TEXAS INSTRUMENTS

OPA836, OPA2836

SLOS712G – JANUARY 2011 – REVISED OCTOBER 2015

OPAx836 Very-Low-Power, Rail-to-Rail Out, Negative-Rail In, Voltage-Feedback Operational Amplifiers

1 Features

- Low Power:
  - Supply Voltage: 2.5 V to 5.5 V
  - Quiescent Current: 1 mA (Typ)
  - Power Down Mode: 0.5 µA Typ)
- Bandwidth: 205 MHz
- Slew Rate: 560 V/µs
- Rise Time: 3 ns (2 V_{STEP})
- Settling Time (0.1%): 22 ns (2 V_{STEP})
- Overdrive Recovery Time: 60 ns
- SNR: 0.00013% (–117.6 dBc) at 1 kHz (1 V_{RMS})
- THD: 0.00003% (–130 dBc) at 1 kHz (1 V_{RMS})
- HD_2/HD_3: –85 dBc/–105 dBc at 1 MHz (2 V_{PP})
- Input Voltage Noise: 4.6 nV/$\sqrt{Hz}$ (f = 100 kHz)
- Input Offset Voltage: 65 µV (±400-µV Max)
- CMRR: 116 dB
- Output Current Drive: 50 mA
- RRO: Rail-to-Rail Output
- Input Voltage Range: –0.2 V to +3.9 V (5-V Supply)
- Operating Temperature Range: –40°C to +125°C

2 Applications

- Low-Power Signal Conditioning
- Audio ADC Input Buffers
- Low-Power SAR and ΔΣ ADC Drivers
- Portable Systems
- Low-Power Systems
- High-Density Systems

3 Description

The OPA836 and OPA2836 devices are single- and dual-channel, ultralow power, rail-to-rail output, negative-rail input, voltage-feedback operational amplifiers designed to operate over a power-supply range of 2.5 V to 5.5 V (single supply), or ±1.25 V to ±2.75 V (dual supply). Consuming only 1 mA per channel and a unity gain bandwidth of 205 MHz, these amplifiers set an industry-leading power-to-performance ratio for rail-to-rail amplifiers.

For battery-powered, portable applications where power is a key importance, the low power consumption and high-frequency performance of the OPA836 and OPA2836 devices offer designers performance versus power that is not attainable in other devices. Coupled with a power-saving mode that reduces current to less than 1.5 µA, these devices offer an attractive solution for high-frequency amplifiers in battery-powered applications.

The OPA836 RUN package option includes integrated gain-setting resistors for the smallest possible footprint on a printed circuit board (approximately 2 mm × 2 mm). By adding circuit traces on the PCB, gains of +1, –1, –1.33, +2, +2.33, –3, +4, –4, +5, –5.33, +6.33, –7, +8 and inverting attenuations of –0.1429, –0.1875, –0.25, –0.33, –0.75 can be achieved. See Table 3 and Table 4 for details.

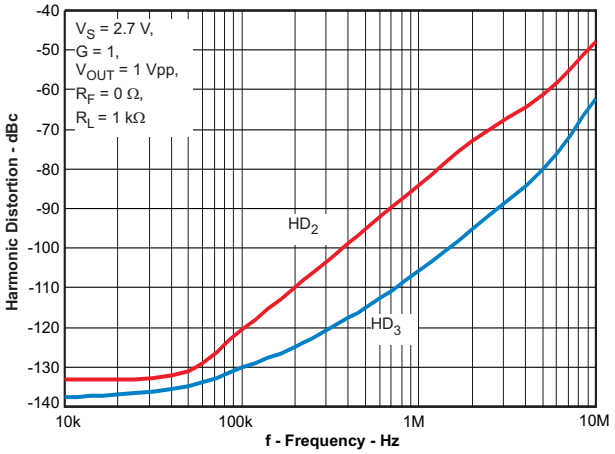
The OPA836 and OPA2836 devices are characterized for operation over the extended industrial temperature range of –40°C to 125°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA836	SOT-23 (6)	2.90 mm × 1.60 mm
	WQFN (10)	2.00 mm × 2.00 mm
OPA2836	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (10)	3.00 mm × 3.00 mm
	UQFN (10)	2.00 mm × 2.00 mm
	WQFN (10)	2.00 mm × 2.00 mm

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

Harmonic Distortion vs Frequency



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- Changed text in first paragraph of *Power-Down Operation* section ... 25

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- Changed *Features* section ... 1
- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1
- Changed *Device Comparison Table* ... 4
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- Changed *Open Loop Gain vs Frequency* graph ... 15
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Changes from Revision D (October 2011) to Revision E — **Page**

- Added OPA2836 RMC package to document ... 1
- Added RMC pin definitions to *Pin Functions* table ... 5
- Deleted Packaging/Ordering Information table, leaving only note to POA ... 6
- Added OPA2836 RMC package to Thermal Information table ... 7

Changes from Revision C (September 2011) to Revision D **Page**

- Removed Product Preview from OPA835IRUNT and OPA835IRUNR ... 4
- Removed Product Preview from OPA836IRUNT and OPA836IRUNR ... 6
- Changed Resistor Temperature Coefficient Typ value From: TBD To: <10 ... 9
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Changes from Revision B (May 2011) to Revision C **Page**

- Added the "The OPA836 RUN package..." text to the Description ... 1
- Removed Product Preview from all devices except OPA835IRUNT and OPA835IRUNR ... 4
- Removed Product Preview from all devices except OPA836IRUNT and OPA836IRUNR ... 6
- Changed - Channel to channel crosstalk (OPA2836) Typ value From: TBD To: –120 dB ... 8
- Changed the Common-mode rejection ratio Min value From: 94 dB To: 91 dB ... 8
- Added GAIN SETTING RESISTORS (OPA836IRUN ONLY) ... 9
- Changed the Quiescent operating current (T_A = 25°C) Min value From: 0.8 mA To: 0.7 mA ... 9
- Changed the Power supply rejection (±PSRR) Min value From: 95 dB To: 91 dB ... 9
- Changed the Power-down pin bias current CONDITIONS From: $\overline{PD}$ = 0.7 V To: $\overline{PD}$ = 0.5V ... 9
- Changed the Power-down quiescent current CONDITIONS From: $\overline{PD}$ = 0.7 V To: $\overline{PD}$ = 0.5V ... 9
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- Changed the Common-mode rejection ratio Min value From: 97 dB To: 94 dB ... 11
- Added GAIN SETTING RESISTORS (OPA836I RUN ONLY) ... 11
- Changed the Quiescent operating current (T_A = 25°C) Min value From: 0.9 mA To: 0.8 mA ... 11
- Changed the Power supply rejection (±PSRR) Min value From: 97 dB To: 94 dB ... 11
- Changed the Power-down quiescent current CONDITIONS From: $\overline{PD}$ = 0.7 V To: $\overline{PD}$ = 0.5 V ... 11
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- Added Figure Crosstalk vs Frequency ... 16
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- Added section *Single Ended to Differential Amplifier* ... 31

Changes from Revision A (March 2011) to Revision B **Page**

- Changed OPA836 from product preview to production data ... 1

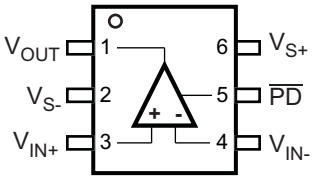
5 OPA836-Related Devices

DEVICE	BW (A_V = 1) (MHz)	SLEW RATE (V/µs)	Iq (+5 V) (mA)	INPUT NOISE (nV/√Hz)	RAIL-TO-RAIL IN/OUT	DUALS
OPA836	205	560	1	4.6	–VS/Out	OPA2836
OPA835	30	110	0.25	9.3	–VS/Out	OPA2835
OPA365	50	25	5	4.5	In/Out	OPA2365
THS4281	95	35	0.75	12.5	In/Out	
LMH6618	140	45	1.25	10	In/Out	LMH6619
OPA830	310	600	3.9	9.5	–VS/Out	OPA2830

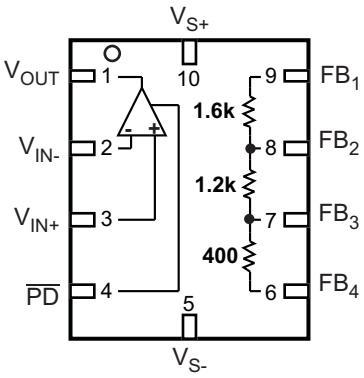
For a complete selection of TI High Speed Amplifiers, visit ti.com.

6 Pin Configuration and Functions

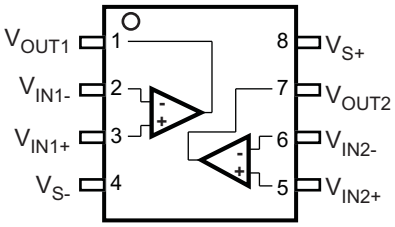
OPA836 DBV Package
6-Pin SOT-23
Top View



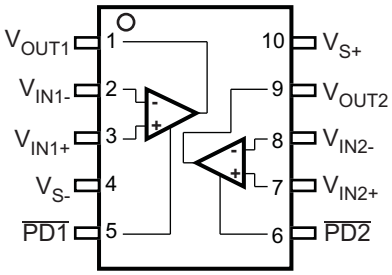
OPA836 RUN Package
10-Pin WQFN
Top View



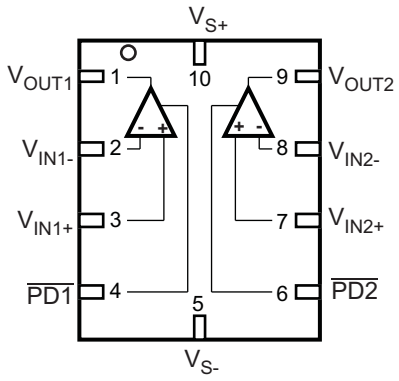
OPA2836 D Package
8-Pin SOIC
Top View



OPA2836 DGS Package
10-Pin VSSOP
Top View



OPA2836 RUN, RMC Packages
10-Pin WQFN, UQFN
Top View



Pin Functions

PIN						TYPE	DESCRIPTION
NAME	OPA836		OPA2836				
	SOT-23	WQFN	SOIC	VSSOP	WQFN, UQFN		
FB_1	—	9	—	—	—	I/O	Connection to top of 2.4-kΩ internal gain setting resistors
FB_2		8				I/O	Connection to junction of 1.8-kΩ and 2.4-kΩ internal gain setting resistors
FB_3		7				I/O	Connection to junction of 600-Ω and 1.8-kΩ internal gain setting resistors
FB_4		6				I/O	Connection to bottom of 600-Ω internal gain setting resistors
$\overline{PD}$	5	4				I	Amplifier Power Down, low = low-power mode, high = normal operation **(pin must be driven)**
$\overline{PD1}$	—	—		5	4	I	Amplifier 1 Power Down, low = low-power mode, high = normal operation **(pin must be driven)**
$\overline{PD2}$				6	6	I	Amplifier 2 Power Down, low = low-power mode, high = normal operation **(pin must be driven)**
V_{IN+}	3	3		—	—	I	Amplifier noninverting input
V_{IN-}	4	2				I	Amplifier inverting input
V_{IN1+}	—	—	3	3	3	I	Amplifier 1 noninverting input
V_{IN1-}			2	2	2	I	Amplifier 1 inverting input
V_{IN2+}			5	7	7	I	Amplifier 2 noninverting input
V_{IN2-}			6	8	8	I	Amplifier 2 inverting input
V_{OUT}	1	1	—	—	—	O	Amplifier output
V_{OUT1}	—	—	1	1	1	O	Amplifier 1 output
V_{OUT2}			7	9	9	O	Amplifier 2 output
V_{S+}	6	10	8	10	10	POW	Positive power supply input
V_{S-}	2	5	4	4	5	POW	Negative power supply input

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
V_{S-} to V_{S+}	Supply voltage		5.5	V
V_I	Input voltage	V_{S-} – 0.7	V_{S+} + 0.7	V
V_{ID}	Differential input voltage		1	V
I_I	Continuous input current		0.85	mA
I_O	Continuous output current		60	mA
	Continuous power dissipation	See *Thermal Information: OPA836* and *Thermal Information: OPA2836*		
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.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±6000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	
		Machine model	±200	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{S+}	Single supply voltage	2.5	5	5.5	V
T_A	Ambient temperature	–40	25	125	°C

7.4 Thermal Information: OPA836

THERMAL METRIC(1)		OPA836		UNIT
		SOT23-6 (DBV)	WQFN-10 (RUN)	
		6 PINS	10 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	194	145.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	129.2	75.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	39.4	38.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	25.6	13.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	38.9	104.5	°C/W

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

7.5 Thermal Information: OPA2836

THERMAL METRIC[1]		OPA2836				UNIT
		SOIC-8 (D)	VSSOP MSOP-10 (DGS)	WQFN-10 (RUN)	UQFN-10 (RMC)	
		8 PINS	10 PINS	10 PINS	10 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	150.1	206	145.8	143.2	°C/W
$R_{\theta JCtop}$	Junction-to-case (top) thermal resistance	83.8	75.3	75.1	49.0	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	68.4	96.2	38.9	61.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	33.0	12.9	13.5	3.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	67.9	94.6	104.5	61.9	°C/W

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

7.6 Electrical Characteristics: V_S = 2.7 V

Test conditions unless otherwise noted: V_{S+} = +2.7 V, V_{S-} = 0 V, V_{OUT} = 1 V_{PP}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL[1]
AC PERFORMANCE						
Small-signal bandwidth	V_{OUT} = 100 mV_{PP}, G = 1		200		MHz	C
	V_{OUT} = 100 mV_{PP}, G = 2		100			
	V_{OUT} = 100 mV_{PP}, G = 5		26			
	V_{OUT} = 100 mV_{PP}, G = 10		11			
Gain-bandwidth product	V_{OUT} = 100 mV_{PP}, G = 10		110		MHz	C
Large-signal bandwidth	V_{OUT} = 1 V_{PP}, G = 2		60		MHz	C
Bandwidth for 0.1-dB flatness	V_{OUT} = 1 V_{PP}, G = 2		25		MHz	C
Slew rate, rise	V_{OUT} = 1 V_{STEP}, G = 2		260		V/µs	C
Slew rate, fall	V_{OUT} = 1 V_{STEP}, G = 2		240		V/µs	C
Rise time	V_{OUT} = 1 V_{STEP}, G = 2		4		ns	C
Fall time	V_{OUT} = 1 V_{STEP}, G = 2		4.5		ns	C
Settling time to 1%, rise	V_{OUT} = 1 V_{STEP}, G = 2		15		ns	C
Settling time to 1%, fall	V_{OUT} = 1 V_{STEP}, G = 2		15		ns	C
Settling time to 0.1%, rise	V_{OUT} = 1 V_{STEP}, G = 2		30		ns	C
Settling time to 0.1%, fall	V_{OUT} = 1 V_{STEP}, G = 2		25		ns	C
Settling time to 0.01%, rise	V_{OUT} = 1 V_{STEP}, G = 2		50		ns	C
Settling time to 0.01%, fall	V_{OUT} = 1 V_{STEP}, G = 2		45		ns	C
Overshoot/Undershoot	V_{OUT} = 1 V_{STEP}, G = 2		5%/3%			C
Second-order harmonic distortion	f = 10 kHz, V_{IN_CM} = mid-supply – 0.5 V		–133		dBc	C
	f = 100 kHz, V_{IN_CM} = mid-supply – 0.5 V		–120			C
	f = 1 MHz, V_{IN_CM} = mid-supply – 0.5 V		–84			C
Third-order harmonic distortion	f = 10 kHz, V_{IN_CM} = mid-supply – 0.5 V		–137		dBc	C
	f = 100 kHz, V_{IN_CM} = mid-supply – 0.5 V		–130			C
	f = 1 MHz, V_{IN_CM} = mid-supply – 0.5 V		–105			C
Second-order intermodulation distortion	f = 1 MHz, 200-kHz Tone Spacing, V_{OUT} Envelope = 1 V_{PP}, V_{IN_CM} = mid-supply – 0.5 V		–90		dBc	C
Third-order intermodulation distortion	f = 1 MHz, 200-kHz Tone Spacing, V_{OUT} Envelope = 1 V_{PP}, V_{IN_CM} = mid-supply – 0.5 V		–90		dBc	C
Input voltage noise	f = 100 KHz		4.6		nV/√Hz	C
Voltage noise 1/f corner frequency			215		Hz	C
Input current noise	f = 1 MHz		0.75		pA/√Hz	C

(1) Test levels (all values set by characterization and simulation): **(A)** 100% tested at 25°C; over temperature limits by characterization and simulation. **(B)** Not tested in production; limits set by characterization and simulation. **(C)** Typical value only for information.

Electrical Characteristics: V_S = 2.7 V (continued)

Test conditions unless otherwise noted: V_{S+} = +2.7 V, $V_{S–}$ = 0 V, V_{OUT} = 1 V_{PP}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL (1)
AC PERFORMANCE (continued)						
Current noise 1/f corner frequency			31.7		kHz	C
Overdrive recovery time, over/under	Overdrive = 0.5 V		55/60		ns	C
Closed-loop output impedance	f = 100 kHz		0.02		Ω	C
Channel-to-channel crosstalk (OPA2836)	f = 10 kHz		–120		dB	C
DC PERFORMANCE						
Open-loop voltage gain (A_{OL})		100	125		dB	A
Input referred offset voltage	T_A = 25°C	–400	±65	400	µV	A
	T_A = 0°C to 70°C	–680		680		B
	T_A = –40°C to 85°C	–760		760		
	T_A = –40°C to 125°C	–1060		1060		
Input offset voltage drift (2)	T_A = 0°C to 70°C	–6.2	±1	6.2	µV/°C	B
	T_A = –40°C to 85°C	–6	±1	6		
	T_A = –40°C to 125°C	–6.6	±1.1	6.6		
Input bias current (3)	T_A = 25°C	300	650	1000	nA	A
	T_A = 0°C to 70°C	190		1400		B
	T_A = –40°C to 85°C	120		1500		
	T_A = –40°C to 125°C	120		1800		
Input bias current drift (2)	T_A = 0°C to 70°C	–2	±0.33	2	nA/°C	B
	T_A = –40°C to 85°C	–1.9	±0.32	1.9		
	T_A = –40°C to 125°C	–2.1	±0.37	2.1		
Input offset current	T_A = 25°C	–180	±30	180	nA	A
	T_A = 0°C to 70°C	–200	±30	200		B
	T_A = –40°C to 85°C	–215	±30	215		
	T_A = –40°C to 125°C	–240	±30	240		
Input offset current drift (2)	T_A = 0°C to 70°C	–460	±77	460	pA/°C	B
	T_A = –40°C to 85°C	–575	±95	575		
	T_A = –40°C to 125°C	–600	±100	600		
INPUT						
Common-mode input range low	T_A = 25°C, <3-dB degradation in CMRR limit		–0.2	0	V	A
	T_A = –40°C to 125°C, <3-dB degradation in CMRR limit		–0.2	0	V	B
Common-mode input range high	T_A = 25°C, <3-dB degradation in CMRR limit	1.5	1.6		V	A
	T_A = –40°C to 125°C, <3-dB degradation in CMRR limit	1.5	1.6		V	B
Input linear operating voltage range	T_A = 25°C, <6-dB degradation in THD		–0.3 to 1.75		V	C
Common-mode rejection ratio		91	114		dB	A
Input impedance common mode			200 || 1.2		kΩ || pF	C
Input impedance differential mode			200 || 1		kΩ || pF	C

(2) 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.
(3) Current is considered positive out of the pin.

Electrical Characteristics: V_S = 2.7 V (continued)

Test conditions unless otherwise noted: V_{S+} = +2.7 V, $V_{S–}$ = 0 V, V_{OUT} = 1 V_{PP}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL(1)
OUTPUT						
Linear output voltage low	T_A = 25°C, G = 5		0.15	0.2	V	A
	T_A = –40°C to 125°C, G = 5		0.15	0.2	V	B
Linear output voltage high	T_A = 25°C, G = 5	2.45	2.5		V	A
	T_A = –40°C to 125°C, G = 5	2.45	2.5		V	B
Output saturation voltage, high/low	T_A = 25°C, G = 5		80/40		mV	C
Linear output current drive	T_A = 25°C	±40	±45		mA	A
	T_A = –40°C to 125°C	±40	±45		mA	B
GAIN SETTING RESISTORS (OPA836IRUN ONLY)						
Resistor FB1 to FB2	DC resistance	1584	1600	1616	Ω	A
Resistor FB2 to FB3	DC resistance	1188	1200	1212	Ω	A
Resistor FB3 to FB4	DC resistance	396	400	404	Ω	A
Resistor tolerance	DC resistance	–1%		1%		A
Resistor temperature coefficient	DC resistance		<10		PPM	C
POWER SUPPLY						
Specified operating voltage		2.5		5.5	V	B
Quiescent operating current per amplifier	T_A = 25°C	0.7	0.95	1.15	mA	A
	T_A = –40°C to 125°C	0.6		1.4	mA	B
Power supply rejection (±PSRR)		91	108		dB	A
POWER DOWN						
Enable voltage threshold	Specified "on" above $V_{S–}$ + 2.1 V			2.1	V	A
Disable voltage threshold	Specified "off" below $V_{S–}$ + 0.7 V	0.7			V	A
Power-down pin bias current	$\overline{PD}$ = 0.5 V		20	500	nA	A
Power-down quiescent current	$\overline{PD}$ = 0. 5 V		0.5	1.5	µA	A
Turnon time delay	Time from $\overline{PD}$ = high to V_{OUT} = 90% of final value		200		ns	C
Turnoff time delay	Time from $\overline{PD}$ = low to V_{OUT} = 10% of original value		25		ns	C

7.7 Electrical Characteristics: V_S = 5 V

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL(1)
AC PERFORMANCE						
Small-signal bandwidth	V_{OUT} = 100 mV_{PP}, G = 1		205		MHz	C
	V_{OUT} = 100 mV_{PP}, G = 2		100			
	V_{OUT} = 100 mV_{PP}, G = 5		28			
	V_{OUT} = 100 mV_{PP}, G = 10		11.8			
Gain-bandwidth product	V_{OUT} = 100 mV_{PP}, G = 10		118		MHz	C
Large-signal bandwidth	V_{OUT} = 2 V_{PP}, G = 2		87		MHz	C
Bandwidth for 0.1-dB flatness	V_{OUT} = 2 V_{PP}, G = 2		29		MHz	C
Slew rate, rise	V_{OUT} = 2-V Step, G = 2		560		V/µs	C
Slew rate, fall	V_{OUT} = 2-V Step, G = 2		580		V/µs	C
Rise time	V_{OUT} = 2-V Step, G = 2		3		ns	C
Fall time	V_{OUT} = 2-V Step, G = 2		3		ns	C

(1) Test levels (all values set by characterization and simulation): **(A)** 100% tested at 25°C; over temperature limits by characterization and simulation. **(B)** Not tested in production; limits set by characterization and simulation. **(C)** Typical value only for information.

