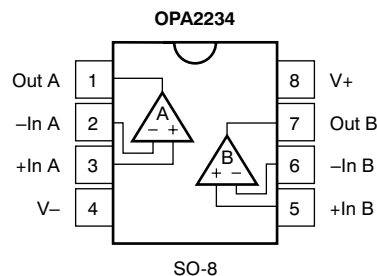


## LOW-POWER, PRECISION SINGLE-SUPPLY OPERATIONAL AMPLIFIERS

Check for Samples: [OPA2234M](#)

### FEATURES

- **Wide Supply Range:**
  - **Single Supply:**  $V_S = 2.7\text{ V to }36\text{ V}$
  - **Dual Supply:**  $V_S = \pm 1.35\text{ V to } \pm 18\text{ V}$
- **Specified Performance:**
  - **2.7 V, 5 V, and  $\pm 15\text{ V}$**
- **Low Quiescent Current: 250  $\mu\text{A/amp}$**
- **Low Input Bias Current: 35 nA Max**
- **Low Offset Voltage: 100  $\mu\text{V Typ}$**
- **High CMRR, PSRR, and  $A_{OL}$**
- **Dual Versions**



### DESCRIPTION

The OPA2234 series low-cost op amps are ideal for single-supply, low-voltage, low-power applications. The series provides lower quiescent current than older “1013”-type products and comes in current industry-standard packages and pinouts. The combination of low offset voltage, high common-mode rejection, high power-supply rejection, and a wide supply range provides excellent accuracy and versatility. Dual versions have identical specifications for maximum design flexibility. These general-purpose op amps are ideal for portable and battery-powered applications.

The OPA2234 series op amps operate from either single or dual supplies. In single-supply operation, the input common-mode range extends below ground and the output can swing to within 50mV of ground. Excellent phase margin makes the OPA2234 series ideal for demanding applications, including high load capacitance. Dual design features completely independent circuitry for lowest crosstalk and freedom from interaction.

Single and dual packages are in an SO-8 surface-mount and are specified for  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  operation.

### ORDERING INFORMATION<sup>(1)</sup>

PRODUCT	PACKAGE	PACKAGE MARKING
OPA2234MDR	SO-8 Surface-Mount	2234M

(1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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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.

## ABSOLUTE MAXIMUM RATINGS

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

		VALUE	UNIT
Supply Voltage, V+ to V–			
Input Voltage		(V–) – 0.7 to (V+) + 0.7	V
Output Short-Circuit <sup>(1)</sup>		Continuous	
Operating Temperature		–55 to 125	°C
Storage Temperature		–55 to 125	°C
Junction Temperature	T <sub>JA</sub>	150	°C/W
	T <sub>JC</sub>	39	
Lead Temperature (soldering, 10 s)		300	°C

(1) Short-circuit to ground, one amplifier per package.

**ELECTRICAL CHARACTERISTICS:  $V_S = 5\text{ V}$** 

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>OFFSET VOLTAGE</b>						
Input Offset Voltage	$V_{OS}$	$T_A = 25^\circ\text{C}$ , $V_{CM} = 2.5\text{ V}$		$\pm 40$	$\pm 100$	$\mu\text{V}$
		$V_{CM} = 2.5\text{ V}$			$\pm 600$	
vs Temperature <sup>(1)</sup>	$dV_{OS}/dT$	Operating Temperature Range		$\pm 3$		$\mu\text{V}/^\circ\text{C}$
vs Power Supply	PSRR	$V_S = 2.7\text{ V}$ to $30\text{ V}$ , $V_{CM} = 1.7\text{ V}$		3	20	$\mu\text{V}/\text{V}$
vs Time				0.2		$\mu\text{V}/\text{mo}$
Channel Separation (Dual)				0.3		$\mu\text{V}/\text{V}$
<b>INPUT BIAS CURRENT</b>						
Input Bias Current <sup>(2)</sup>	$I_B$	$V_{CM} = 2.5\text{ V}$		-15	-35	nA
Input Offset Current	$I_{OS}$	$V_{CM} = 2.5\text{ V}$		$\pm 1$	$\pm 12$	nA
<b>NOISE</b>						
		$f = 1\text{ kHz}$				
Input Voltage Noise Density	$V_n$			25		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$I_n$			80		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT VOLTAGE RANGE</b>						
Common-Mode Voltage Range		0.5			$(V+) - 1$	V
Common-Mode Rejection	CMRR	$V_{CM} = 0.5\text{ V}$ to $4\text{ V}$		86	106	dB
<b>INPUT IMPEDANCE</b>						
Differential				$10^7 \parallel 5$		$\Omega \parallel \text{pF}$
Common-Mode		$V_{CM} = 2.5\text{ V}$		$10^{10} \parallel 6$		$\Omega \parallel \text{pF}$
<b>OPEN-LOOP GAIN</b>						
Open-Loop Voltage Gain	$A_{OL}$	$R_L = 10\text{ k}\Omega$ , $V_O = 0.25\text{ V}$ to $4\text{ V}$		78	120	dB
		$R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V}$ to $4\text{ V}$		75	96	dB
<b>FREQUENCY RESPONSE</b>						
Gain-Bandwidth Product	GBW	$C_L = 100\text{ pF}$		0.35		MHz
Slew Rate	SR			0.2		$\text{V}/\mu\text{s}$
Settling Time:						
0.1%		$G = 1$ , $3\text{ V Step}$ , $C_L = 100\text{ pF}$		15		$\mu\text{s}$
0.01%		$G = 1$ , $3\text{ V Step}$ , $C_L = 100\text{ pF}$		25		$\mu\text{s}$
Overload Recovery Time		$(V_{IN})$ (Gain) = $V_S$		16		$\mu\text{s}$
<b>OUTPUT</b>						
Voltage Output:						
Positive		$R_L = 10\text{ k}\Omega$ to $V_S/2$		$(V+) - 1$	$(V+) - 0.65$	V
Negative		$R_L = 10\text{ k}\Omega$ to $V_S/2$		0.25	0.05	V
Positive		$R_L = 10\text{ k}\Omega$ to Ground		$(V+) - 1$	$(V+) - 0.65$	V
Negative		$R_L = 10\text{ k}\Omega$ to Ground		0.1	0.05	V
Short-Circuit Current	$I_{SC}$			$\pm 11$		mA
Capacitive Load Drive (Stable Operation) <sup>(3)</sup>		$G = 1$		1000		pF
<b>POWER SUPPLY</b>						
Specified Operating Voltage				5		V
Operating Voltage Range				2.7	36	V
Quiescent Current (per amplifier)	$I_Q$	$I_O = 0$		250	550	$\mu\text{A}$

