

## AD8605/AD8606/AD8608

### FEATURES

- Low offset voltage: 65  $\mu$ V maximum**
- Low input bias currents: 1 pA maximum**
- Low noise: 8 nV/ $\sqrt{\text{Hz}}$**
- Wide bandwidth: 10 MHz**
- High open-loop gain: 1000 V/mV**
- Unity gain stable**
- Single-supply operation: 2.7 V to 5.5 V**
- 5-ball WLCSP for single (AD8605) and 8-ball WLCSP for dual (AD8606)**

### APPLICATIONS

- Photodiode amplification**
- Battery-powered instrumentation**
- Multipole filters**
- Sensors**
- Barcode scanners**
- Audio**

### GENERAL DESCRIPTION

The AD8605, AD8606, and AD8608<sup>1</sup> are single, dual, and quad rail-to-rail input and output, single-supply amplifiers. They feature very low offset voltage, low input voltage and current noise, and wide signal bandwidth. They use the Analog Devices, Inc. patented DigiTrim<sup>®</sup> trimming technique, which achieves superior precision without laser trimming.

The combination of low offsets, low noise, very low input bias currents, and high speed makes these amplifiers useful in a wide variety of applications. Filters, integrators, photodiode amplifiers, and high impedance sensors all benefit from the combination of performance features. Audio and other ac applications benefit from the wide bandwidth and low distortion. Applications for these amplifiers include optical control loops, portable and loop-powered instrumentation, and audio amplification for portable devices.

The AD8605, AD8606, and AD8608 are specified over the extended industrial temperature range ( $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ). The AD8605 single is available in 5-lead SOT-23 and 5-ball WLCSP packages. The AD8606 dual is available in an 8-lead MSOP, an 8-ball WLCSP, and a narrow SOIC surface-mounted package. The AD8608 quad is available in a 14-lead TSSOP package and a narrow 14-lead SOIC package. The 5-ball and 8-ball WLCSP offer the smallest available footprint for any surface-mounted operational amplifier. The WLCSP, SOT-23, MSOP, and TSSOP versions are available in tape-and-reel only.

<sup>1</sup> Protected by U.S. Patent No. 5,969,657; other patents pending.

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### FUNCTIONAL BLOCK DIAGRAMS

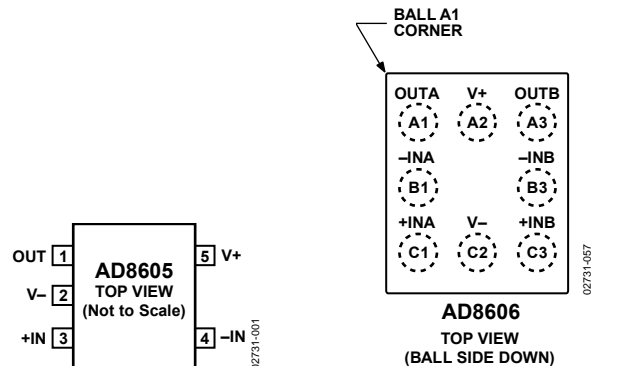


Figure 1. 5-Lead SOT-23 (RJ Suffix)

Figure 2. 8-Ball WLCSP (CB Suffix)

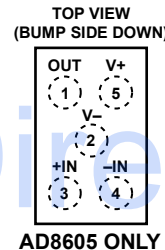


Figure 3. 5-Ball WLCSP (CB Suffix)

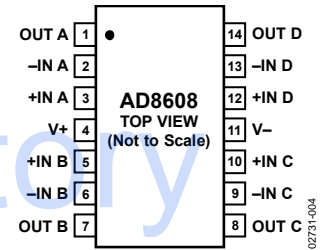


Figure 4. 14-Lead SOIC\_N (R Suffix)

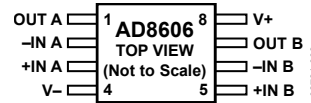


Figure 5. 8-Lead MSOP (RM Suffix), 8-Lead SOIC\_N (R Suffix)

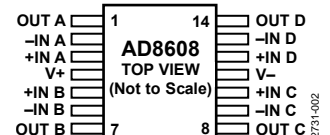


Figure 6. 14-Lead TSSOP (RU Suffix)