Electrical Characteristics: V_S = 5 V (continued)

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL(1)
AC PERFORMANCE (continued)						
Settling time to 1%, rise	V_{OUT} = 2-V Step, G = 2		22		ns	C
Settling time to 1%, fall	V_{OUT} = 2-V Step, G = 2		22		ns	C
Settling time to 0.1%, rise	V_{OUT} = 2-V Step, G = 2		30		ns	C
Settling time to 0.1%, fall	V_{OUT} = 2-V Step, G = 2		30		ns	C
Settling time to 0.01%, rise	V_{OUT} = 2-V Step, G = 2		40		ns	C
Settling time to 0.01%, fall	V_{OUT} = 2-V Step, G = 2		45		ns	C
Overshoot/Undershoot	V_{OUT} = 2-V Step, G = 2		7.5%/5%			C
Second-order harmonic distortion	f = 10 kHz		–133		dBc	C
	f = 100 kHz		–120			
	f = 1 MHz		–85			
Third-order harmonic distortion	f = 10 kHz		–140		dBc	C
	f = 100 kHz		–130			
	f = 1 MHz		–105			
Second-order intermodulation distortion	f = 1 MHz, 200 kHz Tone Spacing, V_{OUT} Envelope = 2 V_{PP}		–79		dBc	C
Third-order intermodulation distortion	f = 1 MHz, 200 kHz Tone Spacing, V_{OUT} Envelope = 2 V_{PP}		–91		dBc	C
Signal-to-noise ratio, SNR	f = 1 kHz, V_{OUT} = 1 V_{RMS}, 22 kHz bandwidth		0.00013%			C
			–117.6		dBc	
Total harmonic distortion, THD	f = 1 kHz, V_{OUT} = 1 V_{RMS}		0.00003%			C
			–130		dBc	
Input voltage noise	f = 100 KHz		4.6		nV/√Hz	C
Voltage noise 1/f corner frequency			215		Hz	C
Input current noise	f > 1 MHz		0.75		pA/√Hz	C
Current noise 1/f corner frequency			31.7		kHz	C
Overdrive recovery time, over/under	Overdrive = 0.5 V		55/60		ns	C
Closed-loop output impedance	f = 100 kHz		0.02		Ω	C
Channel to channel crosstalk (OPA2836)	f = 10 kHz		–120		dB	C
DC PERFORMANCE						
Open-loop voltage gain (A_{OL})		100	122		dB	A
Input referred offset voltage	T_A = 25°C	–400	±65	400	µV	A
	T_A = 0°C to 70°C	–685		685		B
	T_A = –40°C to 85°C	–765		765		
	T_A = –40°C to 125°C	–1080		1080		
Input offset voltage drift(2)	T_A = 0°C to 70°C	–6.3	±1.05	6.3	µV/°C	B
	T_A = –40°C to 85°C	–6.1	±1	6.1		
	T_A = –40°C to 125°C	–6.8	±1.1	6.8		
Input bias current(3)	T_A = 25°C	300	650	1000	nA	A
	T_A = 0°C to 70°C	190		1400		B
	T_A = –40°C to 85°C	120		1550		
	T_A = –40°C to 125°C	120		1850		
Input bias current drift(2)	T_A = 0°C to 70°C		±0.34	±2	nA/°C	B
	T_A = –40°C to 85°C		±0.34	±2		
	T_A = –40°C to 125°C		±0.38	±2.3		

(2) 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.
(3) Current is considered positive out of the pin.

Electrical Characteristics: V_S = 5 V (continued)

Test conditions unless otherwise noted: V_{S+} = +5 V, V_{S-} = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply. T_A = 25°C, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	TEST LEVEL(1)
DC PERFORMANCE (continued)						
Input offset current	T_A = 25°C		±30	±180	nA	A
	T_A = 0°C to 70°C		±30	±200		B
	T_A = –40°C to 85°C		±30	±215		
	T_A = –40°C to 125°C		±30	±250		
Input offset current drift(2)	T_A = 0°C to 70°C		±80	±480	pA/°C	B
	T_A = –40°C to 85°C		±100	±600		
	T_A = –40°C to 125°C		±110	±660		
INPUT						
Common-mode input range low	T_A = 25°C, <3-dB degradation in CMRR limit		–0.2	0	V	A
	T_A = –40°C to 125°C, <3-dB degradation in CMRR limit		–0.2	0	V	B
Common-mode input range high	T_A = 25°C, <3-dB degradation in CMRR limit	3.8	3.9		V	A
	T_A = –40°C to 125°C, <3-dB degradation in CMRR limit	3.8	3.9		V	B
Input linear operating voltage range	T_A = 25°C, <6-dB degradation in THD		–0.3 to 4.05		V	C
Common-mode rejection ratio		94	116		dB	A
Input impedance common mode			200 || 1.2		kΩ || pF	C
Input impedance differential mode			200 || 1		kΩ || pF	C
OUTPUT						
Linear output voltage low	T_A = 25°C, G =		0.15	0.2	V	A
	T_A = –40°C to 125°C, G = 5		0.15	0.2	V	B
Linear output voltage high	T_A = 25°C, G = 5	4.75	4.8		V	A
	T_A = –40°C to 125°C, G = 5	4.75	4.8		V	B
Output saturation voltage, high/low	T_A = 25°C, G = 5		100/50		mV	C
Linear output current drive	T_A = 25°C	±40	±50		mA	A
	T_A = –40°C to 125°C	±40	±50		mA	B
GAIN SETTING RESISTORS (OPA836IRUN ONLY)						
Resistor FB1 to FB2	DC resistance	1584	1600	1616	Ω	A
Resistor FB2 to FB3	DC resistance	1188	1200	1212	Ω	A
Resistor FB3 to FB4	DC resistance	396	400	404	Ω	A
Resistor tolerance	DC resistance	–1		1%		A
Resistor temperature coefficient	DC resistance		<10		PPM	C
POWER SUPPLY						
Specified operating voltage		2.5		5.5	V	B
Quiescent operating current per amplifier	T_A = 25°C	0.8	1.0	1.2	mA	A
	T_A = –40°C to 125°C	0.65		1.5	mA	B
Power supply rejection (±PSRR)		94	108		dB	A
POWER DOWN						
Enable voltage threshold	Specified "on" above V_{S-} + 2.1 V			2.1	V	A
Disable voltage threshold	Specified "off" below V_{S-} + 0.7 V	0.7			V	A
Power-down pin bias current	$\overline{PD}$ = 0.5 V		20	500	nA	A
Power-down quiescent current	$\overline{PD}$ = 0.5 V		0.5	1.5	µA	A
Turnon time delay	Time from $\overline{PD}$ = high to V_{OUT} = 90% of final value		170		ns	C
Turnoff time delay	Time from $\overline{PD}$ = low to V_{OUT} = 10% of original value		35		ns	C

7.8 Typical Characteristics

7.8.1 Typical Characteristics: V_S = 2.7 V

Test conditions unless otherwise noted: V_{S+} = +2.7 V, $V_{S–}$ = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

Table 1. Table of Graphs

FIGURE TITLE		FIGURE LOCATION
Small Signal Frequency Response		Figure 1
Large Signal Frequency Response		Figure 2
Noninverting Pulse Response		Figure 3
Inverting Pulse Response		Figure 4
Slew Rate	vs Output Voltage Step	Figure 5
Output Overdrive Recovery		Figure 6
Harmonic Distortion	vs Frequency	Figure 7
Harmonic Distortion	vs Load Resistance	Figure 8
Harmonic Distortion	vs Output Voltage	Figure 9
Harmonic Distortion	vs Gain	Figure 10
Output Voltage Swing	vs Load Resistance	Figure 11
Output Saturation Voltage	vs Load Current	Figure 12
Output Impedance	vs Frequency	Figure 13
Frequency Response With Capacitive Load		Figure 14
Series Output Resistor	vs Capacitive Load	Figure 17
Input Referred Noise	vs Frequency	Figure 16
Open Loop Gain	vs Frequency	Figure 15
Common Mode/Power Supply Rejection Ratios	vs Frequency	Figure 18
Crosstalk	vs Frequency	Figure 19
Power Down Response		Figure 20
Input Offset Voltage		Figure 23
Input Offset Voltage	vs Free-Air Temperature	Figure 21
Input Offset Voltage Drift		Figure 48
Input Offset Current		Figure 24
Input Offset Current	vs Free-Air Temperature	Figure 25
Input Offset Current Drift		Figure 26

Test conditions unless otherwise noted: V_{S+} = +2.7 V, V_{S-} = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

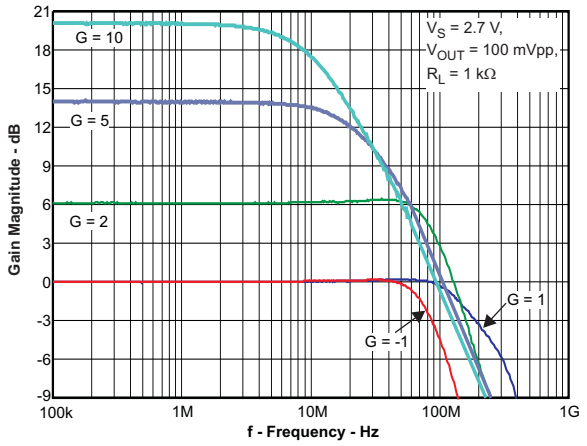


Figure 1. Small Signal Frequency Response

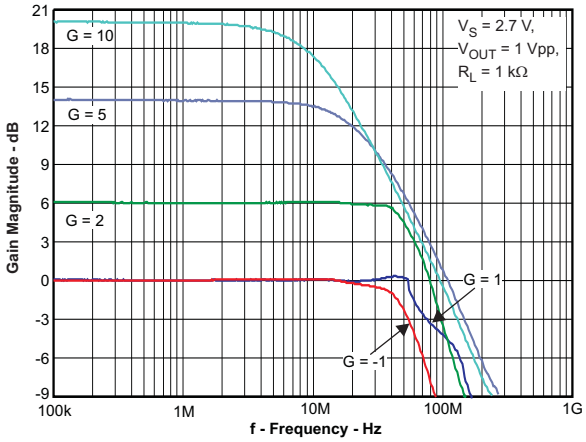


Figure 2. Large Signal Frequency Response

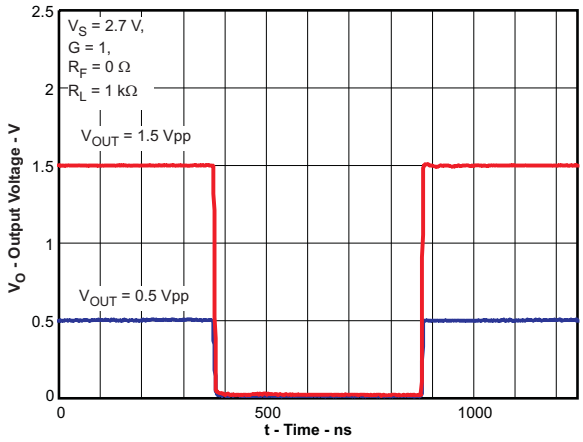


Figure 3. Noninverting Pulse Response

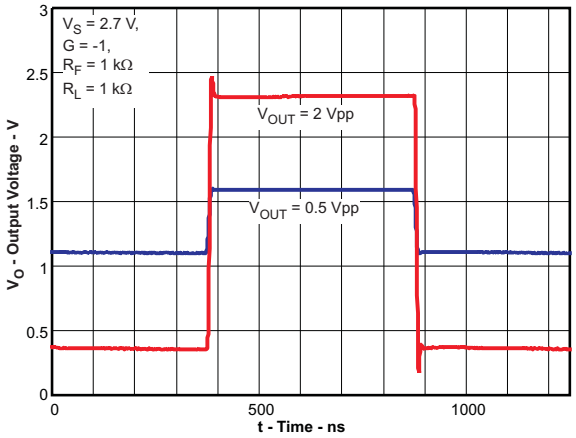


Figure 4. Inverting Pulse Response

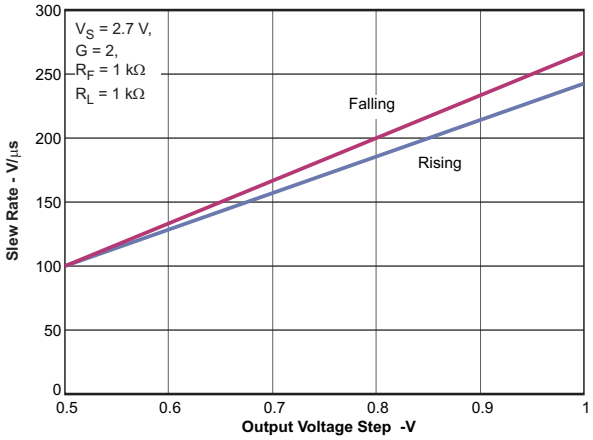


Figure 5. Slew Rate vs Output Voltage Step

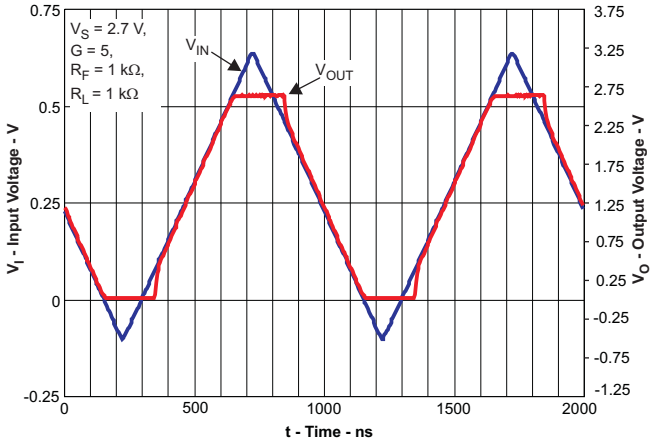


Figure 6. Output Overdrive Recovery

Test conditions unless otherwise noted: V_{S+} = +2.7 V, $V_{S–}$ = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

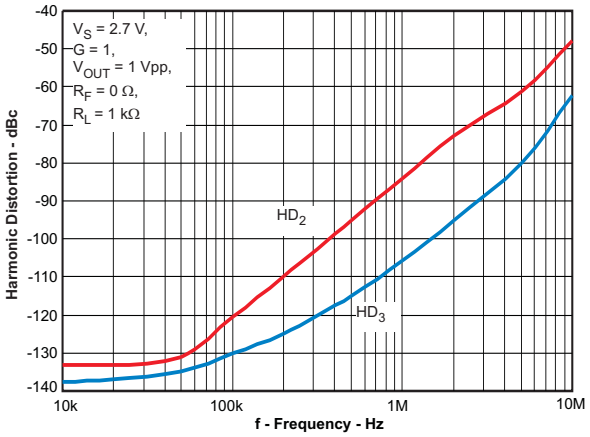


Figure 7. Harmonic Distortion vs Frequency

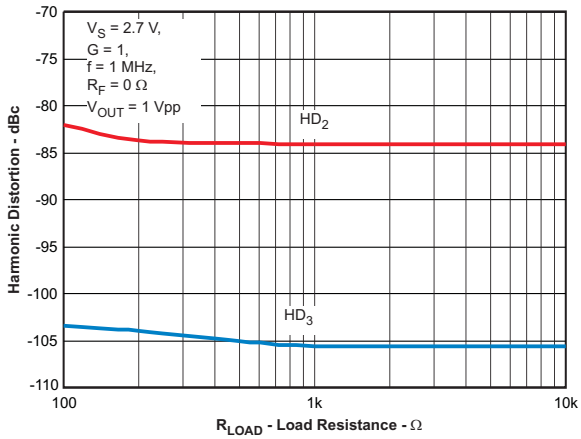


Figure 8. Harmonic Distortion vs Load Resistance

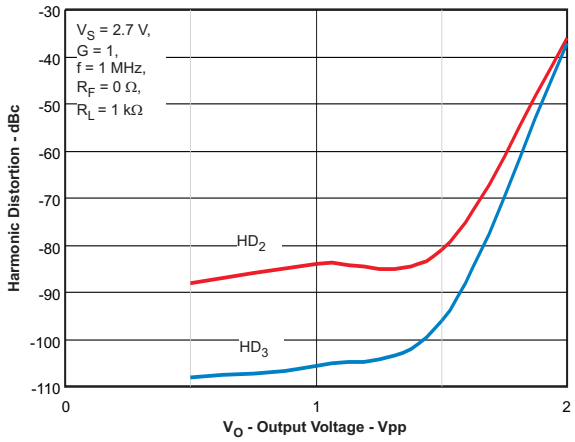


Figure 9. Harmonic Distortion vs Output Voltage

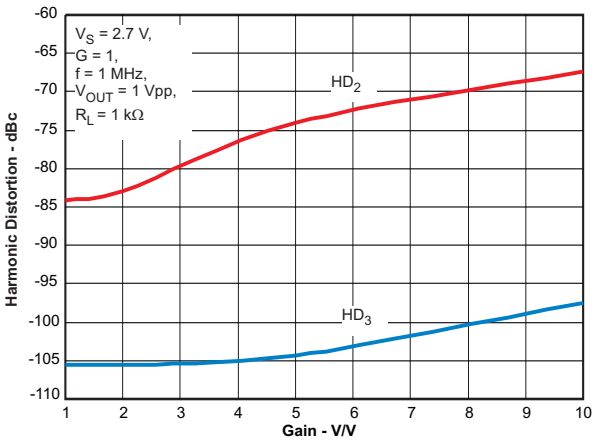


Figure 10. Harmonic Distortion vs Gain

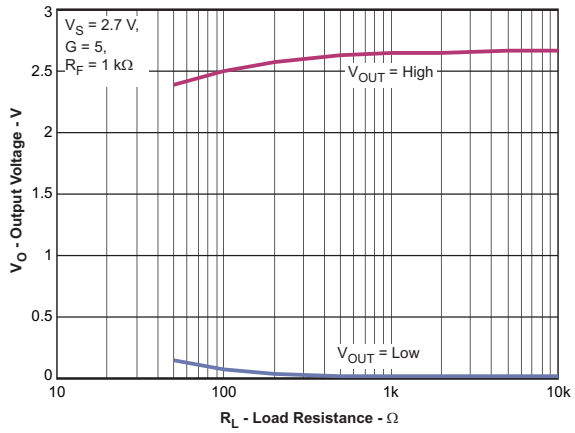


Figure 11. Output Voltage Swing vs Load Resistance

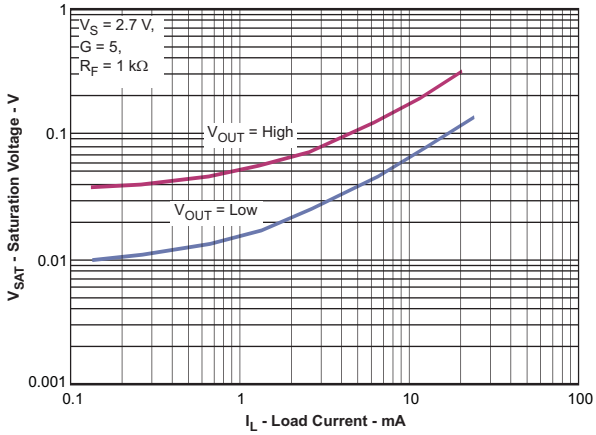


Figure 12. Output Saturation Voltage vs Load Current

Test conditions unless otherwise noted: V_{S+} = +2.7 V, V_{S-} = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

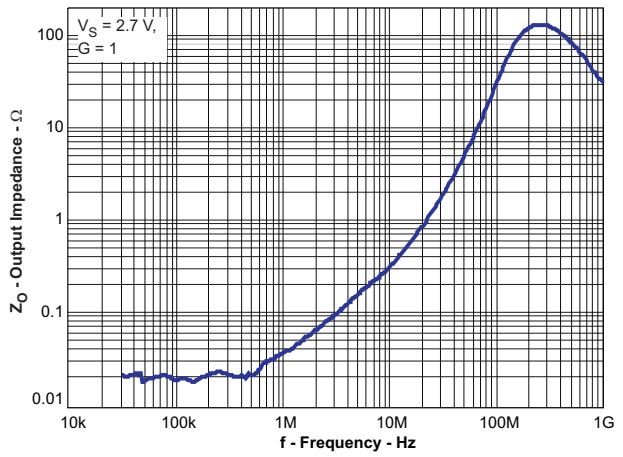


Figure 13. Output Impedance vs Frequency

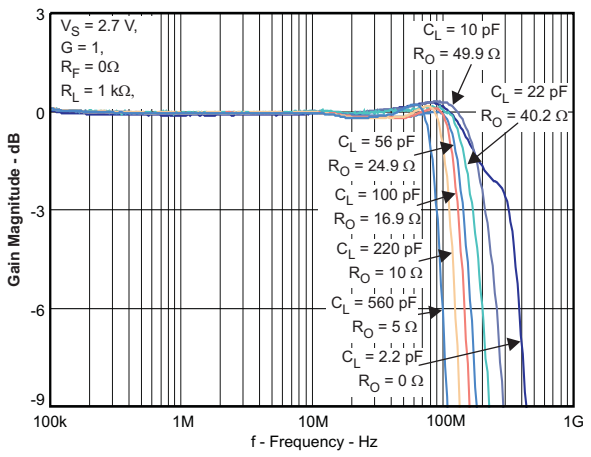
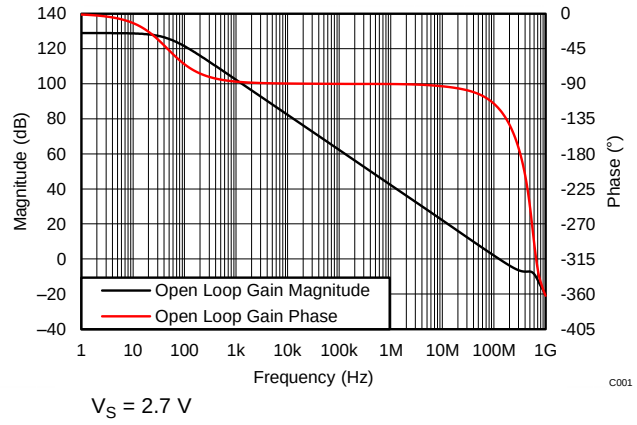
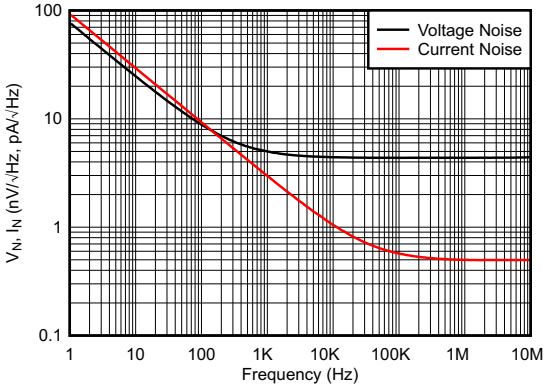