(1) Wafer-level tested to 95% confidence level.

(2) Positive conventional current flows into the input terminals.

(3) See *Small-Signal Overshoot vs Load Capacitance* typical curve.

**ELECTRICAL CHARACTERISTICS:  $V_S = 5\text{ V}$  (continued)**

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>TEMPERATURE RANGE</b>					
Specified Range		-55		125	$^\circ\text{C}$
Operating Range		-55		125	$^\circ\text{C}$
Storage		-55		125	$^\circ\text{C}$
Thermal Resistance $\theta_{JA}$			150		$^\circ\text{C}/\text{W}$

**ELECTRICAL CHARACTERISTICS:  $V_S = 2.7\text{ V}$** 

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 2.7\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
Input Offset Voltage	$V_{OS}$	$T_A = 25^\circ\text{C}$ , $V_{CM} = 1.35\text{ V}$		$\pm 40$	$\pm 100$	$\mu\text{V}$
		$V_{CM} = 1.35\text{ V}$			$\pm 600$	
vs Temperature <sup>(1)</sup>	$dV_{OS}/dT$	Operating Temperature Range		$\pm 3$		$\mu\text{V}/^\circ\text{C}$
vs Power Supply	PSRR	$V_S = 2.7\text{ V}$ to $30\text{ V}$ , $V_{CM} = 1.7\text{ V}$		3	20	$\mu\text{V}/\text{V}$
vs Time				0.2		$\mu\text{V}/\text{mo}$
Channel Separation (Dual)				0.3		$\mu\text{V}/\text{V}$
<b>INPUT BIAS CURRENT</b>						
Input Bias Current <sup>(2)</sup>	$I_B$	$V_{CM} = 1.35\text{ V}$		-15	-35	nA
Input Offset Current	$I_{OS}$	$V_{CM} = 1.35\text{ V}$		$\pm 1$	$\pm 12$	nA
<b>NOISE</b>						
		$f = 1\text{ kHz}$				
Input Voltage Noise Density	$V_n$			25		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$I_n$			80		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT VOLTAGE RANGE</b>						
Common-Mode Voltage Range			0.5		$(V+) - 1.1$	V
Common-Mode Rejection	CMRR	$V_{CM} = 0.5\text{ V}$ to $1.6\text{ V}$	86	106		dB
<b>INPUT IMPEDANCE</b>						
Differential				$10^7 \parallel 5$		$\Omega \parallel \text{pF}$
Common-Mode		$V_{CM} = 1.35\text{ V}$		$10^{10} \parallel 6$		$\Omega \parallel \text{pF}$
<b>OPEN-LOOP GAIN</b>						
Open-Loop Voltage Gain	$A_{OL}$	$R_L = 10\text{ k}\Omega$ , $V_O = 0.25\text{ V}$ to $1.7\text{ V}$	78	125		dB
		$R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V}$ to $1.7\text{ V}$	69	96		dB
<b>FREQUENCY RESPONSE</b>						
Gain-Bandwidth Product	GBW	$C_L = 100\text{ pF}$		0.35		MHz
Slew Rate	SR			0.2		$\text{V}/\mu\text{s}$
Settling Time:						
0.1%		$G = 1$ , $1\text{ V}$ Step, $C_L = 100\text{ pF}$		6		$\mu\text{s}$
0.01%		$G = 1$ , $1\text{ V}$ Step, $C_L = 100\text{ pF}$		16		$\mu\text{s}$
Overload Recovery Time		$(V_{IN})$ (Gain) = $V_S$		8		$\mu\text{s}$
<b>OUTPUT</b>						
Voltage Output:						
Positive		$R_L = 10\text{ k}\Omega$ to $V_S/2$	$(V+) - 1$	$(V+) - 0.6$		V
Negative		$R_L = 10\text{ k}\Omega$ to $V_S/2$	0.25	0.05		V
Positive		$R_L = 10\text{ k}\Omega$ to Ground	$(V+) - 1$	$(V+) - 0.65$		V
Negative		$R_L = 10\text{ k}\Omega$ to Ground	0.1	0.05		V
Short-Circuit Current	$I_{SC}$			$\pm 8$		mA
Capacitive Load Drive (Stable Operation) <sup>(3)</sup>		$G = 1$		1000		pF
<b>POWER SUPPLY</b>						
Specified Operating Voltage				2.7		V
Operating Voltage Range			2.7		36	V
Quiescent Current (per amplifier)	$I_Q$	$I_O = 0$		250	550	$\mu\text{A}$

(1) Wafer-level tested to 95% confidence level.

(2) Positive conventional current flows into the input terminals.

(3) See *Small-Signal Overshoot vs Load Capacitance* typical curve.

