUT1</sub>        | —      | —     | 1       | 1    | O                       | Amplifier 1 output pin                                                                   |
| V <sub>OUT2</sub>        | —      | —     | 7       | 9    | O                       | Amplifier 2 output pin                                                                   |
| V <sub>S−</sub>          | 2      | 2     | 4       | 5    | P                       | Negative power-supply pin                                                                |
| V <sub>S+</sub>          | 6      | 5     | 8       | 10   | P                       | Positive power-supply input                                                              |

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

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

|                      |                                                   | MIN                                             | MAX            | UNIT       |
|----------------------|---------------------------------------------------|-------------------------------------------------|----------------|------------|
| $V_{S-}$ to $V_{S+}$ | Supply voltage                                    |                                                 | 5.5            | V          |
|                      | Supply turn-on/off maximum $dV/dT$ <sup>(2)</sup> |                                                 | 1              | V/ $\mu$ s |
| $V_I$                | Input voltage                                     | $V_{S-} - 0.5$                                  | $V_{S+} + 0.5$ | V          |
| $V_{ID}$             | Differential input voltage                        |                                                 | $\pm 1$        | V          |
| $I_I$                | Continuous input current                          |                                                 | $\pm 10$       | mA         |
| $I_O$                | Continuous output current <sup>(3)</sup>          |                                                 | $\pm 20$       | mA         |
|                      | Continuous power dissipation                      | See <a href="#">Thermal Information: OPA837</a> |                |            |
| $T_J$                | Maximum junction temperature                      |                                                 | 150            | °C         |
| $T_A$                | Operating free-air temperature                    | -40                                             | 125            | °C         |
| $T_{stg}$            | 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) Staying below this  $\pm$  supply turn-on edge rate prevents the edge-triggered ESD absorption device across the supply pins from turning on.
- (3) Long-term continuous output current for electromigration limits.

### 6.2 ESD Ratings

|             |                         |                                                                                | VALUE      | UNIT |
|-------------|-------------------------|--------------------------------------------------------------------------------|------------|------|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | $\pm 1500$ | V    |
|             |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | $\pm 1000$ |      |

- (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 |
|----------|-----------------------|-----|-----|-----|------|
| $V_{S+}$ | Single-supply voltage | 2.7 | 5   | 5.4 | V    |
| $T_A$    | Ambient temperature   | -40 | 25  | 125 | °C   |

## 6.4 Thermal Information: OPA837

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA837           |               | UNIT |
|-------------------------------|----------------------------------------------|------------------|---------------|------|
|                               |                                              | DBV<br>(SOT23-6) | DCK<br>(SC70) |      |
|                               |                                              | 6 PINS           | 5 PINS        |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 194              | 203           | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 129              | 152           | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 39               | 76            | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 26               | 58            | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 39               | 76            | °C/W |

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

## 6.5 Thermal Information: OPA2837

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA2837          |                  | UNIT |
|-------------------------------|----------------------------------------------|------------------|------------------|------|
|                               |                                              | RUN<br>(WQFN-10) | DGK<br>(VSSOP-8) |      |
|                               |                                              | 10 PINS          | 8 PINS           |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 124.9            | 182              | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 72.0             | 63.5             | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 63.2             | 103.6            | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 4.3              | 7.9              | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 63.0             | 101.8            | °C/W |

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

## 6.6 Electrical Characteristics: $V_S = 5\text{ V}$

at  $V_{S+} = 5\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

| PARAMETER             |                                           | TEST CONDITIONS                                                          | MIN  | TYP        | MAX | UNIT                         | TEST LEVEL <sup>(1)</sup> |
|-----------------------|-------------------------------------------|--------------------------------------------------------------------------|------|------------|-----|------------------------------|---------------------------|
| <b>AC PERFORMANCE</b> |                                           |                                                                          |      |            |     |                              |                           |
| SSBW                  | Small-signal bandwidth                    | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 1$                                  | 90   | 105        |     | MHz                          | C                         |
|                       |                                           | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 2$                                  |      | 45         |     |                              | C                         |
|                       |                                           | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 10$                                 |      | 5          |     |                              | C                         |
| GBP                   | Gain-bandwidth product                    | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 10$                                 | 45   | 50         |     | MHz                          | C                         |
| LSBW                  | Large-signal bandwidth                    | $V_{OUT} = 2\text{ V}_{PP}$ , $G = 2$                                    |      | 26         |     | MHz                          | C                         |
|                       | Bandwidth for 0.1-dB flatness             | $V_{OUT} = 200\text{ mV}_{PP}$ , $G = 2$                                 |      | 6          |     | MHz                          | C                         |
| SR                    | Slew rate                                 | From LSBW <sup>(2)</sup>                                                 |      | 105        |     | V/ $\mu\text{s}$             | C                         |
| $t_R$ , $t_F$         | Rise, fall time                           | $V_{OUT} = 0.5\text{-V}$ step, $G = 2$ , input $t_R = 10\text{ ns}$      |      | 10         | 11  | ns                           | C                         |
|                       | Overshoot                                 | $V_{OUT} = 2\text{-V}$ step, $G = 2$ , input $t_R = 40\text{ ns}$        |      | 7.0%       |     |                              | C                         |
|                       | Settling time to 0.1%                     | $V_{OUT} = 2.0\text{-V}$ step, $G = 1$ , input $t_R = 4\text{ ns}$       |      | 25         |     | ns                           | C                         |
|                       | Settling time to 0.01%                    | $V_{OUT} = 2.0\text{-V}$ step, $G = 1$ , input $t_R = 4\text{ ns}$       |      | 40         |     | ns                           | C                         |
| HD2                   | Second-order harmonic distortion          | $f = 100\text{ kHz}$ , $V_O = 2\text{ V}_{PP}$ , $G = 1$ (see Figure 73) |      | -120       |     | dBc                          | C                         |
| HD3                   | Third-order harmonic distortion           | $f = 100\text{ kHz}$ , $V_O = 2\text{ V}_{PP}$ , $G = 1$ (see Figure 73) |      | -145       |     | dBc                          | C                         |
|                       | Input voltage noise                       | $f = 500\text{ Hz}$                                                      |      | 4.7        |     | $\text{nV}/\sqrt{\text{Hz}}$ | C                         |
|                       | Voltage noise 1/f corner frequency        | See Figure 39                                                            |      | 35         |     | Hz                           | C                         |
|                       | Input current noise                       | $f = 20\text{ kHz}$                                                      |      | 0.4        |     | $\text{pA}/\sqrt{\text{Hz}}$ | C                         |
|                       | Current noise 1/f corner frequency        | See Figure 39                                                            |      | 5          |     | kHz                          | C                         |
|                       | Overdrive recovery time                   | $G = 2$ , 2x output overdrive (see Figure 30)                            |      | 75         |     | ns                           | C                         |
|                       | Closed-loop output impedance              | $f = 1\text{ MHz}$ , $G = 1$ (see Figure 38)                             |      | 0.14       |     | $\Omega$                     | C                         |
|                       | Channel-to-channel crosstalk (OPA2837)    | $f = 10\text{ kHz}$                                                      |      | -126       |     | dBc                          | C                         |
| <b>DC PERFORMANCE</b> |                                           |                                                                          |      |            |     |                              |                           |
| $A_{OL}$              | Open-loop voltage gain                    | $V_O = \pm 2\text{ V}$ , $R_L = 2\text{ k}\Omega$                        | 120  | 135        |     | dB                           | A                         |
|                       | Input-referred offset voltage             | $T_A \approx 25^\circ\text{C}$                                           | -165 | $\pm 30$   | 165 | $\mu\text{V}$                | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$ (DCK package)             | -205 | $\pm 30$   | 235 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (DCK package)           | -269 | $\pm 30$   | 261 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (DCK package)          | -269 | $\pm 30$   | 325 |                              | B                         |
|                       | Input offset voltage drift <sup>(3)</sup> | DCK package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$           | -1.6 | $\pm 0.4$  | 1.6 | $\mu\text{V}/^\circ\text{C}$ | B                         |
|                       |                                           | DBV, RUN package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$      | -2.0 | $\pm 0.4$  | 2.0 |                              | B                         |
|                       |                                           | DGK package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$           |      | $\pm 0.67$ |     |                              | B                         |
|                       | Input bias current <sup>(4)</sup>         | $T_A \approx 25^\circ\text{C}$                                           | 150  | 340        | 520 | nA                           | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$                           | 50   | 340        | 664 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$                         | 50   | 340        | 718 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | 50   | 340        | 850 |                              | B                         |
|                       | Input bias current drift <sup>(3)</sup>   | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | 0.8  | 1.5        | 3.3 | $\text{nA}/^\circ\text{C}$   | B                         |
|                       | Input offset current                      | $T_A \approx 25^\circ\text{C}$ (OPA837)                                  | -40  | $\pm 6$    | 40  | nA                           | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$                           | -46  | $\pm 6$    | 52  |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$                         | -56  | $\pm 6$    | 55  |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | -56  | $\pm 6$    | 65  |                              | B                         |
|                       |                                           | $T_A \approx 25^\circ\text{C}$ (OPA2837)                                 | -60  | $\pm 8$    | 60  |                              | A                         |

(1) Test levels (all values set by characterization and simulation): (A) 100% tested at  $25^\circ\text{C}$ , overtemperature limits by characterization and simulation; (B) Not tested in production, limits set by characterization and simulation; (C) Typical value only for information.

(2) This slew rate is the average of the rising and falling time estimated from the large-signal bandwidth as:  $(0.8 \times V_{PEAK} / \sqrt{2}) \times 2\pi \times f_{-3dB}$  where this  $f_{-3dB}$  is the typical measured 2- $V_{PP}$  bandwidth at gains of 1 V/V.

(3) Input offset voltage drift, input bias current drift, and input offset current drift are average values calculated by taking data at the end points, computing the difference, and dividing by the temperature range. Typical drift specifications are  $\pm 1\sigma$ . Maximum drift specifications are set by min/max sample packaged test data using a wafer-level screened drift. Min/Max drift is not specified by final automated test equipment (ATE) nor by QA sample testing.

(4) Current is considered positive out of the pin.

**Electrical Characteristics:  $V_S = 5\text{ V}$  (continued)**

at  $V_{S+} = 5\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                              |                                                        | TEST CONDITIONS                                                                                                       | MIN      | TYP                 | MAX | UNIT                                 | TEST LEVEL <sup>(1)</sup> |
|----------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|----------|---------------------|-----|--------------------------------------|---------------------------|
|                                        | Input offset current drift <sup>(3)</sup>              | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                     | -250     | $\pm 40$            | 250 | $\text{pA}/^\circ\text{C}$           | B                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (OPA2837)                                                           | -270     | $\pm 80$            | 330 |                                      | B                         |
|                                        | Input-referred offset voltage mismatch                 | $T_A \approx 25^\circ\text{C}$ (OPA2837)                                                                              | -220     | 50                  | 220 | $\mu\text{V}$                        | A                         |
| <b>INPUT</b>                           |                                                        |                                                                                                                       |          |                     |     |                                      |                           |
|                                        | Common-mode input range, low                           | $T_A \approx 25^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                                     |          | -0.2                | 0   | V                                    | A                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                  |          | -0.2                | 0   |                                      | B                         |
|                                        | Common-mode input range, high                          | $T_A \approx 25^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                                     | 3.7      | 3.8                 |     | V                                    | A                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                  | 3.7      | 3.8                 |     |                                      | B                         |
| CMRR                                   | Common-mode rejection ratio                            |                                                                                                                       | 91       | 110                 |     | dB                                   | A                         |
|                                        | Input impedance common-mode                            |                                                                                                                       |          | $175 \parallel 1.5$ |     | $\text{M}\Omega \parallel \text{pF}$ | C                         |
|                                        | Input impedance differential mode                      |                                                                                                                       |          | $180 \parallel 0.5$ |     | $\text{k}\Omega \parallel \text{pF}$ | C                         |
| <b>OUTPUT</b>                          |                                                        |                                                                                                                       |          |                     |     |                                      |                           |
| $V_{OL}$                               | Output voltage, low                                    | $T_A \approx 25^\circ\text{C}$ , $G = 2$                                                                              |          | 0.05                | 0.1 | V                                    | A                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $G = 5$                                                           |          | 0.05                | 0.1 |                                      | B                         |
| $V_{OH}$                               | Output voltage, high                                   | $T_A \approx 25^\circ\text{C}$ , $G = 2$                                                                              | 4.9      | 4.95                |     | V                                    | A                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $G = 5$                                                           | 4.8      | 4.9                 |     |                                      | B                         |
|                                        | Maximum current into a resistive load                  | $T_A \approx 25^\circ\text{C}$ , $\pm 1.6\text{ V}$ into $27\ \Omega$ , $V_{IO} < 2\text{ mV}$                        | $\pm 58$ | $\pm 70$            |     | mA                                   | A                         |
|                                        | Linear current into a resistive load                   | $T_A \approx 25^\circ\text{C}$ , $\pm 1.7\text{ V}$ into $37.4\ \Omega$ , $A_{OL} > 80\text{ dB}$                     | $\pm 45$ | $\pm 50$            |     | mA                                   | A                         |
|                                        | Linear current into a resistive load overtemperature   | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $\pm 1.31\text{ V}$ into $37.4\ \Omega$ , $A_{OL} > 80\text{ dB}$ | $\pm 35$ | $\pm 45$            |     | mA                                   | C                         |
|                                        | Closed-loop output impedance                           | Gain of $1\text{ V/V}$ , $\pm 30\text{-mA DC}$                                                                        |          | 0.6                 |     | $\text{m}\Omega$                     | C                         |
| <b>POWER SUPPLY</b>                    |                                                        |                                                                                                                       |          |                     |     |                                      |                           |
|                                        | Specified operating voltage                            |                                                                                                                       | 2.7      |                     | 5.4 | V                                    | B                         |
|                                        | Quiescent operating current per amplifier (5-V supply) | $T_A \approx 25^\circ\text{C}$ <sup>(5)</sup>                                                                         | 564      | 592                 | 625 | $\mu\text{A}$                        | A                         |
|                                        |                                                        | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                     | 408      | 592                 | 865 |                                      | B                         |
|                                        | Supply current temperature coefficient per amplifier   | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (see Figure 57)                                                     | 1.1      | 1.9                 | 2.4 | $\mu\text{A}/^\circ\text{C}$         | B                         |
| +PSRR                                  | Positive power-supply rejection ratio                  |                                                                                                                       | 95       | 110                 |     | dB                                   | A                         |
| -PSRR                                  | Negative power-supply rejection ratio                  |                                                                                                                       | 92       | 108                 |     | dB                                   | A                         |
| <b>POWER DOWN (Pin Must be Driven)</b> |                                                        |                                                                                                                       |          |                     |     |                                      |                           |
|                                        | Enable voltage threshold                               | Specified on above $V_{S-} + 1.5\text{ V}$                                                                            |          |                     | 1.5 | V                                    | A                         |
|                                        | Disable voltage threshold                              | Specified off below $V_{S-} + 0.55\text{ V}$                                                                          | 0.55     |                     |     | V                                    | A                         |
|                                        | Power-down pin bias current                            | $\overline{\text{PD}} = 0\text{ V}$ to $V_{S+}$                                                                       | -50      |                     | 50  | nA                                   | A                         |
|                                        | Power-down quiescent current                           | $\overline{\text{PD}} \leq 0.55\text{ V}$                                                                             | 4        | 5                   | 10  | $\mu\text{A}$                        | A                         |
|                                        | Power-down quiescent current over temperature          | $\overline{\text{PD}} \leq 0.55\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                         |          |                     | 10  | $\mu\text{A}$                        | B                         |
|                                        | Turnon time delay                                      | Time from $\overline{\text{PD}} = \text{high}$ to $V_{OUT} = 90\%$ of final value                                     |          | 300                 |     | ns                                   | C                         |
|                                        | Turnoff time delay                                     | Time from $\overline{\text{PD}} = \text{low}$ to $V_{OUT} = 10\%$ of original value                                   |          | 100                 |     | ns                                   | C                         |

- (5) The typical specification is at  $25^\circ\text{C}$   $T_J$ . The min, max limits are expanded for the automated test equipment (ATE) to account for an ambient range from  $22^\circ\text{C}$  to  $32^\circ\text{C}$  with a  $2\text{-}\mu\text{A}/^\circ\text{C}$  temperature coefficient on the supply current.

## 6.7 Electrical Characteristics: $V_S = 3\text{ V}$

at  $V_{S+} = 3\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

| PARAMETER             |                                           | TEST CONDITIONS                                                          | MIN  | TYP        | MAX | UNIT                         | TEST LEVEL <sup>(1)</sup> |
|-----------------------|-------------------------------------------|--------------------------------------------------------------------------|------|------------|-----|------------------------------|---------------------------|
| <b>AC PERFORMANCE</b> |                                           |                                                                          |      |            |     |                              |                           |
| SSBW                  | Small-signal bandwidth                    | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 1$                                  | 85   | 105        |     | MHz                          | C                         |
|                       |                                           | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 2$                                  |      | 45         |     |                              | C                         |
|                       |                                           | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 10$                                 |      | 5          |     |                              | C                         |
| GBP                   | Gain-bandwidth product                    | $V_{OUT} = 20\text{ mV}_{PP}$ , $G = 10$                                 | 40   | 50         |     | MHz                          | C                         |
| LSBW                  | Large-signal bandwidth                    | $V_{OUT} = 1\text{ V}_{PP}$ , $G = 2$                                    |      | 30         |     | MHz                          | C                         |
|                       | Bandwidth for 0.1-dB flatness             | $V_{OUT} = 200\text{ mV}_{PP}$ , $G = 2$                                 |      | 6          |     | MHz                          | C                         |
| SR                    | Slew rate                                 | From LSBW <sup>(2)</sup>                                                 |      | 65         |     | V/ $\mu\text{s}$             | C                         |
| $t_R$ , $t_F$         | Rise, fall time                           | $V_{OUT} = 0.5\text{-V}$ step, $G = 2$ , input $t_R = 10\text{ ns}$      |      | 10         | 11  | ns                           | C                         |
|                       | Overshoot                                 | $V_{OUT} = 2\text{-V}$ step, $G = 2$ , input $t_R = 40\text{ ns}$        |      | 7%         |     |                              | C                         |
|                       | Settling time to 0.1%                     | $V_{OUT} = 0.5\text{-V}$ step, $G = 1$ , input $t_R = 4\text{ ns}$       |      | 35         |     | ns                           | C                         |
|                       | Settling time to 0.01%                    | $V_{OUT} = 0.5\text{-V}$ step, $G = 1$ , input $t_R = 4\text{ ns}$       |      | 50         |     | ns                           | C                         |
| HD2                   | Second-order harmonic distortion          | $f = 100\text{ kHz}$ , $V_O = 1\text{ V}_{PP}$ , $G = 1$ (see Figure 73) |      | -125       |     | dBc                          | C                         |
| HD3                   | Third-order harmonic distortion           | $f = 100\text{ kHz}$ , $V_O = 1\text{ V}_{PP}$ , $G = 1$ (see Figure 73) |      | -138       |     | dBc                          | C                         |
|                       | Input voltage noise                       | $f = 500\text{ Hz}$                                                      |      | 4.9        |     | $\text{nV}/\sqrt{\text{Hz}}$ | C                         |
|                       | Voltage noise 1/f corner frequency        | See Figure 39                                                            |      | 35         |     | Hz                           | C                         |
|                       | Input current noise                       | $f = 10\text{ kHz}$                                                      |      | 0.4        |     | $\text{pA}/\sqrt{\text{Hz}}$ | C                         |
|                       | Current noise 1/f corner frequency        | See Figure 39                                                            |      | 5          |     | kHz                          | C                         |
|                       | Overdrive recovery time                   | $G = 2$ , 2x output overdrive (see Figure 29)                            |      | 65         |     | ns                           | C                         |
|                       | Closed-loop output impedance              | $f = 1\text{ MHz}$ , $G = 1$ (see Figure 38)                             |      | 0.14       |     | $\Omega$                     | C                         |
|                       | Channel-to-channel crosstalk (OPA2837)    | $f = 10\text{ kHz}$                                                      |      | -126       |     | dBc                          | C                         |
| <b>DC PERFORMANCE</b> |                                           |                                                                          |      |            |     |                              |                           |
| $A_{OL}$              | Open-loop voltage gain                    | $V_O = \pm 1\text{ V}$ , $R_L = 2\text{ k}\Omega$                        | 120  | 133        |     | dB                           | A                         |
|                       |                                           | $V_O = \pm 1\text{ V}$ , $R_L = 2\text{ k}\Omega$ (OPA2837)              | 110  | 133        |     |                              | A                         |
|                       | Input-referred offset voltage             | $T_A \approx 25^\circ\text{C}$                                           | -165 | $\pm 30$   | 165 | $\mu\text{V}$                | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$                           | -205 | $\pm 30$   | 235 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$                         | -269 | $\pm 30$   | 261 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | -269 | $\pm 30$   | 325 |                              | B                         |
|                       | Input offset voltage drift <sup>(3)</sup> | DCK package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$           | -1.6 | $\pm 0.4$  | 1.6 | $\mu\text{V}/^\circ\text{C}$ | B                         |
|                       |                                           | DBV, RUN package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$      | -2.0 | $\pm 0.4$  | 2.0 |                              | B                         |
|                       |                                           | DGK package, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$           |      | $\pm 0.67$ |     |                              | B                         |
|                       | Input bias current <sup>(4)</sup>         | $T_A \approx 25^\circ\text{C}$                                           | 145  | 320        | 510 | nA                           | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$                           | 50   | 320        | 659 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$                         | 50   | 320        | 708 |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | 50   | 320        | 840 |                              | B                         |
|                       | Input bias current drift <sup>(3)</sup>   | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | 0.8  | 1.5        | 3.3 | $\text{nA}/^\circ\text{C}$   | B                         |
|                       | Input offset current                      | $T_A \approx 25^\circ\text{C}$ (OPA837)                                  | -40  | $\pm 6$    | 40  | nA                           | A                         |
|                       |                                           | $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$                           | -46  | $\pm 6$    | 52  |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$                         | -56  | $\pm 6$    | 55  |                              | B                         |
|                       |                                           | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                        | -56  | $\pm 6$    | 65  |                              | B                         |
|                       |                                           | $T_A \approx 25^\circ\text{C}$ (OPA2837)                                 | -60  | $\pm 8$    | 60  |                              | A                         |

- (1) Test levels (all values set by characterization and simulation): (A) 100% tested at  $25^\circ\text{C}$ , overtemperature limits by characterization and simulation; (B) Not tested in production, limits set by characterization and simulation; (C) Typical value only for information.
- (2) This slew rate is the average of the rising and falling time estimated from the large-signal bandwidth as:  $(0.8 \times V_{PEAK} / \sqrt{2}) \times 2\pi \times f_{-3dB}$  where this  $f_{-3dB}$  is the typical measured 2-Vpp bandwidth at gains of 1V/V.
- (3) Input offset voltage drift, input bias current drift, and input offset current drift are average values calculated by taking data at the end points, computing the difference, and dividing by the temperature range. Typical drift specifications are  $\pm 1\sigma$ . Maximum drift specifications are set by min/max sample packaged test data using a wafer-level screened drift. Min/Max drift is not specified by final automated test equipment (ATE) nor by QA sample testing.
- (4) Current is considered positive out of the pin.