Figure 14. Frequency Response With Capacitive Load



V_S = 2.7 V

Figure 15. Open Loop Gain vs Frequency



V_S = 2.7 V

Figure 16. Input Referred Noise vs Frequency

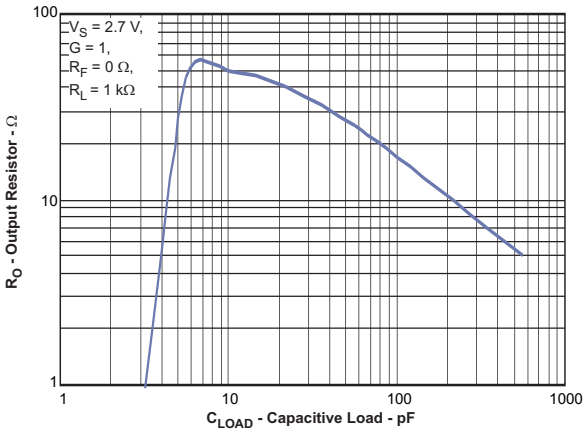


Figure 17. Series Output Resistor vs Capacitive Load

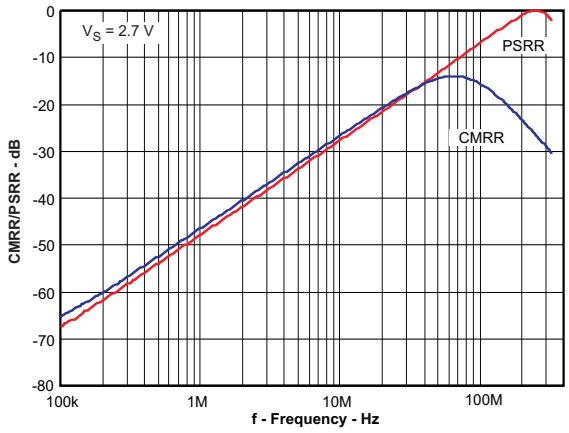


Figure 18. Common Mode/Power Supply Rejection Ratios vs Frequency

Test conditions unless otherwise noted: V_{S+} = +2.7 V, V_{S-} = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

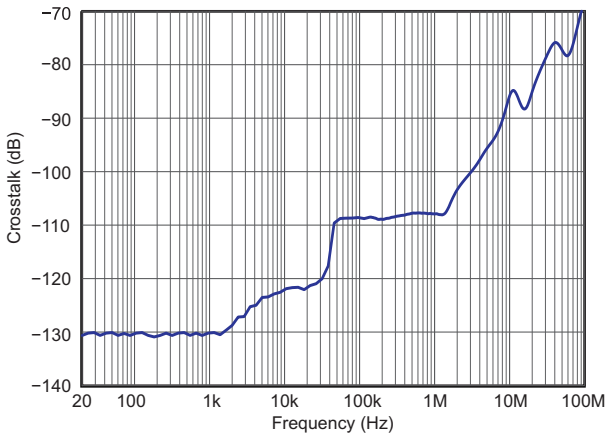


Figure 19. Crosstalk vs Frequency

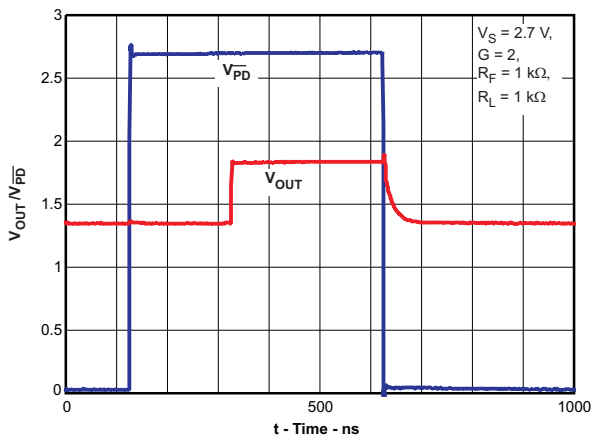


Figure 20. Power Down Response

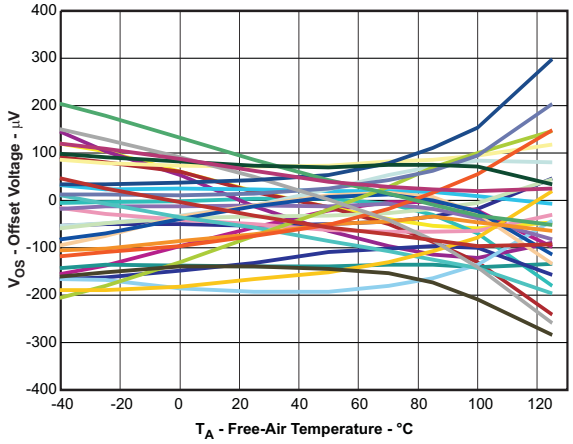


Figure 21. Input Offset Voltage vs Free-Air Temperature

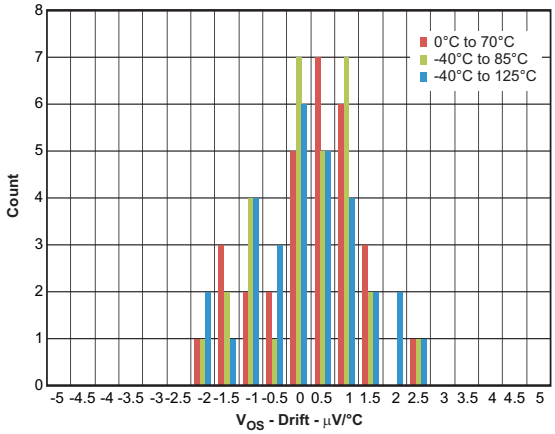


Figure 22. Input Offset Voltage Drift

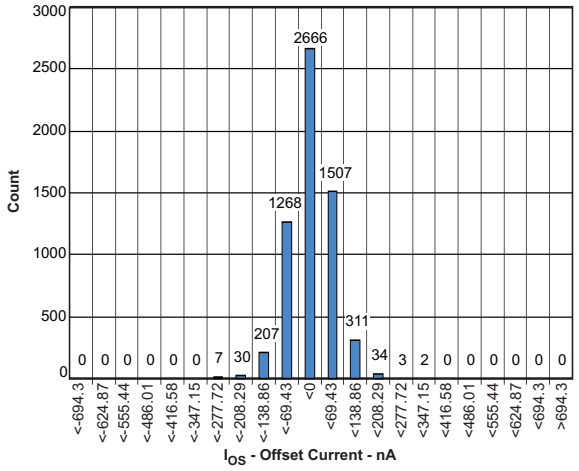


Figure 23. Input Offset Voltage

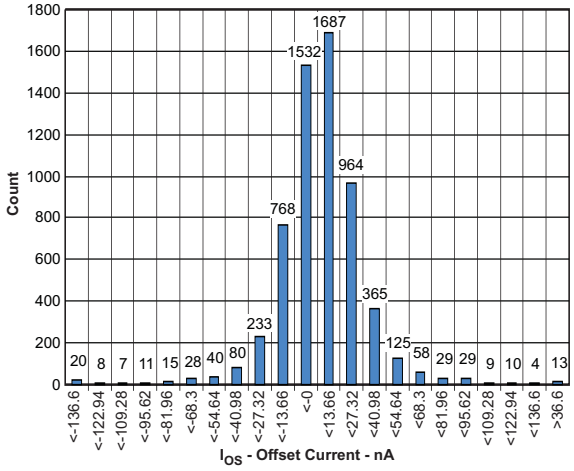


Figure 24. Input Offset Current

Test conditions unless otherwise noted: V_{S+} = +2.7 V, V_{S-} = 0 V, V_{OUT} = 1 V_{pp}, R_F = 0 Ω, R_L = 2 kΩ, G = 1 V/V, input and output referenced to mid-supply, V_{IN_CM} = mid-supply – 0.5 V. T_A = 25°C, unless otherwise noted.

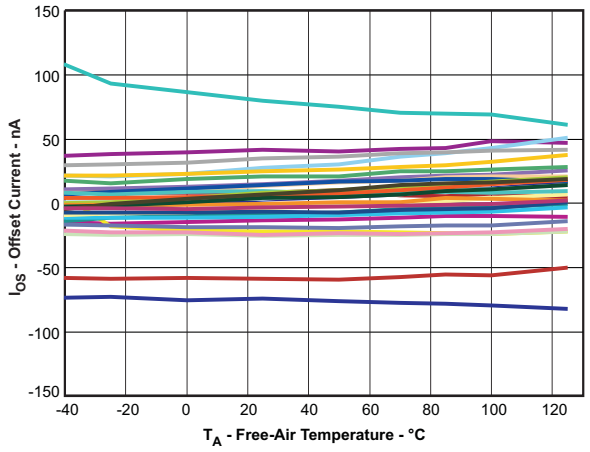


Figure 25. Input Offset Current vs Free-Air Temperature

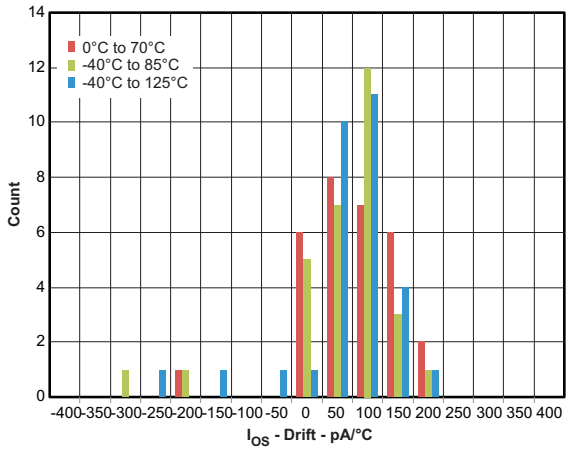


Figure 26. Input Offset Current Drift

7.8.2 Typical Performance Graphs: V_S = 5 V

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

Table 2. Table of Graphs

FIGURE TITLE		FIGURE LOCATION
Small Signal Frequency Response		Figure 27
Large Signal Frequency Response		Figure 28
Noninverting Pulse Response		Figure 29
Inverting Pulse Response		Figure 30
Slew Rate	vs Output Voltage Step	Figure 31
Output Overdrive Recovery		Figure 32
Harmonic Distortion	vs Frequency	Figure 33
Harmonic Distortion	vs Load Resistance	Figure 34
Harmonic Distortion	vs Output Voltage	Figure 35
Harmonic Distortion	vs Gain	Figure 36
Output Voltage Swing	vs Load Resistance	Figure 37
Output Saturation Voltage	vs Load Current	Figure 38
Output Impedance	vs Frequency	Figure 39
Frequency Response With Capacitive Load		Figure 40
Series Output Resistor	vs Capacitive Load	Figure 43
Input Referred Noise	vs Frequency	Figure 41
Open Loop Gain	vs Frequency	Figure 42
Common Mode/Power Supply Rejection Ratios	vs Frequency	Figure 44
Crosstalk	vs Frequency	Figure 45
Power Down Response		Figure 46
Input Offset Voltage		Figure 49
Input Offset Voltage	vs Free-Air Temperature	Figure 47
Input Offset Voltage Drift		Figure 48
Input Offset Current		Figure 50
Input Offset Current	vs Free-Air Temperature	Figure 51
Input Offset Current Drift		Figure 52

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

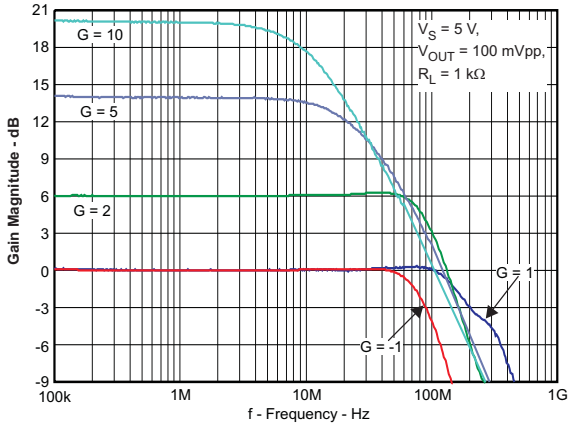


Figure 27. Small Signal Frequency Response

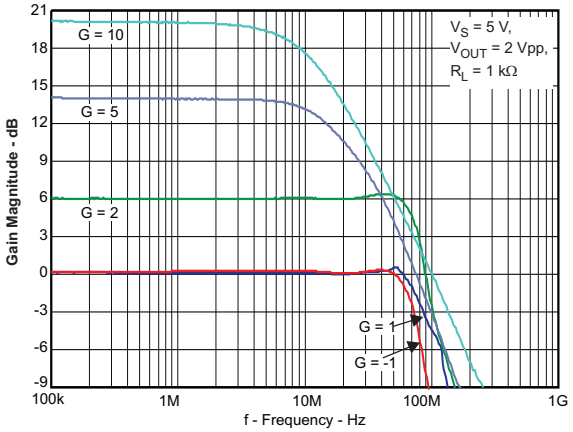


Figure 28. Large Signal Frequency Response

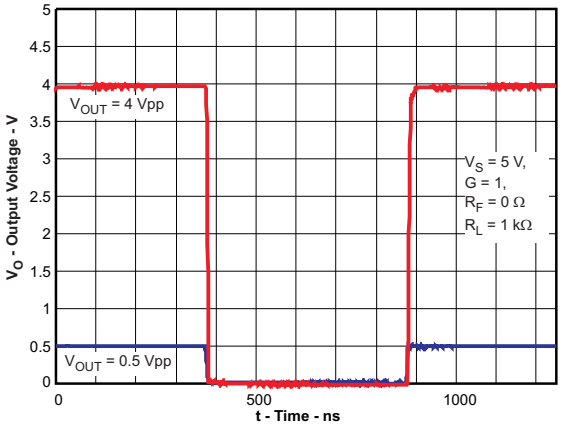


Figure 29. Noninverting Pulse Response

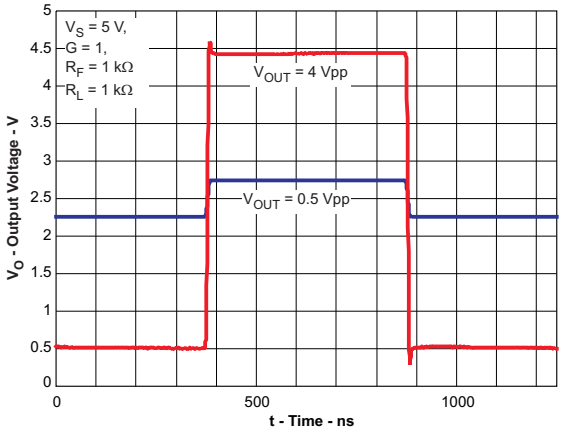


Figure 30. Inverting Pulse Response

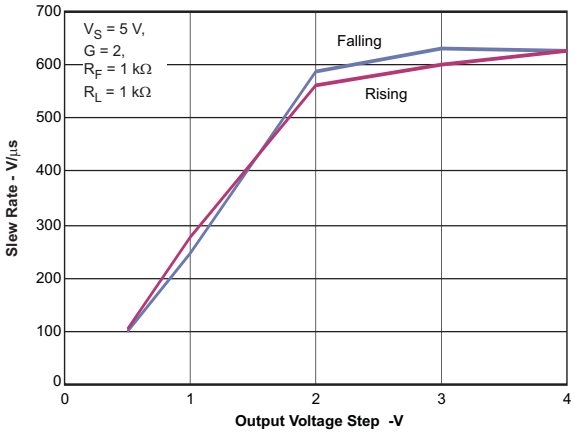


Figure 31. Slew Rate vs Output Voltage Step

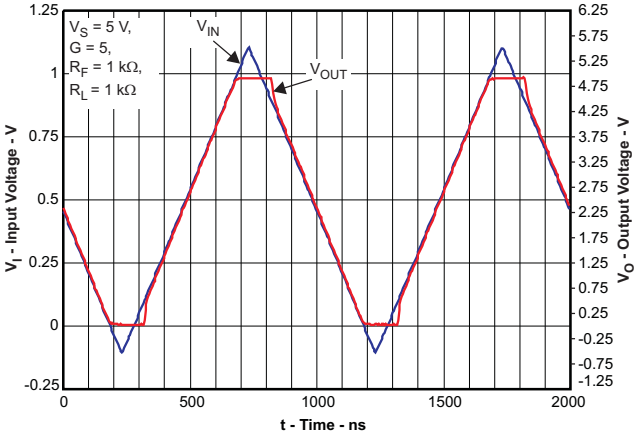


Figure 32. Output Overdrive Recovery

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

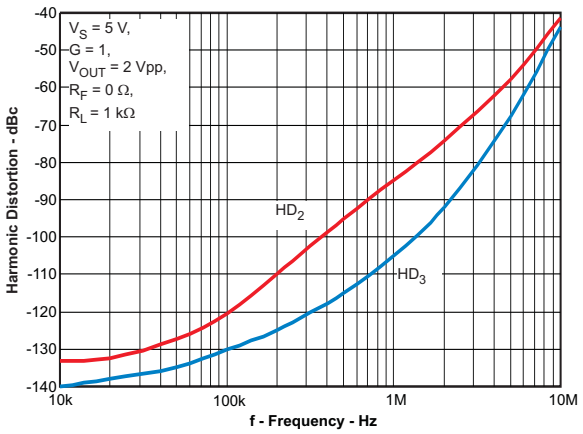


Figure 33. Harmonic Distortion vs Frequency

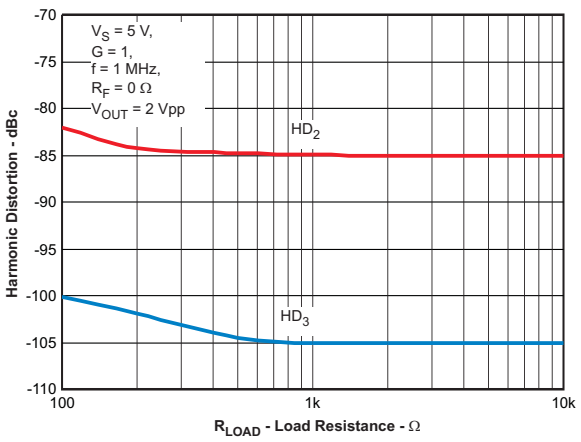


Figure 34. Harmonic Distortion vs Load Resistance

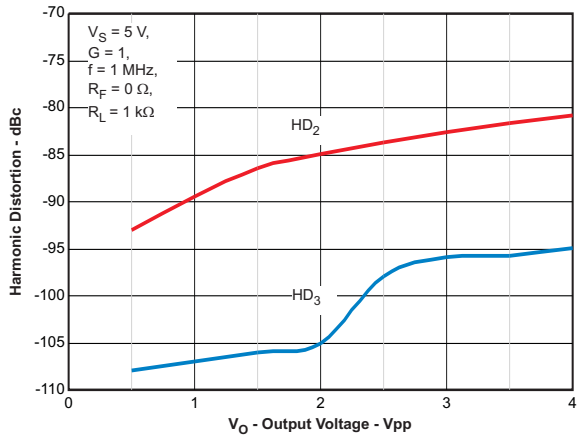


Figure 35. Harmonic Distortion vs Output Voltage

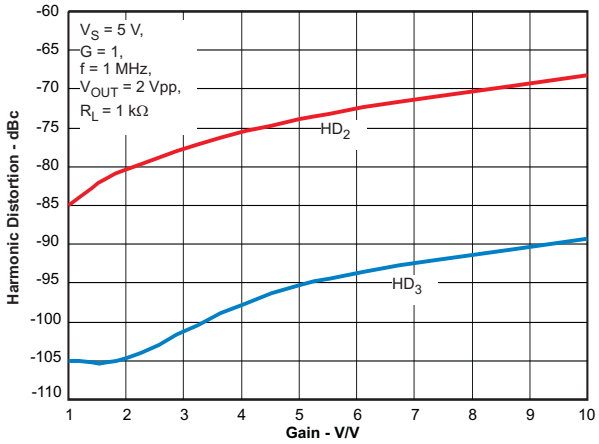


Figure 36. Harmonic Distortion vs Gain

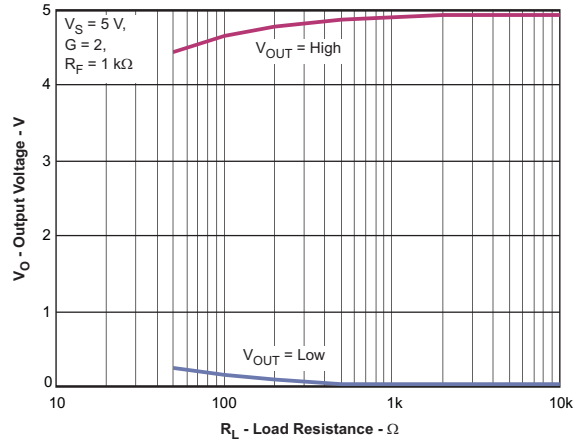


Figure 37. Output Voltage Swing vs Load Resistance

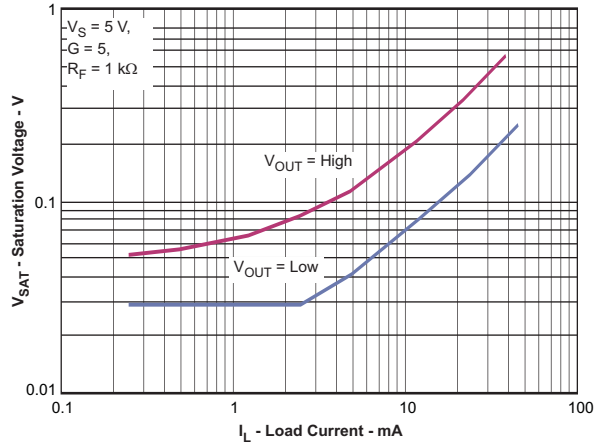


Figure 38. Output Saturation Voltage vs Load Current

Test conditions unless otherwise noted: V_{S+} = +5 V, $V_{S–}$ = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