**ELECTRICAL CHARACTERISTICS:  $V_S = 2.7\text{ V}$  (continued)**

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = 2.7\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>TEMPERATURE RANGE</b>					
Specified Range		-55		125	$^\circ\text{C}$
Operating Range		-55		125	$^\circ\text{C}$
Storage		-55		125	$^\circ\text{C}$
Thermal Resistance $\theta_{JA}$			150		$^\circ\text{C}/\text{W}$

**ELECTRICAL CHARACTERISTICS:  $V_S = \pm 15\text{ V}$** 

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = \pm 15\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
Input Offset Voltage	$V_{OS}$	$T_A = 25^\circ\text{C}$ , $V_{CM} = 0\text{ V}$		$\pm 70$	$\pm 250$	$\mu\text{V}$
		$V_{CM} = 0\text{ V}$			$\pm 750$	
vs Temperature <sup>(1)</sup>	$dV_{OS}/dT$	Operating Temperature Range		$\pm 3$		$\mu\text{V}/^\circ\text{C}$
vs Power Supply	PSRR	$V_S = \pm 1.35\text{ V}$ to $\pm 18\text{ V}$ , $V_{CM} = 0\text{ V}$		3	20	$\mu\text{V}/\text{V}$
vs Time				0.2		$\mu\text{V}/\text{mo}$
Channel Separation (Dual)				0.3		$\mu\text{V}/\text{V}$
<b>INPUT BIAS CURRENT</b>						
Input Bias Current <sup>(2)</sup>	$I_B$	$V_{CM} = 0\text{ V}$		-12	-30	nA
Input Offset Current	$I_{OS}$	$V_{CM} = 0\text{ V}$		$\pm 1$	$\pm 12$	nA
<b>NOISE</b>						
		$f = 1\text{ kHz}$				
Input Voltage Noise Density	$V_n$			25		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$I_n$			80		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT VOLTAGE RANGE</b>						
Common-Mode Voltage Range			$(V_-) + 1$		$(V_+) - 1$	V
Common-Mode Rejection	CMRR	$V_{CM} = -14\text{ V}$ to $14\text{ V}$	86	106		dB
<b>INPUT IMPEDANCE</b>						
Differential				$10^7 \parallel 5$		$\Omega \parallel \text{pF}$
Common-Mode		$V_{CM} = 0\text{ V}$		$10^{10} \parallel 6$		$\Omega \parallel \text{pF}$
<b>OPEN-LOOP GAIN</b>						
Open-Loop Voltage Gain	$A_{OL}$	$V_O = -13.5\text{ V}$ to $13\text{ V}$	87	120		dB
<b>FREQUENCY RESPONSE</b>						
Gain-Bandwidth Product	GBW	$C_L = 100\text{ pF}$		0.35		MHz
Slew Rate	SR			0.2		$\text{V}/\mu\text{s}$
Settling Time:						
0.1%		$G = 1$ , 10 V Step, $C_L = 100\text{ pF}$		41		$\mu\text{s}$
0.01%		$G = 1$ , 10 V Step, $C_L = 100\text{ pF}$		47		$\mu\text{s}$
Overload Recovery Time		$(V_{IN})$ (Gain) = $V_S$		22		$\mu\text{s}$
<b>OUTPUT</b>						
Voltage Output:						
Positive			$(V_+) - 2$	$(V_+) - 0.7$		V
Negative			$(V_-) + 1.5$	$(V_-) + 0.15$		V
Short-Circuit Current	$I_{SC}$			$\pm 22$		mA
Capacitive Load Drive (Stable Operation) <sup>(3)</sup>		$G = 1$		1000		pF
<b>POWER SUPPLY</b>						
Specified Operating Voltage				$\pm 15$		V
Operating Voltage Range			$\pm 1.35$		$\pm 18$	V
Quiescent Current (per amplifier)	$I_Q$	$I_O = 0$		$\pm 275$	$\pm 550$	$\mu\text{A}$

(1) Wafer-level tested to 95% confidence level.

(2) Positive conventional current flows into the input terminals.

(3) See *Small-Signal Overshoot vs Load Capacitance* typical curve.