**Electrical Characteristics:  $V_S = 3\text{ V}$  (continued)**

at  $V_{S+} = 3\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

| PARAMETER                              |                                                                 | TEST CONDITIONS                                                                                                     | MIN      | TYP                 | MAX | UNIT                                 | TEST LEVEL <sup>(1)</sup> |
|----------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|----------|---------------------|-----|--------------------------------------|---------------------------|
|                                        | Input offset current drift <sup>(3)</sup>                       | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                   | -250     | $\pm 40$            | 250 | $\text{pA}/^\circ\text{C}$           | B                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (OPA2837)                                                         | -250     | $\pm 80$            | 330 |                                      | B                         |
|                                        | Input-referred offset voltage mismatch                          | $T_A \approx 25^\circ\text{C}$ (OPA2837)                                                                            | -220     | 50                  | 220 | $\mu\text{V}$                        | A                         |
| <b>INPUT</b>                           |                                                                 |                                                                                                                     |          |                     |     |                                      |                           |
|                                        | Common-mode input range, low                                    | $T_A \approx 25^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                                   |          | -0.2                | 0   | V                                    | A                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                |          | -0.2                | 0   |                                      | B                         |
|                                        | Common-mode input range, high                                   | $T_A \approx 25^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                                   | 1.7      | 1.8                 |     | V                                    | A                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , < 3-dB degradation in CMRR limit                                | 1.7      | 1.8                 |     |                                      | B                         |
| CMRR                                   | Common-mode rejection ratio                                     |                                                                                                                     | 90       | 105                 |     | dB                                   | A                         |
|                                        | Input impedance common-mode                                     |                                                                                                                     |          | $300 \parallel 1.5$ |     | $\text{M}\Omega \parallel \text{pF}$ | C                         |
|                                        | Input impedance differential mode                               |                                                                                                                     |          | $180 \parallel 0.5$ |     | $\text{k}\Omega \parallel \text{pF}$ | C                         |
| <b>OUTPUT</b>                          |                                                                 |                                                                                                                     |          |                     |     |                                      |                           |
| $V_{OL}$                               | Output voltage, low                                             | $T_A \approx 25^\circ\text{C}$ , $G = 2$                                                                            |          | 0.05                | 0.1 | V                                    | A                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $G = 2$                                                         |          | 0.10                | 0.2 |                                      | B                         |
| $V_{OH}$                               | Output voltage, high                                            | $T_A \approx 25^\circ\text{C}$ , $G = 2$                                                                            | 2.9      | 2.95                |     | V                                    | A                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $G = 2$                                                         | 2.8      | 2.9                 |     |                                      | B                         |
|                                        | Maximum current into a resistive load                           | $T_A \approx 25^\circ\text{C}$ , $\pm 0.8\text{ V}$ into $17.5\ \Omega$ , $V_{IO} < 2\text{ mV}$                    | $\pm 45$ | $\pm 55$            |     | mA                                   | A                         |
|                                        | Linear current into a resistive load                            | $T_A \approx 25^\circ\text{C}$ , $\pm 0.9\text{ V}$ into $21.5\ \Omega$ , $A_{OL} > 80\text{ dB}$                   | $\pm 40$ | $\pm 45$            |     | mA                                   | A                         |
|                                        | Linear current into a resistive load overtemperature            | $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$ , $\pm 0.7\text{ V}$ into $21.5\ \Omega$ , $A_{OL} > 80\text{ dB}$ | $\pm 32$ | $\pm 40$            |     | mA                                   | C                         |
| <b>POWER SUPPLY</b>                    |                                                                 |                                                                                                                     |          |                     |     |                                      |                           |
|                                        | Specified operating voltage                                     |                                                                                                                     | 2.7      |                     | 5.4 | V                                    | B                         |
|                                        | Quiescent operating current per amplifier (OPA837, 3-V supply)  | $T_A \approx 25^\circ\text{C}$ <sup>(5)</sup>                                                                       | 547      | 570                 | 607 | $\mu\text{A}$                        | A                         |
|                                        |                                                                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                   | 404      | 570                 | 817 |                                      | B                         |
|                                        | Quiescent operating current per amplifier (OPA2837, 3-V supply) | $T_A \approx 25^\circ\text{C}$ <sup>(5)</sup>                                                                       | 540      | 570                 | 607 | $\mu\text{A}$                        | A                         |
|                                        | Supply current temperature coefficient per amplifier            | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ (see Figure 57)                                                   | 0.8      | 1.7                 | 2.2 | $\mu\text{A}/^\circ\text{C}$         | B                         |
| +PSRR                                  | Positive power-supply rejection ratio                           |                                                                                                                     | 90       | 110                 |     | dB                                   | A                         |
| -PSRR                                  | Negative power-supply rejection ratio                           |                                                                                                                     | 88       | 105                 |     | dB                                   | A                         |
| <b>POWER DOWN (Pin Must be Driven)</b> |                                                                 |                                                                                                                     |          |                     |     |                                      |                           |
|                                        | Enable voltage threshold                                        | Specified on above $V_{S-} + 1.5\text{ V}$                                                                          |          |                     | 1.5 | V                                    | A                         |
|                                        | Disable voltage threshold                                       | Specified off below $V_{S-} + 0.55\text{ V}$                                                                        | 0.55     |                     |     | V                                    | A                         |
|                                        | Power-down pin bias current                                     | $\overline{\text{PD}} = 0\text{ V}$ to $V_{S+}$                                                                     | -50      |                     | 50  | nA                                   | A                         |
|                                        | Power-down quiescent current                                    | $\overline{\text{PD}} \leq 0.55\text{ V}$                                                                           | 1        | 3                   | 8   | $\mu\text{A}$                        | A                         |
|                                        | Power-down quiescent current over temperature                   | $\overline{\text{PD}} \leq 0.55\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                       |          |                     | 8   | $\mu\text{A}$                        | B                         |
|                                        | Turnon time delay                                               | Time from $\overline{\text{PD}} = \text{high}$ to $V_{OUT} = 90\%$ of final value                                   |          | 300                 |     | ns                                   | C                         |
|                                        | Turnoff time delay                                              | Time from $\overline{\text{PD}} = \text{low}$ to $V_{OUT} = 10\%$ of original value                                 |          | 100                 |     | ns                                   | C                         |

(5) The typical spec is at  $25^\circ\text{C}$   $T_j$ . The min, max limits are expanded for ATE to account for ambient range from  $22^\circ\text{C}$  to  $32^\circ\text{C}$  with a  $+4\text{-}\mu\text{A}/^\circ\text{C}$  temperature coefficient on the supply current.

## 6.8 Typical Characteristics: $V_S = 5.0\text{ V}$

at  $V_{S+} = 5.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 2\text{ V}_{PP}$ ,  $R_F = 0\text{ }\Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

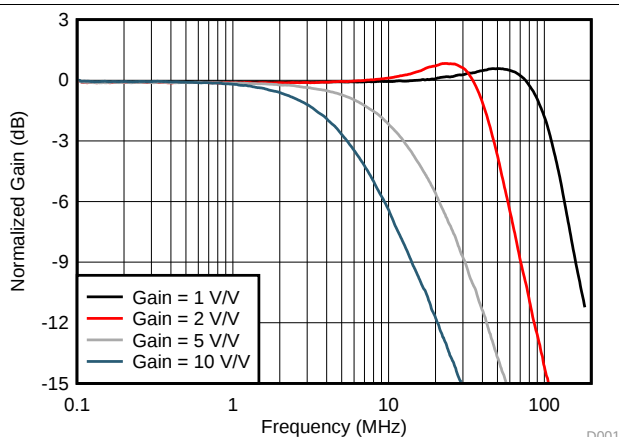


图 1. Noninverting Small-Signal Frequency Response vs Gain

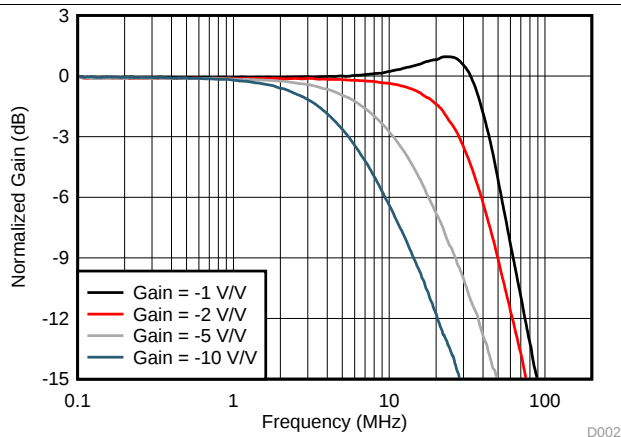


图 2. Inverting Small-Signal Frequency Response vs Gain

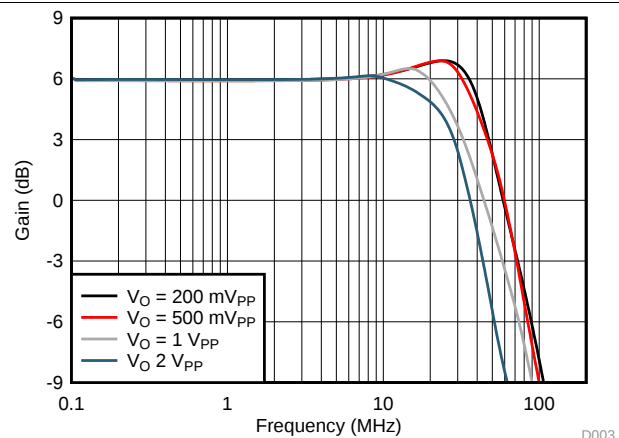


图 3. Noninverting Large-Signal Bandwidth vs  $V_{OPP}$

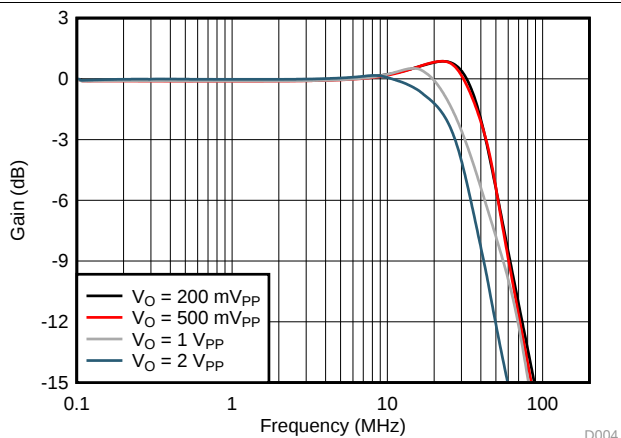


图 4. Inverting Large-Signal Bandwidth vs  $V_{OPP}$

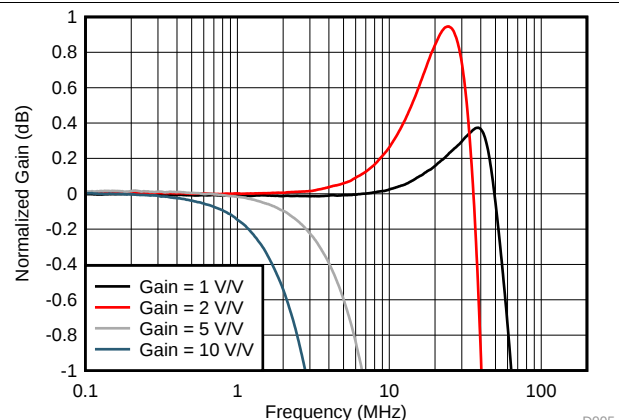


图 5. Noninverting Response Flatness vs Gain

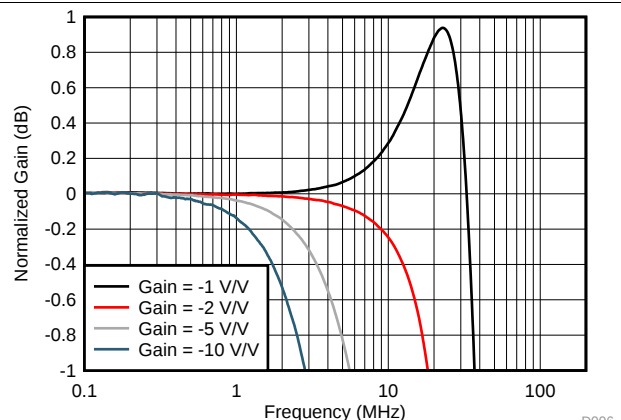
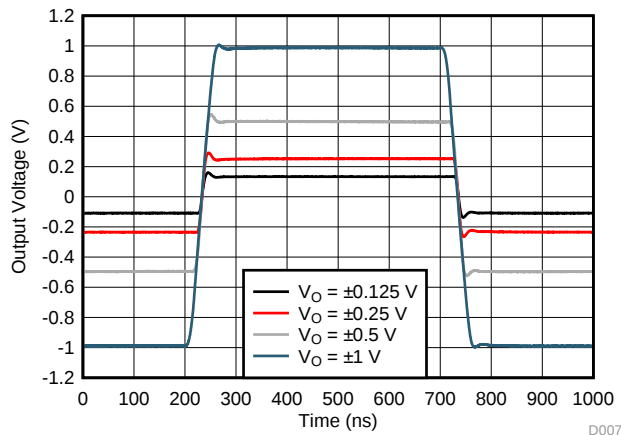


图 6. Inverting Response Flatness vs Gain

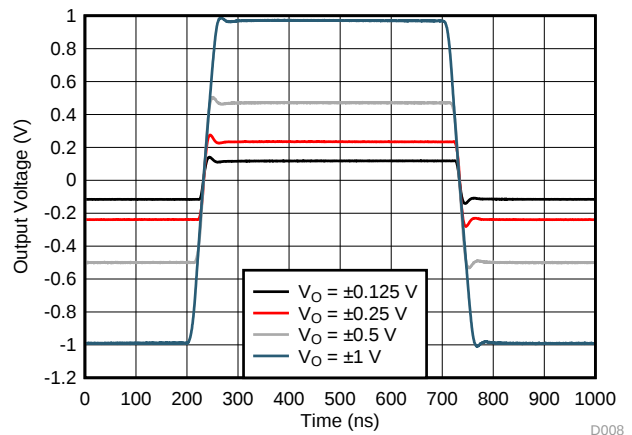
## Typical Characteristics: $V_S = 5.0\text{ V}$ (continued)

at  $V_{S+} = 5.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 2\text{ V}_{PP}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)



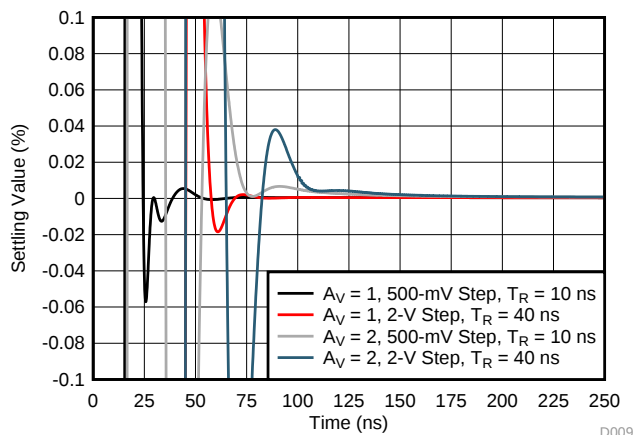
See Figure 74, gain = 2 V/V,  
input edge rate set to stay below slew limiting

Figure 7. Noninverting Step Response vs Time and  $V_{OPP}$



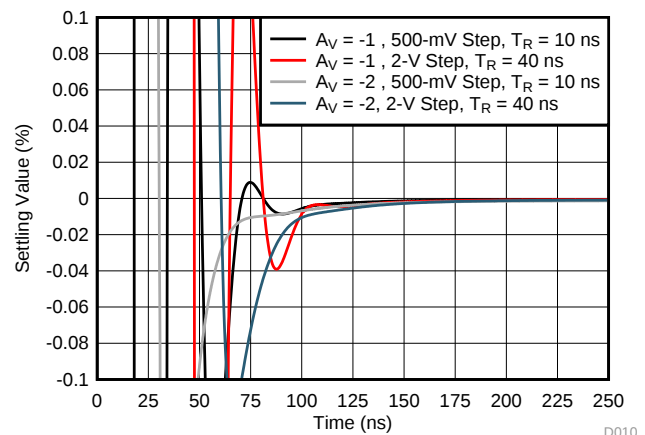
See Figure 75, gain = -1 V/V,  
input edge rate set to stay below slew limiting

Figure 8. Inverting Step Response vs Time and  $V_{OPP}$



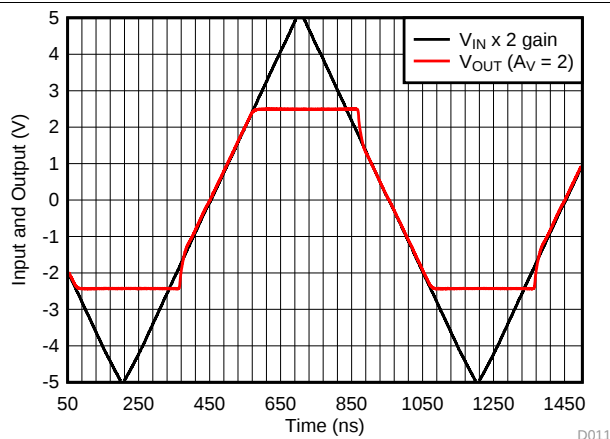
See Figure 74 and Table 2

Figure 9. Simulated Noninverting Settling Time



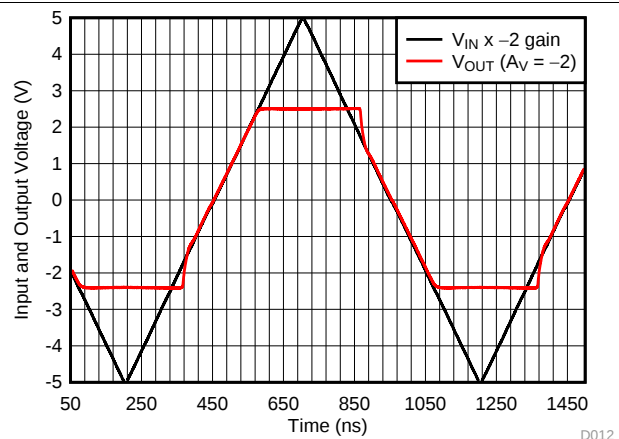
See Figure 75 and Table 3

Figure 10. Simulated Inverting Settling Time



See Figure 74 and Table 2, gain = 2 V/V

Figure 11. Noninverting Overdrive Recovery



See Figure 75 and Table 3, gain -2 V/V

Figure 12. Inverting Overdrive Recovery

## Typical Characteristics: $V_S = 5.0\text{ V}$ (continued)

at  $V_{S+} = 5.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 2\text{ V}_{PP}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

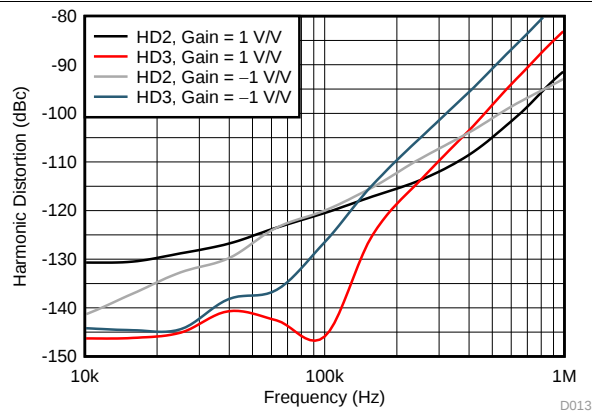


Figure 13. Harmonic Distortion vs Frequency

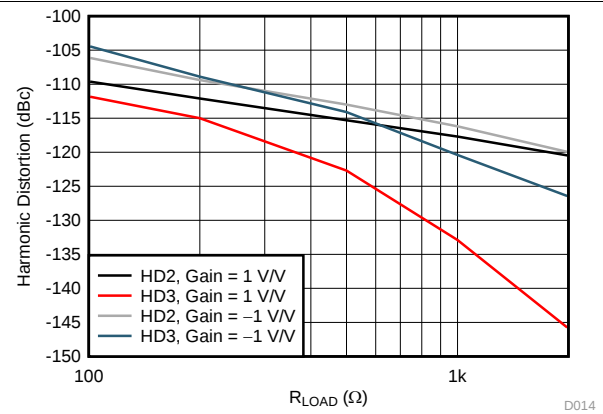


Figure 14. Harmonic Distortion vs  $R_{LOAD}$

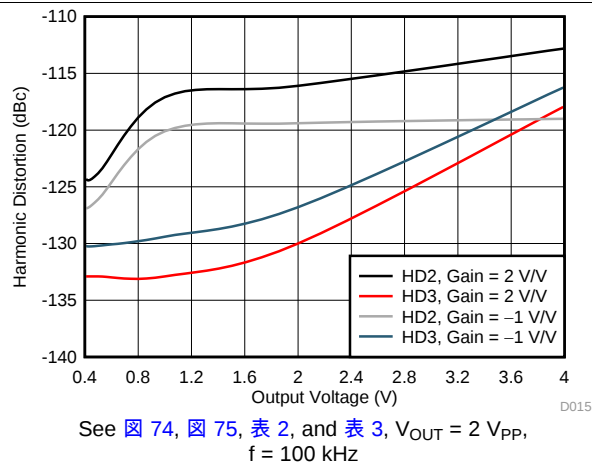


Figure 15. Harmonic Distortion vs Output Voltage

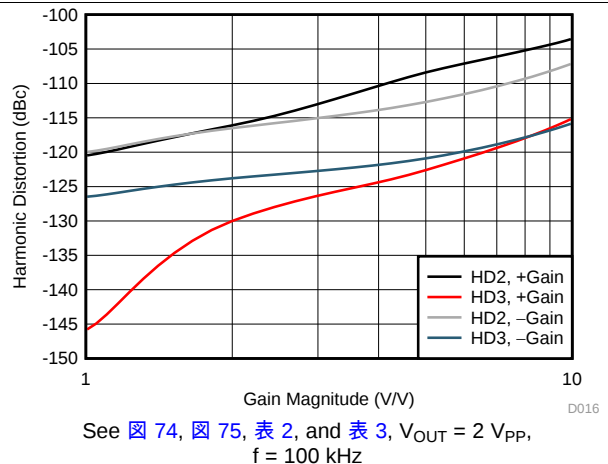


Figure 16. Harmonic Distortion vs Gain Magnitude

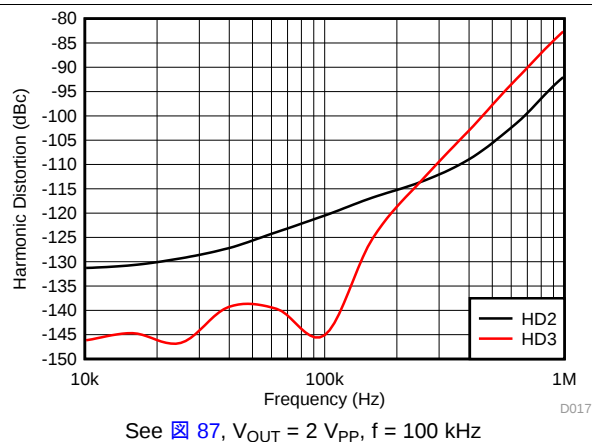


Figure 17. Harmonic Distortion as Active Mux

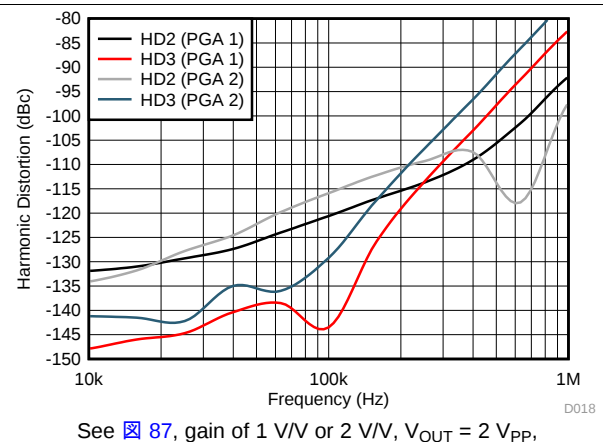


Figure 18. Harmonic Distortion as 1-Bit PGA

## 6.9 Typical Characteristics: $V_S = 3.0\text{ V}$

at  $V_{S+} = 3.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_F = 0\text{ }\Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