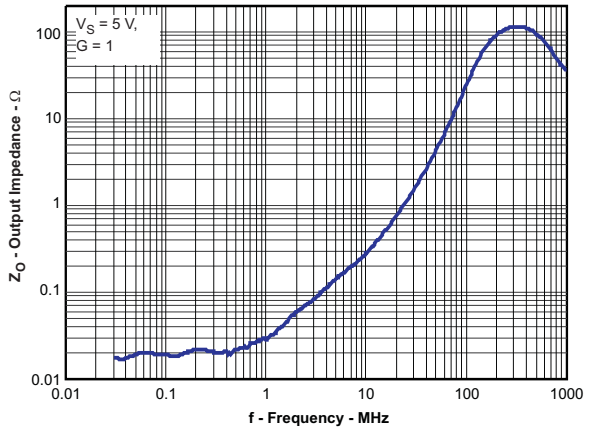


Figure 39. Output Impedance vs Frequency

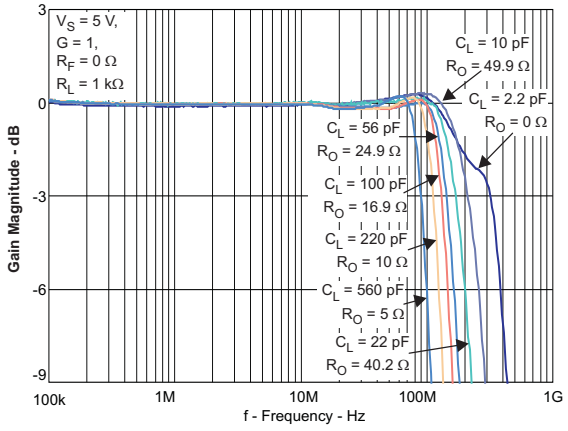
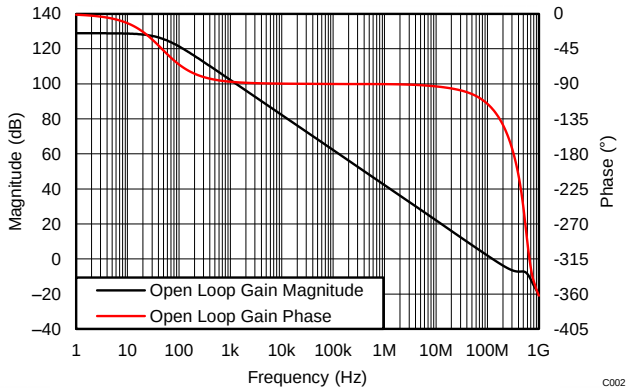
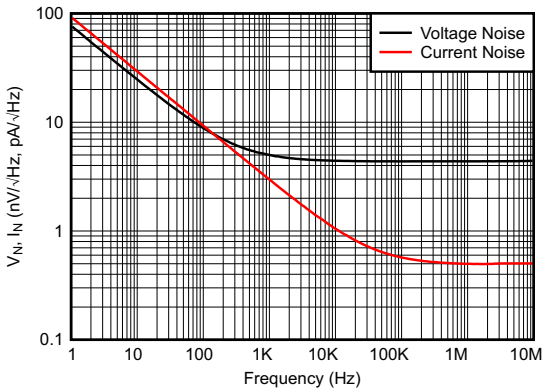


Figure 40. Frequency Response With Capacitive Load



V_S = 5.0 V

Figure 41. Open Loop Gain vs Frequency



V_S = 5.0 V

Figure 42. Input Referred Noise vs Frequency

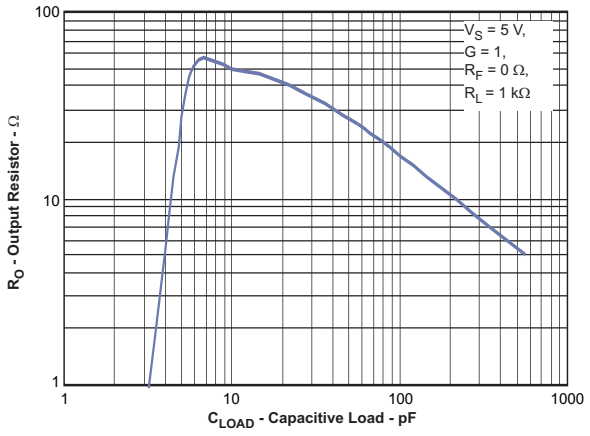


Figure 43. Series Output Resistor vs Capacitive Load

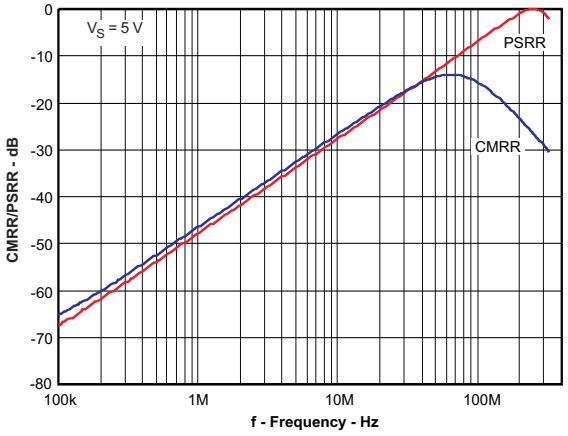


Figure 44. Common Mode/Power Supply Rejection Ratios vs Frequency

Test conditions unless otherwise noted: V_{S+} = +5 V, V_{S-} = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

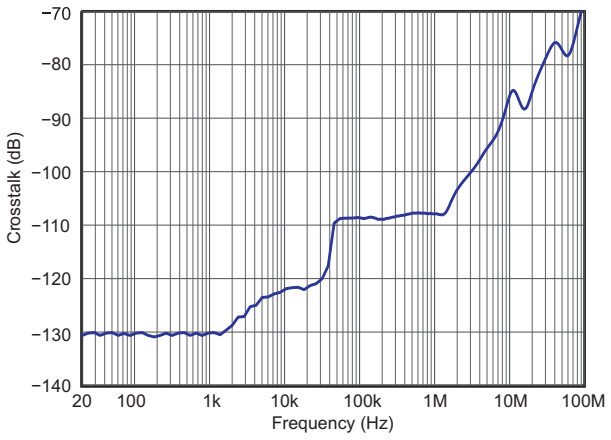


Figure 45. Crosstalk vs Frequency

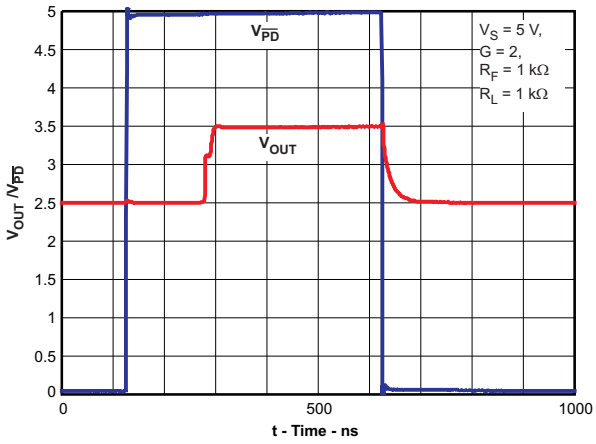


Figure 46. Power Down Response

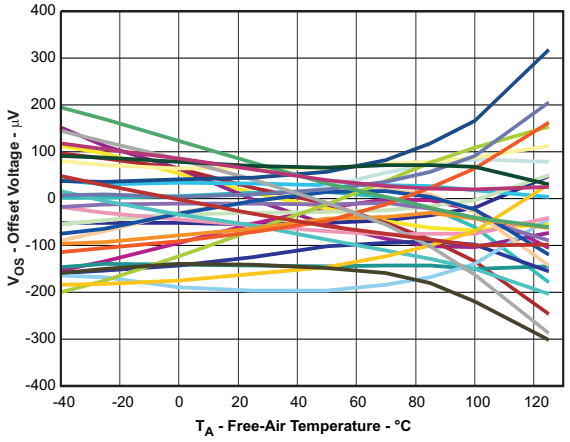


Figure 47. Input Offset Voltage vs Free-Air Temperature

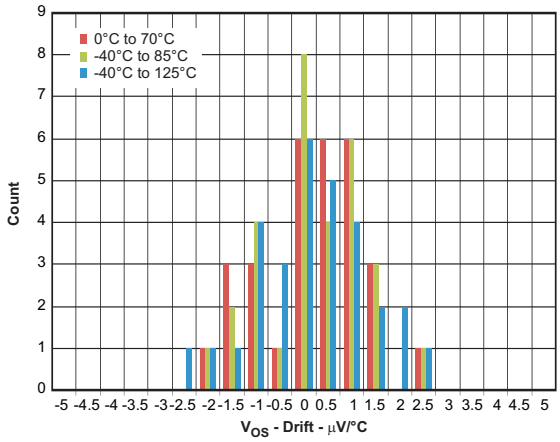


Figure 48. Input Offset Voltage Drift

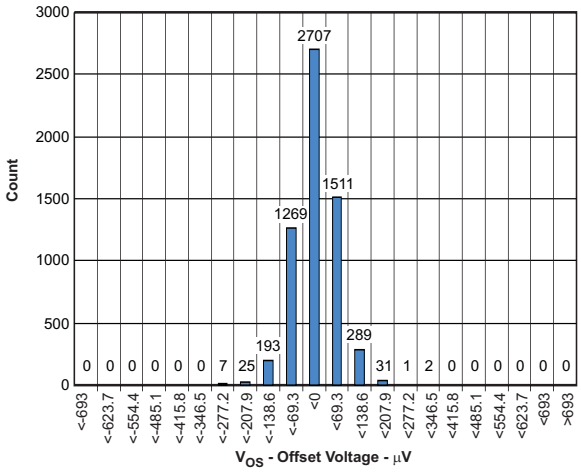


Figure 49. Input Offset Voltage

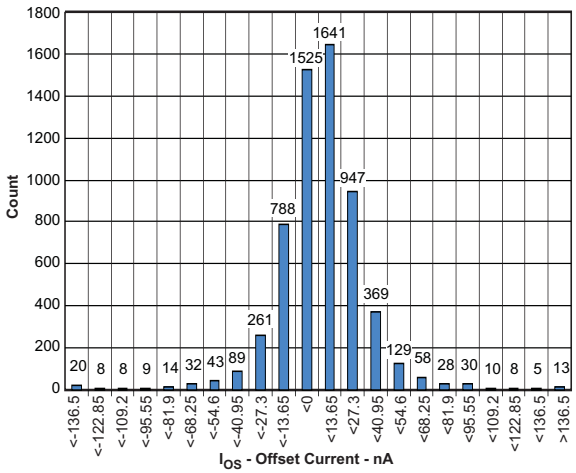


Figure 50. Input Offset Current

Test conditions unless otherwise noted: V_{S+} = +5 V, V_{S-} = 0 V, V_{OUT} = 2 V_{PP}, R_F = 0 Ω, R_L = 1 kΩ, G = 1 V/V, input and output referenced to mid-supply unless otherwise noted. T_A = 25°C, unless otherwise noted.

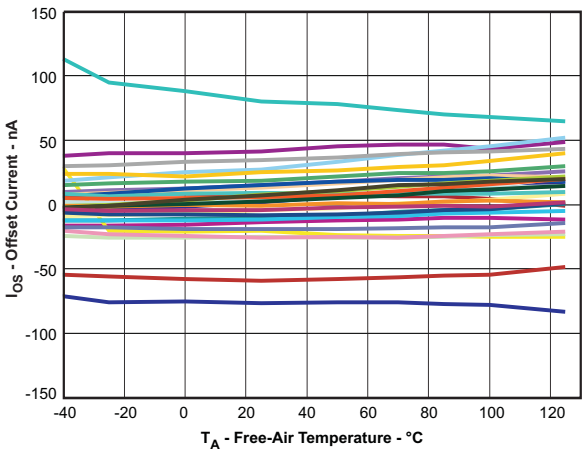


Figure 51. Input Offset Current vs Free-Air Temperature

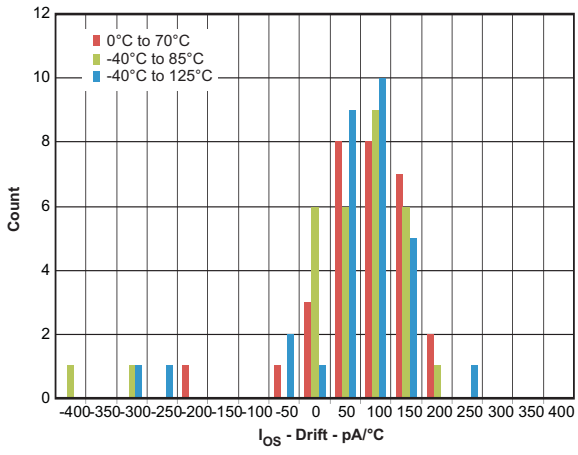


Figure 52. Input Offset Current Drift

8 Detailed Description

8.1 Overview

The OPAx836 family of bipolar-input operational amplifiers offer an excellent bandwidth of 205 MHz with ultra-low THD of 0.00003% at 1 kHz. The OPAx836 device can swing to within 200 mV of the supply rails while driving a 1-kΩ load. The input common mode of the amplifier can swing to 200 mV below the negative supply rail. This level of performance is achieved at 1 mA of quiescent current per amplifier channel.

8.2 Functional Block Diagrams

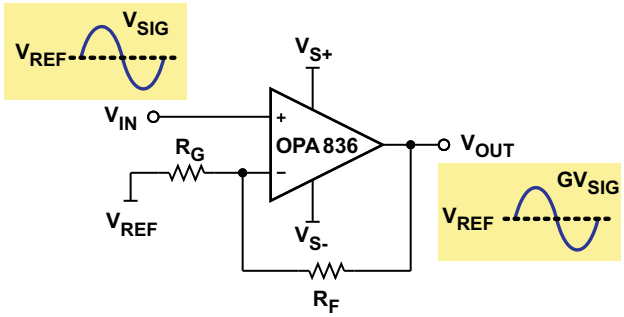


Figure 53. Noninverting Amplifier

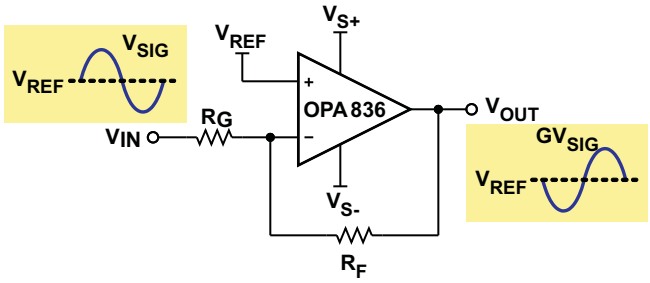


Figure 54. Inverting Amplifier

8.3 Feature Description

8.3.1 Input Common-Mode Voltage Range

When the primary design goal is a linear amplifier, with high CMRR, it is important to not violate the input common-mode voltage range (V_{ICR}) of an operational amplifier.

Common-mode input range low and high specifications in the table data use CMRR to set the limit. The limits are chosen to ensure CMRR will not degrade more than 3 dB below its limit if the input voltage is kept within the specified range. The limits cover all process variations and most parts will be better than specified. The typical specifications are from 0.2 V below the negative rail to 1.1 V below the positive rail.

Assuming the operational amplifier is in linear operation the voltage difference between the input pins is very small (ideally 0 V) and input common-mode voltage can be analyzed at either input pin and the other input pin is assumed to be at the same potential. The voltage at V_{IN+} is easy to evaluate. In noninverting configuration, Figure 53, the input signal, V_{IN}, must not violate the V_{ICR}. In inverting configuration, Figure 54, 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 linear input voltage range is –0.2 V to 3.9 V and with 2.7-V supply it is –0.2 V to 1.6 V. The delta from each power supply rail is the same in either case: –0.2 V and 1.1 V.

Feature Description (continued)

8.3.2 Output Voltage Range

The OPA836 and OPA2836 devices are rail-to-rail output (RRO) operational amplifiers. Rail-to-rail output typically means the output voltage can swing to within a couple hundred millivolts of the supply rails. There are different ways to specify this; 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 linear outputs, but the signal is not a linear representation of the input. Linear output is a better representation of how well a device performs when used as a linear amplifier. Both saturation and linear operation limits are affected by the current in the output, where higher currents lead to more loss in the output transistors.

Data in the *Specifications* tables list both linear and saturated output voltage specifications with 1-kΩ load. Figure 11 and Figure 37 show saturated voltage swing limits versus output load resistance and Figure 12 and Figure 38 show 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 2-kΩ load and single 5-V supply the linear output voltage range is 0.15 V to 4.8 V and with 2.7-V supply it is 0.15 V to 2.5 V. The delta from each power supply rail is the same in either case; 0.15 V and 0.2 V.

With devices like the OPA836 and OPA2836, where the input range is lower than the output range, it is typical that the input will limit the available signal swing only in noninverting gain of 1. Signal swing in noninverting configurations in gains > +1 and inverting configurations in any gain is generally limited by the output voltage limits of the operational amplifier.

8.3.3 Power-Down Operation

The OPA836 and OPA2836 devices include a power-down mode. Under logic control, the amplifiers can be switched from normal operation to a standby current of <1.5 µA. When the $\overline{PD}$ pin is connected high, the amplifier is active. Connecting $\overline{PD}$ 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. In order to protect the input stage of the amplifier, these devices use internal, back-to-back ESD diodes between the inverting and noninverting input pins. This configuration creates a parallel low-impedance path from the amplifier output to the noninverting pin when the differential voltage between the pins exceeds a diode voltage drop. When the op amp is configured in other gains, the feedback (RF) and gain (RG) resistor network forms a parallel load.

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

$\overline{PD}$ logic states are TTL with reference to the negative supply rail, V_{S-}. When the operational amplifier is powered from single supply and ground, driving from logic devices with similar V_{DD} voltages to the operational amplifier should not require any special consideration. When the operational amplifier is powered from split supply, V_{S-} is below ground and an open collector type of interface with pullup resistor is more appropriate. Pullup resistor values must be lower than 100 kΩ. Additionally, the drive logic must be negated due to the inverting action of an open collector gate.

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

The OPA836 and OPA2836 devices are designed for the nominal value of R_F to be 1 kΩ in gains other than +1. This gives excellent distortion performance, maximum bandwidth, best flatness, and best pulse response. It also loads the amplifier. For example; in gain of 2 with $R_F = R_G = 1$ kΩ, R_G to ground, and $V_{OUT} = 4$ V, 2 mA of current will flow through the feedback path to ground. In gain of +1, R_G is open and no current will flow to ground. In low power applications, it is desirable to reduce this current by increasing the gain setting resistors values. Using larger value gain resistors has two primary side effects (other than lower power) due to their interaction with parasitic circuit capacitance.

- Lowers the bandwidth
- Lowers the phase margin
  - This causes peaking in the frequency response
  - This also causes over shoot and ringing in the pulse response

Figure 55 shows the small signal frequency response on OPA836EVM for noninverting gain of 2 with R_F and R_G equal to 1 kΩ, 10 kΩ, and 100 kΩ. The test was done with $R_L = 1$ kΩ. Due to loading effects of R_L, lower values may reduce the peaking, but higher values will not have a significant effect.

Feature Description (continued)

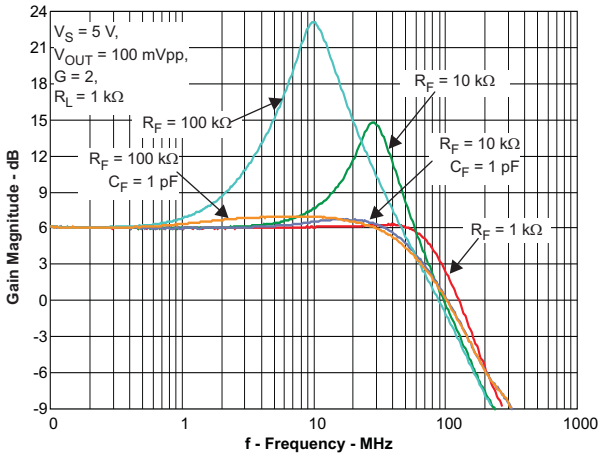


Figure 55. Frequency Response With Various Gain Setting Resistor Values

As expected, larger value gain resistors cause lower bandwidth and peaking in the response (peaking in frequency response is synonymous with overshoot and ringing in pulse response). Adding 1-pF capacitors in parallel with R_F helps compensate the phase margin and restores flat frequency response. Figure 56 shows the test circuit used.

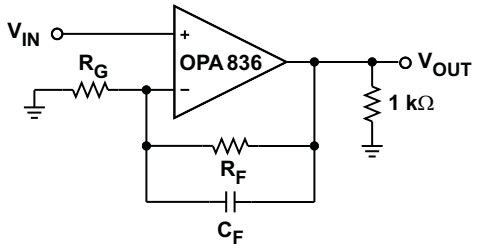


Figure 56. G = 2 Test Circuit for Various Gain Setting Resistor Values

8.3.5 Driving Capacitive Loads

The OPA836 and OPA2836 devices can drive up to a nominal capacitive load of 2.2 pF on the output with no special consideration. When driving capacitive loads greater than this, it is recommended to use a small resister (R_O) in series with the output as close to the device as possible. Without R_O, capacitance on the output will interact with the output impedance of the amplifier causing phase shift in the loop gain of the amplifier that will reduce the phase margin. This will cause peaking in the frequency response and overshoot and ringing in the pulses response. Interaction with other parasitic elements may lead to instability or oscillation. Inserting R_O will isolate the phase shift from the loop gain path and restore the phase margin; however, it will also limit the bandwidth.