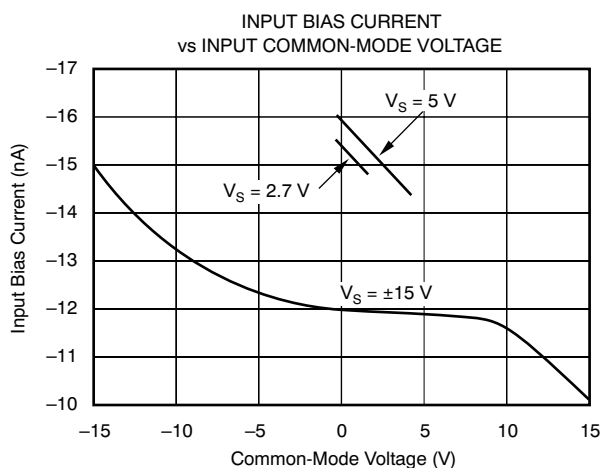
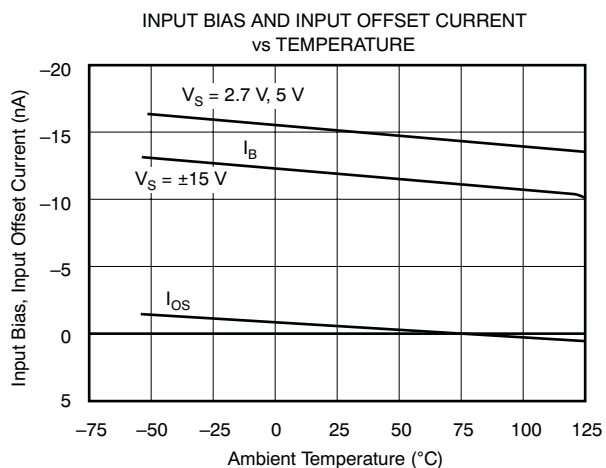
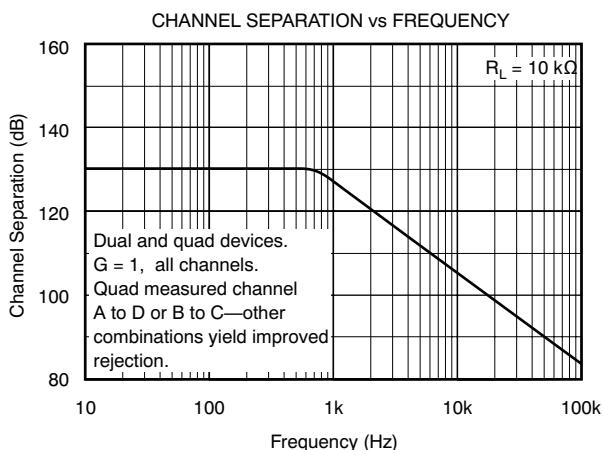
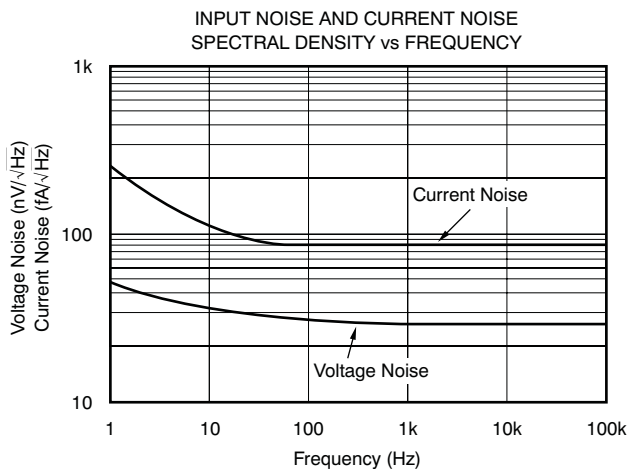
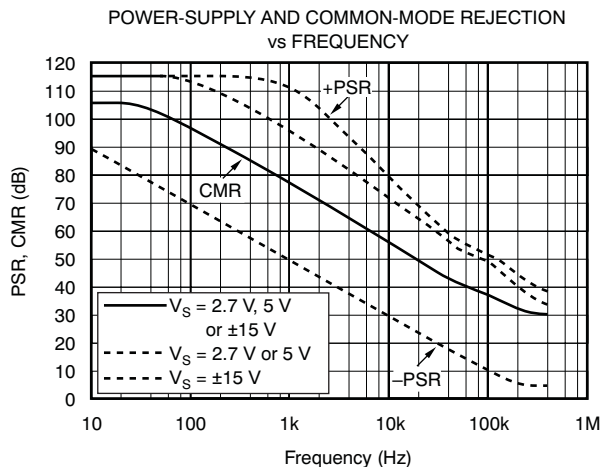
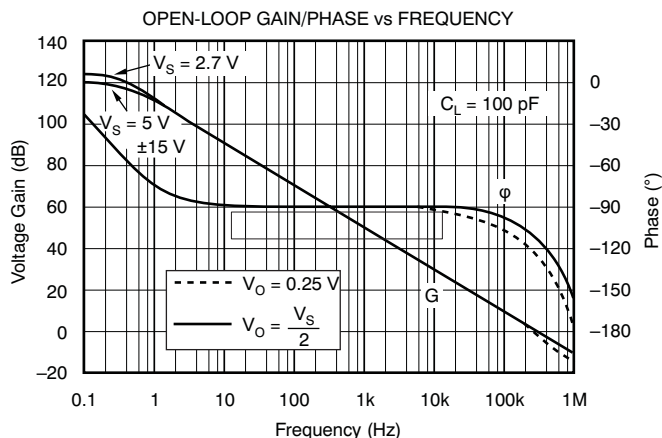
**ELECTRICAL CHARACTERISTICS:  $V_S = \pm 15\text{ V}$  (continued)**

At  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ,  $V_S = \pm 15\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.