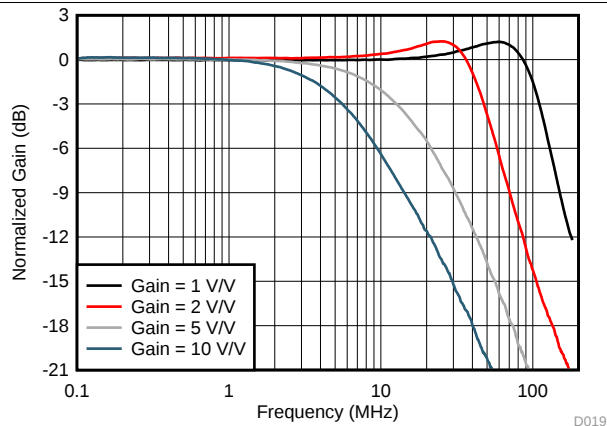


Figure 19. Noninverting Small-Signal Response vs Gain

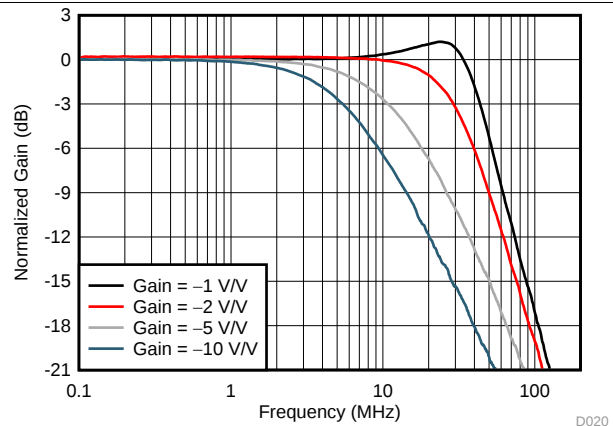


Figure 20. Inverting Small-Signal Response vs Gain

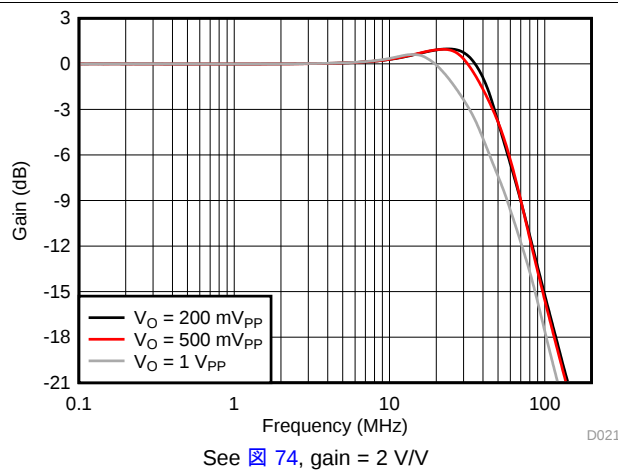


Figure 21. Noninverting Large-Signal Bandwidth vs  $V_{OPP}$

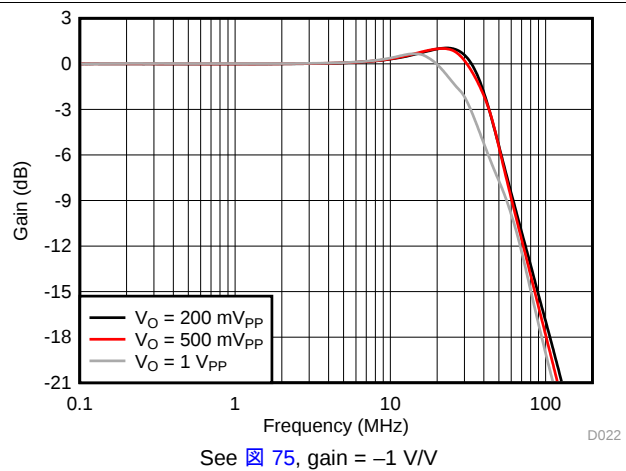


Figure 22. Inverting Large-Signal Bandwidth vs  $V_{OPP}$

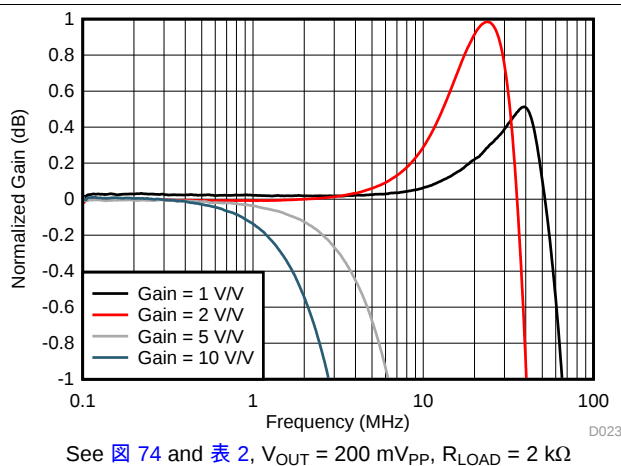


Figure 23. Noninverting Response Flatness vs Gain

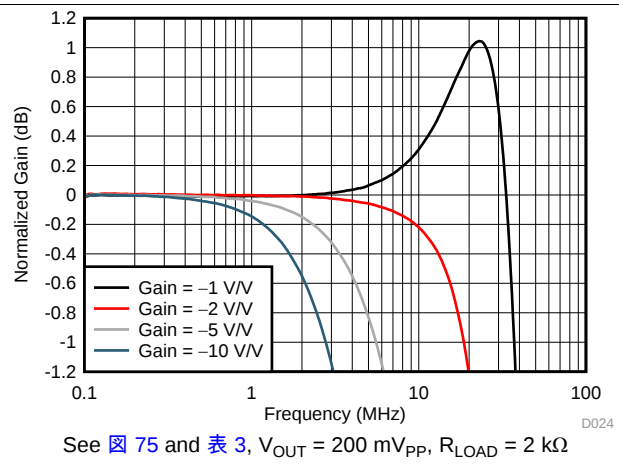
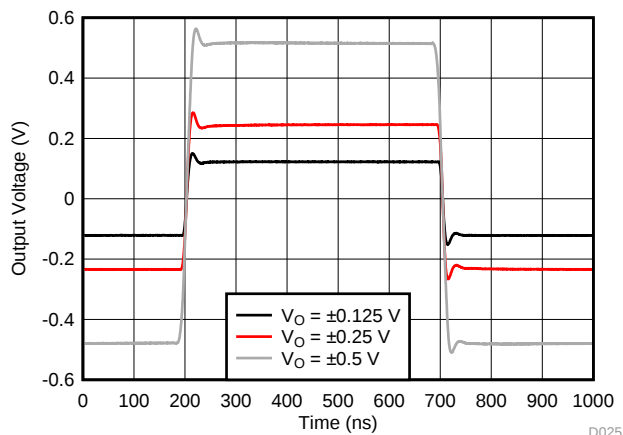


Figure 24. Inverting Response Flatness vs Gain

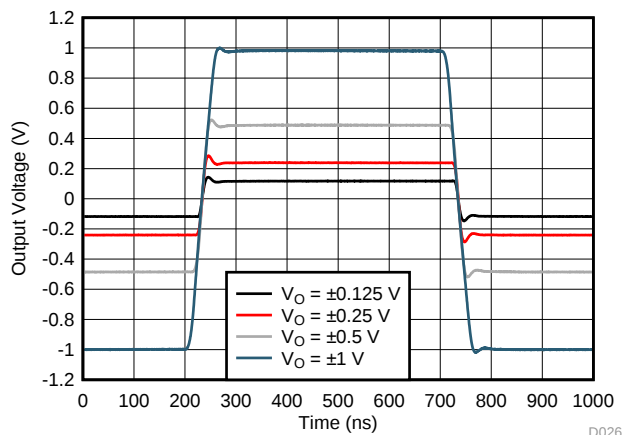
## Typical Characteristics: $V_S = 3.0\text{ V}$ (continued)

at  $V_{S+} = 3.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_F = 0\ \Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)



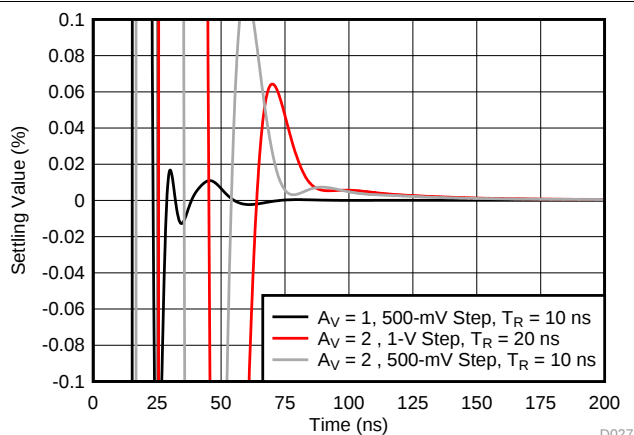
See Figure 74 and Table 2, gain = 2 V/V,  
input edge rate set to stay below slew limiting

Figure 25. Noninverting Step Response vs  $V_{OPP}$



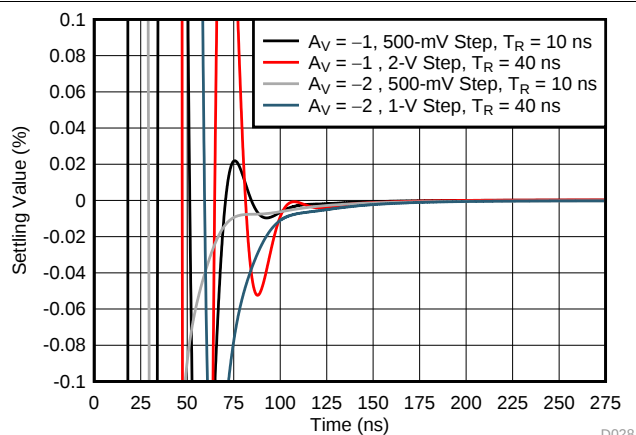
See Figure 75 and Table 3, gain = -1 V/V,  
input edge rate set to stay below slew limiting

Figure 26. Inverting Step Response vs  $V_{OPP}$



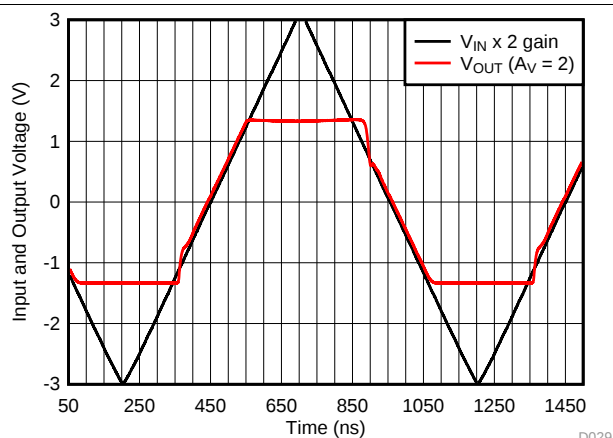
See Figure 74 and Table 2

Figure 27. Simulated Noninverting Settling Time



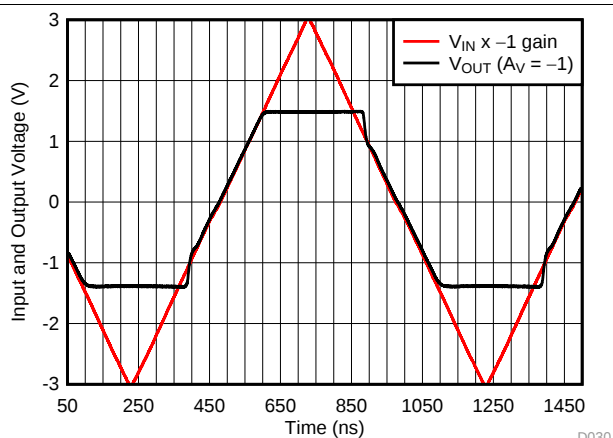
See Figure 75 and Table 3

Figure 28. Simulated Inverting Settling Time



See Figure 74 and Table 2, gain = 2 V/V

Figure 29. Noninverting Overdrive Recovery

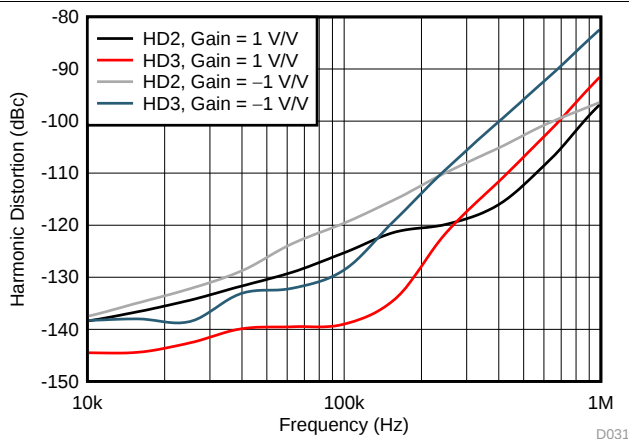


See Figure 75 and Table 3, gain = -1 V/V

Figure 30. Inverting Overdrive Recovery

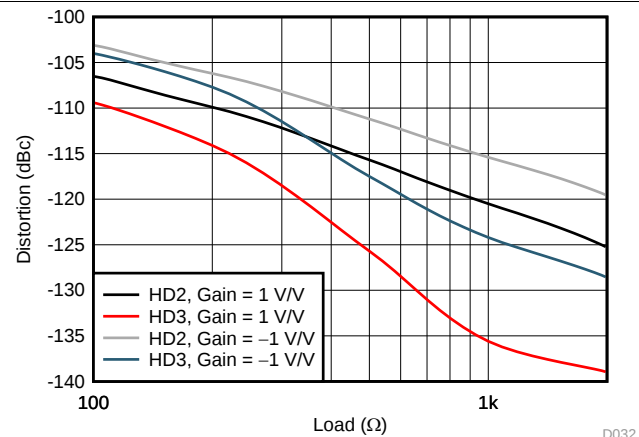
## Typical Characteristics: $V_S = 3.0\text{ V}$ (continued)

at  $V_{S+} = 3.0\text{ V}$ ,  $V_{S-} = 0\text{ V}$ ,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_F = 0\text{ }\Omega$ ,  $R_L = 2\text{ k}\Omega$ ,  $G = 1\text{ V/V}$ , input and output referenced to mid-supply, and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)



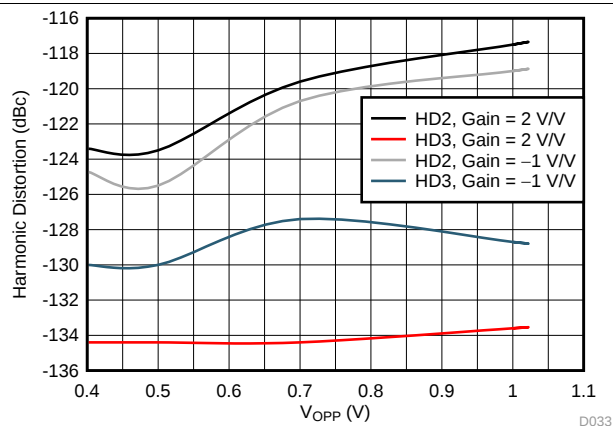
See Figure 74, Figure 75, Table 2, and Table 3,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_{LOAD} = 2\text{ k}\Omega$

Figure 31. Harmonic Distortion vs Frequency



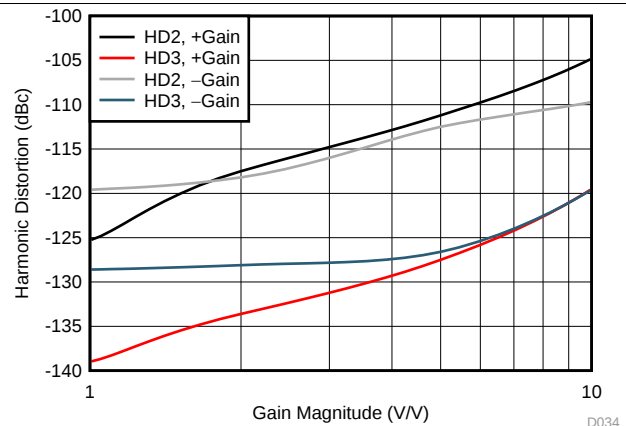
See Figure 74, Figure 75, Table 2, and Table 3,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $f = 100\text{ kHz}$ ,  $R_{LOAD} = 2\text{ k}\Omega$

Figure 32. Harmonic Distortion vs  $R_{LOAD}$



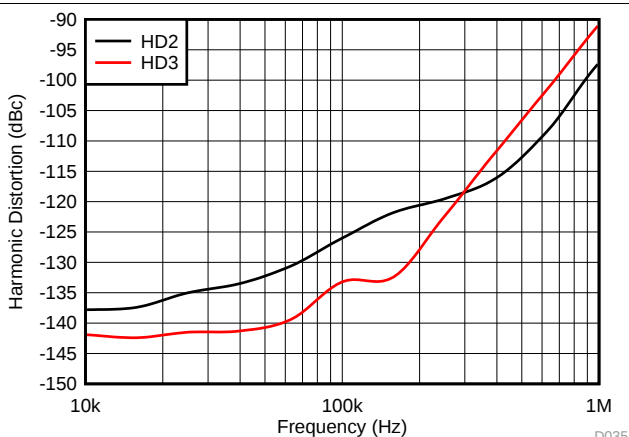
See Figure 74, Figure 75, Table 2, and Table 3,  $R_{LOAD} = 2\text{ k}\Omega$ ,  $f = 100\text{ kHz}$

Figure 33. Harmonic Distortion vs Output Swing



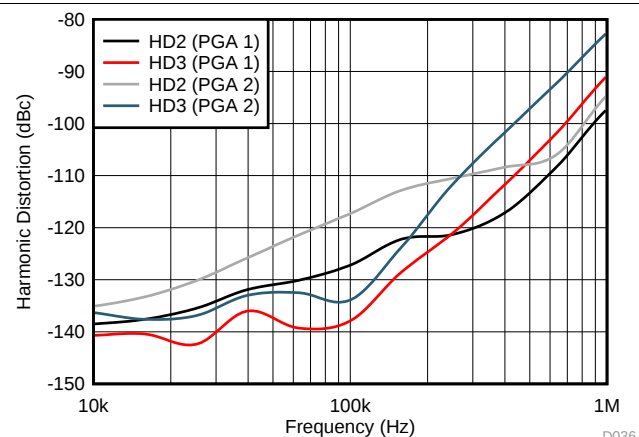
See Figure 74, Figure 75, Table 2, and Table 3,  $R_{LOAD} = 2\text{ k}\Omega$ ,  $f = 100\text{ kHz}$ ,  $V_{OUT} = 1\text{ V}_{PP}$

Figure 34. Harmonic Distortion vs Gain Magnitude



See Figure 87, gain = 1 V/V,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_{LOAD} = 2\text{ k}\Omega$

Figure 35. Harmonic Distortion as Active Mux



See Figure 88, gain of 1 V/V and 2 V/V,  $V_{OUT} = 1\text{ V}_{PP}$ ,  $R_{LOAD} = 2\text{ k}\Omega$

Figure 36. Harmonic Distortion as 1-Bit PGA

## 6.10 Typical Characteristics: $\pm 2.5\text{-V}$ to $\pm 1.5\text{-V}$ Split Supply

with  $P_D = V_{CC}$  and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

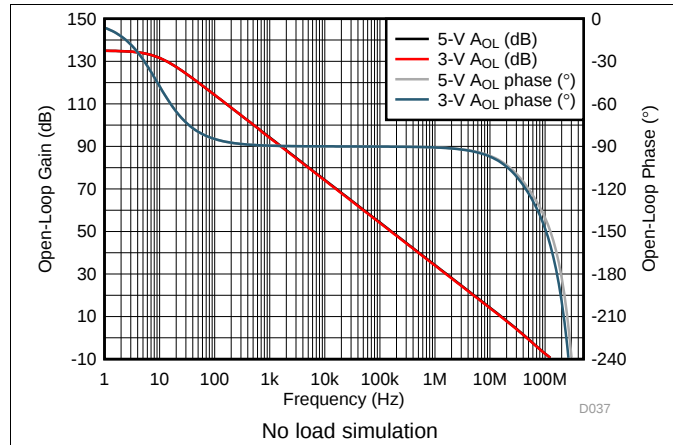


Figure 37. Open-Loop Gain and Phase vs Frequency

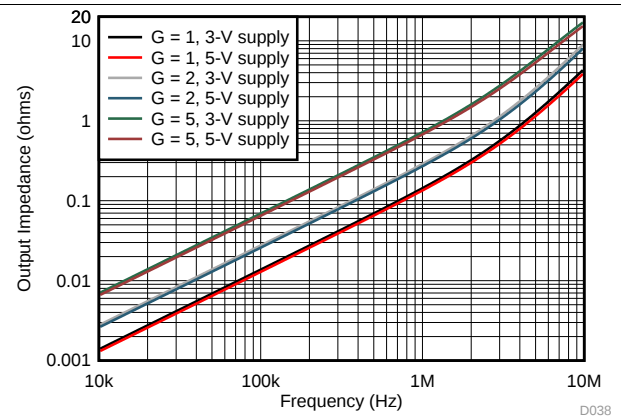


Figure 74 and Table 2 (simulation)