Figure 57 shows the test circuit and Figure 43 shows the recommended values of R_O versus capacitive loads, C_L. See Figure 40 for frequency response with various values.

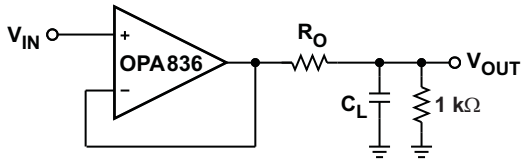


Figure 57. R_O versus C_L Test Circuit

8.4 Device Functional Modes

8.4.1 Split-Supply Operation (±1.25 V to ±2.75 V)

To facilitate testing with common lab equipment, the OPA836 EVM (see *OPA835DBV, OPA836DBV EVM*, SLOU314) is built to allow for 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 reference their inputs and outputs to ground.

Figure 58 shows a simple noninverting configuration analogous to Figure 53 with ±2.5-V supply and V_{REF} equal to ground. The input and output will swing symmetrically around ground. Due to its ease of use, split supply operation is preferred in systems where signals swing around ground, but it requires generation of two supply rails.

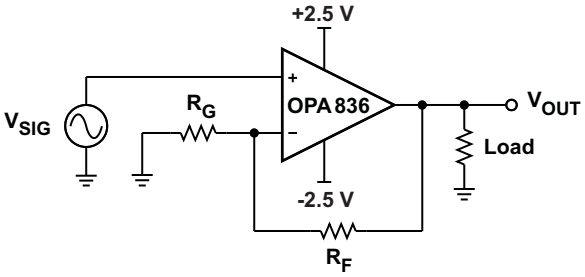


Figure 58. Split Supply Operation

8.4.2 Single-Supply Operation (2.5 V to 5.5 V)

Many newer systems use single power supply to improve efficiency and reduce the cost of the power supply. The OPA836 and OPA2836 devices are designed for use with single-supply power operation and can be used with single-supply power with no change in performance from split supply as long as the input and output are biased within the linear operation of the device.

To change the circuit from split supply to single supply, level shift of all voltages by ½ the difference between the power supply rails. For example, changing from ±2.5-V split supply to 5-V single supply is shown conceptually in Figure 59.

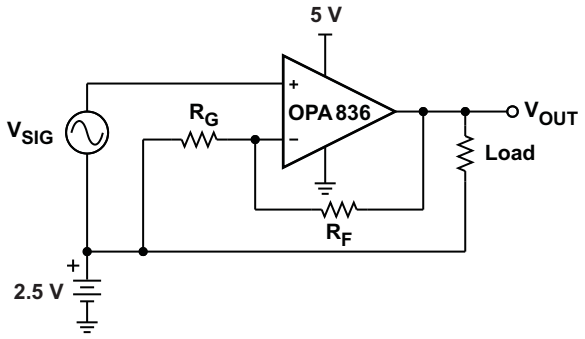


Figure 59. Single Supply Concept

A more practical circuit will have an amplifier or other circuit before to provide the bias voltage for the input and the output provides the bias for the next stage.

Figure 60 shows a typical noninverting amplifier situation. 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 would otherwise be caused by the input bias currents, R_1 is chosen to be equal to R_F in parallel with R_G. For example if gain of 2 is required and R_F = 1 kΩ, select R_G = 1 kΩ to set the gain and R_1 = 499 Ω for bias current cancellation. The value for C is dependent on the reference, but at least 0.1 µF is recommended to limit noise.

Device Functional Modes (continued)

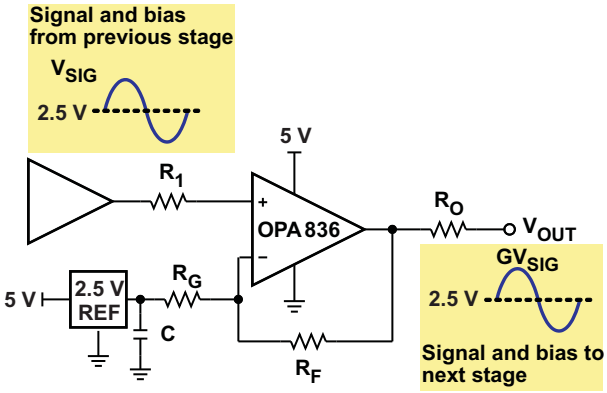


Figure 60. Noninverting Single Supply With Reference

Figure 61 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 their parallel sum equal to the equivalent R_G to set the gain. To cancel the voltage offset that would otherwise be caused by the input bias currents, R_1 in is chosen to be equal to R_F in parallel with R_G' in parallel with R_G" (R_1= R_F || R_G' || R_G"). For example if gain of 2 is required and R_F = 1 kΩ, selecting R_G' = R_G" = 2 kΩ gives equivalent parallel sum of 1 kΩ, sets the gain to 2, and references the input to mid supply (2.5 V). R_1 is then set to 499 Ω for bias current cancellation, which can be lower cost, but consider the extra current draw required in the resistor divider.

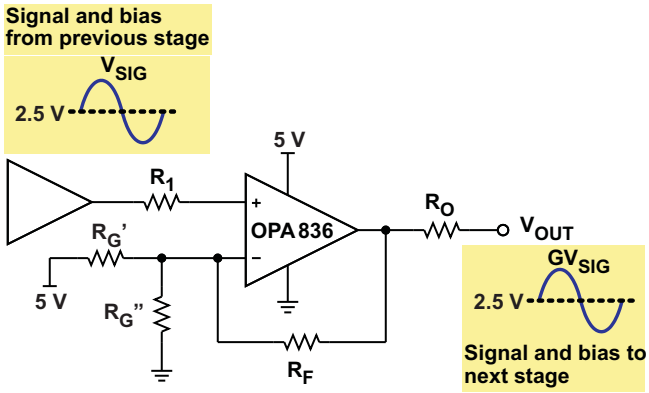


Figure 61. Noninverting Single Supply With Resistors

Figure 62 shows a typical inverting amplifier situation. With 5-V single supply, a mid-supply reference generator is needed to bias the positive side via R_1. To cancel the voltage offset that would otherwise be caused by the input bias currents, R_1 is chosen to be equal to R_F in parallel with R_G. For example if gain of –2 is required and R_F = 1 kΩ, select R_G = 499 Ω to set the gain and R_1 = 332 Ω for bias current cancellation. The value for C is dependent on the reference, but at least 0.1 µF is recommended to limit noise into the operational amplifier.

Device Functional Modes (continued)

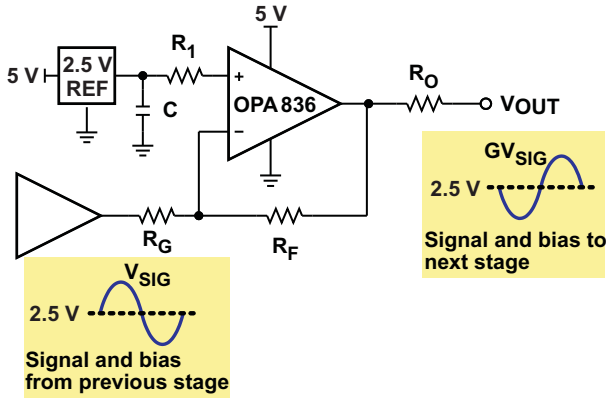


Figure 62. Inverting Single Supply With Reference

Figure 63 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 would otherwise be caused by the input bias currents, set the parallel sum of R_1 and R_2 equal to the parallel sum 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 is required and R_F = 1 kΩ, select R_G = 499 Ω to set the gain. R_1 = R_2 = 665 Ω for mid-supply voltage bias and for operational amplifier input bias current cancellation. A good value for C is 0.1 µF. This can be lower cost, but consider the extra current draw required in the resistor divider.

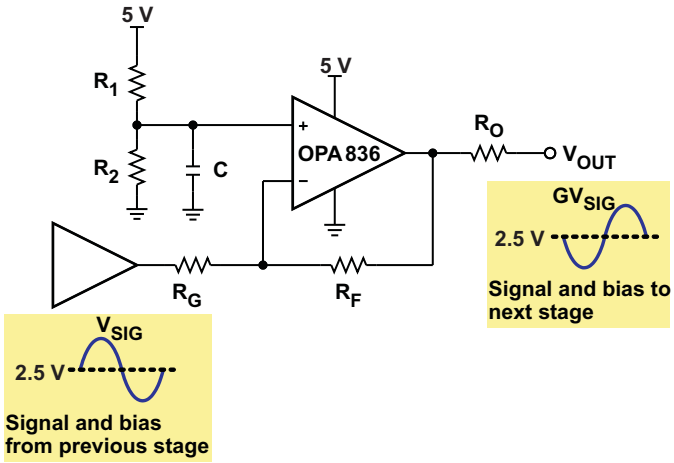


Figure 63. Inverting Single Supply With Resistors

9 Application and Implementation

NOTE

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

9.1 Application Information

9.1.1 Noninverting Amplifier

The OPA836 and OPA2836 devices can be used as noninverting amplifiers with signal input to the noninverting input, V_{IN+} . A basic block diagram of the circuit is shown in Figure 53.

If $V_{IN} = V_{REF} + V_{SIG}$, then the output of the amplifier may be calculated according to Equation 1.

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

The signal gain of the circuit is set by: $G = 1 + \frac{R_F}{R_G}$, and V_{REF} provides a reference around which the input and output signals swing. Output signals are in-phase with the input signals.

The OPA836 and OPA2836 devices are designed for the nominal value of R_F to be 1 kΩ in gains other than +1. This gives excellent distortion performance, maximum bandwidth, best flatness, and best pulse response. R_F = 1 kΩ must be used as a default unless other design goals require changing to other values All test circuits used to collect data for this data sheet had R_F = 1 kΩ for all gains other than +1. Gain of +1 is a special case where R_F is shorted and R_G is left open.

9.1.2 Inverting Amplifier

The OPA836 and OPA2836 devices can be used as inverting amplifiers with signal input to the inverting input, $V_{IN–}$, through the gain setting resistor R_G. A basic block diagram of the circuit is shown in Figure 54.

If $V_{IN} = V_{REF} + V_{SIG}$, then the output of the amplifier may be calculated according to Equation 2.

$$V_{OUT} = V_{SIG}\left(\frac{-R_F}{R_G}\right) + V_{REF} \quad (2)$$

The signal gain of the circuit is set by: $G = \frac{-R_F}{R_G}$, and V_{REF} provides a reference point around which the input and output signals swing. Output signals are 180° out-of-phase with the input signals. The nominal value of R_F must be 1 kΩ for inverting gains.

9.1.3 Instrumentation Amplifier

Figure 64 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 like taps from a differential line or in cases where the signal source is a high impedance.

If $V_{IN+} = V_{CM} + V_{SIG+}$ and $V_{IN–} = V_{CM} + V_{SIG–}$, then the output of the amplifier may be calculated according to Equation 3.

$$V_{OUT} = (V_{IN+} - V_{IN–}) \times \left(1 + \frac{2R_{F1}}{R_{G1}}\right)\left(\frac{R_{F2}}{R_{G2}}\right) + V_{REF} \quad (3)$$

Application Information (continued)

The signal gain of the circuit is set by: $G = \left(1 + \frac{2R_{F1}}{R_{G1}}\right)\left(\frac{R_{F2}}{R_{G2}}\right)$. V_{CM} is rejected and V_{REF} provides a level shift around which the output signal swings. The single ended output signal is in-phase with the differential input signal.

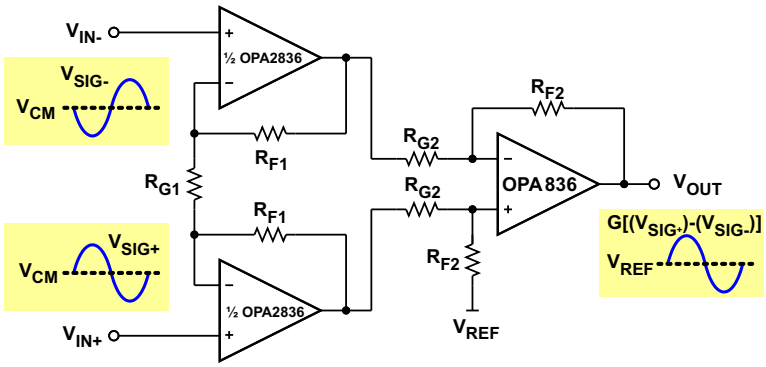


Figure 64. Instrumentation Amplifier

Integrated solutions are available, but the OPA836 device provides a much lower-power, high-frequency solution. For best CMRR performance, resistors must be matched. Assuming CMRR ≈ the resistor tolerance; so 0.1% tolerance will provide about 60-dB CMRR.

9.1.4 Attenuators

The noninverting circuit of Figure 53 has minimum gain of 1. To implement attenuation, a resistor divider can be placed in series with the positive input, and the amplifier set for gain of 1 by shorting V_{OUT} to $V_{IN–}$ and removing R_G. Because the operational amplifier input is high impedance, the attenuation is set by the resistor divider.

The inverting circuit of Figure 54 can be used as an attenuator by making R_G larger than R_F. The attenuation is simply the resistor ratio. For example, a 10:1 attenuator can be implemented with R_F = 1 kΩ and R_G = 10 kΩ.

9.1.5 Single Ended to Differential Amplifier

Figure 65 shows an amplifier circuit that is used to convert single-ended signals to differential, and provides gain and level shifting. This circuit can be used for converting signals to differential in applications like line drivers for Cat5 cabling or driving differential input SAR and ΔΣ ADCs.

By setting $V_{IN} = V_{REF} + V_{SIG}$, then the output of the amplifier may be calculated according to Equation 4.

$$V_{OUT+} = G \times V_{IN} + V_{REF} \quad \text{and} \quad V_{OUT-} = -G \times V_{IN} + V_{REF} \quad \text{Where: } G = 1 + \frac{R_F}{R_G} \tag{4}$$

The differential signal gain of the circuit is 2 × G, and V_{REF} provides a reference around which the output signal swings. The differential output signal is in-phase with the single ended input signal.

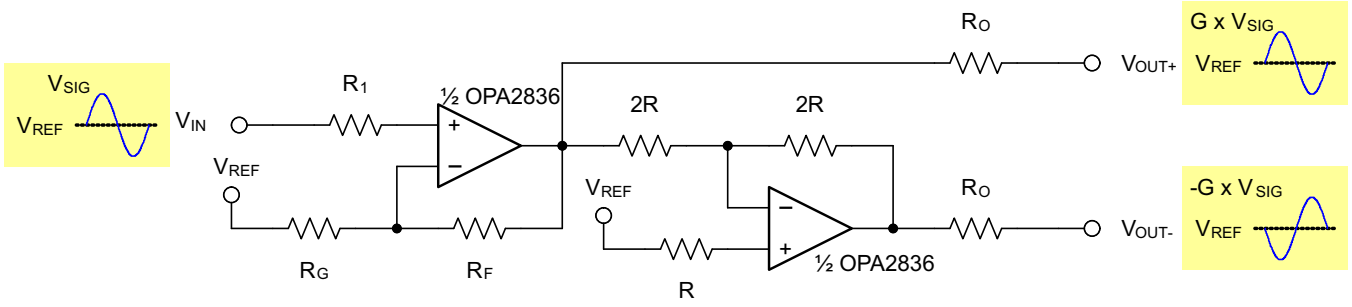


Figure 65. Single Ended to Differential Amplifier

Application Information (continued)

Line termination on the output can be accomplished with resistors R_O. The impedance seen differential from the line will be 2 × R_O. For example if 100-Ω Cat5 cable is used with double termination, the amplifier is typically set for a differential gain of 2 V/V (6 dB) with R_F = 0 Ω (short) R_G = ∞Ω (open), 2R = 1 kΩ, R1 = 0 Ω, R = 499 Ω to balance the input bias currents, and R_O = 49.9 Ω for output line termination. This configuration is shown in Figure 66.

For driving a differential input ADC the situation is similar, but the output resistors (R_O) are typically chosen along with a capacitor across the ADC input for optimum filtering and settling time performance.

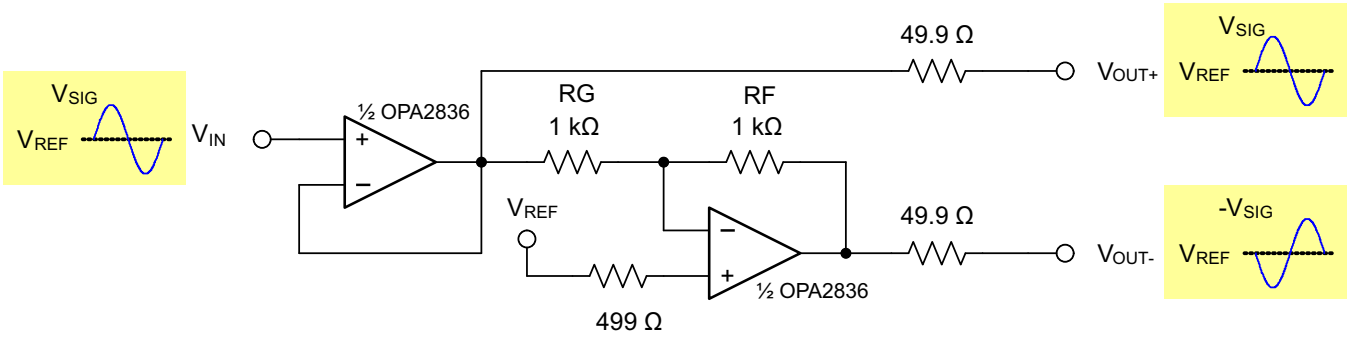


Figure 66. Cat5 Line Driver With Gain = 2 V/V (6 dB)

9.1.6 Differential to Signal Ended Amplifier

Figure 67 shows a differential amplifier that is used to convert differential signals to single-ended and provides gain (or attenuation) and level shifting. This circuit can be used in applications like a line receiver for converting a differential signal from a Cat5 cable to single-ended.

If we set $V_{IN+} = V_{CM} + V_{SIG+}$ and $V_{IN-} = V_{CM} + V_{SIG-}$, then the output of the amplifier may be calculated according to Equation 5.

$$V_{OUT} = \left(V_{IN+} - V_{IN-}\right) \times \left(\frac{R_F}{R_G}\right) + V_{REF} \tag{5}$$

The signal gain of the circuit is set by: $G = \frac{R_F}{R_G}$. V_{CM} is rejected and V_{REF} provides a level shift around which the output signal swings. The single ended output signal is in-phase with the differential input signal.

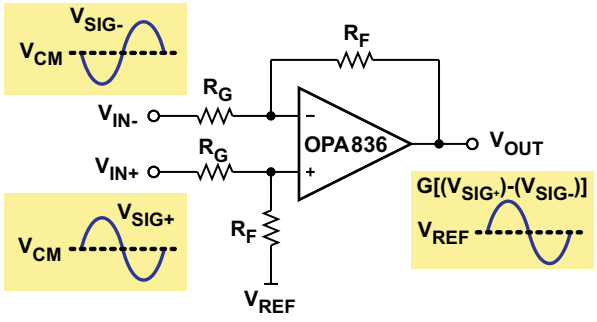


Figure 67. Differential to Single Ended Amplifier

Line termination can be accomplished with a resistor shunt across the input. The impedance seen differential from the line will be the resistor value in parallel with the amplifier circuit. For low gain and low line impedance the resistor value to add is approximately the impedance of the line. For example if 100-Ω Cat5 cable is used with a gain of 1 amplifier and R_F = R_G = 1 kΩ, adding a 100-Ω shunt across the input will give a differential impedance of 98 Ω; this will be adequate for most applications.

Application Information (continued)

For best CMRR performance, resistors must be matched. A rule of thumb is CMRR ≈ the resistor tolerance; so 0.1% tolerance will provide about 60-dB CMRR.

9.1.7 Differential to Differential Amplifier

Figure 68 shows a differential amplifier that is used to amplify differential signals. This circuit has high input impedance and is often 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.

If we set $V_{IN\pm} = V_{CM} + V_{SIG\pm}$, then the output of the amplifier may be calculated according to Equation 6.

$$V_{OUT\pm} = V_{IN\pm} \times \left(1 + \frac{2R_F}{R_G}\right) + V_{CM} \tag{6}$$

The signal gain of the circuit is set by: $G = 1 + \frac{2R_F}{R_G}$, and V_{CM} passes with unity gain. The amplifier in essence combines two noninverting amplifiers into one differential amplifier with the R_G resistor shared, which makes R_G effectively ½ its value when calculating the gain. The output signals are in-phase with the input signals.

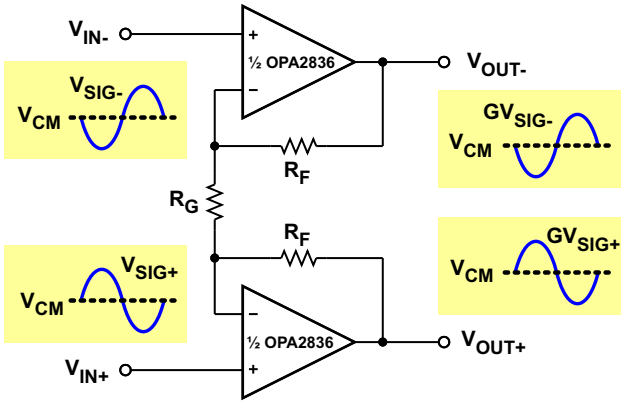


Figure 68. Differential to Differential Amplifier

9.1.8 Gain Setting With OPA836 RUN Integrated Resistors

The OPA836 RUN package option includes integrated gain setting resistors for smallest possible footprint on a printed circuit board (≈ 2 mm × 2 mm). By adding circuit traces on the PCB, gains of +1, –1, –1.33, +2, +2.33, –3, +4, –4, +5, –5.33, +6.33, –7, +8 and inverting attenuations of –0.1429, –0.1875, –0.25, –0.33, –0.75 can be achieved.