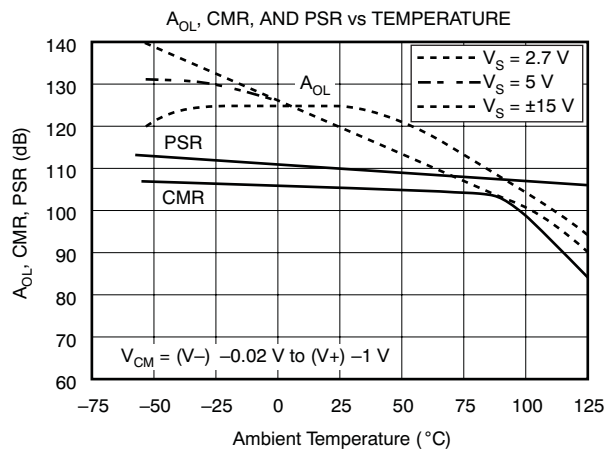
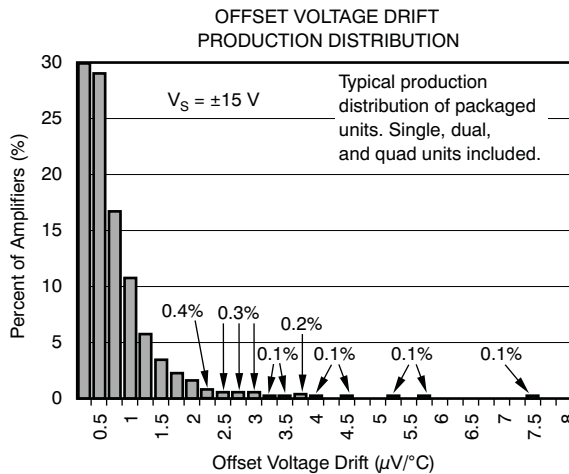
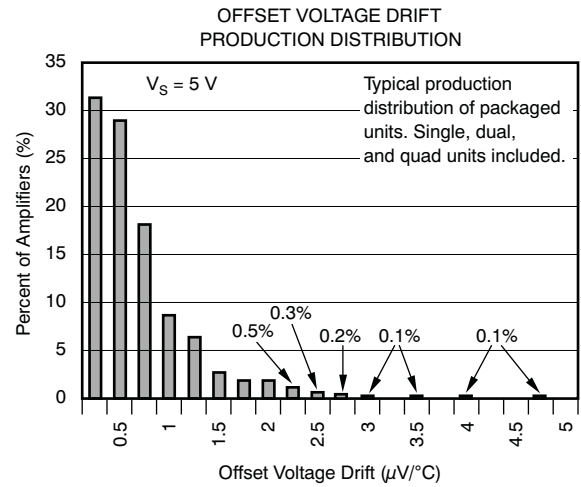
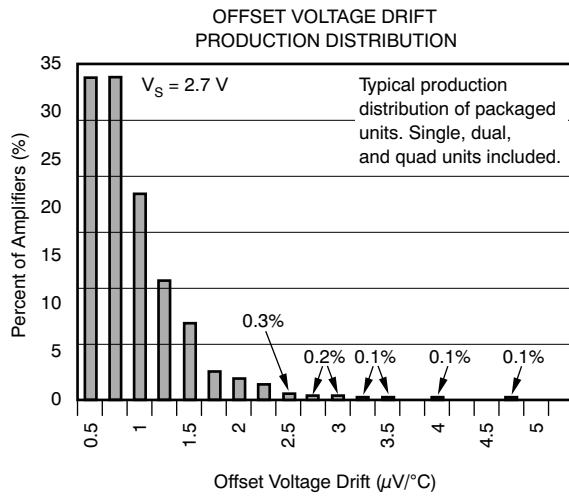
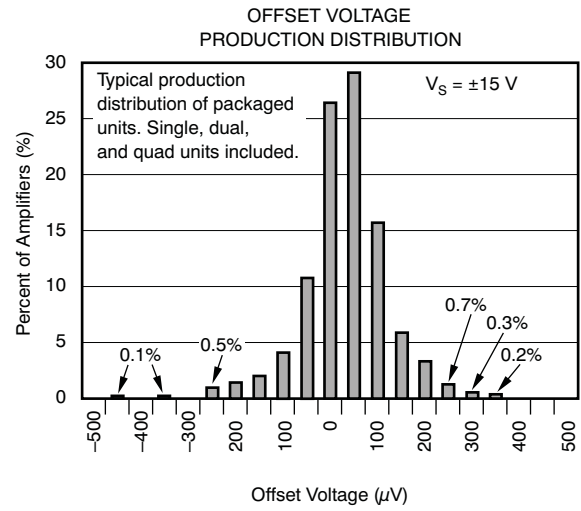
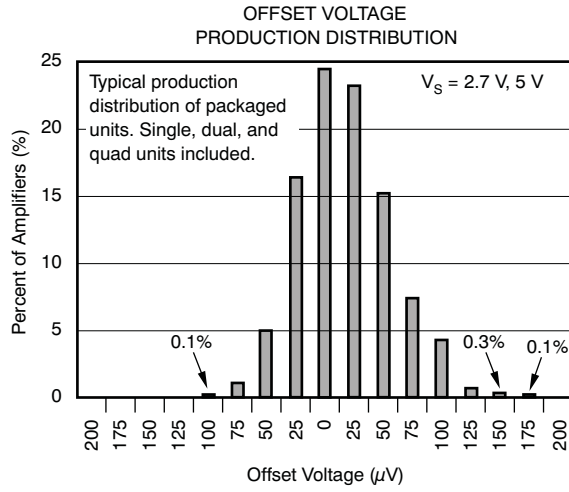
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>TEMPERATURE RANGE</b>					
Specified Range		-55		125	$^\circ\text{C}$
Operating Range		-55		125	$^\circ\text{C}$
Storage		-55		125	$^\circ\text{C}$
Thermal Resistance	$\theta_{JA}$		150		$^\circ\text{C/W}$



TYPICAL CHARACTERISTICS

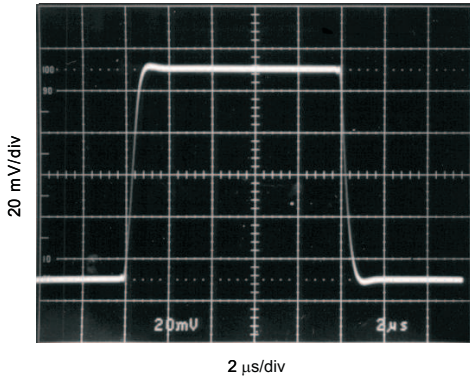


**TYPICAL CHARACTERISTICS (continued)**

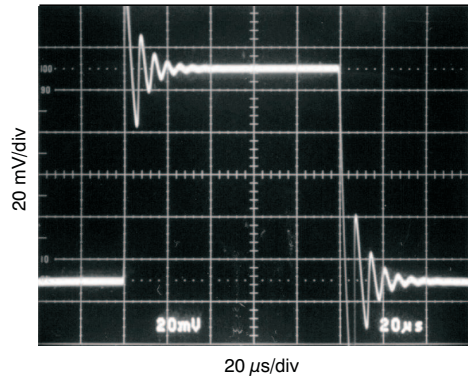


TYPICAL CHARACTERISTICS (continued)