# AD8605/AD8606/AD8608

## 5 V ELECTRICAL SPECIFICATIONS

$V_S = 5\text{ V}$ ,  $V_{CM} = V_S/2$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 1.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage	$V_{OS}$					
AD8605/AD8606 (Except WLCSP)		$V_S = 3.5\text{ V}$ , $V_{CM} = 3\text{ V}$		20	65	$\mu\text{V}$
AD8608		$V_S = 3.5\text{ V}$ , $V_{CM} = 2.7\text{ V}$		20	75	$\mu\text{V}$
AD8605/AD8606/AD8608		$V_S = 5\text{ V}$ , $V_{CM} = 0\text{ V to } 5\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		80	300	$\mu\text{V}$
					750	$\mu\text{V}$
Input Bias Current	$I_B$			0.2	1	$\text{pA}$
AD8605/AD8606		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			50	$\text{pA}$
AD8605/AD8606		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			250	$\text{pA}$
AD8608		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			100	$\text{pA}$
AD8608		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			300	$\text{pA}$
Input Offset Current	$I_{OS}$			0.1	0.5	$\text{pA}$
		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			20	$\text{pA}$
		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			75	$\text{pA}$
Input Voltage Range			0		5	$\text{V}$
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to } 5\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	85	100		$\text{dB}$
			75	90		$\text{dB}$
Large Signal Voltage Gain	$A_{VO}$	$R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V to } 4.5\text{ V}$	300	1000		$\text{V/mV}$
Offset Voltage Drift						
AD8605/AD8606	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1	4.5	$\mu\text{V}/^\circ\text{C}$
AD8608	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1.5	6.0	$\mu\text{V}/^\circ\text{C}$
<b>INPUT CAPACITANCE</b>						
Common-Mode Input Capacitance	$C_{COM}$			8.8		$\text{pF}$
Differential Input Capacitance	$C_{DIFF}$			2.6		$\text{pF}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage High	$V_{OH}$	$I_L = 1\text{ mA}$ $I_L = 10\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	4.96 4.7 4.6	4.98 4.79		$\text{V}$ $\text{V}$ $\text{V}$
Output Voltage Low	$V_{OL}$	$I_L = 1\text{ mA}$ $I_L = 10\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		20 170	40 210	$\text{mV}$ $\text{mV}$ $\text{mV}$
					290	$\text{mV}$
Output Current	$I_{OUT}$			$\pm 80$		$\text{mA}$
Closed-Loop Output Impedance	$Z_{OUT}$	$f = 1\text{ MHz}$ , $A_V = 1$		1		$\Omega$
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR					
AD8605/AD8606		$V_S = 2.7\text{ V to } 5.5\text{ V}$	80	95		$\text{dB}$
AD8605/AD8606 WLCSP		$V_S = 2.7\text{ V to } 5.5\text{ V}$	75	92		$\text{dB}$
AD8608		$V_S = 2.7\text{ V to } 5.5\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	77 70	92 90		$\text{dB}$ $\text{dB}$
Supply Current/Amplifier	$I_{SY}$	$I_{OUT} = 0\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1	1.2	$\text{mA}$
					1.4	$\text{mA}$
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 2\text{ k}\Omega$ , $C_L = 16\text{ pF}$		5		$\text{V}/\mu\text{s}$
Settling Time	$t_s$	To 0.01%, 0 V to 2 V step, $A_V = 1$		<1		$\mu\text{s}$
Unity Gain Bandwidth Product	GBP			10		$\text{MHz}$
Phase Margin	$\Phi_M$			65		Degrees

**AD8605/AD8606/AD8608**

<b>Parameter</b>	<b>Symbol</b>	<b>Conditions</b>	<b>Min</b>	<b>Typ</b>	<b>Max</b>	<b>Unit</b>
NOISE PERFORMANCE						
Peak-to-Peak Noise	$e_n$ p-p	$f = 0.1 \text{ Hz to } 10 \text{ Hz}$		2.3	3.5	$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	$f = 1 \text{ kHz}$		8	12	$\text{nV}/\sqrt{\text{Hz}}$
	$e_n$	$f = 10 \text{ kHz}$		6.5		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$	$f = 1 \text{ kHz}$		0.01		$\text{pA}/\sqrt{\text{Hz}}$