Figure 38. Closed-Loop Output Impedance vs Frequency

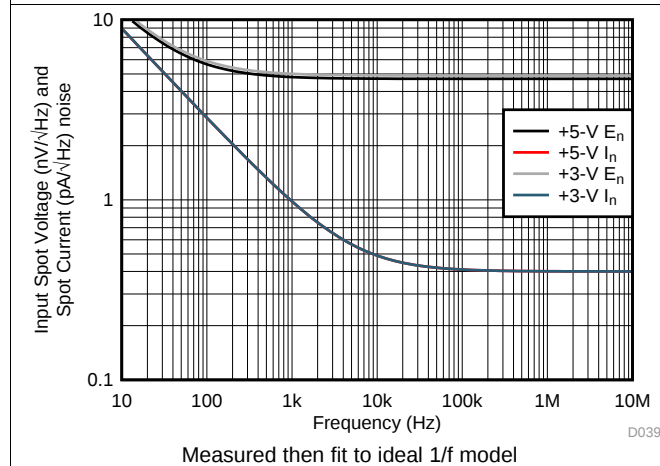


Figure 39. Input Spot Noise Density vs Frequency

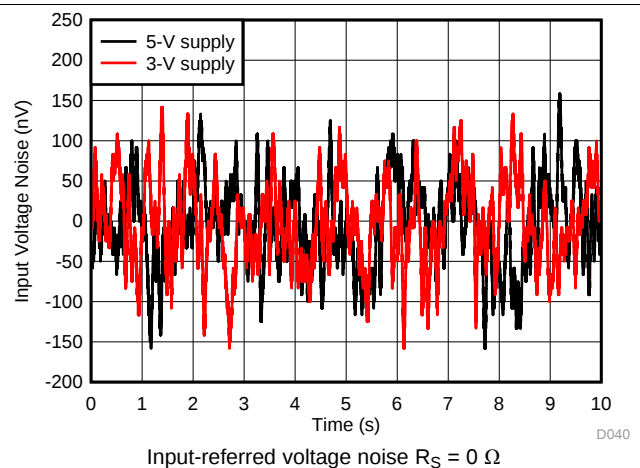


Figure 40. Low-Frequency Voltage Noise vs Time

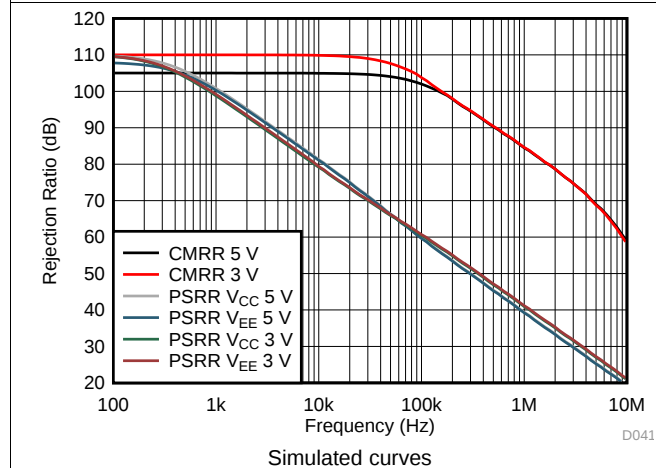


Figure 41. CMRR and PSRR vs Frequency

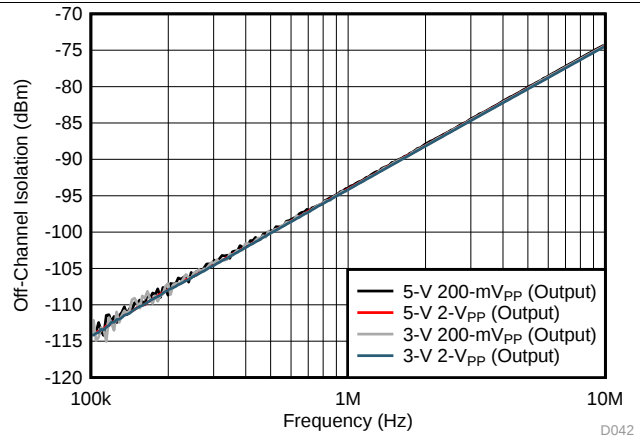


Figure 42. Disabled Isolation Noninverting Input to Output vs Frequency

## Typical Characteristics: $\pm 2.5\text{-V}$ to $\pm 1.5\text{-V}$ Split Supply (continued)

with  $P_D = V_{CC}$  and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

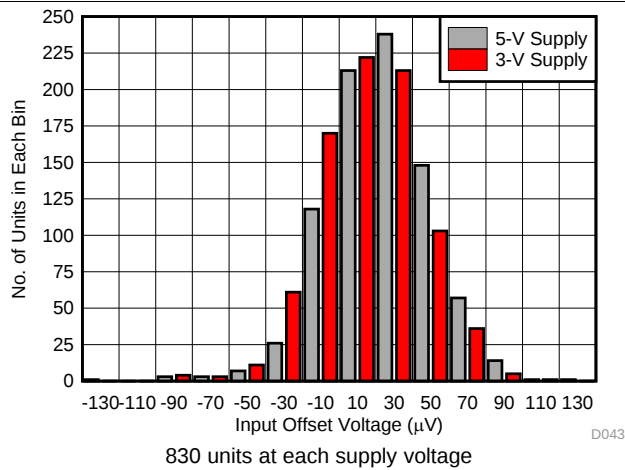


FIG 43. Input Offset Voltage Distribution

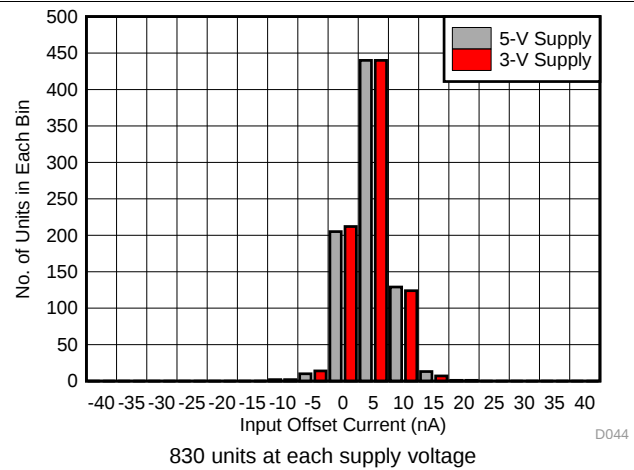


FIG 44. Input Offset Current Distribution

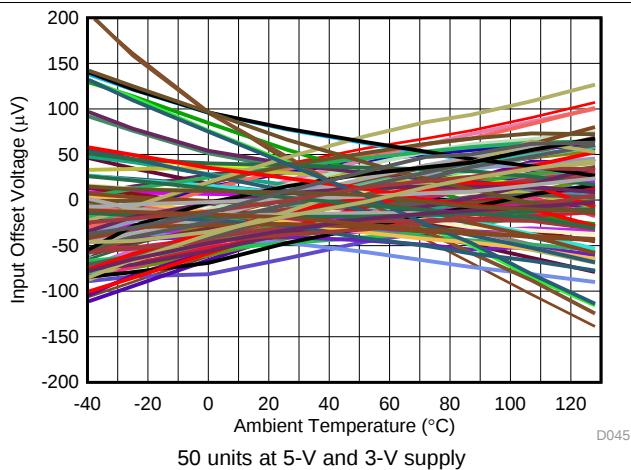


FIG 45. Input Offset Voltage vs Ambient Temperature

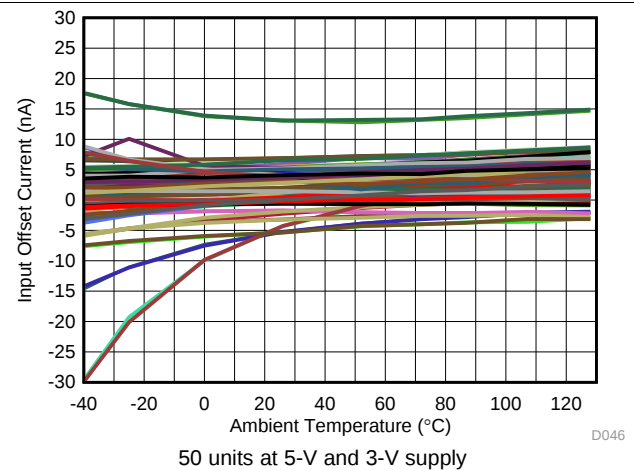


FIG 46. Input Offset Current vs Ambient Temperature

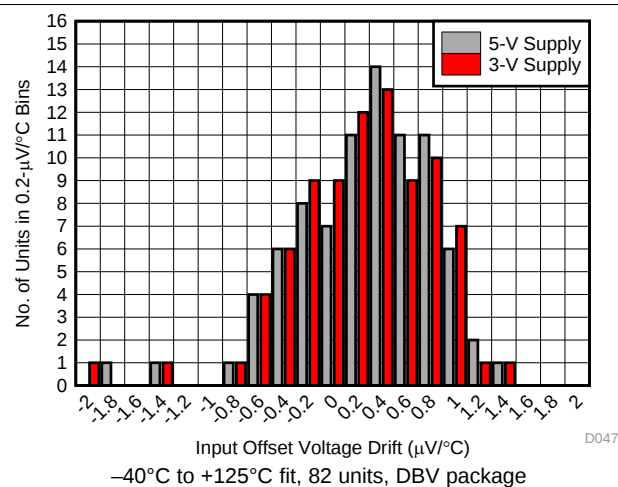


FIG 47. Input Offset Voltage Drift Distribution

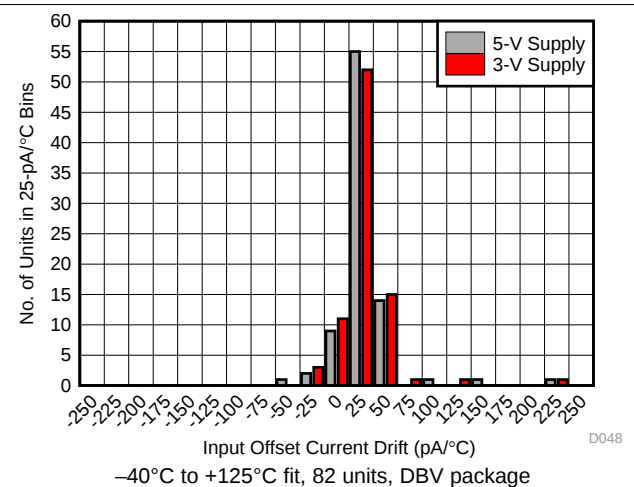
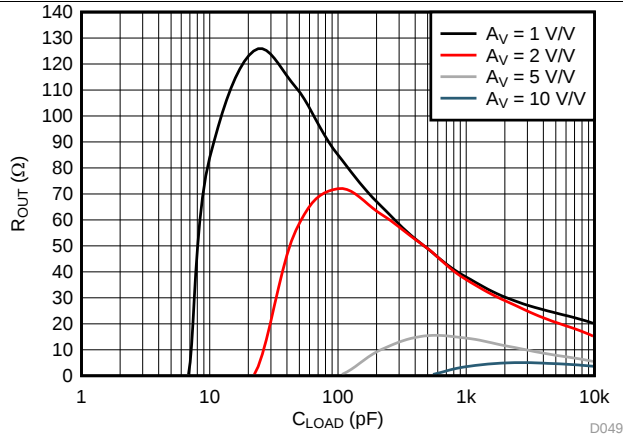


FIG 48. Input Offset Current Drift Distribution

## Typical Characteristics: $\pm 2.5\text{-V}$ to $\pm 1.5\text{-V}$ Split Supply (continued)

with  $P_D = V_{CC}$  and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)



See 图 66 and 表 2, small signal,  
targeting  $30^\circ$  phase margin

图 49. Output Resistor vs  $C_{LOAD}$

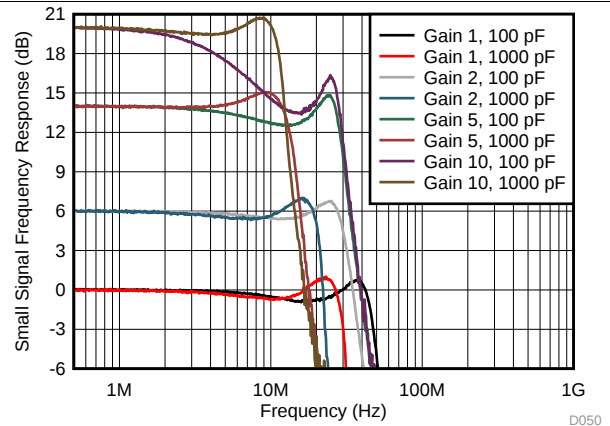


图 50. Small-Signal Frequency Response vs  $C_{LOAD}$   
With Recommended  $R_{OUT}$

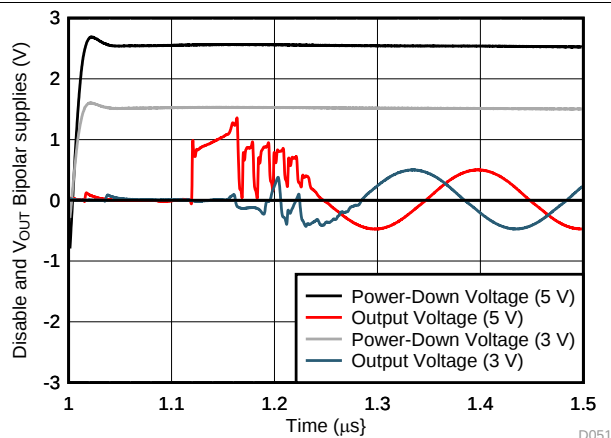


图 51. Turn-On Time to Sinusoidal Input

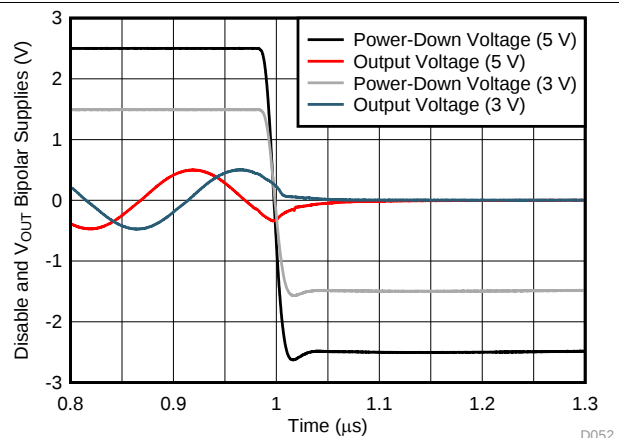


图 52. Turn-Off Time to Sinusoidal Input

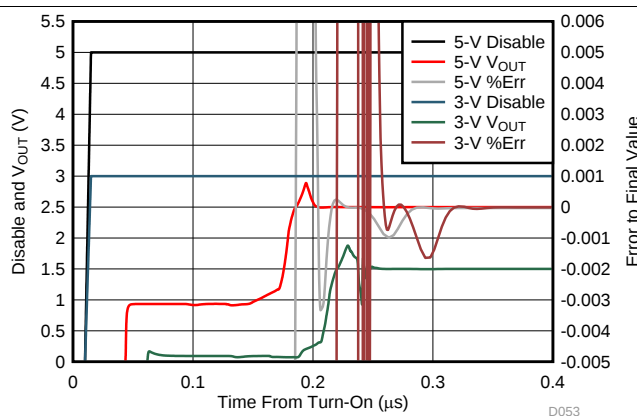


图 53. Gain of 1 Turn-On Time to Final DC Value at Midscale  
(Simulated)

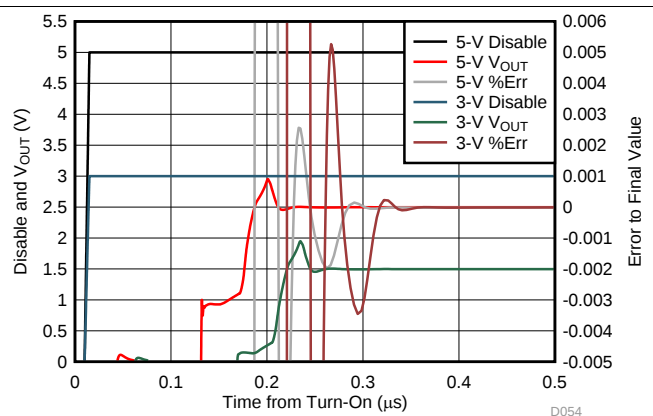


图 54. Gain of 2 Turn-On Time to Final DC Value at Midscale  
(Simulated)

## Typical Characteristics: $\pm 2.5\text{-V}$ to $\pm 1.5\text{-V}$ Split Supply (continued)

with  $P_D = V_{CC}$  and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)

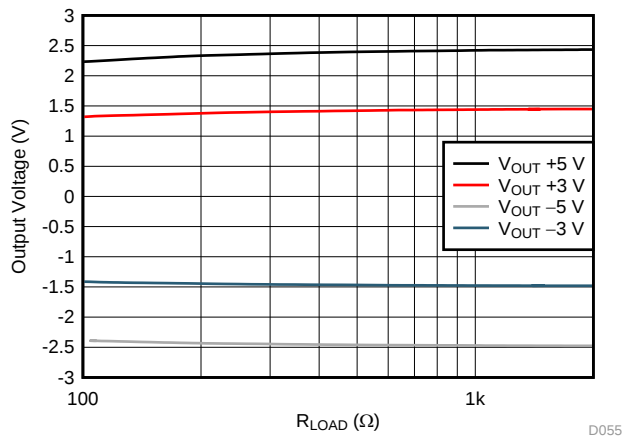


Figure 55. Output Voltage Swing vs Load Resistor

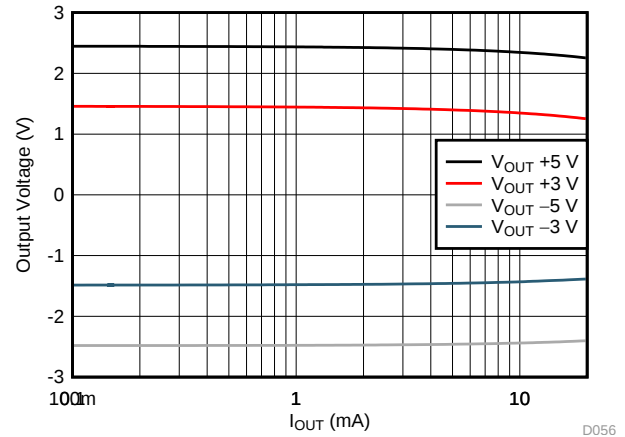


Figure 56. Output Saturation Voltage vs Load Current

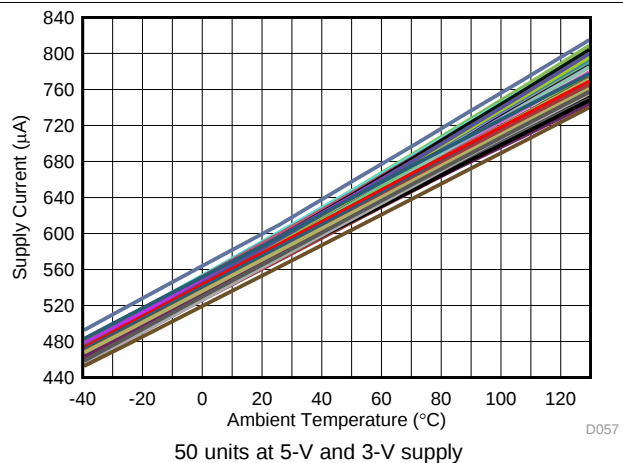


Figure 57. Supply Current vs Ambient Temperature

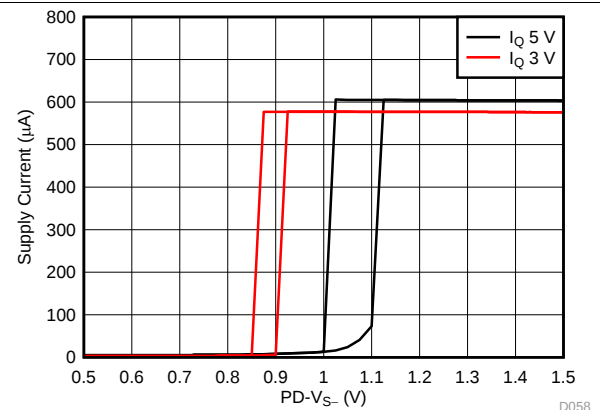


Figure 58. Supply Current vs Power-Down Voltage (Turn-On Higher Than Turn-Off)

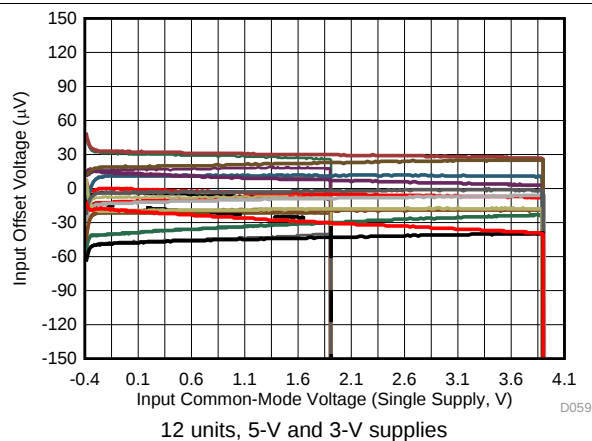


Figure 59. Input Offset Voltage vs Input Common-Mode Voltage

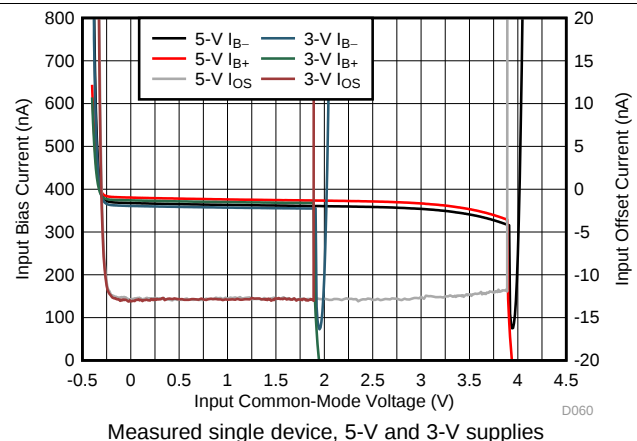
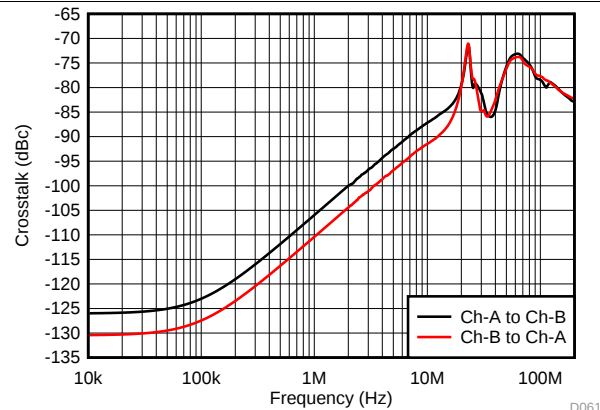


Figure 60. Input Bias and Offset Current vs  $V_{ICM}$

## Typical Characteristics: $\pm 2.5\text{-V}$ to $\pm 1.5\text{-V}$ Split Supply (continued)

with  $P_D = V_{CC}$  and  $T_A \approx 25^\circ\text{C}$  (unless otherwise noted)



Crosstalk for the OPA2837 only

Figure 61. Crosstalk vs Frequency

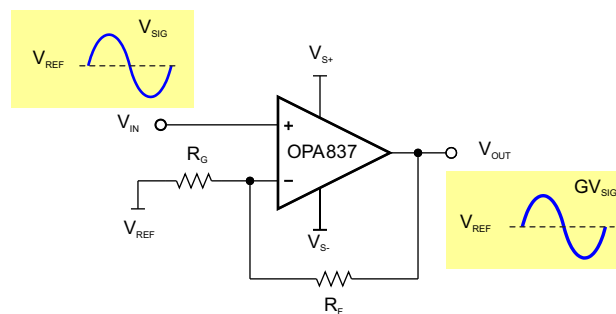
## 7 Detailed Description

### 7.1 Overview

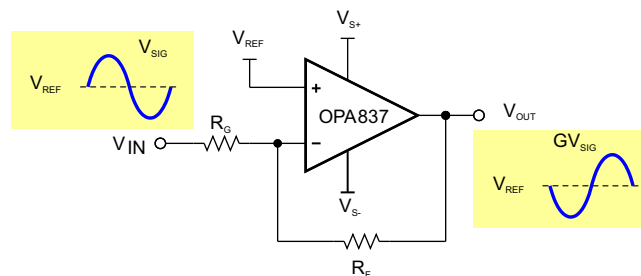
The OPA837 and OPA2837 are single- and dual-channel, power efficient, unity-gain stable, voltage-feedback amplifiers (VFAs). Combining a negative rail input stage and a rail-to-rail output (RRO) stage, the OPAx837 provides a flexible solution where exceptional precision and wide bandwidth at low power are required. This 50-MHz gain bandwidth product (GBP) amplifier requires less than 0.65 mA of supply current per channel over a 2.7-V to 5.4-V total supply operating range. A shutdown feature on the OPA837 6-pin package version provides power savings where the system requires less than 10  $\mu$ A when shut down. Offering a unity-gain bandwidth greater than 100 MHz, the OPAx837 provides less than  $-118$ -dBc THD at 100 kHz and a  $2$ -V<sub>PP</sub> output.

### 7.2 Functional Block Diagrams

The OPAx837 is a standard voltage-feedback op amp with two high-impedance inputs and a low-impedance output. [Figure 62](#) and [Figure 63](#) show the supported standard applications circuits. These application circuits are shown with a DC  $V_{REF}$  on the inputs that set the DC operating points for single-supply designs. The  $V_{REF}$  is often ground, especially for split-supply applications.



**Figure 62. Noninverting Amplifier**



**Figure 63. Inverting Amplifier**

## 7.3 Feature Description

### 7.3.1 OPA837 Comparison

表 1 lists several members of the device family that includes the OPA837.

**表 1. Device Family Comparison<sup>(1)</sup>**

| PART NUMBER | $A_v = +1$<br>BANDWIDTH (MHz) | 5-V $I_O$<br>(mA, Max 25°C) | INPUT NOISE<br>VOLTAGE<br>(nV/√Hz) | 2- $V_{PP}$ THD<br>(dBc, 100 kHz) | RAIL-TO-RAIL<br>INPUT/OUTPUT | DUALS   |
|-------------|-------------------------------|-----------------------------|------------------------------------|-----------------------------------|------------------------------|---------|
| OPA837      | 105                           | 0.63                        | 4.7                                | –118                              | $V_{S-}$ , output            | OPA2837 |
| OPA838      | —                             | 0.99                        | 1.9                                | –110                              | $V_{S-}$ , output            | —       |
| LMV118      | 45                            | 0.9                         | 40                                 | —                                 | $V_{S-}$ , output            | —       |
| LMH6647     | 55                            | 1.6                         | 17                                 | –75                               | Input, output                | LMH6646 |
| OPA835      | 56                            | 0.35                        | 9.4                                | –104                              | $V_{S-}$ , output            | OPA2835 |
| OPA625      | 120                           | 2.2                         | 2.5                                | –120                              | $V_{S-}$ , output            | OPA2625 |
| OPA836      | 205                           | 1.0                         | 4.6                                | –118                              | $V_{S-}$ , output            | OPA2836 |

(1) For a complete selection of TI high speed amplifiers, visit [www.ti.com](http://www.ti.com).

### 7.3.2 Input Common-Mode Voltage Range

When the primary design goal is a linear amplifier with high CMRR, the design must remain within the input common-mode voltage range ( $V_{ICR}$ ) of an op amp. These ranges are referenced off of each supply as an input headroom requirement. Ensured operation at 25°C is maintained to the negative supply voltage and to within 1.3 V of the positive supply voltage. The common-mode input range specifications in the [Electrical Characteristics](#) table use CMRR to set the limit. The limits are selected to ensure CMRR does not degrade more than 3 dB below the minimum CMRR value if the input voltage is within the specified range.

Assuming the op amp is in linear operation, the voltage difference between the input pins is small (ideally 0 V); and the input common-mode voltage is analyzed at either input pin with the other input pin assumed to be at the same potential. The voltage at  $V_{IN+}$  is simple to evaluate. In the noninverting configuration of [Figure 62](#), the input signal,  $V_{IN}$ , must not violate the  $V_{ICR}$ . In the inverting configuration of [Figure 63](#), the reference voltage,  $V_{REF}$ , must be within the  $V_{ICR}$ .

The input voltage limits have fixed headroom to the power rails and track the power-supply voltages. For one 5-V supply, the typical linear input voltage ranges from –0.2 V to 3.8 V and –0.2 V to 1.5 V for a 2.7-V supply. The delta headroom from each power-supply rail is the same in either case: –0.2 V and 1.2 V, respectively.

### 7.3.3 Output Voltage Range

The OPAx837 is a rail-to-rail output op amp. Rail-to-rail output typically means that the output voltage swings to within 100 mV of the supply rails. There are two different ways to specify this feature: one is with the output still in linear operation and another is with the output saturated. Saturated output voltages are closer to the power-supply rails than the linear outputs, but the signal is not a linear representation of the input. Saturation and linear operation limits are affected by the output current, where higher currents lead to more voltage loss in the output transistors; see [Figure 55](#).

The [Electrical Characteristics](#) tables list saturated output voltage specifications with a 2-kΩ load. [Figure 55](#) illustrates the saturated voltage-swing limits versus output load resistance, and [Figure 56](#) illustrates the output saturation voltage versus load current. Given a light load, the output voltage limits have nearly constant headroom to the power rails and track the power-supply voltages. For example, with a 2-kΩ load and a single 5-V supply, the linear output voltage ranges from 0.10 V to 4.9 V and ranges from 0.1 V to 2.6 V for a 2.7-V supply. The delta from each power-supply rail is the same in either case: 0.1 V.

With devices like the OPA837 and OPA2837 where the input range is lower than the output range, typically the input limits the available signal swing only in a noninverting gain of 1 V/V. Signal swing in noninverting configurations in gains greater than +1 V/V and inverting configurations in any gain are typically limited by the output voltage limits of the op amp.