Figure 69 shows a simplified view of how the OPA836IRUN integrated gain setting network is implemented. Table 3 shows the required pin connections for various noninverting and inverting gains (reference Figure 53 and Figure 54). Table 4 shows the required pin connections for various attenuations using the inverting amplifier architecture (reference Figure 54). Due to ESD protection devices being used on all pins, the absolute maximum and minimum input voltage range, $V_{S-} - 0.7$ V to $V_{S+} + 0.7$ V, applies to the gain setting resistors, and so attenuation of large input voltages will require external resistors to implement.

The gain setting resistors are laser trimmed to 1% tolerance with nominal values of 1.6 kΩ, 1.2 kΩ, and 400 Ω. They have excellent temperature coefficient and gain tracking is superior to using external gain setting resistors. The 500-Ω and 1.5-pF capacitor in parallel with the 1.6-kΩ gain setting resistor provide compensation for best stability and pulse response.

Application Information (continued)

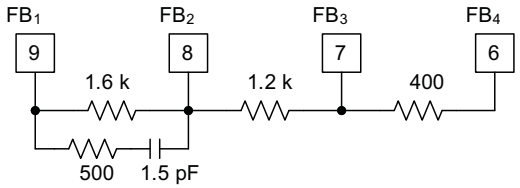


Figure 69. OPA836IRUN Gain Setting Network

Table 3. Gains Setting

NONINVERTING GAIN (Figure 53)	INVERTING GAIN (Figure 54)	SHORT PINS	SHORT PINS	SHORT PINS	SHORT PINS
1 V/V (0 dB)	—	1 to 9			—
2 V/V (6.02 dB)	–1 V/V (0 dB)	1 to 9	2 to 8	6 to GND	—
2.33 V/V (7.36 dB)	–1.33 V/V (2.5 dB)	1 to 9	2 to 8	7 to GND	—
4 V/V (12.04 dB)	–3 V/V (9.54 dB)	1 to 8	2 to 7	6 to GND	—
5 V/V (13.98 dB)	–4 V/V (12.04 dB)	1 to 9	2 to 7 or 8	7 to 8	6 to GND
6.33 V/V (16.03 dB)	–5.33 V/V (14.54 dB)	1 to 9	2 to 6 or 8	6 to 8	7 to GND
8 V/V (18.06 dB)	–7 V/V (16.90 dB)	1 to 9	2 to 7	6 to GND	—

Table 4. Attenuator Settings

INVERTING GAIN (Figure 54)	SHORT PINS	SHORT PINS	SHORT PINS	SHORT PINS
–0.75 V/V (–2.5 dB)	1 to 7	2 to 8	9 to GND	—
–0.333 V/V (–9.54 dB)	1 to 6	2 to 7	8 to GND	—
–0.25 V/V (–12.04 dB)	1 to 6	2 to 7 or 8	7 to 8	9 to GND
–0.1875 V/V (–14.54 dB)	1 to 7	2 to 6 or 8	6 to 8	9 to GND
–0.1429 V/V (–16.90 dB)	1 to 6	2 to 7	9 to GND	—

9.1.9 Pulse Application With Single-Supply

For pulsed applications, where the signal is at ground and pulses to some positive or negative voltage, the circuit bias voltage considerations are different than with a signal that swings symmetrical about a reference point and the circuit configuration must be adjusted accordingly. Figure 70 shows a pulsed situation where the signal is at ground (0 V) and pulses to a positive value.

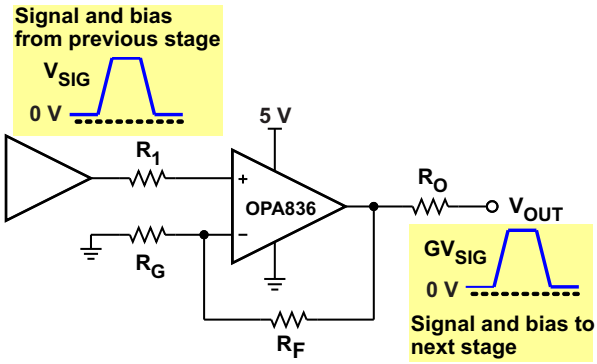


Figure 70. Noninverting Single Supply With Pulse

If the input signal pulses negative from ground, an inverting amplifier is more appropriate as shown in Figure 71. A key consideration in both 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 OPA836 device includes the negative supply rail, the operational amplifier lends itself to this application.

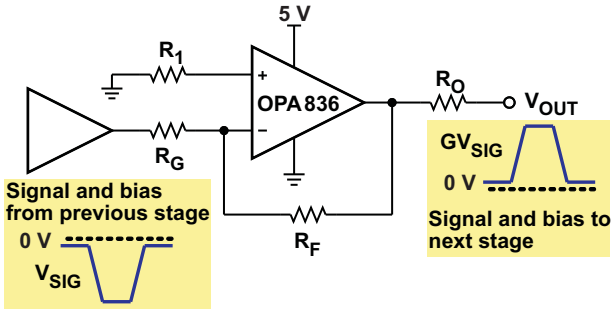


Figure 71. Inverting Single Supply With Pulse

9.1.10 ADC Driver Performance

The OPA836 device provides excellent performance when driving high performance delta-sigma (ΔΣ) and successive approximation register (SAR) ADCs in low-power audio and industrial applications.

To show achievable performance, the OPA836 device is tested as the drive amplifier for the ADS8326. The ADS8326 is a 16-bit, micro power, SAR ADC with pseudo-differential inputs and sample rates up to 250 kSPS. It offers excellent noise and distortion performance in a small 8-pin SOIC or VSSOP (MSOP) package. Low power and small size make the ADS8326 and OPA836 devices an ideal solution for portable and battery-operated systems, for remote data-acquisition modules, simultaneous multichannel systems, and isolated data acquisition.

The circuit shown in Figure 72 is used to test the performance, Figure 73 is the FFT plot with 10-kHz input frequency showing the spectral performance, and the tabulated AC analysis results are in Table 5.

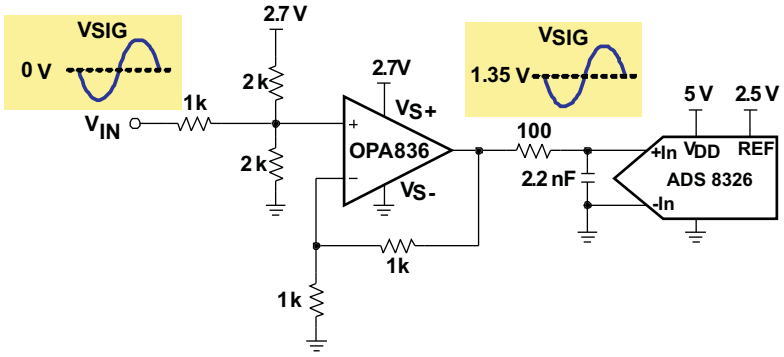


Figure 72. OPA836 and ADS8326 Test Circuit

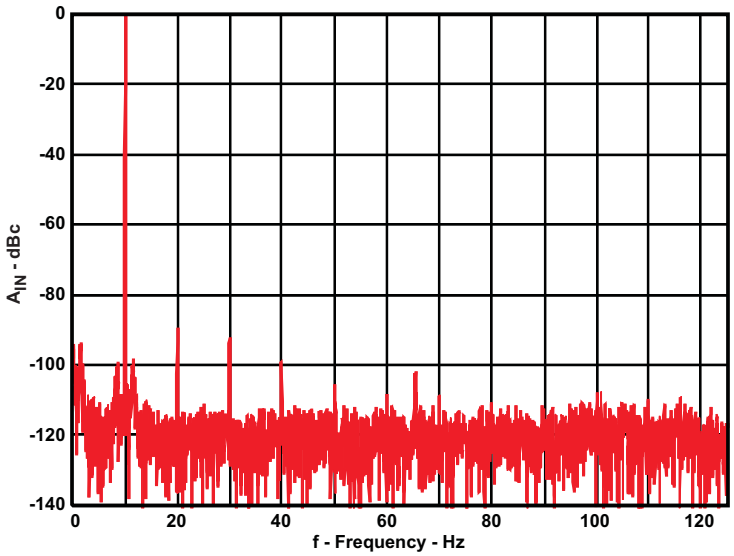


Figure 73. ADS8326 and OPA836 10-kHz FFT

Table 5. AC Analysis

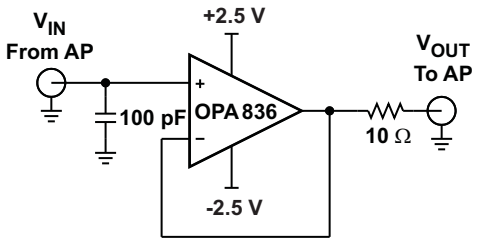
TONE (Hz)	SIGNAL (dBFS)	SNR (dBc)	THD (dBc)	SINAD (dBc)	SFDR (dBc)
10k	–0.85	83.3	–86.6	81.65	88.9

9.2 Typical Applications

9.2.1 Audio Frequency Performance

The OPA836 and OPA2836 devices provide excellent audio performance with very low-quiescent power. To show performance in the audio band, a 2700 series audio analyzer from Audio Precision is used to test THD+N and FFT at 1 V_{RMS} output voltage.

Figure 74 shows the test circuit used for the audio-frequency performance application.



The 100-pF capacitor to ground on the input helped to decouple noise pick up in the lab and improved noise performance.

Figure 74. OPA836 Audio Precision Analyzer Test Circuit

Typical Applications (continued)

9.2.1.1 Design Requirements

Design a low distortion, single-ended input to single-ended output audio amplifier using the OPA836 device. The 2700 series audio analyzer from Audio Precision is used as the signal source and also as the measurement system.

Table 6. Design Requirements

CONFIGURATION	INPUT EXCITATION	PERFORMANCE TARGET	R_{Load}
OPA836 Unity Gain Config.	1 KHz Tone Frequency	>110 dBc SFDR	300 Ω and 100 kΩ

9.2.1.2 Detailed Design Procedure

The OPA836 device is tested in this application in a unity-gain buffer configuration. A buffer configuration is chosen as it maximizes the loop gain of the amplifier configuration. At higher closed-loop gains, the loop gain of the circuit reduces, which results in degraded harmonic distortion. The relationship between distortion and closed loop gain at a fixed input frequency can be seen in Figure 36 in Typical Performance Graphs: V_S = 5 V. The test was performed under varying output load conditions using a resistive load of 300 Ω and 100K Ω. Figure 34 shows the distortion performance of the amplifier versus output resistive load. Output loading, output swing, and closed-loop gain play a key role in determining the distortion performance of the amplifier.

NOTE

The 100-pF capacitor to ground on the input helped to decouple noise pickup in the lab and improved noise performance.

The Audio Precision was configured as a single-ended output in this application circuit. In applications where a differential output is available, the OPA836 device can be configured as a differential to single-ended amplifier as shown in Figure 67. Power supply bypassing is critical in order to reject noise from the power supplies. A 2.2-µF power supply decoupling capacitor must be placed within 2 inches of the device and can be shared with other operational amplifiers on the same board. A 0.1-µF power supply decoupling capacitor must be placed as close to the power supply pins as possible, preferably within 0.1 inch. For split supply, a capacitor is required for both supplies. A 0.1-µF capacitor placed directly between the supplies is also beneficial for improving system noise performance. If the output load is very heavy, in the order of 16 Ω to 32 Ω, performance of the amplifier could begin to degrade. In order to drive such heavy loads, both channels of the OPA2836 device can be paralleled with their outputs isolated with 1-Ω resistors to reduce the loading effects.

9.2.1.3 Application Curves

A 10-Ω series resistor can be inserted between the capacitor and the noninverting pin to isolate the capacitance.

Figure 75 shows the THD+N performance with 100-kΩ and 300-Ω loads, with A-weighting and with no weighting. Both loads show similar performance. With no weighting, the THD+N performance is dominated by the noise; whereas A-weighting provides filtering that improves the noise.

Figure 76 and Figure 77 show FFT output with a 1-kHz tone and 100-kΩ and 300-Ω loads. To show relative performance of the device versus the test set, one channel has the OPA836 device in line between generator output and analyzer input and the other channel is in “Gen Mon” loopback mode, which internally connects the signal generator to the analyzer input. With 100-kΩ load, Figure 76, the curves are basically indistinguishable from each other except for noise, which means the OPA836 device cannot be directly measured. With 300-Ω load, Figure 77, the main difference between the curves is the OPA836 device shows slightly higher even-order harmonics, but odd order is masked by the test set performance.

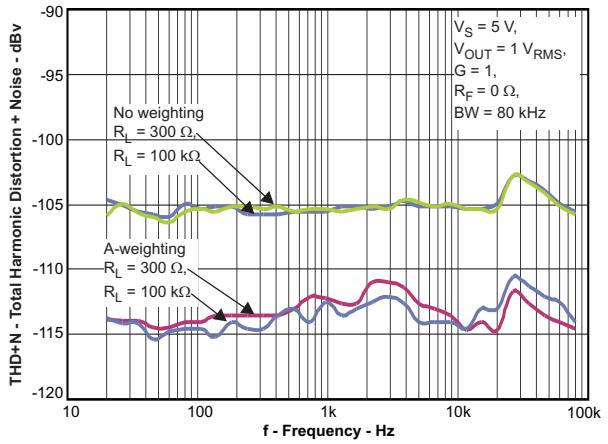


Figure 75. OPA836 1 V_{RMS} 20-Hz to 80-kHz THD+N

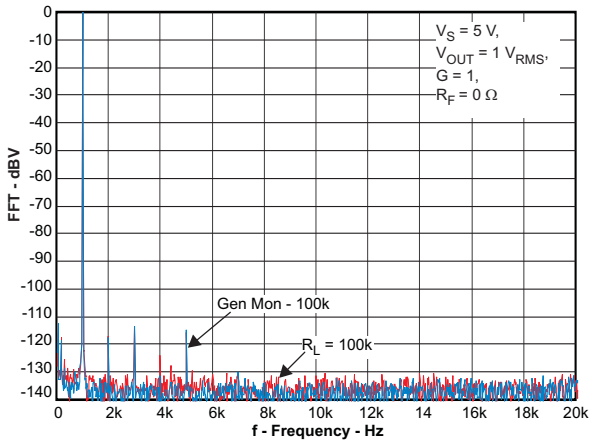


Figure 76. OPA836 and AP Gen Mon 10-kHz FFT Plot; V_{OUT} = 1 V_{RMS}, R_L = 100 kΩ

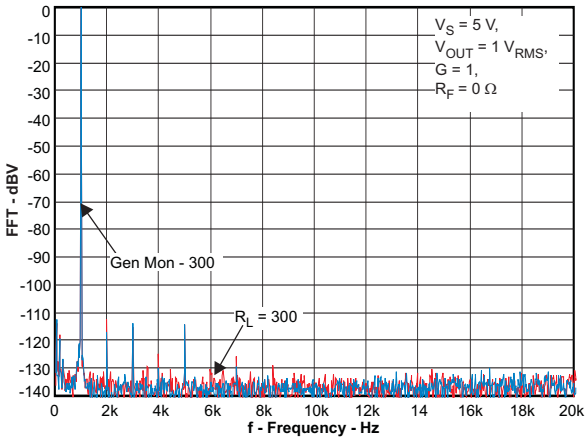


Figure 77. OPA836 and AP Gen Mon 10-kHz FFT Plot; V_{OUT} = 1 V_{RMS}, R_L = 300 Ω

9.2.2 Active Filters

The OPA836 and OPA2836 devices can be used to design active filters. Figure 78 and Figure 79 show MFB and Sallen-Key circuits designed using the WEBENCH® Filter Designer (focus.ti.com) to implement second order low-pass butterworth filter circuits. Figure 80 shows the frequency response.

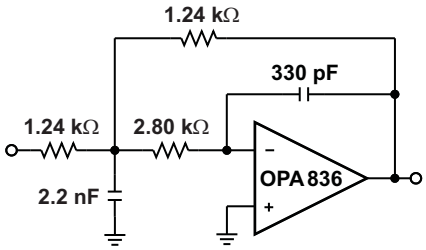


Figure 78. MFB 100-kHz Second Order Low-Pass Butterworth Filter Circuit

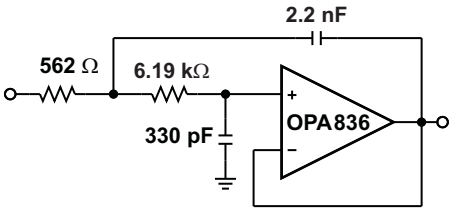


Figure 79. Sallen-Key 100-kHz Second Order Low-Pass Butterworth Filter Circuit

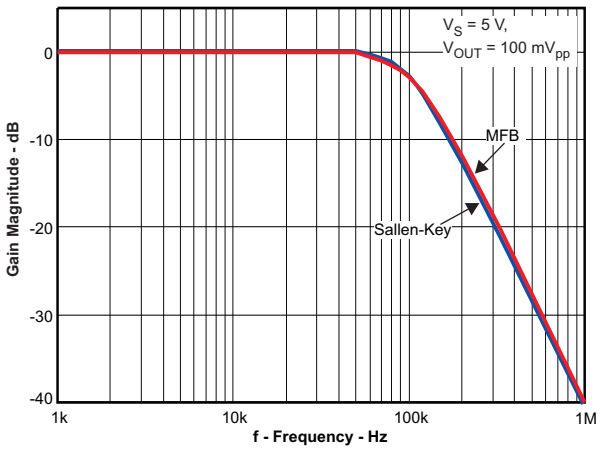


Figure 80. MFB and Sallen-Key Second Order Low-Pass Butterworth Filter Response

MFB and Sallen-Key filter circuits offer similar performance. The main difference is the MFB is an inverting amplifier in the pass band and the Sallen-Key is noninverting. The primary pro for each is the Sallen-Key in unity gain has no resistor gain error term, and thus no sensitivity to gain error, while the MFB has inherently better attenuation properties beyond the bandwidth of the operational amplifier.

10 Power Supply Recommendations

The OPAx836 device is principally intended to work in a supply range of 2.7 V to 5 V. Supply voltage tolerances are supported with the specified operating range of 2.5 V (7% on a 2.7-V supply) and 5.5 V (10% 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. Often a larger capacitor (2.2 µF, 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 somewhat farther from the device and share these capacitors among several devices in the same area of the 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) improves second harmonic distortion performance.

11 Layout

11.1 Layout Guidelines

The *OPA835DBV, OPA836DBV EVM* (SLOU314) must be used as a reference when designing the circuit board. It is recommended to follow the EVM layout of the external components near to the amplifier, ground plane construction, and power routing as closely as possible. General guidelines are:

1. Signal routing must be direct and as short as possible into an out of the operational amplifier.
2. The feedback path must be short and direct avoiding vias if possible especially with G = +1.
3. Ground or power planes must be removed from directly under the negative input and output pins of the amplifier.
4. A series output resistor is recommended to be placed as near to the output pin as possible. See *Series Output Resistor vs Capacitive Load* (Figure 17) for recommended values given expected capacitive load of design.
5. A 2.2-µF power supply decoupling capacitor must be placed within 2 inches of the device and can be shared with other operational amplifiers. For spit supply, a capacitor is required for both supplies.
6. A 0.1-µF power supply decoupling capacitor must be placed as near to the power 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 TTL logic levels. If not used it must tied to the positive supply to enable the amplifier. If used, it must be actively driven. A bypass capacitor is not necessary, but can be used for robustness in noisy environments.

11.2 Layout Example

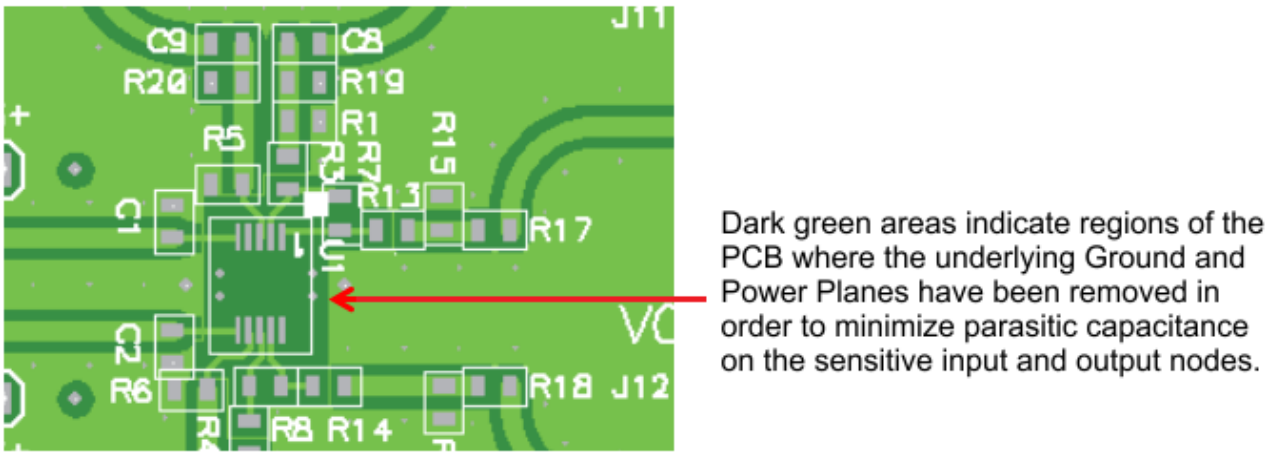


Figure 81. Top Layer

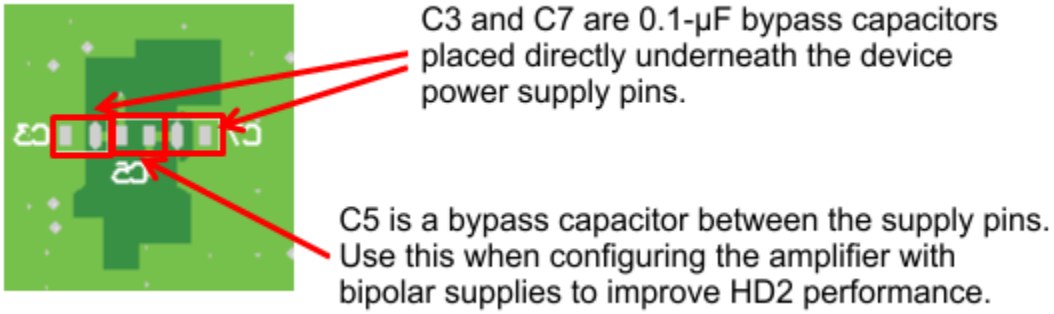


Figure 82. Bottom Layer

12 Device and Documentation Support

12.1 Device Support

12.1.1 Development Support

WEBENCH® Filter Designer (focus.ti.com)

12.1.2 Related Documentation

For related documentation see the following:

OPA835DBV, OPA836DBV EVM (SLOU314)

12.2 Related Links

Table 7 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 7. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
OPA836	Click here	Click here	Click here	Click here	Click here
OPA2836	Click here	Click here	Click here	Click here	Click here

12.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks

E2E is a trademark of Texas Instruments.
WEBENCH is a registered trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution

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

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

12.6 Glossary

SLYZ022 — *TI Glossary*.