# AD8605/AD8606/AD8608

## 2.7 V ELECTRICAL SPECIFICATIONS

$V_S = 2.7\text{ V}$ ,  $V_{CM} = V_S/2$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 2.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage	$V_{OS}$					
AD8605/AD8606 (Except WLCSP)		$V_S = 3.5\text{ V}$ , $V_{CM} = 3\text{ V}$		20	65	$\mu\text{V}$
AD8608		$V_S = 3.5\text{ V}$ , $V_{CM} = 2.7\text{ V}$		20	75	$\mu\text{V}$
AD8605/AD8606/AD8608		$V_S = 2.7\text{ V}$ , $V_{CM} = 0\text{ V to }2.7\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		80	300	$\mu\text{V}$
					750	$\mu\text{V}$
Input Bias Current	$I_B$			0.2	1	pA
AD8605/AD8606		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			50	pA
AD8605/AD8606		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			250	pA
AD8608		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			100	pA
AD8608		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			300	pA
Input Offset Current	$I_{OS}$			0.1	0.5	pA
		$-40^\circ\text{C} < T_A < +85^\circ\text{C}$			20	pA
		$-40^\circ\text{C} < T_A < +125^\circ\text{C}$			75	pA
Input Voltage Range			0		2.7	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to }2.7\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	80	95		dB
			70	85		dB
Large Signal Voltage Gain	$A_{VO}$	$R_L = 2\text{ k}\Omega$ , $V_O = 0.5\text{ V to }2.2\text{ V}$	110	350		V/mV
Offset Voltage Drift						
AD8605/AD8606	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1	4.5	$\mu\text{V}/^\circ\text{C}$
AD8608	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1.5	6.0	$\mu\text{V}/^\circ\text{C}$
<b>INPUT CAPACITANCE</b>						
Common-Mode Input Capacitance	$C_{COM}$			8.8		pF
Differential Input Capacitance	$C_{DIFF}$			2.6		pF
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage High	$V_{OH}$	$I_L = 1\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	2.6	2.66		V
			2.6			V
Output Voltage Low	$V_{OL}$	$I_L = 1\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		25	40	mV
					50	mV
Output Current	$I_{OUT}$			$\pm 30$		mA
Closed-Loop Output Impedance	$Z_{OUT}$	$f = 1\text{ MHz}$ , $A_V = 1$		1.2		$\Omega$
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR					
AD8605/AD8606		$V_S = 2.7\text{ V to }5.5\text{ V}$	80	95		dB
AD8605/AD8606 WLCSP		$V_S = 2.7\text{ V to }5.5\text{ V}$	75	92		dB
AD8608		$V_S = 2.7\text{ V to }5.5\text{ V}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$	77	92		dB
			70	90		dB
Supply Current/Amplifier	$I_{SY}$	$I_{OUT} = 0\text{ mA}$ $-40^\circ\text{C} < T_A < +125^\circ\text{C}$		1.15	1.4	mA
					1.5	mA
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 2\text{ k}\Omega$ , $C_L = 16\text{ pF}$		5		V/ $\mu\text{s}$
Settling Time	$t_s$	To 0.01%, 0 V to 1 V step, $A_V = 1$		<0.5		$\mu\text{s}$
Unity Gain Bandwidth Product	GBP			9		MHz
Phase Margin	$\Phi_M$			50		Degrees

**AD8605/AD8606/AD8608**

<b>Parameter</b>	<b>Symbol</b>	<b>Conditions</b>	<b>Min</b>	<b>Typ</b>	<b>Max</b>	<b>Unit</b>
NOISE PERFORMANCE						
Peak-to-Peak Noise	$e_n$ p-p	f = 0.1 Hz to 10 Hz		2.3	3.5	$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	f = 1 kHz		8	12	$\text{nV}/\sqrt{\text{Hz}}$
	$e_n$	f = 10 kHz		6.5		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$	f = 1 kHz		0.01		$\text{pA}/\sqrt{\text{Hz}}$

## ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Rating
Supply Voltage	6 V
Input Voltage	GND to $V_S$
Differential Input Voltage	6 V
Output Short-Circuit Duration to GND	Observe Derating Curves
Storage Temperature Range	
All Packages	−65°C to +150°C
Operating Temperature Range	
All Packages	−40°C to +125°C
Junction Temperature Range	
All Packages	−65°C to +150°C
Lead Temperature (Soldering, 60 sec)	300°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 4.