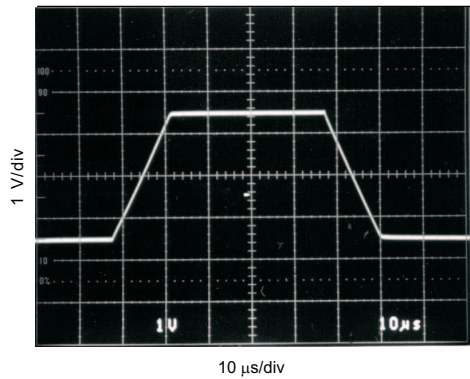
SMALL-SIGNAL STEP RESPONSE  
 $G = 1, C_L = 100 \text{ pF}, V_S = 5 \text{ V}$



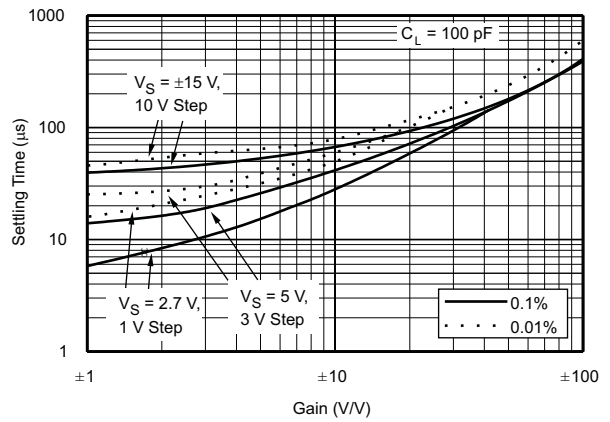
SMALL-SIGNAL STEP RESPONSE  
 $G = 1, C_L = 10,000 \text{ pF}, V_S = 5 \text{ V}$



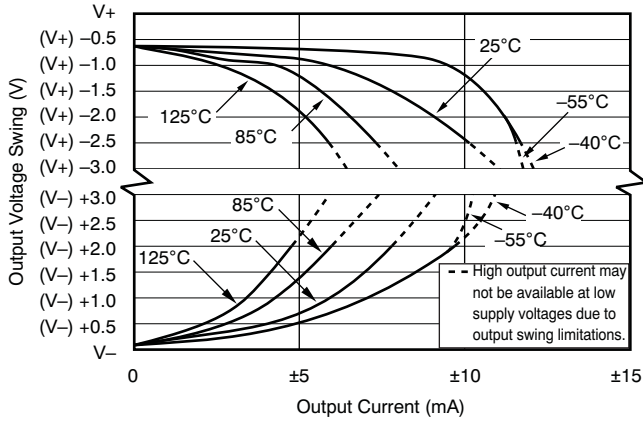
LARGE-SIGNAL STEP RESPONSE  
 $G = 1, C_L = 100 \text{ pF}, V_S = 5 \text{ V}$



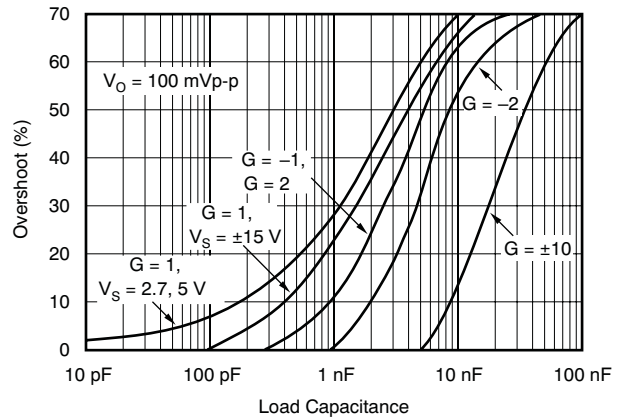
SETTLING TIME vs CLOSED-LOOP GAIN



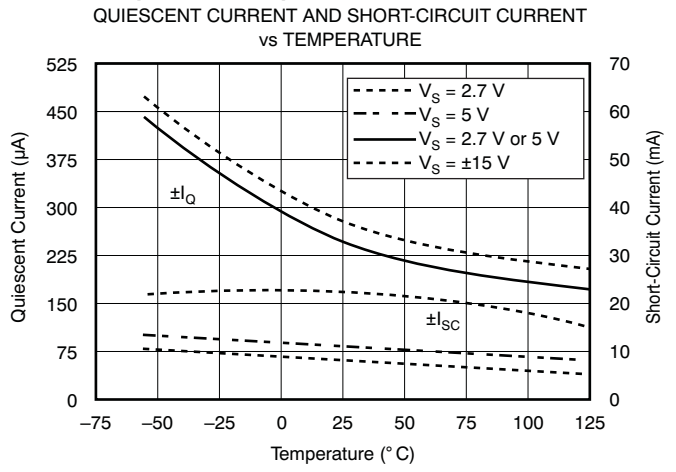
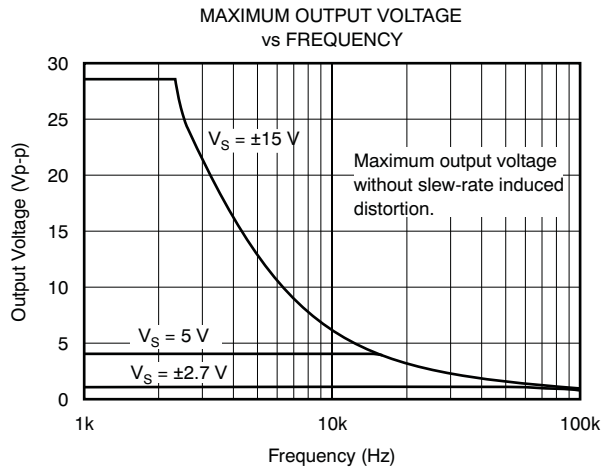
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE



**TYPICAL CHARACTERISTICS (continued)**



## APPLICATION INFORMATION

The OPA2234 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. Power-supply pins should be bypassed with 10 nF ceramic capacitors.