### 7.3.4 Power-Down Operation

The OPA837 includes a power-down mode in the 6-pin SOT23-6 package. Under logic control, the amplifier can switch from normal operation to a standby current of less than 10  $\mu\text{A}$ . When the PD pin is connected high, the amplifier is active. Connecting the PD pin low disables the amplifier and places the output in a high-impedance state. When the amplifier is configured as a unity-gain buffer, the output stage is in a high DC-impedance state. A new feature in the OPA837 is a switch from the external inverting input pin to the internal active transistors. This switch operates with the disable pin function to open up the connection to the internal devices when powered down. Operating in unity gain provides a high-impedance voltage into both the output and inverting input pins. This feature allows direct active multiplexer operation to be implemented; see [Figure 87](#). The [TIDA-01565 Wired OR MUX and PGA Reference Design](#) demonstrates the use of the OPAX837 in wired-OR multiplexer and programmable gain amplifier applications. When disabled, the internal input devices on the inverting input approximately follow the noninverting input on the other side of the open switch through the back-to-back protection diodes across the inputs. When powered up, these diodes (two in each direction) act to limit overdrive currents into the active transistors.

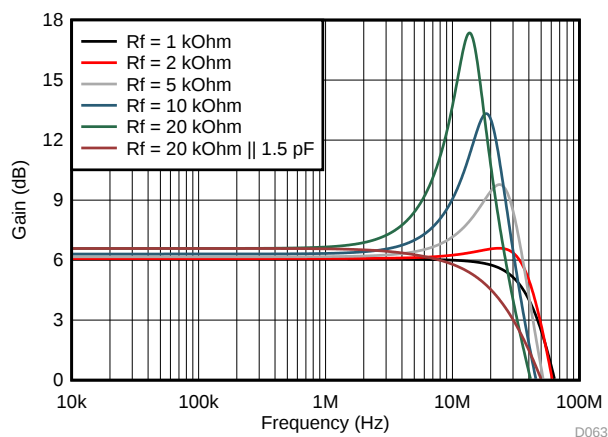
The PD pin must be actively driven high or low and must not be left floating. If the power-down mode is not used, PD must be tied to the positive supply rail.

PD logic states are referenced relatively low to the negative supply rail,  $V_{S-}$ . When the op amp is powered from a single-supply and ground, and the disable line is driven from logic devices with similar  $V_{DD}$  voltages to the op amp, the disable operation does not require any special consideration. The OPA837 is specified to be off with PD driven to within 0.55 V of the negative supply and specified to be on when driven more than 1.5 V above the negative supply. Slight hysteresis is provided around a nominal 1-V switch point; see [Figure 58](#). When the op amp is powered from a split supply with  $V_{S-}$  below ground, a level shift logic swing below ground is required to operate the disable function.

### 7.3.5 Low-Power Applications and the Effects of Resistor Values on Bandwidth

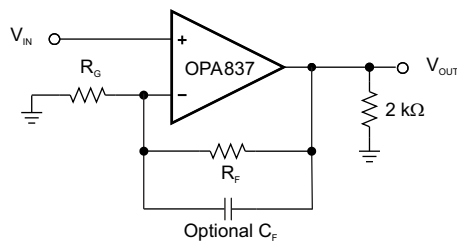
The OPAX837 can use a direct short in the feedback for a gain of 1 V/V. [Table 2](#) gives a list of recommended values over gain for an increasing noninverting gain target. This table was produced by increasing the R values until they added 50% of the total output noise power. Higher values can be used to reduce power at the cost of higher noise. Lower values can be used to reduce the total output noise at the cost of more load power in the feedback network. Stability is also impaired going to very high values because of the pole introduced into the feedback path with the inverting input capacitance (1.5-pF common-mode). In low-power applications, reducing the current in the feedback path is preferable by increasing the resistor values. Using larger value resistors has two primary side effects (other than lower power) because of the interactions with the inverting input parasitic capacitance. Using large value resistors lowers the bandwidth and lowers the phase margin. When the phase margin is lowered, peaking in the frequency response and overshoot and ringing in the pulse response results.

[Figure 64](#) shows the gain = 2 V/V (6 dB) small-signal frequency response with  $R_F$  and  $R_G$  equal to 1 k $\Omega$ , 2 k $\Omega$ , 5 k $\Omega$ , 10 k $\Omega$ , and 20 k $\Omega$ . This test was done with  $R_L = 2$  k $\Omega$ . Lower  $R_L$  values can reduce the peaking because of  $R_L$  loading effects, but higher values do not have a significant effect.



**Figure 64. Frequency Response With Various  $R_F = R_G$  Resistor Values**

As expected, larger value resistors cause lower bandwidth and peaking in the response (peaking in frequency response is synonymous with overshoot and ringing in pulse response). Adding a 1.5-pF capacitor in parallel with  $R_F$  (equal to the input common-mode capacitance) helps compensate the phase margin loss and restores flat frequency response. [Figure 65](#) shows the test circuit.

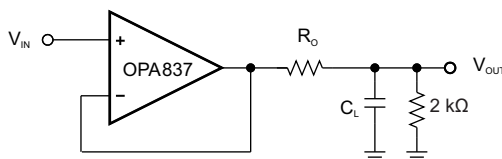


**Figure 65. G = 2 Test Circuit for Various Gain-Setting Resistor Values**

### 7.3.6 Driving Capacitive Loads

The OPAx837 can drive a parasitic load capacitance up through 4 pF on the output with no special considerations. When driving capacitive loads greater than 4 pF, TI recommends using a small resistor ( $R_O$ ) in series with the output as close to the device as possible. Without  $R_O$ , output capacitance interacts with the output impedance of the amplifier causing phase shift in the loop gain of the amplifier that reduces the phase margin. This reduction causes peaking in the frequency response and overshoot and ringing in the pulse response. Inserting  $R_O$  isolates the phase shift from the loop-gain path and restores the phase margin; however  $R_O$  can also limit bandwidth to the capacitive load.

[Figure 66](#) shows the test and [Figure 49](#) illustrates the recommended values of  $R_O$  versus capacitive loads,  $C_L$  using a 30° phase margin target for the op amp. See [Figure 50](#) for the frequency responses with various values of  $C_L$  and  $R_{OUT}$  parametric on gain.



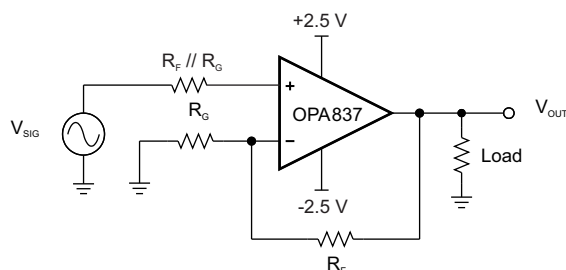
**Figure 66.  $R_{OUT}$  versus  $C_L$  Test Circuit**

## 7.4 Device Functional Modes

### 7.4.1 Split-Supply Operation ( $\pm 1.35\text{ V}$ to $\pm 2.7\text{ V}$ )

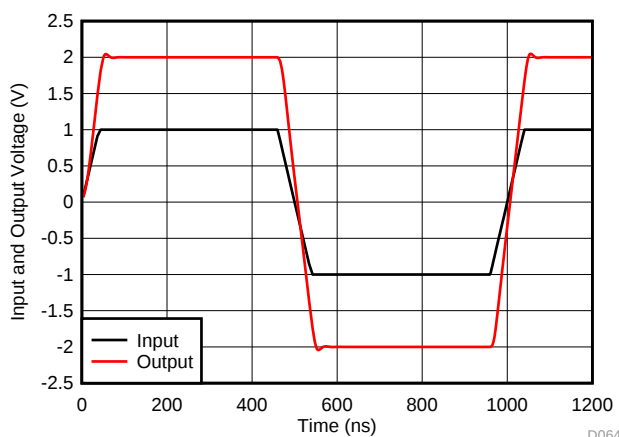
To facilitate testing with common lab equipment, the OPA837EVM (see the [OPA835DBV and OPA836DBV EVM User's Guide](#)) allows split-supply operation. This configuration eases lab testing because the mid-point between the power rails is ground, and most signal generators, network analyzers, oscilloscopes, spectrum analyzers, and other lab equipment have inputs and outputs that prefer a ground reference for DC-coupled testing.

Figure 67 shows a simple noninverting configuration analogous to Figure 62 with a  $\pm 2.5\text{-V}$  supply and  $V_{\text{REF}}$  equal to ground. The input and output swing symmetrically around ground. For ease of use, split supplies are preferred in systems where signals swing around ground. In this example, an optional bias current cancellation resistor is used in series with the noninverting input. For DC-coupled applications, set this resistor to be equal to the parallel combination of  $R_F$  and  $R_G$ . This resistor increases the noise contribution at the input because of that resistor noise (see the [Output Noise Calculations](#) section).



**Figure 67. Split-Supply Operation**

Figure 68 shows the step response for this gain of 2-V/V circuit with a  $\pm 1\text{-V}$  input to a  $\pm 2\text{-V}$  output. For a 4-V output step, the input edge rate is set to 40 ns to avoid slew limiting.



**Figure 68.  $V_{\text{IN}}$  and  $V_{\text{OUT}}$  vs Time**

## Device Functional Modes (continued)

### 7.4.2 Single-Supply Operation (2.7 V to 5.4 V)

Most newer systems use a single power supply to improve efficiency and to simplify power-supply design. The OPAx837 can be used with single-supply power (ground for the negative supply) with no change in performance from split supply, as long as the input and output pins are biased within the linear operating region of the device. The outputs nominally swing rail-to-rail with approximately a 100-mV headroom required for linear operation. The inputs can typically swing 0.2 V below the negative rail (typically ground) and to within 1.2 V of the positive supply. For DC-coupled single-supply operation, the input swing is below the available output swing range for noninverting gains greater than 1.30 V/V. Typically, the 1.2-V input headroom required to the positive supply only limits output swing range for a unity-gain buffer.

To change the circuit from split supply to single-supply, level shift all voltages by half the difference between the power-supply rails. For example, [Figure 69](#) depicts changing from a  $\pm 2.5$ -V split supply to a 5-V single-supply. The load is shown as mid-supply referenced but can be grounded as well.

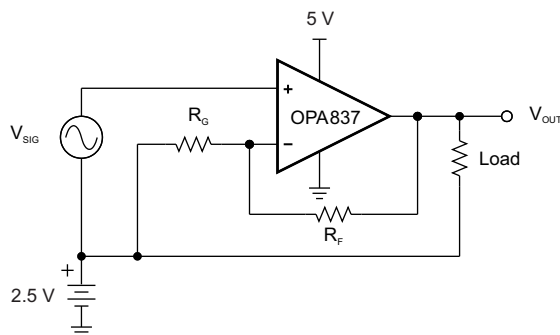


Figure 69. Single-Supply Concept

A practical circuit has an amplifier or other circuit providing the bias voltage for the input, and the output of this amplifier stage provides the bias for the next stage.

[Figure 70](#) shows a typical noninverting amplifier circuit. With 5-V single-supply, a mid-supply reference generator is needed to bias the negative side through  $R_G$ . To cancel the voltage offset that is otherwise caused by the input bias currents,  $R_1$  is selected to be equal to  $R_F$  in parallel with  $R_G$ . For example, if a gain of 2 V/V is required and  $R_F = 2$  k $\Omega$ , select  $R_G = 2$  k $\Omega$  to set the gain, and  $R_1 = 1$  k $\Omega$  for bias current cancellation which reduces the output DC error to  $I_{OS} \times R_F$ . The value for C is dependent on the reference, and TI recommends a value of at least 0.1  $\mu$ F to limit noise. The frequency response flatness is impacted by the AC impedance, including the reference and capacitor added to the  $R_G$  element.

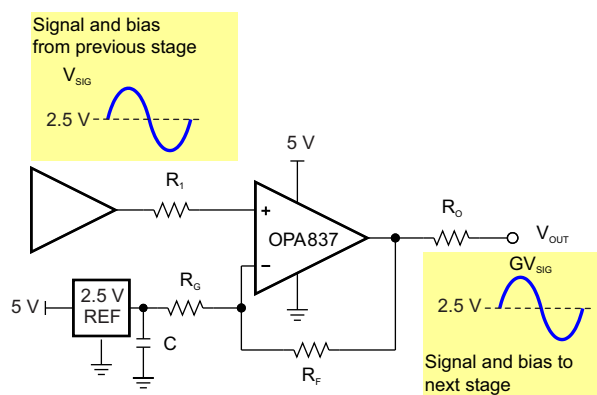
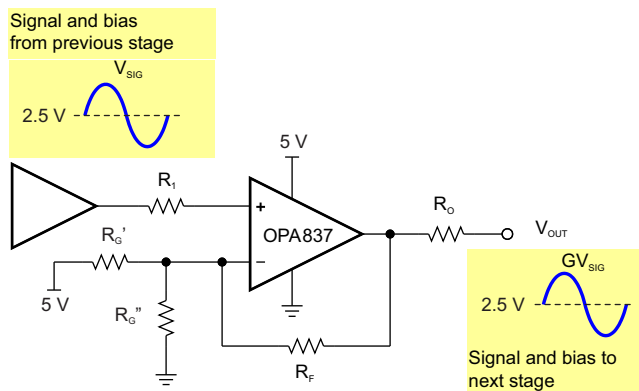


Figure 70. Noninverting Single-Supply Operation With Reference

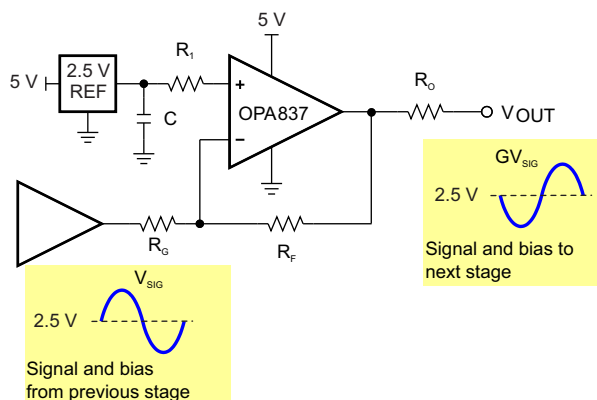
## Device Functional Modes (continued)

Figure 71 shows a similar noninverting single-supply scenario with the reference generator replaced by the Thevenin equivalent using resistors and the positive supply.  $R_G'$  and  $R_G''$  form a resistor divider from the 5-V supply and are used to bias the negative side with the parallel sum equal to the equivalent  $R_G$  to set the gain. To cancel the voltage offset that is otherwise caused by the input bias currents,  $R_1$  is selected to be equal to  $R_F$  in parallel with  $R_G'$  in parallel with  $R_G''$  ( $R_1 = R_F \parallel R_G' \parallel R_G''$ ). For example, if a gain of 2 V/V is required and  $R_F = 2\text{ k}\Omega$ , selecting  $R_G' = R_G'' = 4\text{ k}\Omega$  gives an equivalent parallel sum of  $2\text{ k}\Omega$ , sets the gain to 2, and references the input to mid-supply (2.5 V).  $R_1$  is set to  $1\text{ k}\Omega$  for bias current cancellation. The resistor divider costs less than the 2.5-V reference in Figure 70 but increases the current from the 5-V supply. Any noise or variation on the 5-V supply now also comes into the circuit as an input through the biasing path.



**Figure 71. Noninverting Single-Supply Operation With Resistor Mid-Supply Biasing**

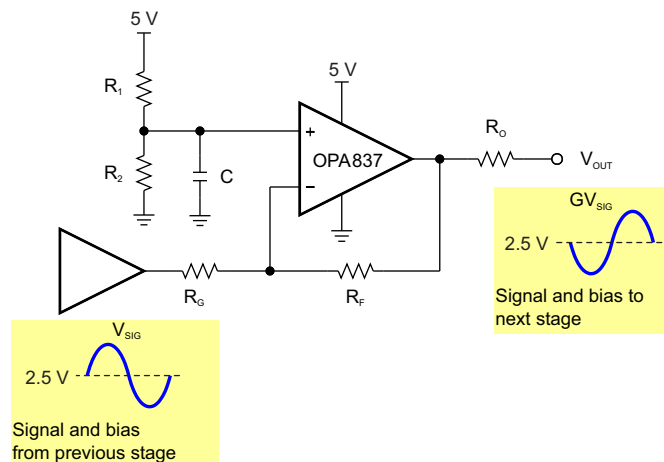
Figure 72 shows a typical inverting amplifier circuit. With a 5-V single supply, a mid-supply reference generator is needed to bias the positive side through  $R_1$ . To cancel the voltage offset that is otherwise caused by the input bias currents,  $R_1$  is selected to be equal to  $R_F$  in parallel with  $R_G$ . For example, if a gain of  $-2\text{ V/V}$  is required and  $R_F = 2\text{ k}\Omega$ , select  $R_G = 1\text{ k}\Omega$  to set the gain and  $R_1 = 667\text{ }\Omega$  for bias current cancellation. The value for  $C$  is dependent on the reference, but TI recommends a value of at least  $0.1\text{ }\mu\text{F}$  to limit noise into the op amp.



**Figure 72. Inverting Single-Supply Operation With Reference**

## Device Functional Modes (continued)

Figure 73 shows a similar inverting single-supply scenario with the reference generator replaced by the Thevenin equivalent using resistors and the positive supply.  $R_1$  and  $R_2$  form a resistor divider from the 5-V supply and are used to bias the positive side. To cancel the voltage offset that is otherwise caused by the input bias currents, set the parallel value of  $R_1$  and  $R_2$  equal to the parallel value of  $R_F$  and  $R_G$ .  $C$  must be added to limit coupling of noise into the positive input. For example, if gain of  $-2$  V/V is required and  $R_F = 2$  k $\Omega$ , select  $R_G = 1$  k $\Omega$  to set the gain.  $R_1 = R_2 = 2 \times 667 \Omega = 1.33$  k $\Omega$  for the mid-supply voltage bias and for op-amp input-bias current cancellation. A good value for  $C$  is 0.1  $\mu$ F. The resistor divider costs less than the 2.5-V reference in Figure 72 but increases the current from the 5-V supply. Any noise or variation in the 5-V supply also comes into the circuit through this bias setup but be band-limited by the pole formed with  $R_1 \parallel R_2$  and  $C$ .



**Figure 73. Inverting Single-Supply Operation With Resistor Midsupply Biasing**

These examples are only a few of the ways to implement a single-supply design. Many other designs exist that can often be simpler if AC-coupled inputs are allowed. A good compilation of options can be found in the [Single-Supply Op Amp Design Techniques](#) application report.

## 8 Application and Implementation

### 注

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

#### 8.1.1 Noninverting Amplifier

The OPAX837 can be used as a noninverting amplifier with a signal input to the noninverting input,  $V_{IN+}$ . A basic block diagram of the circuit is illustrated in 図 62.  $V_{REF}$  is often ground when split supplies are used.

Calculate the amplifier output according to 式 1 if  $V_{IN} = V_{REF} + V_{SIG}$ .

$$V_{OUT} = V_{SIG} \left( 1 + \frac{R_F}{R_G} \right) + V_{REF} \quad (1)$$

The signal gain of the circuit is set by 式 2, and  $V_{REF}$  provides a reference around which the input and output signals swing. Output signals are in-phase with the input signals within the flat portion of the frequency response. For a high-speed, low-noise device such as the OPAX837, the values selected for  $R_F$  (and  $R_G$  for the desired gain) can strongly influence the operation of the circuit. For the characteristic curves, the noninverting circuit of 図 74 shows the test configuration set for a gain of 2 V/V. 表 2 lists the recommended resistor values over gain.

$$G = 1 + \frac{R_F}{R_G} \quad (2)$$

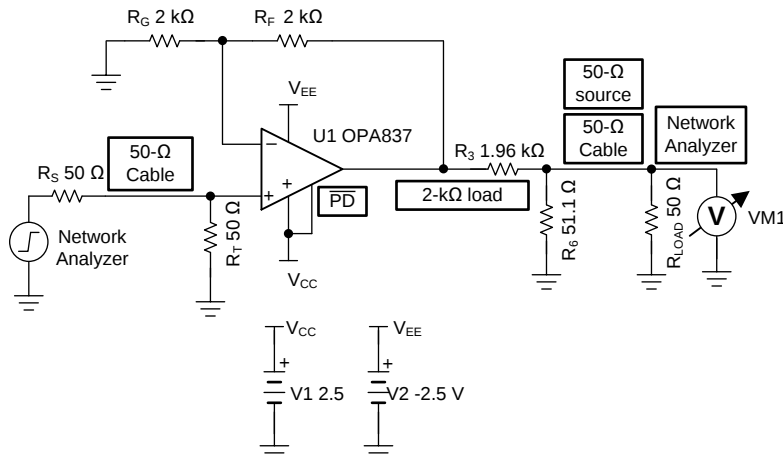


図 74. Characterization Test Circuit for Network, Spectrum Analyzer

## Application Information (continued)

表 2 lists the recommended resistor values from target gains of 1 V/V to 10 V/V where standard E96 values are shown. This table controls the  $R_F$  and  $R_G$  values to set the resistor noise contribution at approximately 50% of the total output noise power. These values increase the spot noise at the output over what the op amp voltage noise produces by 41%. Lower values reduce the output noise of any design at the cost of more power in the feedback circuit. Using the [TINA model and simulation tool](#) shows the impact of different resistor value choices on response shape and noise.

**表 2. Noninverting Recommended Resistor Values**

| TARGET GAIN (V/V) | $R_F$ ( $\Omega$ ) | $R_G$ ( $\Omega$ ) | ACTUAL GAIN (V/V) | GAIN (dB) |
|-------------------|--------------------|--------------------|-------------------|-----------|
| 1                 | 0                  | Open               | 1.00              | 0.00      |
| 1.5               | 1190               | 2370               | 1.50              | 3.53      |
| 2                 | 2000               | 2000               | 2.00              | 6.02      |
| 3                 | 2260               | 1130               | 3.00              | 9.54      |
| 4                 | 2370               | 787                | 4.01              | 12.07     |
| 5                 | 2490               | 619                | 5.02              | 14.02     |
| 6                 | 2550               | 511                | 5.99              | 15.55     |
| 7                 | 2610               | 432                | 7.04              | 16.95     |
| 8                 | 2670               | 383                | 7.97              | 18.03     |
| 9                 | 2670               | 332                | 9.04              | 19.13     |
| 10                | 2670               | 294                | 10.08             | 20.07     |

### 8.1.2 Inverting Amplifier

The OPAx837 can be used as an inverting amplifier with a signal input to the inverting input,  $V_{IN-}$ , through the gain-setting resistor  $R_G$ . A basic block diagram of the circuit is illustrated in [图 63](#).