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

13 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA2836ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IDGS	ACTIVE	VSSOP	DGS	10	80	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IDGSR	ACTIVE	VSSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IRMCR	ACTIVE	UQFN	RMC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IRMCT	ACTIVE	UQFN	RMC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IRUNR	ACTIVE	QFN	RUN	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA2836IRUNT	ACTIVE	QFN	RUN	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	2836	Samples
OPA836IDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	QTL	Samples
OPA836IDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	QTL	Samples
OPA836IRUNR	ACTIVE	QFN	RUN	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	836	Samples
OPA836IRUNT	ACTIVE	QFN	RUN	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	836	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

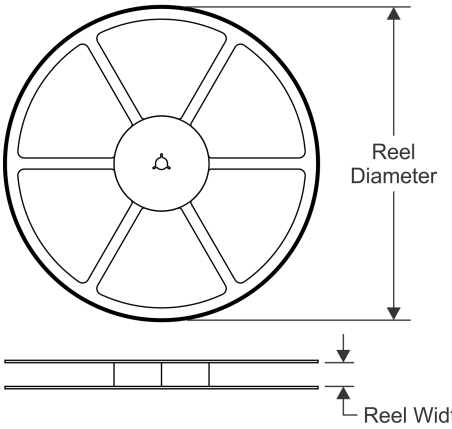
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

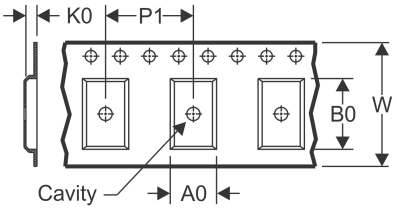
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

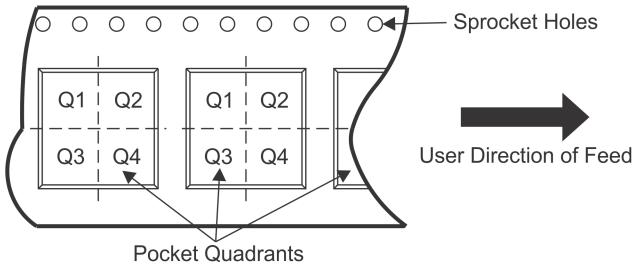


TAPE DIMENSIONS



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

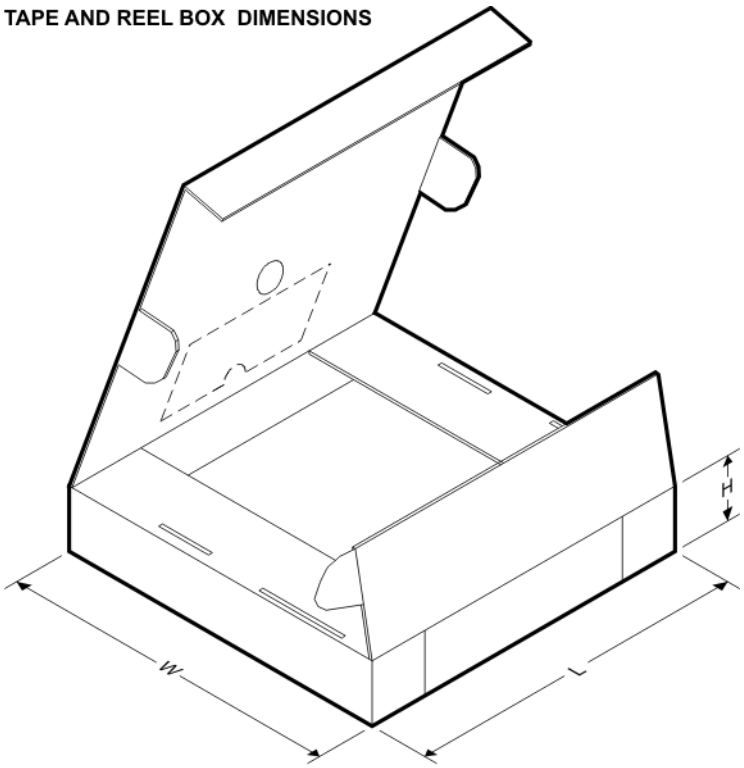
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
OPA2836IDGSR	VSSOP	DGS	10	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2836IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA2836IRMCR	UQFN	RMC	10	3000	180.0	9.5	2.3	2.3	1.1	2.0	8.0	Q2
OPA2836IRMCT	UQFN	RMC	10	250	180.0	9.5	2.3	2.3	1.1	2.0	8.0	Q2
OPA2836IRUNR	QFN	RUN	10	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
OPA2836IRUNT	QFN	RUN	10	250	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
OPA836IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
OPA836IDBVT	SOT-23	DBV	6	250	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
OPA836IRUNR	QFN	RUN	10	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
OPA836IRUNT	QFN	RUN	10	250	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2

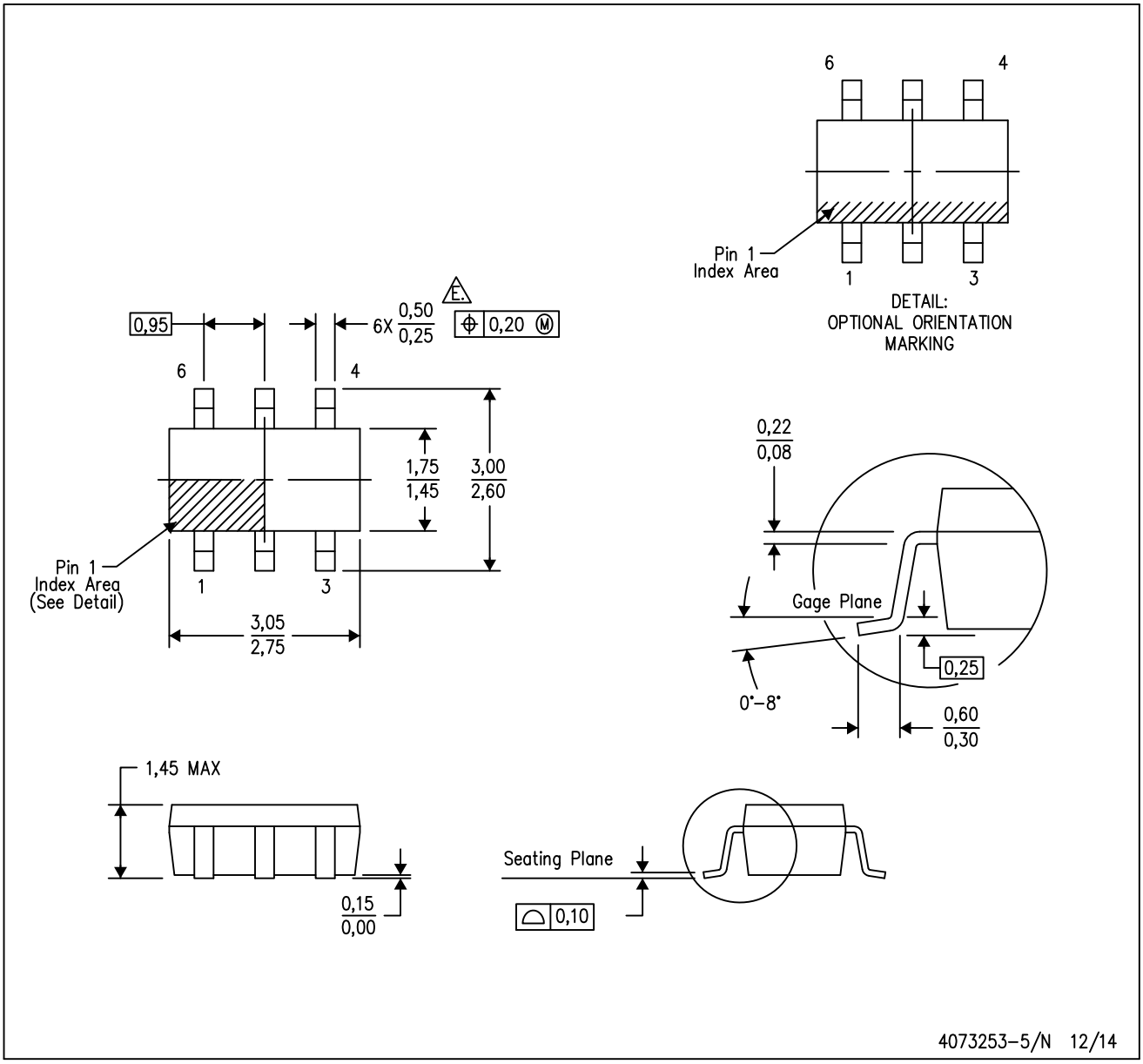
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

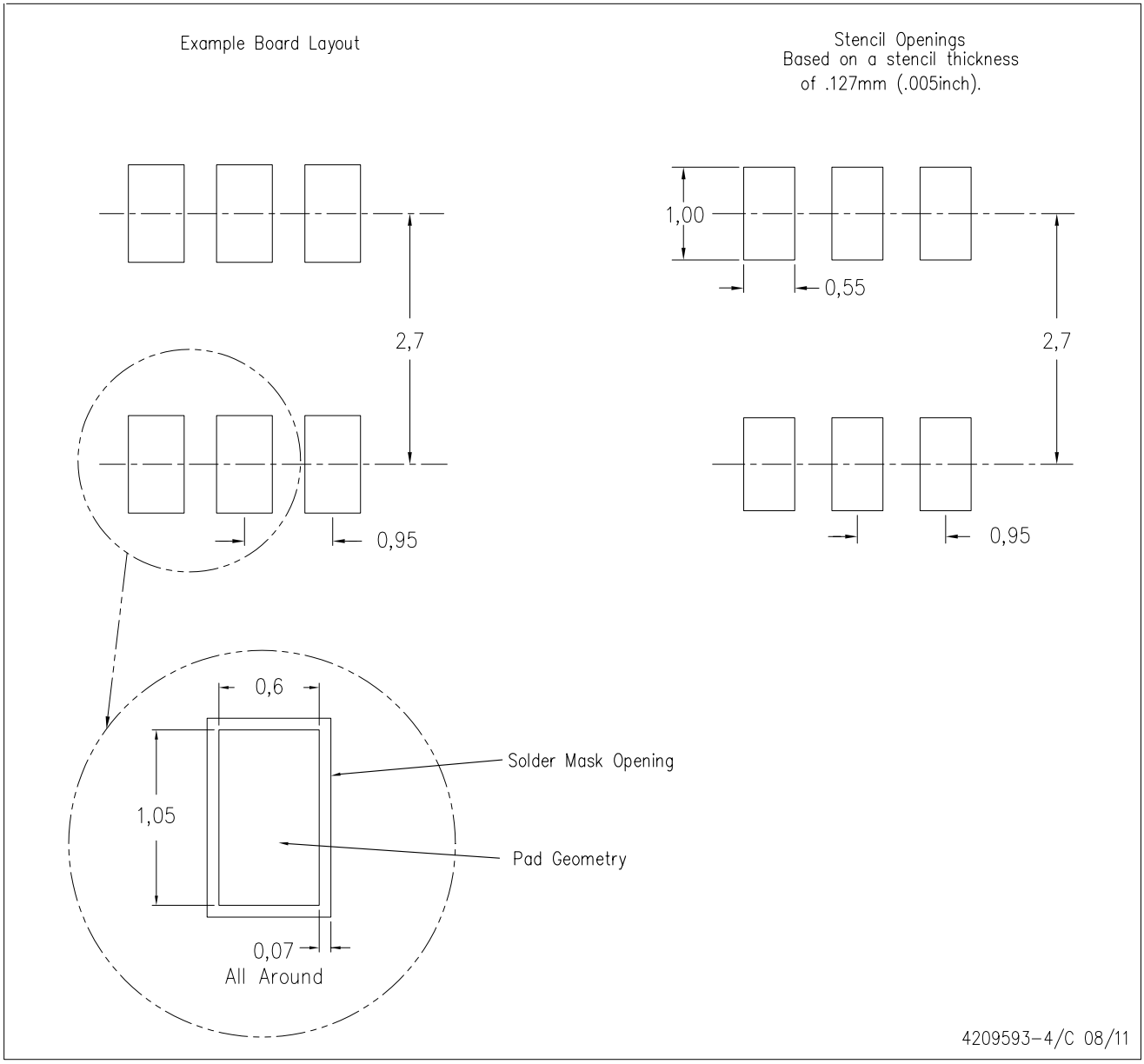
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA2836IDGSR	VSSOP	DGS	10	2500	366.0	364.0	50.0
OPA2836IDR	SOIC	D	8	2500	340.5	338.1	20.6
OPA2836IRMCR	UQFN	RMC	10	3000	205.0	200.0	30.0
OPA2836IRMCT	UQFN	RMC	10	250	205.0	200.0	30.0
OPA2836IRUNR	QFN	RUN	10	3000	210.0	185.0	35.0
OPA2836IRUNT	QFN	RUN	10	250	210.0	185.0	35.0
OPA836IDBVR	SOT-23	DBV	6	3000	180.0	180.0	18.0
OPA836IDBVT	SOT-23	DBV	6	250	180.0	180.0	18.0
OPA836IRUNR	QFN	RUN	10	3000	210.0	185.0	35.0
OPA836IRUNT	QFN	RUN	10	250	210.0	185.0	35.0

DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE



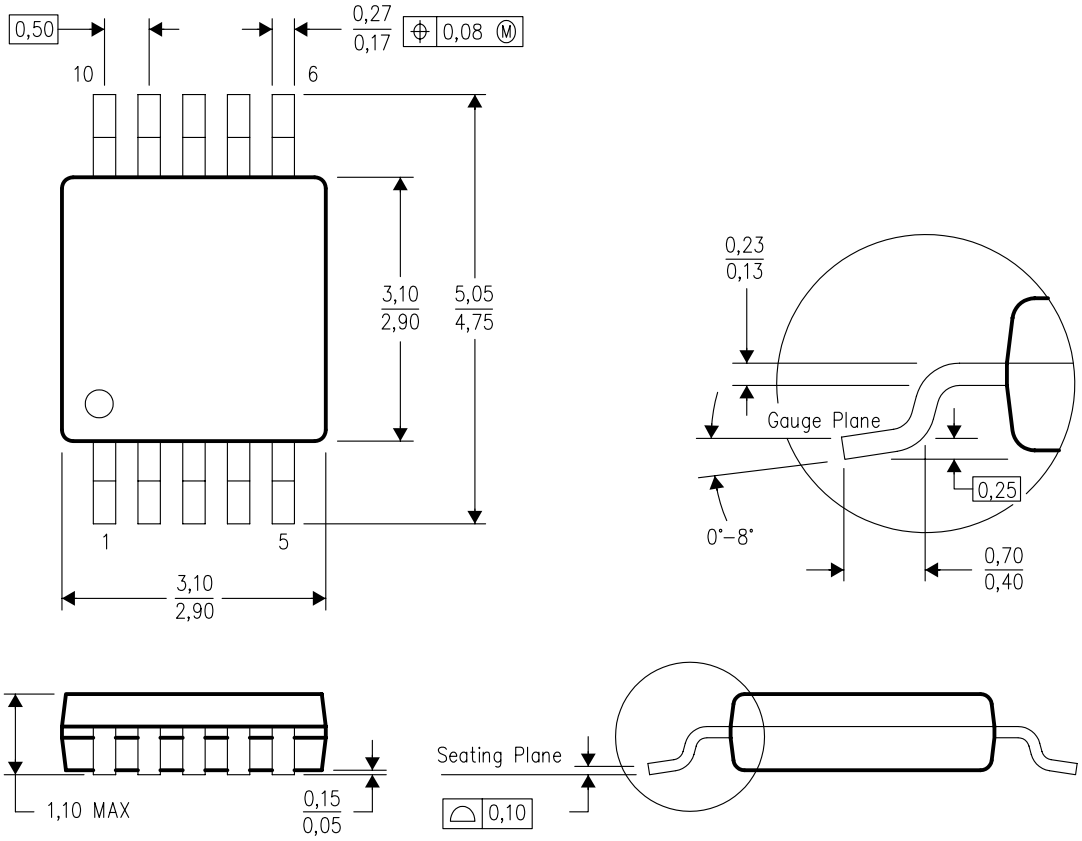
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

DBV (R–PDSO–G6) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

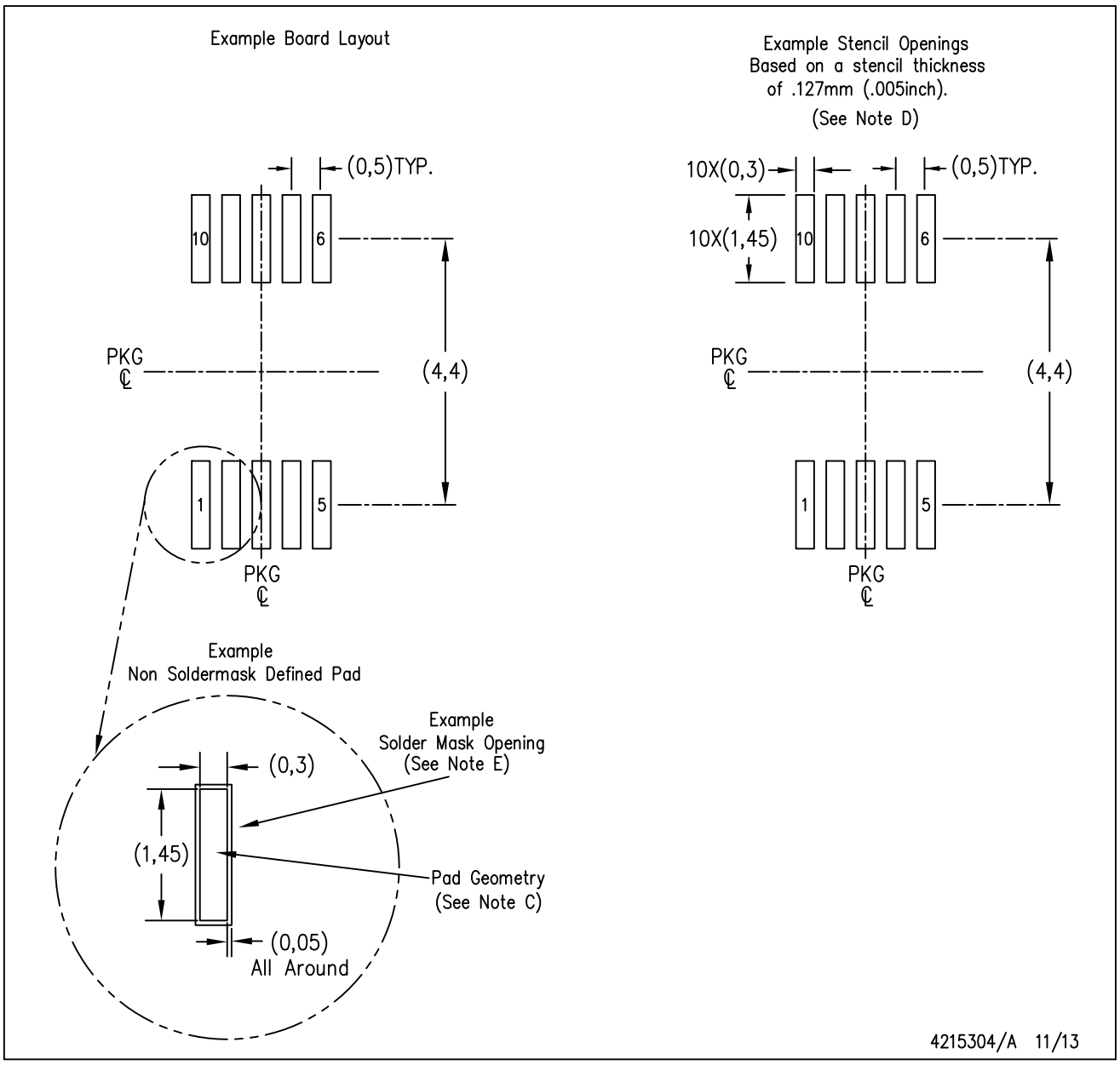
DGS (S–PDSO–G10) PLASTIC SMALL–OUTLINE PACKAGE



4073272/C 02/04

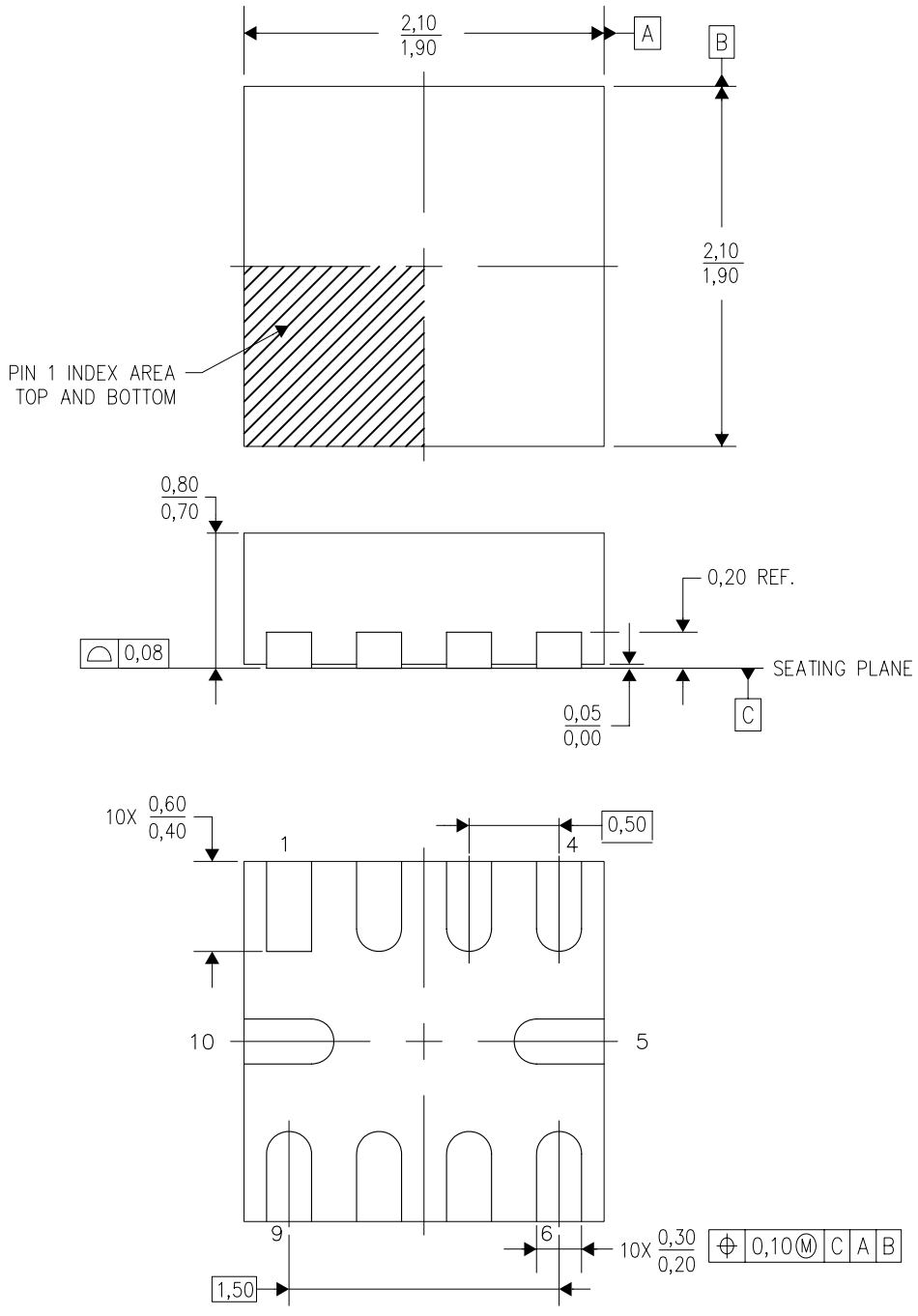
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–187 variation BA.