### OPERATING VOLTAGE

The OPA2234 series op amps operate from single (2.7 V to 36 V) or dual ( $\pm 1.35$  V to  $\pm 18$  V) supplies with excellent performance. Specifications are production tested with 2.7 V, 5 V, and  $\pm 15$  V supplies. Most behavior remains unchanged throughout the full operating voltage range. Parameters which vary significantly with operating voltage are shown in the Typical Characteristic curves.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
OPA2234MDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	

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

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

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

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

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

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

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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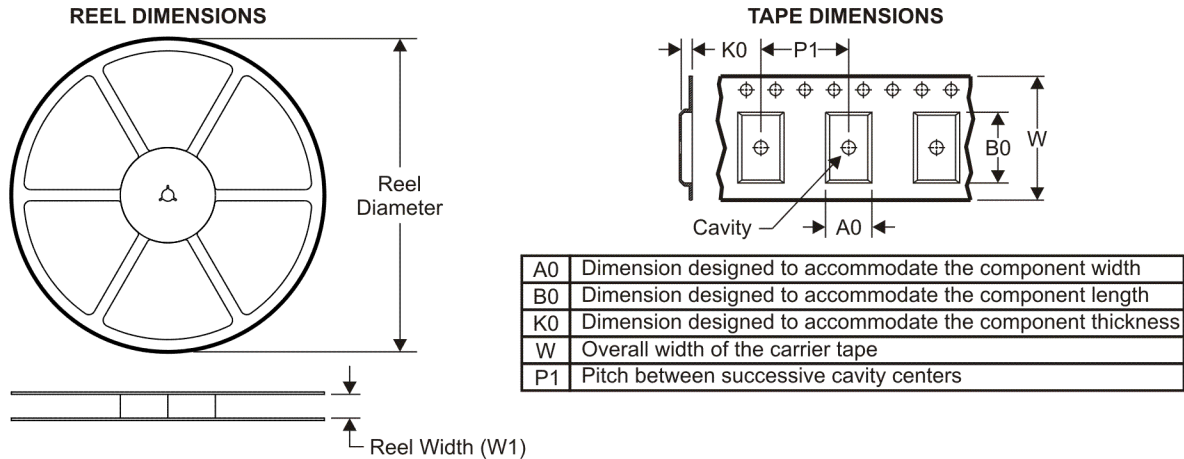
**OTHER QUALIFIED VERSIONS OF OPA2234M :**

- Catalog: [OPA2234](#)

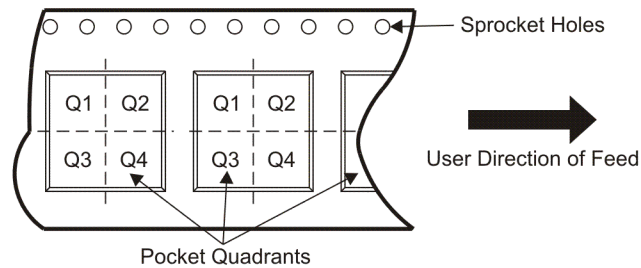
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

## TAPE AND REEL INFORMATION



### 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
OPA2234MDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



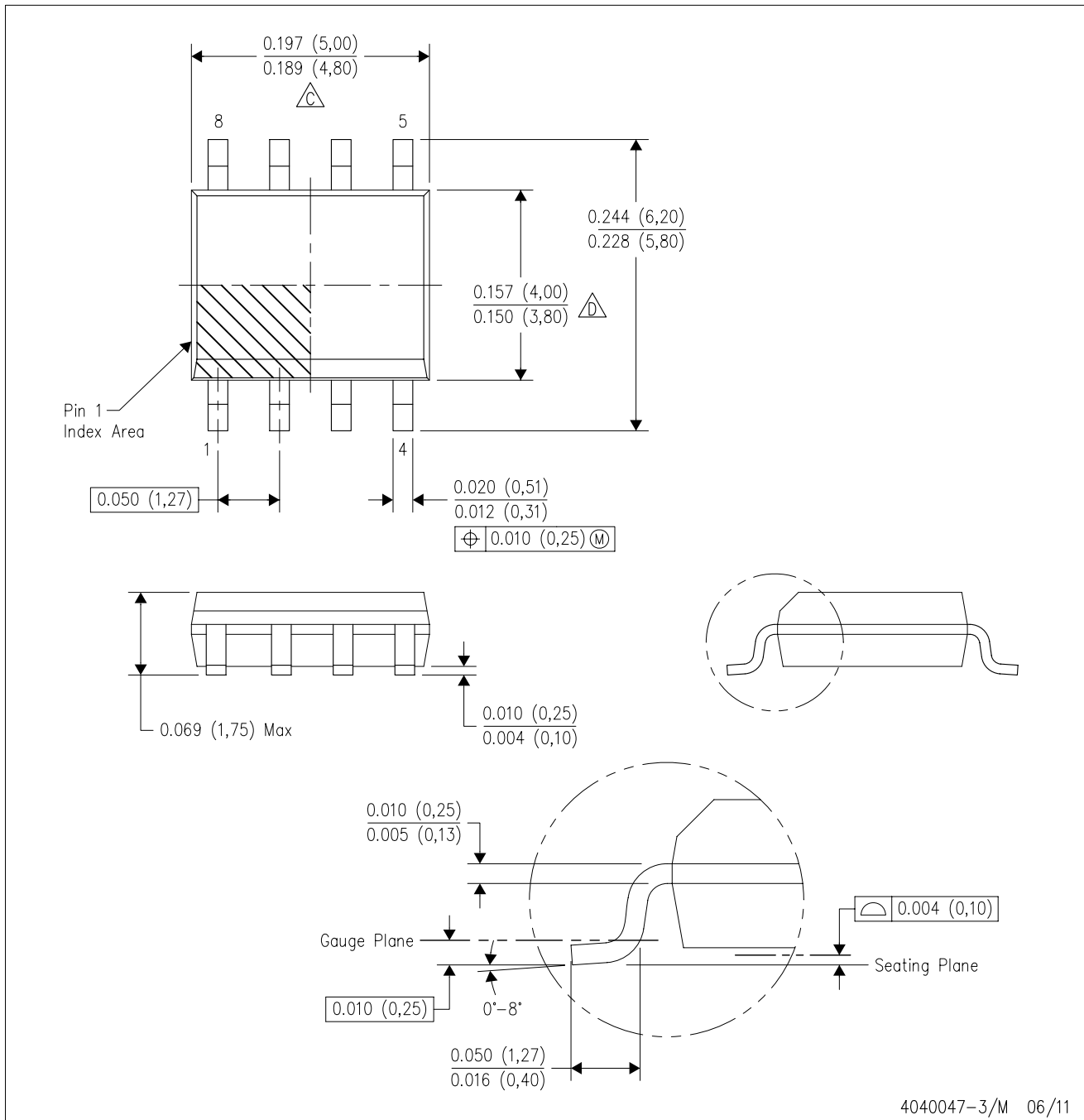
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA2234MDR	SOIC	D	8	2500	346.0	346.0	29.0