The output of the amplifier can be calculated according to [式 3](#) if  $V_{IN} = V_{REF} + V_{SIG}$  and the noninverting input is biased to  $V_{REF}$ .

$$V_{OUT} = V_{SIG} \left( \frac{-R_F}{R_G} \right) + V_{REF} \quad (3)$$

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The signal gain of the circuit is set by 式 4 and  $V_{REF}$  provides a reference point around which the input and output signals swing. For bipolar-supply operation,  $V_{REF}$  is often ground. The output signal is 180° out-of-phase with the input signal in the pass band of the application. 图 75 shows the 50-Ω input matched configuration used for the inverting characterization plots set up for a gain of -1 V/V. In this case, an added termination resistor,  $R_T$ , is placed in parallel with the input  $R_G$  resistor to provide an impedance match to 50-Ω test equipment. The output network appears as a 2-kΩ load but with a 50-Ω source to the network analyzer. This output interface network does add a 37.9-dB insertion loss that is normalized out in the characterization curves. 表 3 lists the suggested values for  $R_F$ ,  $R_G$ , and  $R_T$  for inverting gains from -0.5 V/V to -10 V/V. If a 50-Ω input match is not required, eliminate the  $R_T$  element.

$$G = \frac{-R_F}{R_G} \quad (4)$$

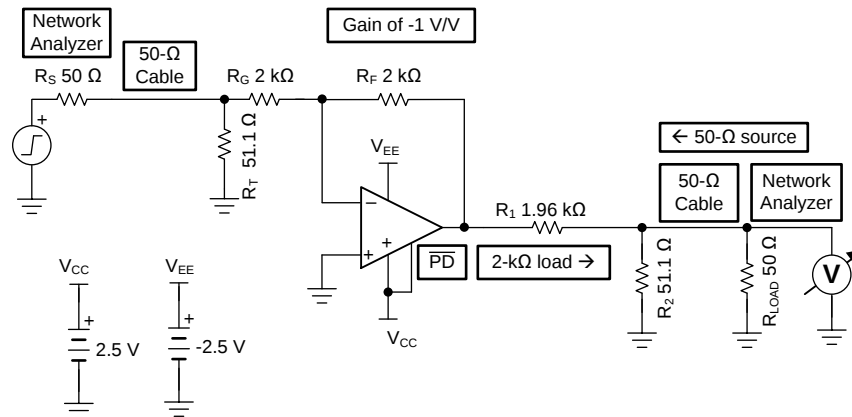


图 75. Inverting Characterization Circuit for Network Analyzer

表 3. Inverting Recommended Resistor Values

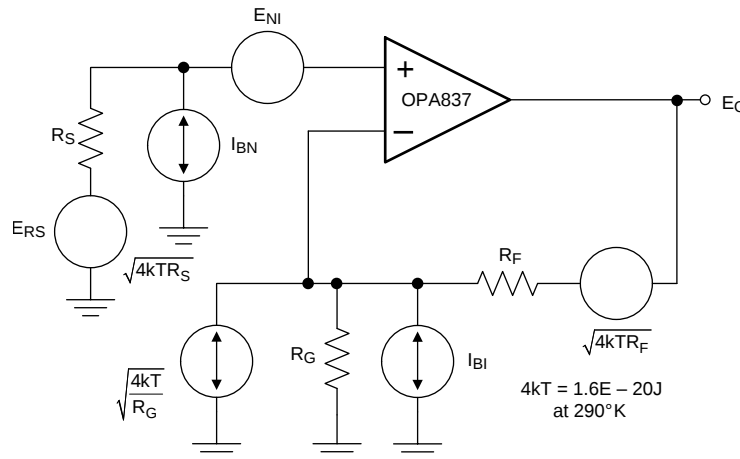
| INVERTING GAIN (V/V) | $R_F$ (Ω) | $R_G$ (Ω) | STANDARD $R_T$ (Ω) | INPUT $Z_i$ (Ω) | ACTUAL (V/V) | GAIN (dB) |
|----------------------|-----------|-----------|--------------------|-----------------|--------------|-----------|
| -0.5                 | 1190      | 2370      | 51.1               | 50.02           | -0.50        | -5.98     |
| -1                   | 2000      | 2000      | 51.1               | 49.83           | -1.00        | 0.00      |
| -2                   | 2260      | 1130      | 52.3               | 49.99           | -2.00        | 6.02      |
| -3                   | 2370      | 787       | 53.6               | 50.18           | -3.01        | 9.58      |
| -4                   | 2490      | 619       | 54.9               | 50.43           | -4.02        | 12.09     |
| -5                   | 2550      | 511       | 54.9               | 49.57           | -4.99        | 13.96     |
| -6                   | 2610      | 432       | 56.2               | 49.73           | -6.04        | 15.62     |
| -7                   | 2670      | 383       | 57.6               | 50.07           | -6.97        | 16.87     |
| -8                   | 2670      | 332       | 59                 | 50.10           | -8.04        | 18.11     |
| -9                   | 2670      | 294       | 60.4               | 50.11           | -9.08        | 19.16     |
| -10                  | 2670      | 267       | 61.9               | 50.25           | -10.00       | 20.00     |

### 8.1.3 Output DC Error Calculations

The OPAx837 can provide excellent DC signal accuracy because of its high open-loop gain, high common-mode rejection, high power-supply rejection, and low input offset voltage and bias current offset errors. To take full advantage of this low input offset voltage, pay careful attention to input bias current cancellation. The low-noise input stage for the OPAx837 has a relatively high input bias current (0.34  $\mu\text{A}$  typical out the pins) but with a close match between the two input currents. The OPAx837 is a negative rail input device using PNP input devices where the base current flows out of the device pins. A large resistor to ground on the V+ input shifts the pin voltage positively because of the input bias current. The mismatch between the two input bias currents is very low, typically only  $\pm 10$  nA of input offset current. Match the DC source impedances out of the two inputs to reduce the total output offset voltage. [Figure 67](#) illustrates an example of resistor matching for bias current cancellation. Analyzing the simple circuit of [Figure 67](#) (using a gain of 2-V/V target with  $R_F = R_G = 2$  k $\Omega$ ) illustrates that the noise gain for the input offset voltage drift is  $1 + 2$  k $\Omega$  /  $2$  k $\Omega$  = 2 V/V. This value results in an output drift term of  $\pm 1.6$   $\mu\text{V}/^\circ\text{C} \times 2 = \pm 3.2$   $\mu\text{V}/^\circ\text{C}$  (DCK package). Because the two impedances out of the inputs are matched, the residual error from the maximum  $\pm 250$  pA/ $^\circ\text{C}$  offset current drift is this maximum  $I_{OS}$  drift times the 2-k $\Omega$  feedback resistor value, or  $\pm 50$   $\mu\text{V}/^\circ\text{C}$ . The total output DC error drift band is  $\pm 53.2$   $\mu\text{V}/^\circ\text{C}$ . If the output DC drift is more important than reduced feedback currents, lower the resistor values to reduce the dominant drift term resulting from the  $I_{OS}$  term.

### 8.1.4 Output Noise Calculations

The unity-gain stable, voltage-feedback OPAx837 op amp offers among the lowest input voltage and current noise terms for any device with a supply current less than 0.7 mA. [Figure 76](#) shows the op amp noise analysis model that includes all noise terms. In this model, all noise terms are shown as noise voltage or current density terms in nV/ $\sqrt{\text{Hz}}$  or pA/ $\sqrt{\text{Hz}}$ .



**Figure 76. Op Amp Noise Analysis Model**

The total output spot noise voltage is computed as the square root of the squared contributing terms to the output noise voltage. This computation is adding all the contributing noise powers at the output by superposition, then taking the square root to return to a spot noise voltage. The last term includes the noise for both the  $R_G$  and  $R_F$  resistors. [Equation 5](#) shows the general form for this output noise voltage using the terms presented in [Figure 76](#).

$$E_O = \sqrt{[E_{NI}^2 + (I_{BN}R_S)^2 + 4kTR_S]NG^2 + (I_{BI}R_F)^2 + 4kTR_FNG} \quad (5)$$

Dividing this expression by the noise gain ( $NG = 1 + R_F / R_G$ ), as shown in [Equation 6](#), gives the equivalent input referred spot noise voltage at the noninverting input.

$$E_N = \sqrt{E_{NI}^2 + (I_{BN}R_S)^2 + 4kTR_S + \left(\frac{I_{BI}R_F}{NG}\right)^2 + \frac{4kTR_F}{NG}} \quad (6)$$

Using the resistor values listed in 表 2 with  $R_S = 0 \Omega$  results in a constant input-referred voltage noise of  $< 7 \text{ nV}/\sqrt{\text{Hz}}$ . Reducing the resistor values can reduce this noise value towards the  $4.7 \text{ nV}/\sqrt{\text{Hz}}$  intrinsic to the OPA837. As shown in 式 5, adding the  $R_S$  for bias current cancellation in noninverting mode adds the noise from the  $R_S$  to the total output noise. In inverting mode, bypass the  $R_S$  bias current cancellation resistor with a capacitor for the best noise performance. For more details on op amp noise analysis, see the [Noise Analysis for High-Speed Op Amps](#) application report.

### 8.1.5 Instrumentation Amplifier

图 77 is an instrumentation amplifier that combines the high input impedance of the differential-to-differential amplifier circuit and the common-mode rejection of the differential-to-single-ended amplifier circuit. This circuit is often used in applications where high input impedance is required (such as taps from a differential line) or in cases where the signal source is a high impedance.

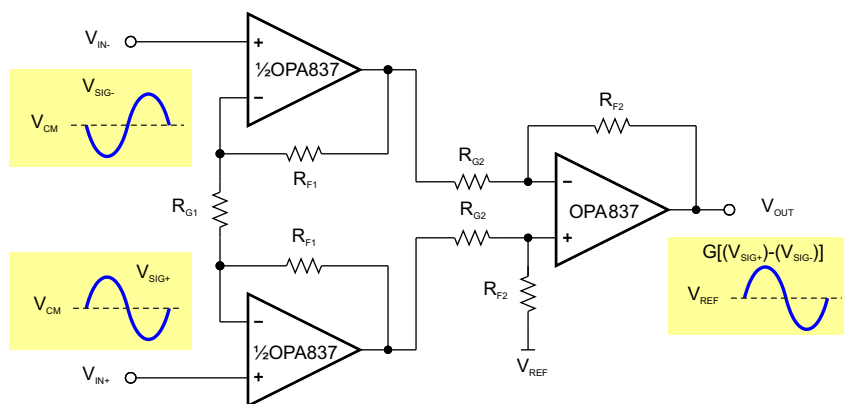


图 77. Instrumentation Amplifier (INA)

The output of the amplifier can be calculated according to 式 7 if  $V_{IN+} = V_{CM} + V_{SIG+}$  and  $V_{IN-} = V_{CM} + V_{SIG-}$ .

$$V_{OUT} = (V_{IN+} - V_{IN-}) \times \left( 1 + \frac{2R_{F1}}{R_{G1}} \right) \left( \frac{R_{F2}}{R_{G2}} \right) + V_{REF} \quad (7)$$

式 8 shows the signal gain of the circuit. The input  $V_{CM}$  is rejected, and  $V_{REF}$  provides a reference voltage or level shift around which the output signal swings. The single-ended output signal is in-phase to the lower input signal polarity.

$$G = \left( 1 + \frac{2R_{F1}}{R_{G1}} \right) \left( \frac{R_{F2}}{R_{G2}} \right) \quad (8)$$

Integrated INA solutions are available, but the OPAx837 device provides a high-frequency solution at relatively low power ( $< 1.8 \text{ mA}$  for the three op-amp solution). For best CMRR performance, resistors must be matched. A good rule of thumb is  $\text{CMRR} \approx$  the resistor tolerance; so a 0.1% tolerance provides approximately 60-dB CMRR. For higher gain INA implementations with higher bandwidths, apply the OPA838 to the circuit of 图 77.

### 8.1.6 Attenuators

The noninverting circuit of 图 62 has a minimum gain of 1. To implement attenuation, a resistor divider can be placed in series with the positive input, and the amplifier set for a gain of 1 V/V by shorting  $V_{OUT}$  to  $V_{IN-}$  and removing  $R_G$ . Because the op amp input is high impedance, the resistor divider sets the attenuation.

The inverting circuit of 图 63 is used as an attenuator by making  $R_G$  larger than  $R_F$ . The attenuation is the resistor ratio. For example, a 10:1 attenuator can be implemented with  $R_F = 2 \text{ k}\Omega$  and  $R_G = 20 \text{ k}\Omega$ .

### 8.1.7 Differential to Single-Ended Amplifier

Figure 78 shows a differential amplifier that converts differential signals to single-ended in a single stage and provides gain (or attenuation) and level shifting. This circuit can be used in applications such as a line receiver for converting a differential signal from a Cat5 cable to a single-ended output signal.

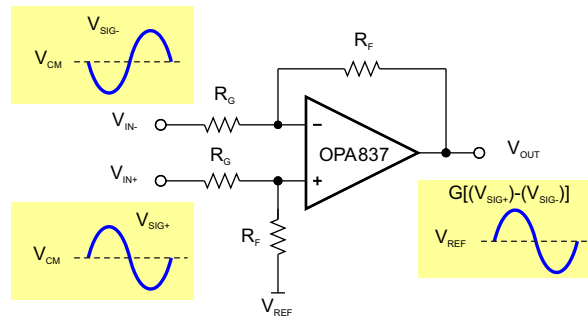


Figure 78. Differential to Single-Ended Amplifier

The output of the amplifier can be calculated according to Equation 9 if  $V_{IN+} = V_{CM} + V_{SIG+}$  and  $V_{IN-} = V_{CM} + V_{SIG-}$ .

$$V_{OUT} = (V_{IN+} - V_{IN-}) \times \left( \frac{R_F}{R_G} \right) + V_{REF} \quad (9)$$

The signal gain of the circuit is shown in Equation 10,  $V_{CM}$  is rejected, and  $V_{REF}$  provides a level shift or reference voltage around which the output signal swings. The single-ended output signal is in-phase with the noninverting input signal.  $V_{REF}$  is often ground when split supplies are used on the op amp.

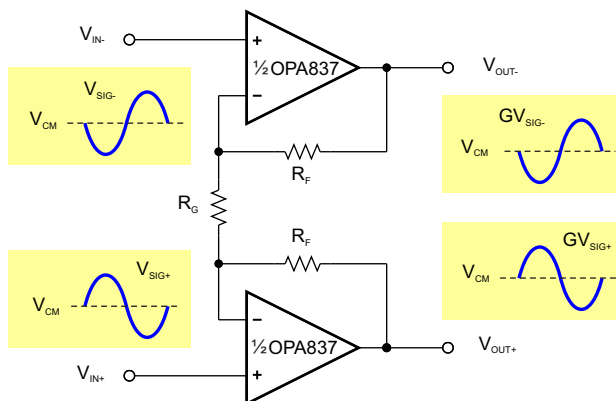
$$G = \frac{R_F}{R_G} \quad (10)$$

Line termination can be accomplished by adding a shunt resistor across the  $V_{IN+}$  and  $V_{IN-}$  inputs. The differential impedance is the shunt resistance in parallel with the input impedance of the amplifier circuit, which is usually much higher. For low gain and low line impedance, the resistor value to add is approximately the impedance of the line. For example, if a 100-Ω Cat5 cable is used with a gain of 1 V/V amplifier and  $R_F = R_G = 2 \text{ k}\Omega$ , adding a 100-Ω shunt across the input gives a differential impedance of 99 Ω, which is an adequate match for most applications.

For best CMRR performance, resistors must be matched. Assuming  $\text{CMRR} \approx$  the resistor tolerance, a 0.1% tolerance provides approximately 60-dB CMRR.

### 8.1.8 Differential-to-Differential Amplifier

Figure 79 shows a differential amplifier that is used to amplify differential signals to a differential output. This circuit has high input impedance and is used in differential line driver applications where the signal source is a high-impedance driver (for example, a differential DAC) that must drive a line.



**Figure 79. Differential-to-Differential Amplifier**

The output of the amplifier can be calculated according to Equation 11 if  $V_{IN\pm}$  is set to  $V_{CM} + V_{SIG\pm}$ .

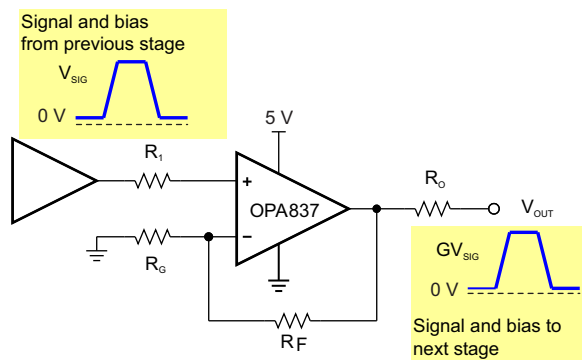
$$V_{OUT\pm} = V_{IN\pm} \times \left( 1 + \frac{2R_F}{R_G} \right) + V_{CM} \quad (11)$$

The signal gain of the circuit is shown in Equation 12, and  $V_{CM}$  passes with unity gain. The amplifier combines two noninverting amplifiers into one differential amplifier that shares the  $R_G$  resistor, which makes  $R_G$  effectively half its value when calculating the gain. The output signals are in-phase with the input signals.

$$G = 1 + \frac{2R_F}{R_G} \quad (12)$$

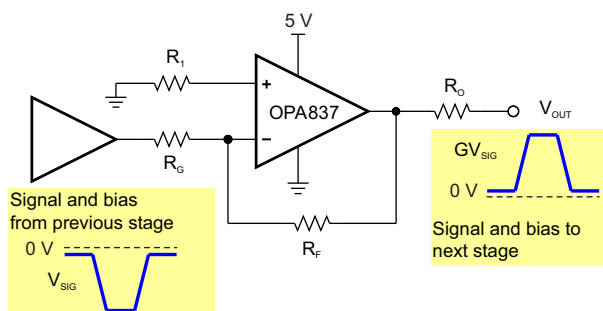
### 8.1.9 Pulse Application With Single-Supply Circuit

For pulsed applications where the signal is at ground and pulses to a positive or negative voltage, the circuit bias-voltage considerations differ from those in an application with a signal that swings symmetrically around a reference point. [Figure 80](#) shows a circuit where the signal is at ground (0 V) and pulses to a positive value. The waveforms are shown slightly above ground because the output stage requires approximately 100 mV headroom to the supplies. To operate with the I/O swing truly to ground on a single-supply setup, consider using the fixed  $-0.23\text{-V}$  output [LM7705](#).



**Figure 80. Noninverting Single-Supply Circuit With Pulse**

As shown in [Figure 81](#), an inverting amplifier is more appropriate if the input signal pulses negative from ground. A key consideration in noninverting and inverting cases is that the input and output voltages are kept within the limits of the amplifier. Because the  $V_{ICR}$  of the OPA837 includes the negative supply rail, the OPA837 op amp is well-suited for this application.



**Figure 81. Inverting Single-Supply Circuit With Pulse**

### 8.1.10 ADC Driver Performance

The OPAx837 provides excellent performance when driving high-performance delta-sigma ( $\Delta\Sigma$ ) or successive-approximation-register (SAR) ADCs in low-power audio and industrial applications.

Figure 82 repeats the front page diagram. Many designs prefer to work with a true 0-V input range to 0-V output at the ADC. The 100-mV output headroom requirement for the OPAx837 then requires a small negative supply to hold the output linearity to ground. This supply is provided in this example using the low-cost LM7705 fixed negative,  $-0.23\text{-V}$  output regulator. On a 5-V supply, the input headroom requires at least a 1.2-V headroom to that supply. As shown in Figure 82, this requirement limits the maximum input to 3.8 V. The SAR operates with a precision 4.096-V reference provided by the REF5040, where the gain of 1.05 V/V takes the 3.8-V maximum input to a 4.0-V maximum output. The RC values have been set to limit the overshoot at the OPAx837 output pin to reduce clipping on fast (50 ns) transitions.

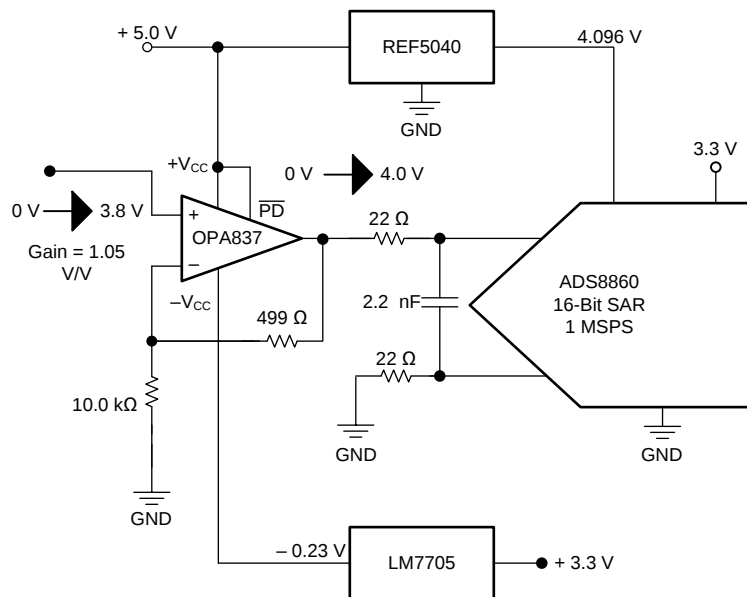


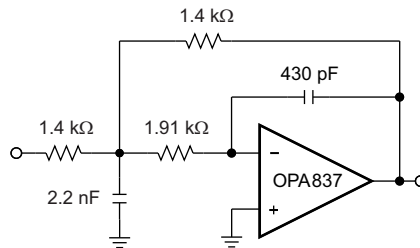
Figure 82. OPA837 and ADS8860 Example Circuit

## 8.2 Typical Applications

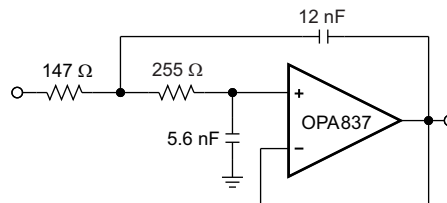
### 8.2.1 Active Filters

The OPAx837 is a good choice for active filters. [Figure 83](#) and [Figure 84](#) show MFB and Sallen-Key circuits designed implementing second-order, low-pass Butterworth filter circuits. [Figure 85](#) illustrates the frequency response.

The main difference is that the MFB active filter provides an inverting amplifier in the pass band and the Sallen-Key active filter is noninverting. The primary advantage for each active filter is that the Sallen-Key filter in unity gain has no resistor gain error term or feedback resistor noise contribution. The MFB active filter has better attenuation properties beyond the bandwidth of the op amp. The example circuits are assuming a split-supply operation but single-supply operation is possible with midscale biasing.



**Figure 83. MFB Active Filter, 100-kHz, Second-Order, Low-Pass Butterworth Filter Circuit**



**Figure 84. Sallen-Key Active Filter, 100-kHz, Second-Order, Low-Pass Butterworth Filter Circuit**

#### 8.2.1.1 Design Requirements

For both designs, target the following filter shape characteristic:

- Gain of 1 V/V
- 100-kHz Butterworth response
- $Q = 0.707$  gives a flat Butterworth design

Scale the resistors down to reduce their noise contribution. In the MFB design, the input resistor is the in-band load to the prior stage. Use values slightly below the gain of  $-1$  V/V in [Table 3](#). The Sallen-Key filter shows a high impedance input in-band, so scale those resistors down further to improve noise.

The output DC error and drift can be improved by adding bias current cancellation resistors. For the MFB filter that is a resistor (and a noise filter capacitor) on the noninverting input to ground equal to the resistor inside the loop times the noise gain. For the Sallen-Key design, add a feedback resistor equal to the sum of the two input resistors.

#### 8.2.1.2 Detailed Design Procedure

The filter designs shown in this section used an improved design flow that reduces the resistor noise and noise gain peaking. For the MFB filter, the design was based on the information in the [Design Methodology for MFB Filters in ADC Interface Applications](#) application note.

For the Sallen-Key design, the solution is based on the information in the [Component Pre-Distortion for Sallen Key Filters](#) application note.

## Typical Applications (continued)

### 8.2.1.3 Application Curves

Figure 85 shows the comparative response curves for each of the filter design examples. Both filters hit the desired response shape exactly. However, notice the loss of stop-band rejection in the Sallen-Key design. This loss results from the op amp output impedance increasing at higher frequencies and allowing the signal to feed through the feedback capacitor to the output.

Figure 86 shows a comparison of the output spot noise for the two designs. The Sallen-Key is much lower because of the lower resistor values used. Also, the MFB shows a noise gain of 2 V/V versus the Sallen-Key gain of 1 V/V. This difference immediately increases the MFB output noise by at least twice the input voltage noise from the op amp. The higher resistor values also increase the total output noise for the MFB.