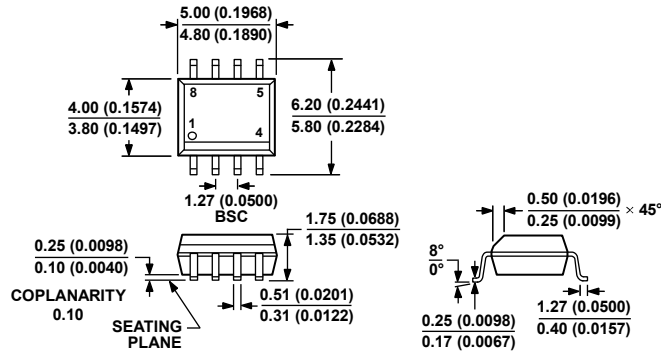
Package Type	$\theta_{JA}^1$	$\theta_{JC}$	Unit
5-Ball WLCSP (CB)	170		°C/W
5-Lead SOT-23 (RJ)	240	92	°C/W
8-Ball WLCSP (CB)	115		°C/W
8-Lead MSOP (RM)	206	44	°C/W
8-Lead SOIC_N (R)	157	56	°C/W
14-Lead SOIC_N (R)	105	36	°C/W
14-Lead TSSOP (RU)	148	23	°C/W

<sup>1</sup>  $\theta_{JA}$  is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

### ESD CAUTION



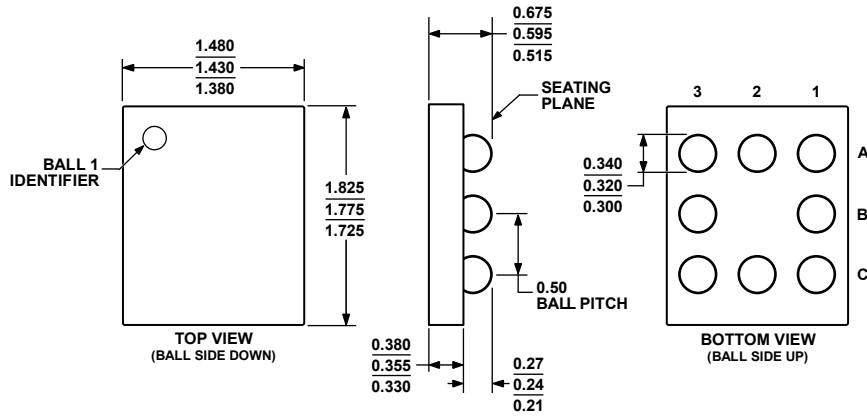
**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.



COMPLIANT TO JEDEC STANDARDS MS-012-AA  
 CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS  
 (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR  
 REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

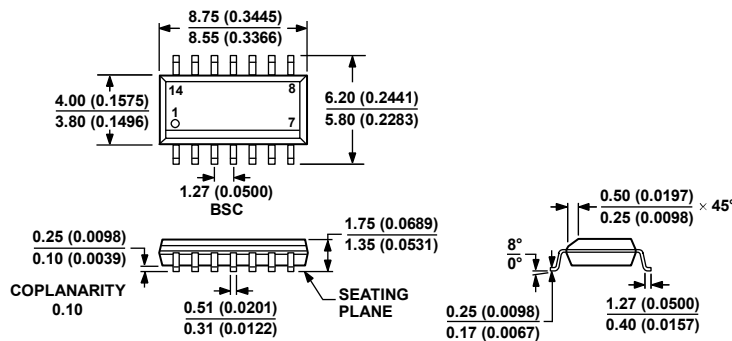
012407-A

Figure 60. 8-Lead Standard Small Outline Package [SOIC\_N]  
 Narrow Body (R-8)  
 Dimensions shown in millimeters and (inches)