D (R-PDSO-G8)

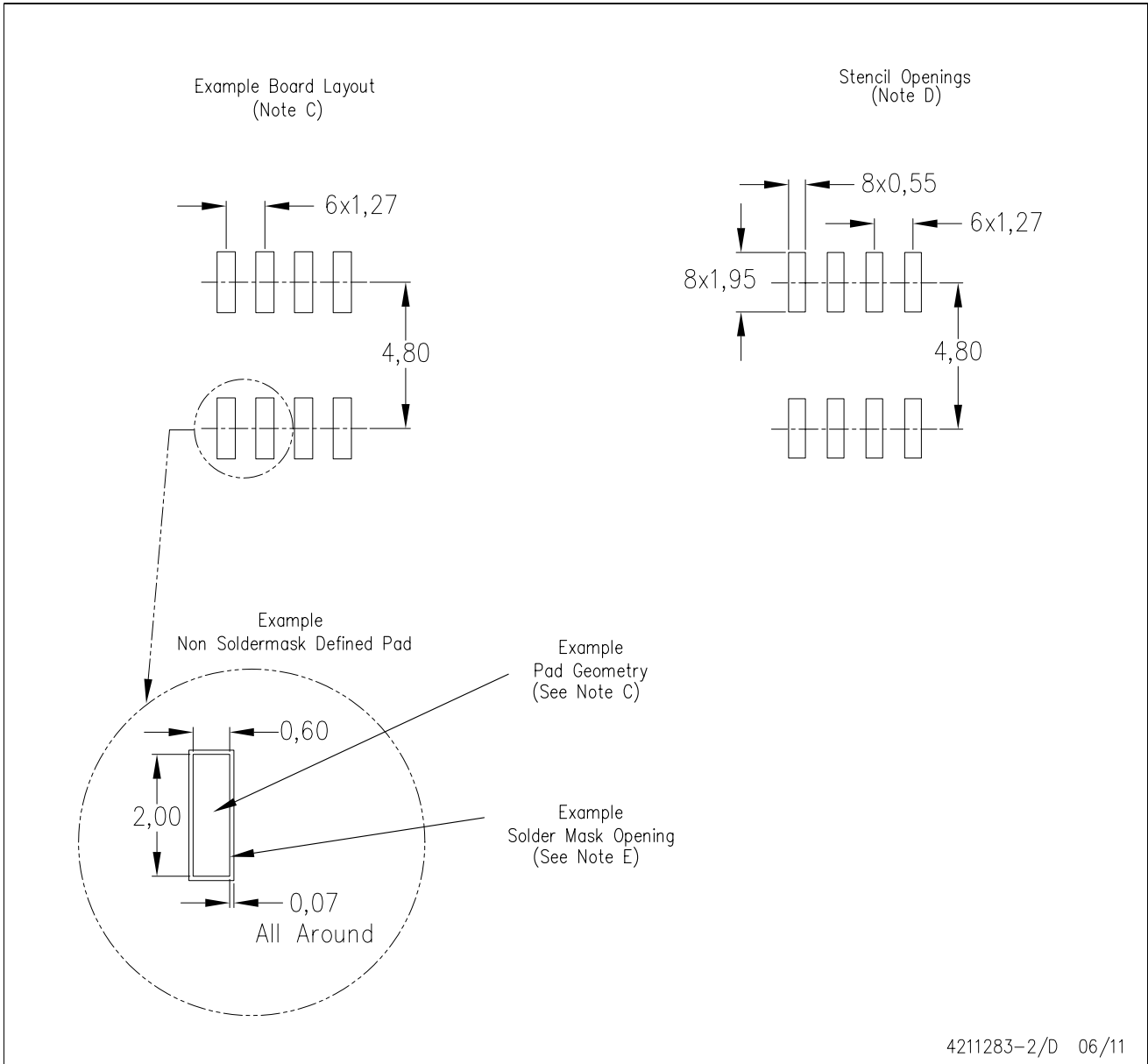
PLASTIC SMALL OUTLINE



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

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