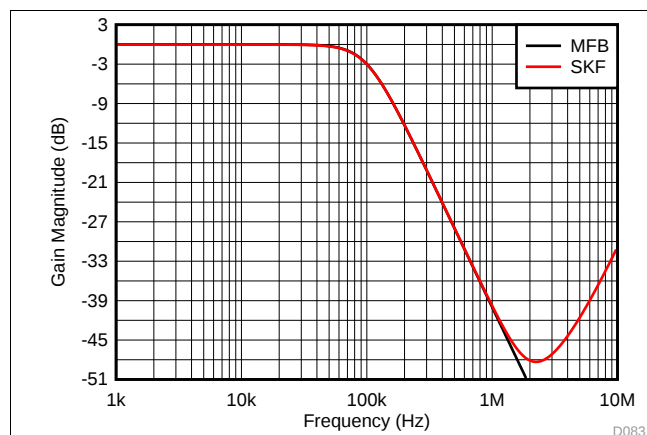


Figure 85. MFB and Sallen-Key Active Filters, Second-Order, Low-Pass Butterworth Filter Response

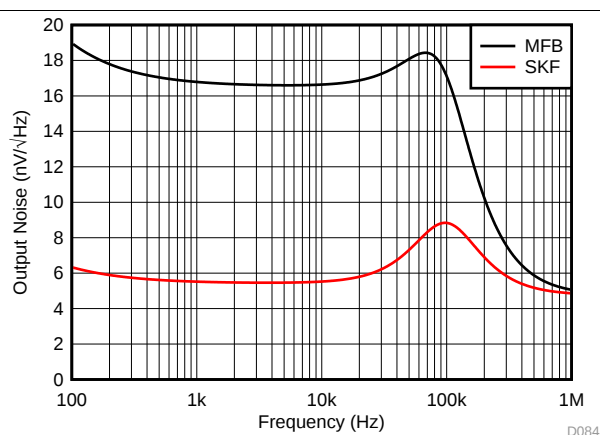
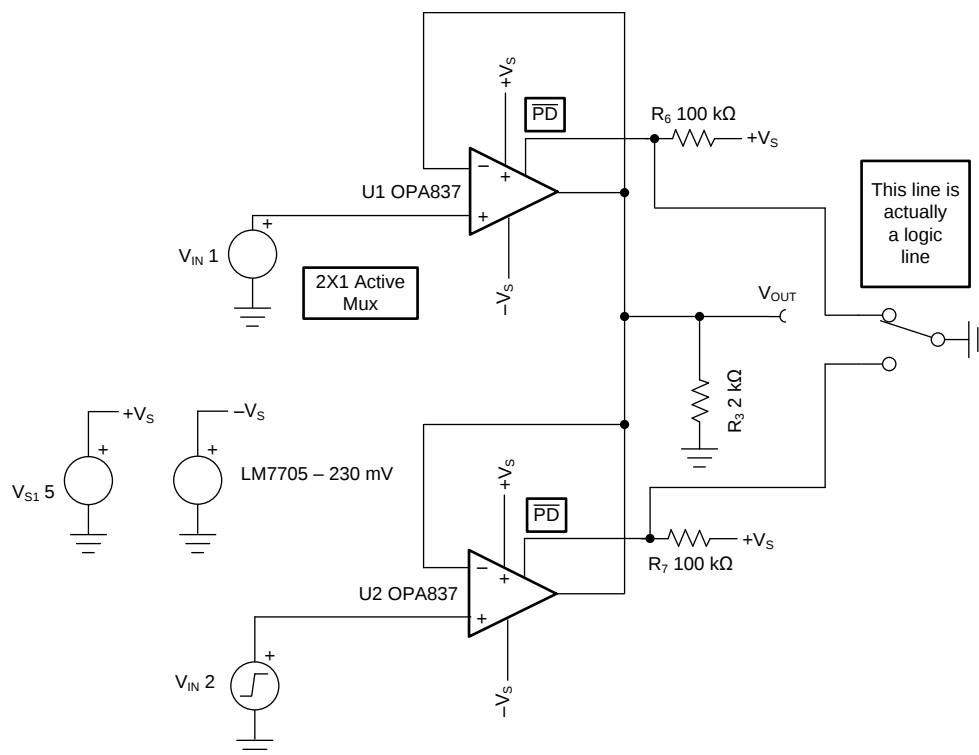


Figure 86. Output Spot Noise Comparison

### 8.2.2 Implementing a 2:1 Active Multiplexer

The OPA837 includes a unique feature that enables a much improved wired-or mux operation. When disabled, an internal switch opens from the inverting input to the active transistors isolating those nonlinear loads from the signal being driven back into the inverting input through the active channel. Figure 87 illustrates a simple example of this multiplexer. In this figure, one of two signals are selected to be passed on to a shared output. The logic control turns both amplifiers off (logic low) prior to turning one of them on. This control eliminates both outputs being active at the same time. If both amplifiers must be on, as in the simple switch illustrated in Figure 87, adding 100-Ω isolating resistors inside the loop at the outputs limits the current flow when both amplifiers are turned on. This solution offers a very high input impedance to both inputs, very low buffered output drive, and nearly perfect channel-to-channel isolation. The example of Figure 87 also includes a -0.23-V supply generator to allow true swing to ground on the output pins. This negative supply generator is optional if the outputs are more than 0.1 V above ground or intended to be AC-coupled. Testing with a single channel active and an off channel attached to the output showed no degradation in harmonic distortion; see Figure 17 and Figure 35. This approach can be expanded to more than two channels or to operate with gain in the channels. Adding more than two select channels in parallel should add 100-Ω feedback resistors to isolate the inverting input capacitance from the active output channel.

## Typical Applications (continued)



✎ 87. 2:1 Active Multiplexer

### 8.2.2.1 Design Requirements

To implement a 2:1 active mux, connect the outputs of two OPA837 devices together with separate input signals. If termination is required for the input signals, add this termination as a resistor to ground on the noninverting inputs. The inputs accept an input range from 0 V to 3.8 V by using a negative 0.23-V supply generator, such as the LM7705.

### 8.2.2.2 Detailed Design Procedure

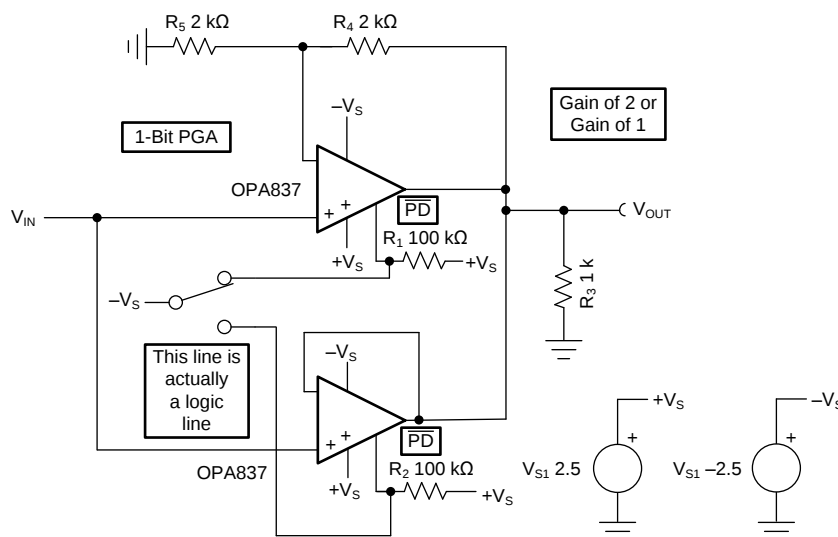
Aside from simply connecting the two outputs together as shown in ✎ 87, there are several other considerations as well:

- If the source impedance is not 0  $\Omega$ , consider adding a resistor in the feedback networks equal to that source impedance to reduce the output DC error resulting from bias currents
- If the logic control can place both channels on at the same time, place 100- $\Omega$  resistors inside the feedback loop to limit supply currents when both outputs are active
- If a matched gain is desired for the two inputs, configure the op amps for that gain instead of gain of 1 V/V
- If the load is capacitive, add the required  $R_{OUT}$  before the summing point on each op amp output

## Typical Applications (continued)

### 8.2.3 1-Bit PGA Operation

Using the internal inverting input switch that operates along with the power disable function can also allow a simple gain selection on a single input signal. [Figure 88](#) shows an example gain select of either 1 V/V or 2 V/V from a single input to a single output. The logic disables both channels before turning one of them on to avoid high currents in both outputs to be active at the same time. If this approach is not possible, as in the simple switch shown in [Figure 88](#), insert 100- $\Omega$  resistors inside the loop of each op amp output. A bipolar supply is shown in [Figure 88](#), but any of the single-supply options are also possible. Any combination of gains can be implemented, but wide gain ranges show a larger change in signal bandwidth. This approach can be expanded to more than two gain settings. Testing with the circuit of [Figure 88](#) showed no change in harmonic distortion; see [Figure 18](#) and [Figure 36](#).



**Figure 88. 1-Bit PGA**

#### 8.2.3.1 Design Requirements

Configure two OPA837 device outputs in different gains when driving the noninverting input with the same input signal. Select one of the two channels using the disable control. Set one channel to a gain of 1 V/V and the second channel to a gain of 2 V/V using the recommended 2-k $\Omega$  values from [Table 2](#).

#### 8.2.3.2 Detailed Design Procedure

The simple design of [Figure 88](#) has several options and details to consider, which include:

- For split-supply operation, the disable control line must operate to within 0.55 V of the negative supply to disable a channel. A logic level shift is required.
- Any combination of gains can be implemented. However, the signal bandwidths may vary widely through the gain bandwidth product effect between the two channels if the gains are widely separated. If a more constant bandwidth between gains is desired, consider adding a fixed RC filter after the combined outputs at a lower cutoff frequency than the slowest gain setting.

The [TIDA-01565 Wired OR MUX and PGA Reference Design](#) demonstrates the use of the OPAx837 in wired-OR multiplexer and programmable gain amplifier applications.

## 9 Power Supply Recommendations

The OPAx837 is intended to work in a nominal supply range of 3.0 V to 5 V. Supply-voltage tolerances are supported with the specified operating range of 2.7 V (–10% on a 3-V supply) and 5.4 V (+8% on a 5-V supply). Good power-supply bypassing is required. Minimize the distance (< 0.1 inch) from the power-supply pins to high-frequency, 0.1-μF decoupling capacitors. A larger capacitor (2.2 μF is typical) is used along with a high-frequency, 0.1-μF supply-decoupling capacitor at the device supply pins. For single-supply operation, only the positive supply has these capacitors. When a split supply is used, use these capacitors for each supply to ground. If necessary, place the larger capacitors further from the device and share these capacitors among several devices in the same area of the printed circuit board (PCB). Avoid narrow power and ground traces to minimize inductance between the pins and the decoupling capacitors. An optional supply decoupling capacitor across the two power supplies (for bipolar operation) reduces second harmonic distortion.

The OPA837 has a positive supply current temperature coefficient; see [Figure 57](#). This coefficient helps improve the input offset voltage drift. Supply current requirements in the system design must account for this effect using the maximum intended ambient and [Figure 57](#) to size the supply required. The very low power dissipation for the OPA837 typically does not require any special thermal design considerations. For the extreme case of 125°C operating ambient, use the approximate maximum 200°C/W for the two packages, and a maximum internal power of 5.4-V supply × 0.8-mA 125°C supply current from [Figure 57](#) gives a maximum internal power of 4.3 mW. This power only gives a 0.86°C rise from ambient to junction temperature, which is well below the maximum 150°C junction temperature. Load power adds to this value, but also increases the junction temperature only slightly over ambient temperature.

## 10 Layout

### 10.1 Layout Guidelines

The [OPA837EVM](#) can be used as a reference when designing the circuit board. TI recommends following the EVM layout of the external components near to the amplifier, ground plane construction, and power routing as closely as possible. General guidelines are listed below:

1. Signal routing must be direct and as short as possible into and out of the op amp.
2. The feedback path must be short and direct avoiding vias if possible, especially with  $G = 1$  V/V.
3. Ground or power planes must be removed from directly under the negative input and output pins of the amplifier.
4. TI recommends placing a series output resistor as close to the output pin as possible. See [Figure 49](#) for recommended values for the expected capacitive load. These values are derived targeting a 30° phase margin to the output of the op amp.
5. A 2.2-μF power-supply decoupling capacitor must be placed within two inches of the device and can be shared with other op amps. For split supply, a capacitor is required for both supplies.
6. A 0.1-μF power-supply decoupling capacitor must be placed as close to the supply pins as possible, preferably within 0.1 inch. For split supply, a capacitor is required for both supplies.
7. The  $\overline{\text{PD}}$  pin uses low logic swing levels. If the pin is not used,  $\overline{\text{PD}}$  must be tied to the positive supply to enable the amplifier. If the pin is used,  $\overline{\text{PD}}$  must be actively driven. A bypass capacitor is not necessary, but can be used for robustness in noisy environments.

## 10.2 Layout Example

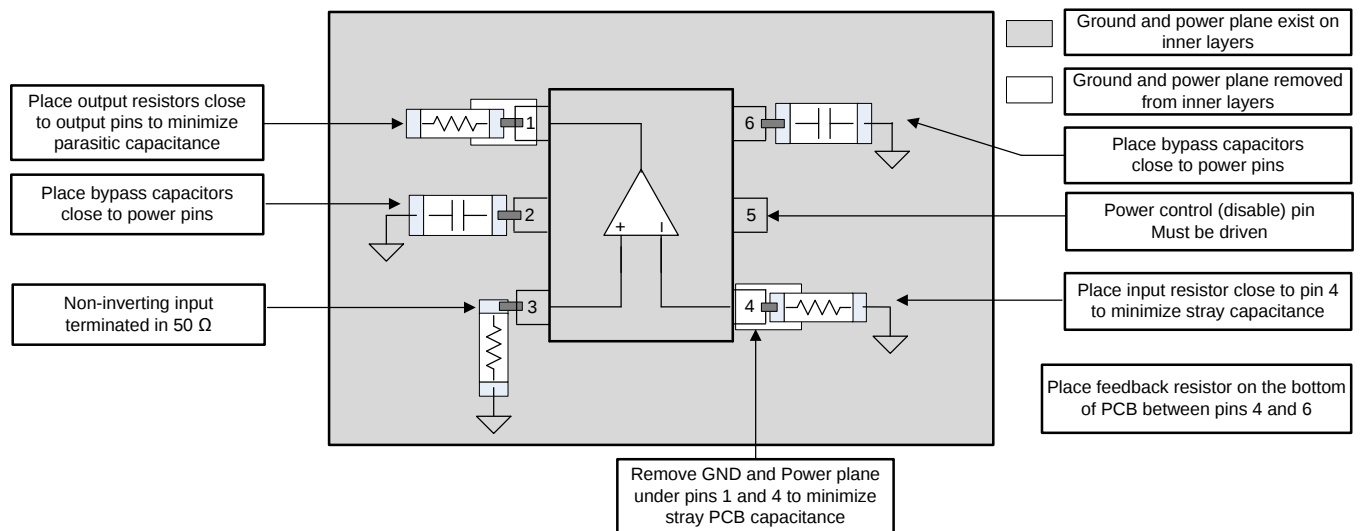


图 89. EVM Layout Example

## 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、『[ADS8860 16ビット、1MSPS、シリアル・インターフェイス、microPower、小型、シングルエンド入力、SARアナログ・デジタル・コンバータ](#)』データシート
- テキサス・インスツルメンツ、『[LM7705 低ノイズ、負のバイアス・ジェネレータ](#)』データシート
- テキサス・インスツルメンツ、『[OPA838 1mA、300MHzゲイン帯域幅、電圧帰還型オペアンプ](#)』データシート
- テキサス・インスツルメンツ、『[REF50xx 低ノイズ、超低ドリフト、高精度基準電圧](#)』データシート
- テキサス・インスツルメンツ、『[OPA837DBV, OPA836DBV EVM](#)』ユーザー・ガイド
- テキサス・インスツルメンツ、『[単一電源オペアンプの設計テクニック](#)』アプリケーション・レポート
- テキサス・インスツルメンツ、『[高速オペアンプのノイズ解析](#)』アプリケーション・レポート
- テキサス・インスツルメンツ、『[ADCインターフェイス・アプリケーションにおけるMFBフィルタ用の設計方法論](#)』アプリケーション・ノート
- テキサス・インスツルメンツ、『[サレン・キー・フィルタのコンポーネント・ブリディストーション](#)』アプリケーション・ノート
- テキサス・インスツルメンツ、『[TIDA-01565 有線OR MUXおよびPGAのリファレンス・デザイン](#)』デザイン・ガイド
- テキサス・インスツルメンツ、[TINAモデルおよびシミュレーション・ツール](#)

#### 11.2 関連リンク

次の表に、クイック・アクセス・リンクを示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびご注文へのクイック・アクセスが含まれます。

表 4. 関連リンク

| 製品      | プロダクト・フォルダ              | ご注文はこちら                 | 技術資料                    | ツールとソフトウェア              | サポートとコミュニティ             |
|---------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| OPA837  | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> |
| OPA2837 | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> |

#### 11.3 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](#)のデバイス製品フォルダを開いてください。右上の隅にある「通知を受け取る」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。

#### 11.4 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™ オンライン・コミュニティ** TIのE2E ( *Engineer-to-Engineer* ) コミュニティ。エンジニア間の共同作業を促進するために開設されたものです。e2e.ti.comでは、他のエンジニアに質問し、知識を共有し、アイデアを検討して、問題解決に役立てることができます。

**設計サポート** TIの設計サポート役に立つE2Eフォーラムや、設計サポート・ツールをすばやく見つけることができます。技術サポート用の連絡先情報も参照できます。

#### 11.5 商標

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

#### 11.6 静電気放電に関する注意事項



これらのデバイスは、限定的なESD (静電破壊) 保護機能を内蔵しています。保存時または取り扱い時は、MOSゲートに対する静電破壊を防止するために、リード線同士をショートさせておくか、デバイスを導電フォームに入れる必要があります。

## 11.7 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 part number        | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">OPA2837IDGKR</a> | Active        | Production           | VSSOP (DGK)   8  | 2500   LARGE T&R      | Yes         | NIPDAUAG   SN                        | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IDGKR.B               | Active        | Production           | VSSOP (DGK)   8  | 2500   LARGE T&R      | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| <a href="#">OPA2837IDGKT</a> | Active        | Production           | VSSOP (DGK)   8  | 250   SMALL T&R       | Yes         | NIPDAUAG   SN                        | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IDGKT.B               | Active        | Production           | VSSOP (DGK)   8  | 250   SMALL T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| <a href="#">OPA2837IRUNR</a> | Active        | Production           | QFN (RUN)   10   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IRUNR.B               | Active        | Production           | QFN (RUN)   10   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IRUNRG4               | Active        | Production           | QFN (RUN)   10   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IRUNRG4.B             | Active        | Production           | QFN (RUN)   10   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| <a href="#">OPA2837IRUNT</a> | Active        | Production           | QFN (RUN)   10   | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| OPA2837IRUNT.B               | Active        | Production           | QFN (RUN)   10   | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2837                |
| <a href="#">OPA837IDBVR</a>  | Active        | Production           | SOT-23 (DBV)   6 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| OPA837IDBVR.B                | Active        | Production           | SOT-23 (DBV)   6 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| <a href="#">OPA837IDBVR2</a> | Active        | Production           | SOT-23 (DBV)   6 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| OPA837IDBVR2.B               | Active        | Production           | SOT-23 (DBV)   6 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| <a href="#">OPA837IDBVT</a>  | Active        | Production           | SOT-23 (DBV)   6 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| OPA837IDBVT.B                | Active        | Production           | SOT-23 (DBV)   6 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 19FF                |
| <a href="#">OPA837IDCKR</a>  | Active        | Production           | SC70 (DCK)   5   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |
| OPA837IDCKR.B                | Active        | Production           | SC70 (DCK)   5   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |
| OPA837IDCKRG4                | Active        | Production           | SC70 (DCK)   5   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |
| OPA837IDCKRG4.B              | Active        | Production           | SC70 (DCK)   5   | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |
| <a href="#">OPA837IDCKT</a>  | Active        | Production           | SC70 (DCK)   5   | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |
| OPA837IDCKT.B                | Active        | Production           | SC70 (DCK)   5   | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 16K                 |

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

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

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

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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

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

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

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

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

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

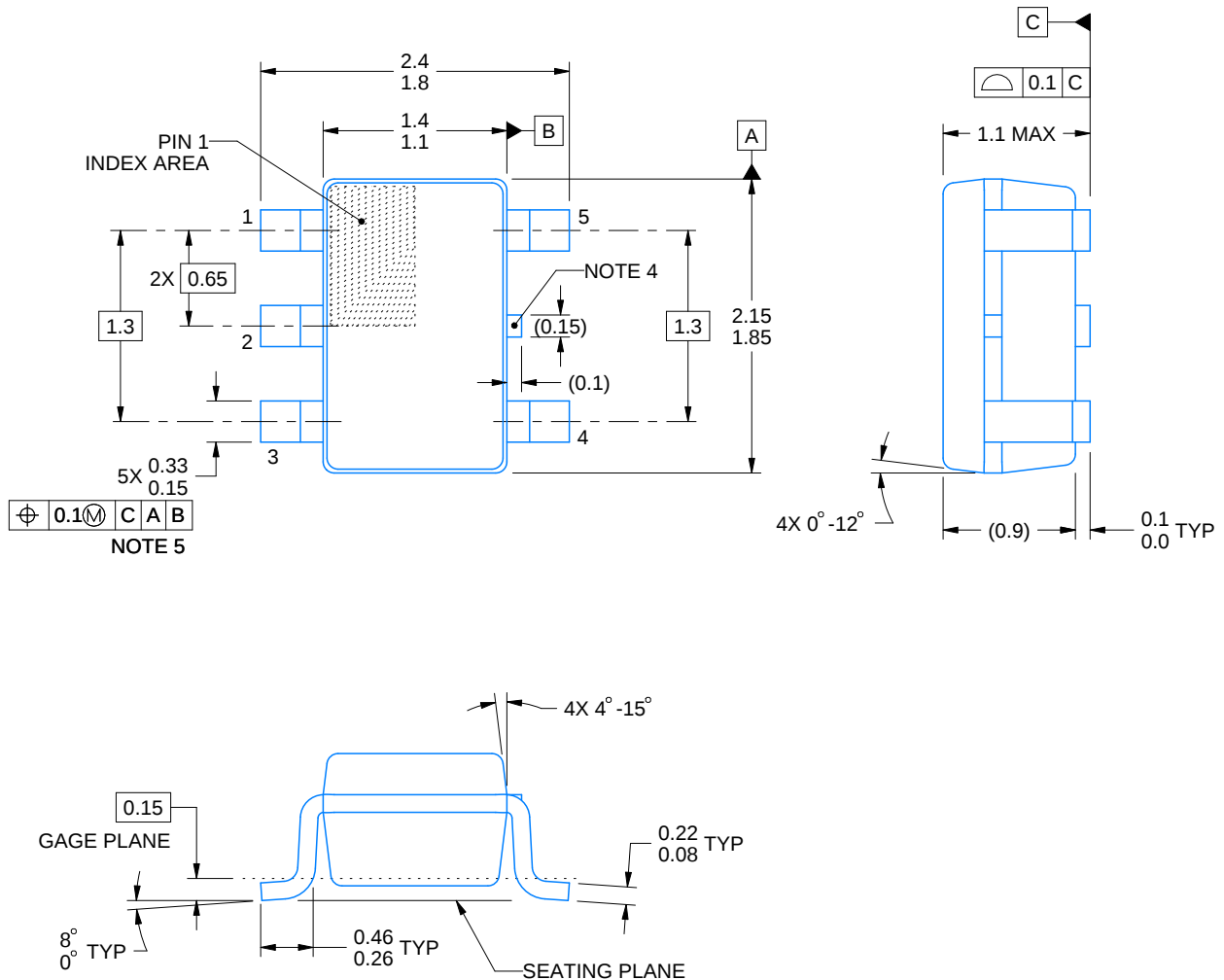
| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| OPA2837IDGKR   | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.25    | 3.35    | 1.25    | 8.0     | 12.0   | Q1            |
| OPA2837IDGKT   | VSSOP        | DGK             | 8    | 250  | 330.0              | 12.4               | 5.25    | 3.35    | 1.25    | 8.0     | 12.0   | Q1            |
| OPA2837IRUNR   | QFN          | RUN             | 10   | 3000 | 180.0              | 8.4                | 2.3     | 2.3     | 1.15    | 4.0     | 8.0    | Q2            |
| OPA2837IRUNRG4 | QFN          | RUN             | 10   | 3000 | 180.0              | 8.4                | 2.3     | 2.3     | 1.15    | 4.0     | 8.0    | Q2            |
| OPA2837IRUNT   | QFN          | RUN             | 10   | 250  | 180.0              | 8.4                | 2.3     | 2.3     | 1.15    | 4.0     | 8.0    | Q2            |
| OPA837IDBVR    | SOT-23       | DBV             | 6    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA837IDBVR2   | SOT-23       | DBV             | 6    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q2            |
| OPA837IDBVT    | SOT-23       | DBV             | 6    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA837IDCKR    | SC70         | DCK             | 5    | 3000 | 178.0              | 9.0                | 2.4     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA837IDCKRG4  | SC70         | DCK             | 5    | 3000 | 178.0              | 9.0                | 2.4     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA837IDCKT    | SC70         | DCK             | 5    | 250  | 178.0              | 9.0                | 2.4     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

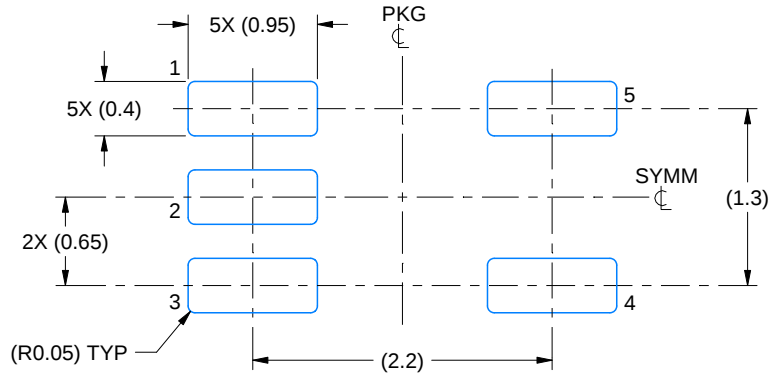
| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| OPA2837IDGKR   | VSSOP        | DGK             | 8    | 2500 | 366.0       | 364.0      | 50.0        |
| OPA2837IDGKT   | VSSOP        | DGK             | 8    | 250  | 366.0       | 364.0      | 50.0        |
| OPA2837IRUNR   | QFN          | RUN             | 10   | 3000 | 210.0       | 185.0      | 35.0        |
| OPA2837IRUNRG4 | QFN          | RUN             | 10   | 3000 | 210.0       | 185.0      | 35.0        |
| OPA2837IRUNT   | QFN          | RUN             | 10   | 250  | 210.0       | 185.0      | 35.0        |
| OPA837IDBVR    | SOT-23       | DBV             | 6    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA837IDBVR2   | SOT-23       | DBV             | 6    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA837IDBVT    | SOT-23       | DBV             | 6    | 250  | 180.0       | 180.0      | 18.0        |
| OPA837IDCKR    | SC70         | DCK             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA837IDCKRG4  | SC70         | DCK             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA837IDCKT    | SC70         | DCK             | 5    | 250  | 180.0       | 180.0      | 18.0        |