DGS (S–PDSO–G10) PLASTIC SMALL OUTLINE PACKAGE



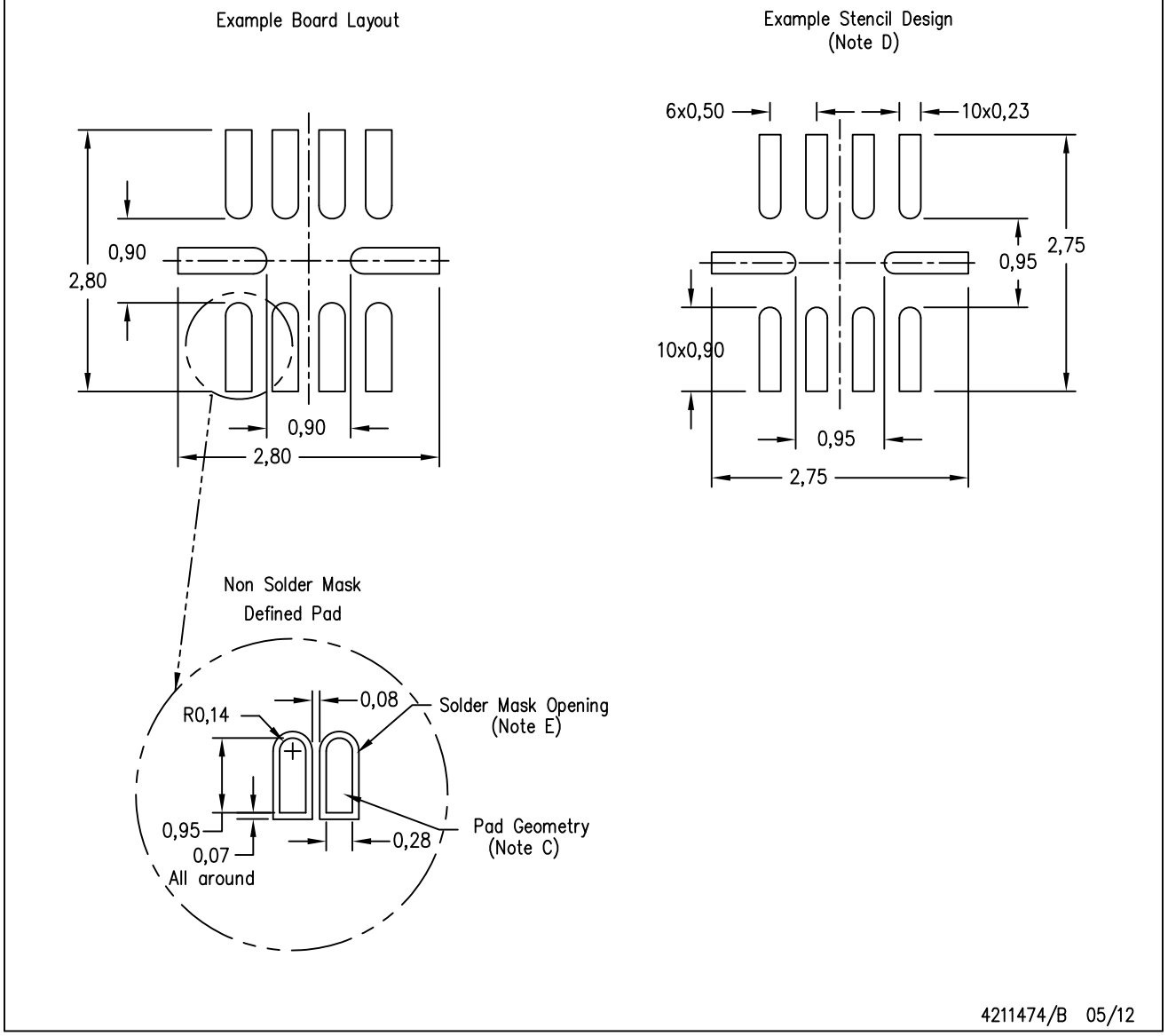
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

RUN (S–PWQFN–N10) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Quad Flatpack, No–Leads (QFN) package configuration.

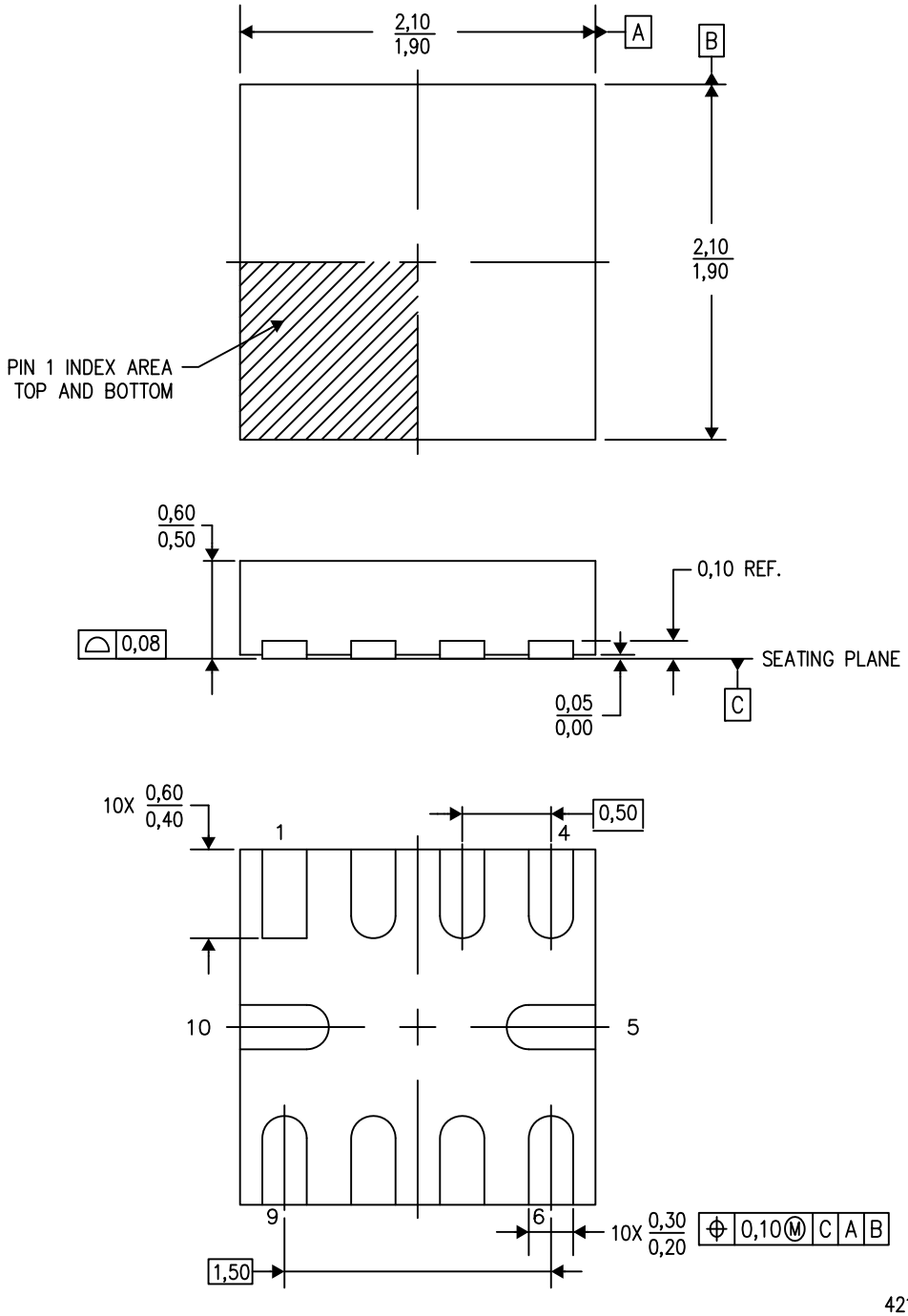
RUN (S–PWQFN–N10) PLASTIC QUAD FLATPACK NO–LEAD



4211474/B 05/12

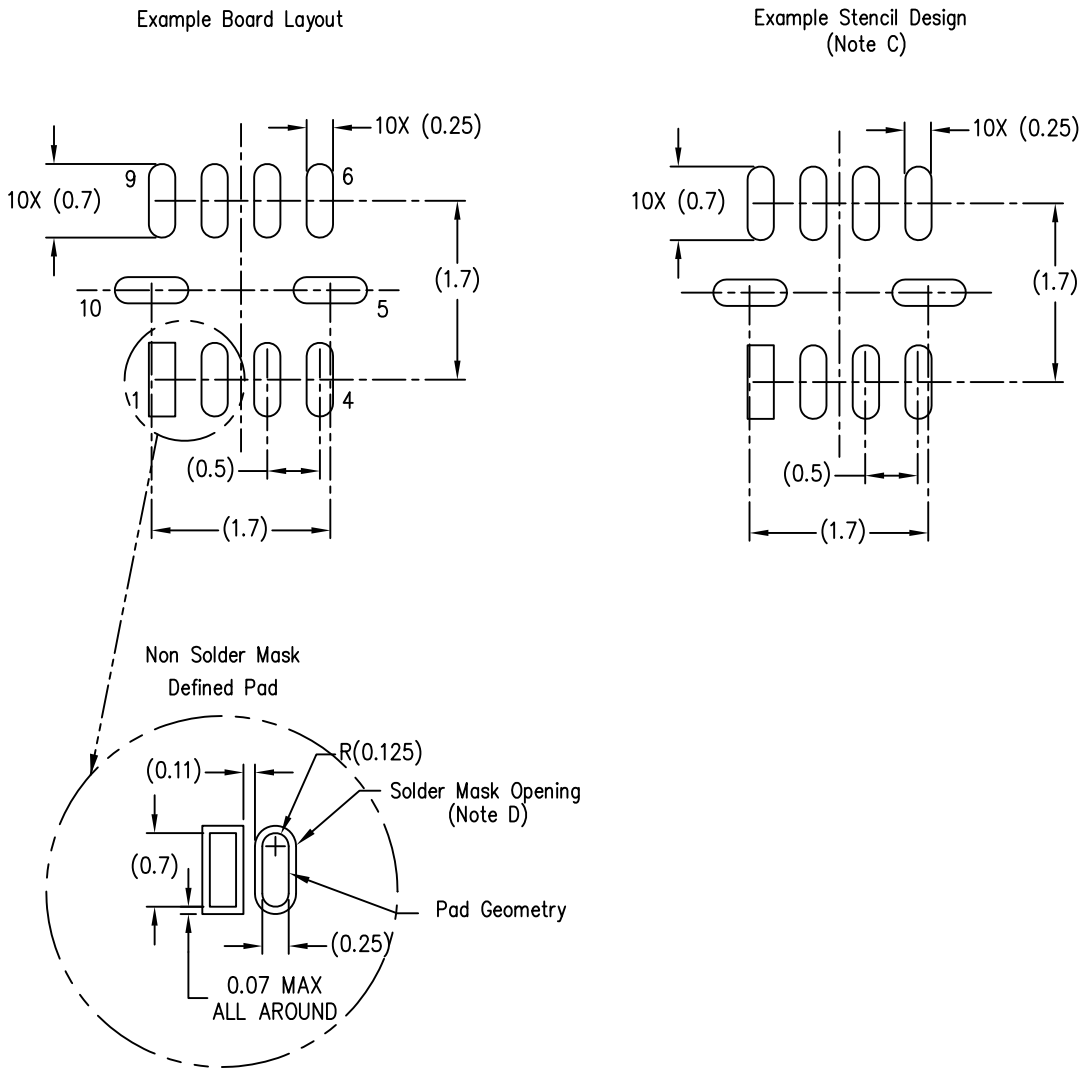
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

RMC (S–PUQFN–N10) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Quad Flatpack, No–Leads (QFN) package configuration.

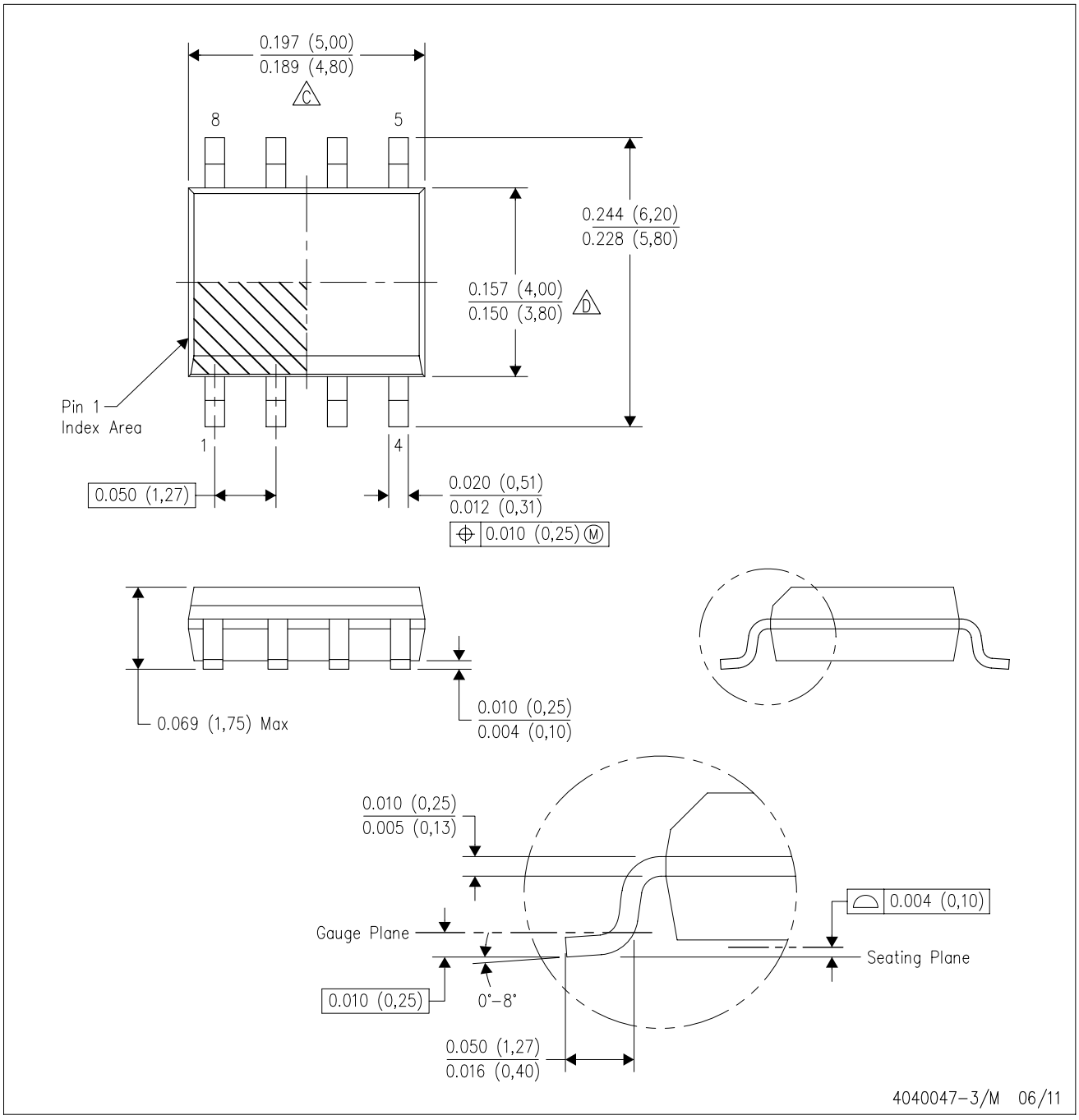
RMC (S–PUQFN–N10) PLASTIC QUAD FLATPACK NO–LEAD



4221693/A 10/2014

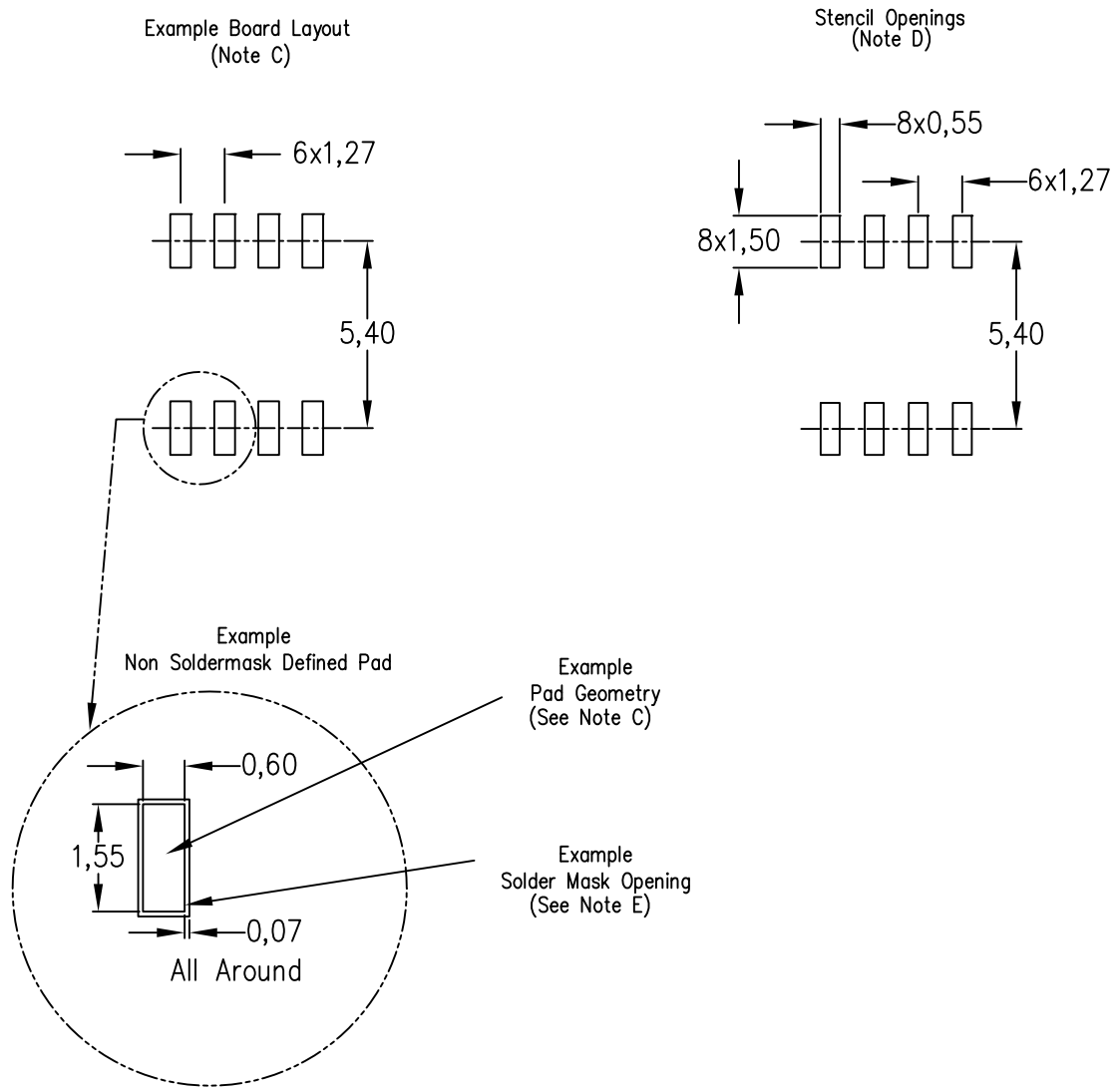
NOTES:
A. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only.
B. This drawing is subject to change without notice.
C. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
D. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



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

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



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

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TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
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Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
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