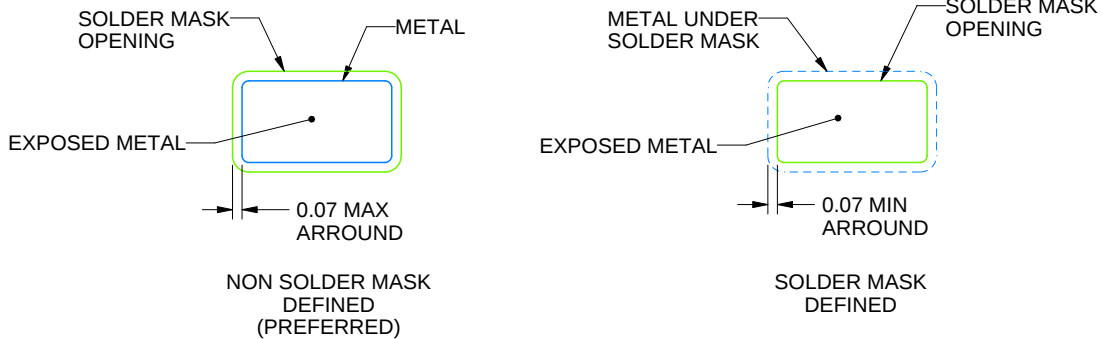
4214834/G 11/2024

## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:18X

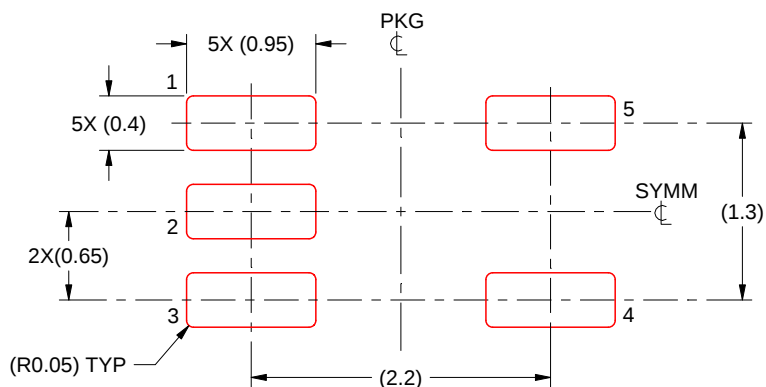


SOLDER MASK DETAILS

4214834/G 11/2024

NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE  
BASED ON 0.125 THICK STENCIL  
SCALE:18X

4214834/G 11/2024

NOTES: (continued)

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

## GENERIC PACKAGE VIEW

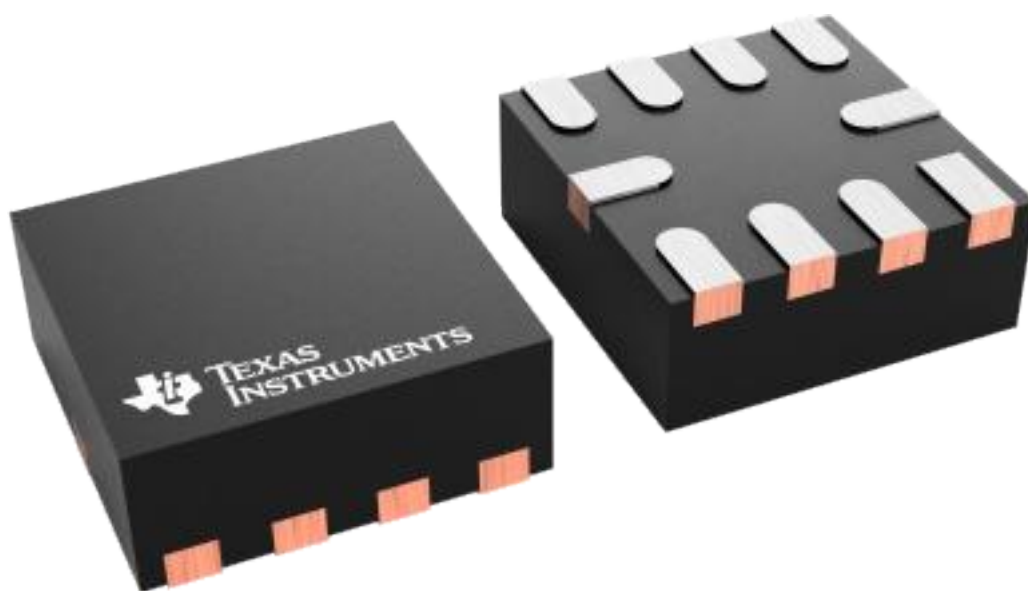
**RUN 10**

**WQFN - 0.8 mm max height**

2 X 2, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4228249/A



1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

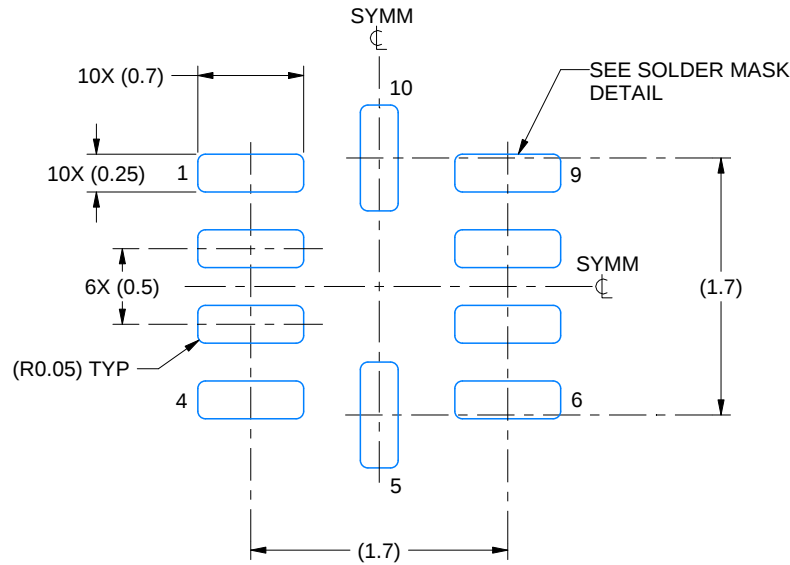
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

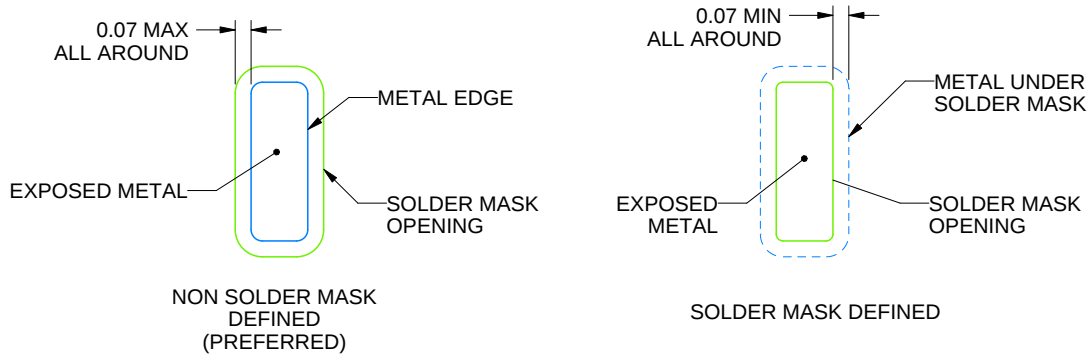
RUN0010A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 20X



SOLDER MASK DETAILS

4220470/A 05/2020

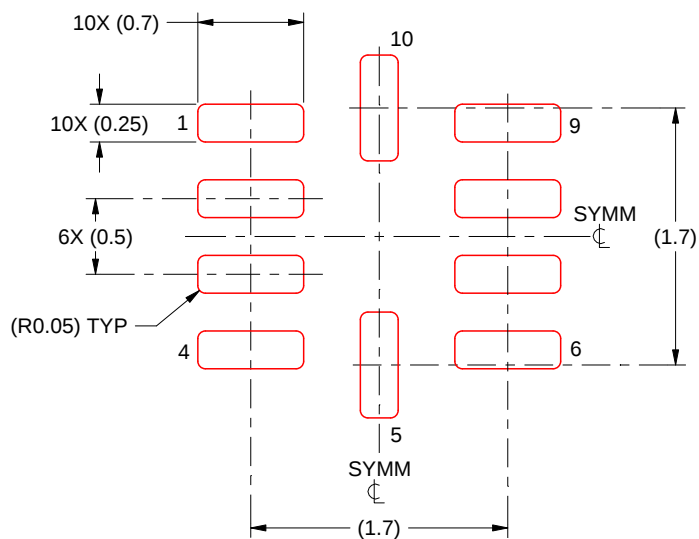
NOTES: (continued)

- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).

**RUN0010A**

**WQFN - 0.8 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.125 MM THICK STENCIL  
SCALE: 20X

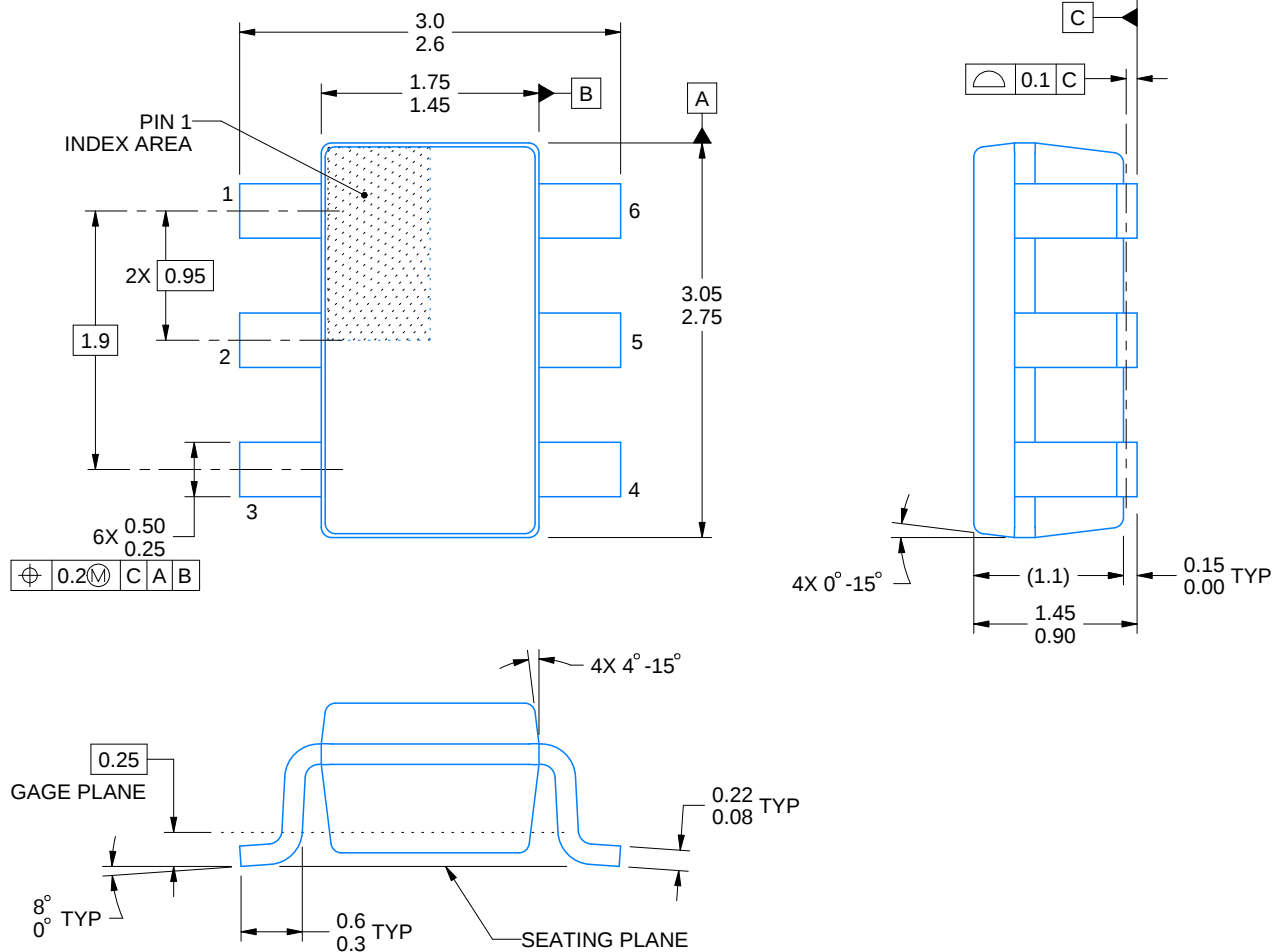
4220470/A 05/2020

NOTES: (continued)

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

**DBV0006A****PACKAGE OUTLINE****SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



4214840/G 08/2024

**NOTES:**

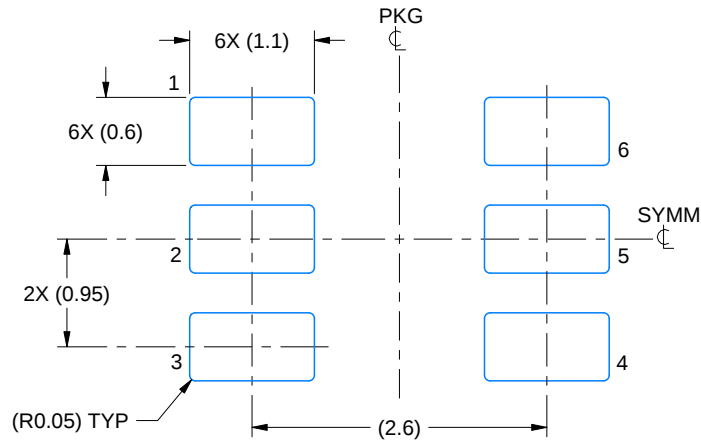
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Reference JEDEC MO-178.

# EXAMPLE BOARD LAYOUT

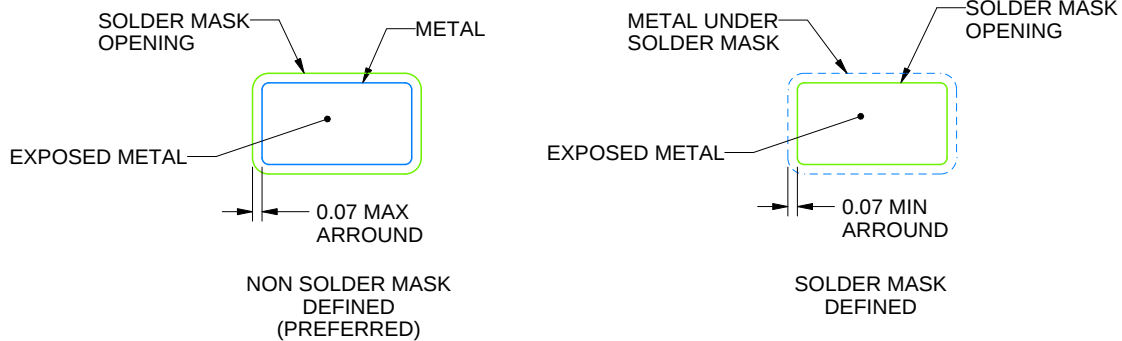
DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4214840/G 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

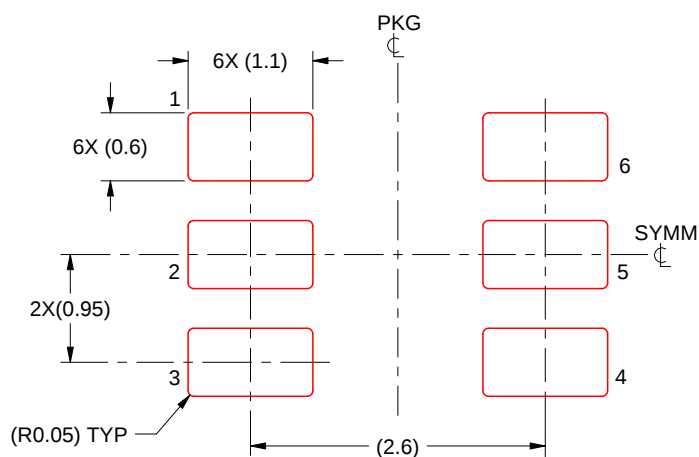
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR

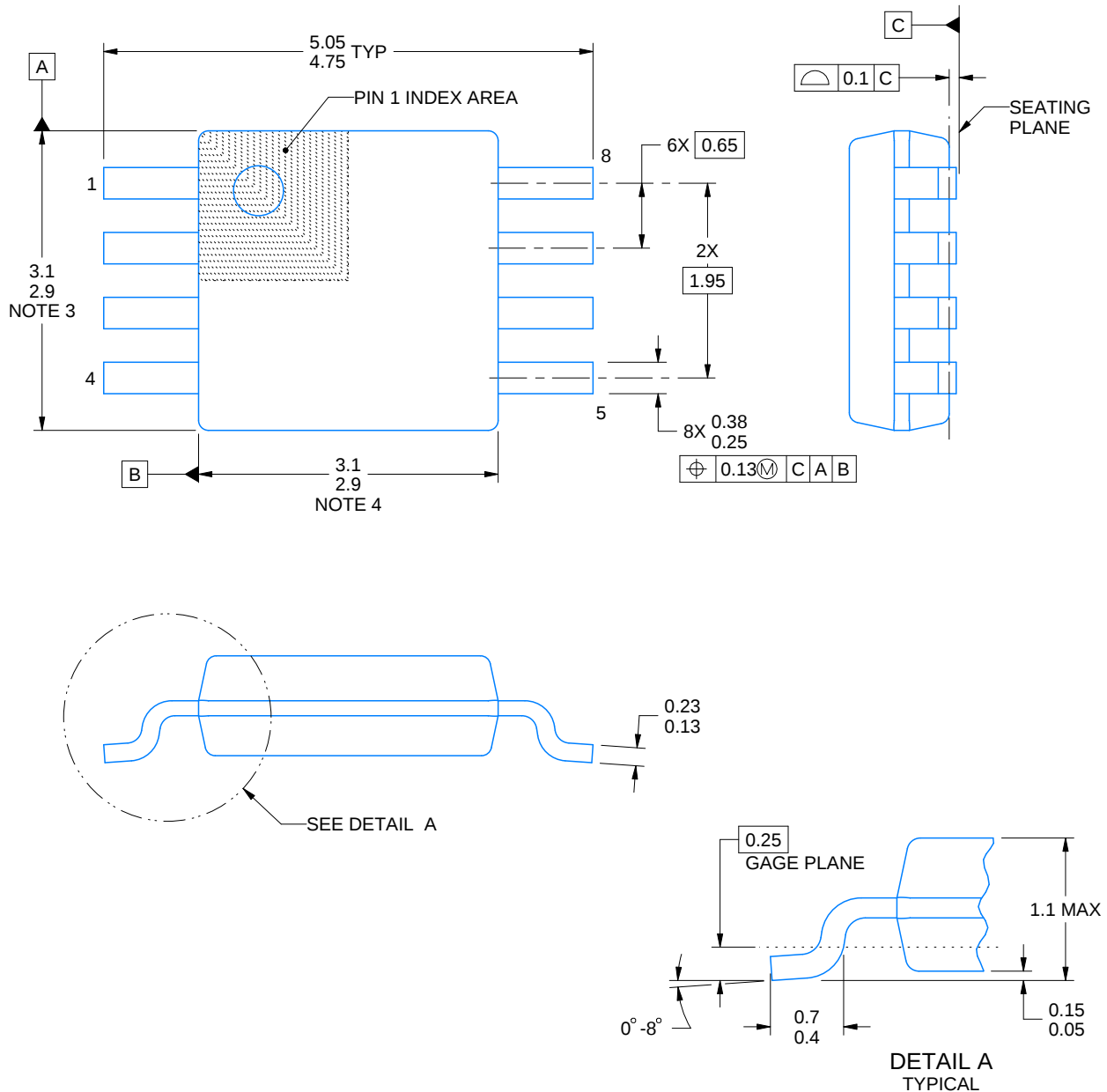
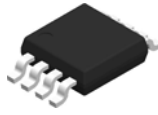


SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4214840/G 08/2024

NOTES: (continued)

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



4214862/A 04/2023

NOTES:

PowerPAD is a trademark of Texas Instruments.

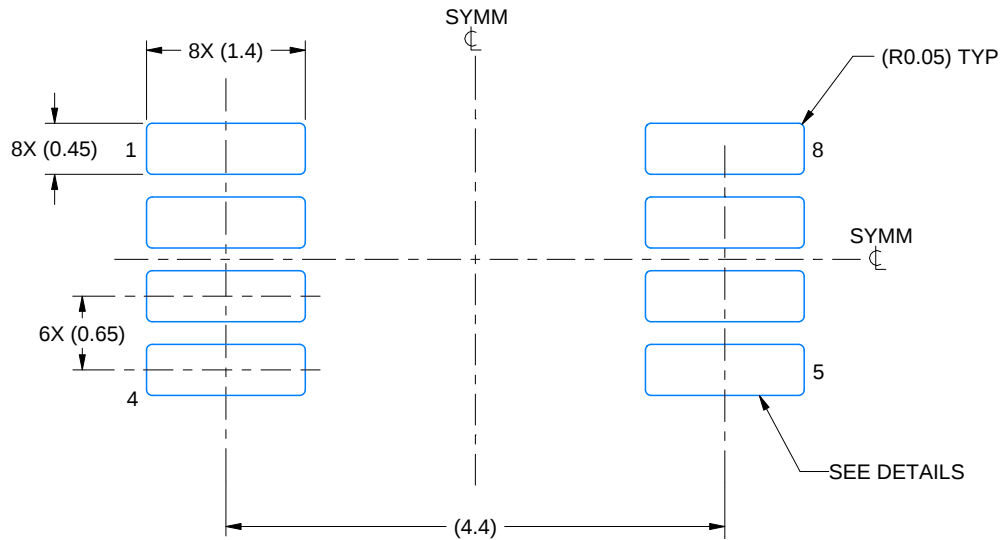
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

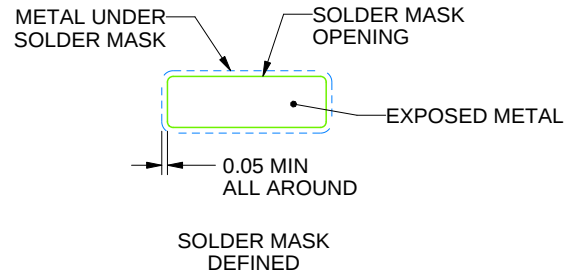
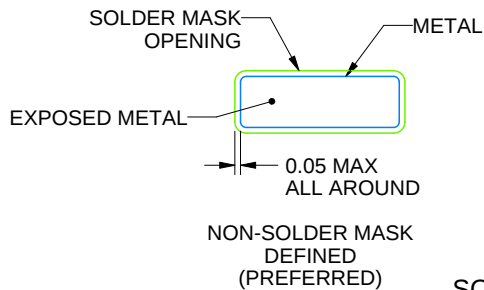
DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

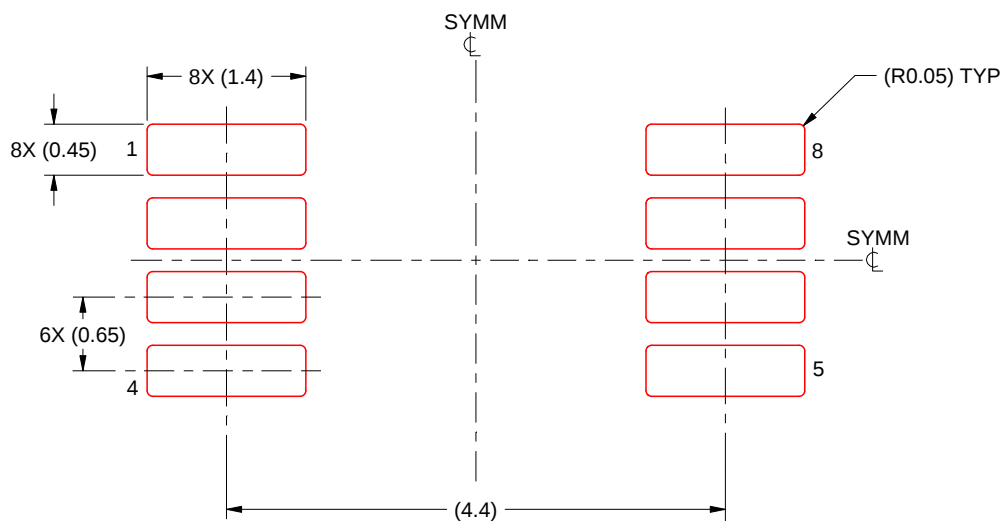
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

## EXAMPLE STENCIL DESIGN

DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

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

## 重要なお知らせと免責事項

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