090706-B

Figure 61. 8-Ball Wafer Level Chip Scale Package [WLCSP]  
 (CB-8-1)  
 Dimensions shown in millimeters

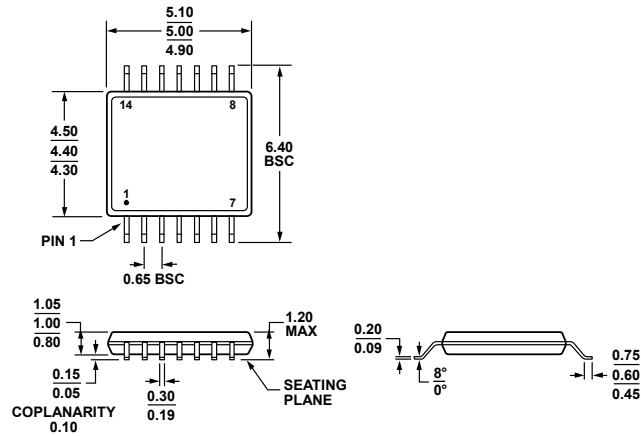


COMPLIANT TO JEDEC STANDARDS MS-012-AB  
 CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS  
 (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR  
 REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

060606-A

Figure 62. 14-Lead Standard Small Outline Package [SOIC\_N]  
 Narrow Body (R-14)  
 Dimensions shown in millimeters and (inches)

# AD8605/AD8606/AD8608



COMPLIANT TO JEDEC STANDARDS MO-153-AB-1

Figure 63. 14-Lead Thin Shrink Small Outline Package [TSSOP] (RU-14)

Dimensions shown in millimeters

## ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option	Branding
AD8605ACB-REEL	-40°C to +125°C	5-Ball WLCSP	CB-5-1	B3A
AD8605ACB-REEL7	-40°C to +125°C	5-Ball WLCSP	CB-5-1	B3A
AD8605ACBZ-REEL <sup>1</sup>	-40°C to +125°C	5-Ball WLCSP	CB-5-1	A1J
AD8605ACBZ-REEL7 <sup>1</sup>	-40°C to +125°C	5-Ball WLCSP	CB-5-1	A1J
AD8605ART-R2	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A
AD8605ART-REEL	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A
AD8605ART-REEL7	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A
AD8605ARTZ-R2 <sup>1</sup>	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A#
AD8605ARTZ-REEL <sup>1</sup>	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A#
AD8605ARTZ-REEL7 <sup>1</sup>	-40°C to +125°C	5-Lead SOT-23	RJ-5	B3A#
AD8606ARM-R2	-40°C to +125°C	8-Lead MSOP	RM-8	B6A
AD8606ARM-REEL	-40°C to +125°C	8-Lead MSOP	RM-8	B6A
AD8606ARMZ <sup>1</sup>	-40°C to +125°C	8-Lead MSOP	RM-8	B6A#
AD8606ARMZ-R2 <sup>1</sup>	-40°C to +125°C	8-Lead MSOP	RM-8	B6A#
AD8606ARMZ-REEL <sup>1</sup>	-40°C to +125°C	8-Lead MSOP	RM-8	B6A#
AD8606AR	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606AR-REEL	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606AR-REEL7	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ARZ <sup>1</sup>	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ARZ-REEL <sup>1</sup>	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ARZ-REEL7 <sup>1</sup>	-40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ACBZ-REEL <sup>1</sup>	-40°C to +125°C	8-Ball WLCSP	CB-8-1	B6A#
AD8606ACBZ-REEL7 <sup>1</sup>	-40°C to +125°C	8-Ball WLCSP	CB-8-1	B6A#
AD8608AR	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608AR-REEL	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608AR-REEL7	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARZ <sup>1</sup>	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARZ-REEL <sup>1</sup>	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARZ-REEL7 <sup>1</sup>	-40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARU	-40°C to +125°C	14-Lead TSSOP	RU-14	
AD8608ARU-REEL	-40°C to +125°C	14-Lead TSSOP	RU-14	
AD8608ARUZ <sup>1</sup>	-40°C to +125°C	14-Lead TSSOP	RU-14	
AD8608ARUZ-REEL <sup>1</sup>	-40°C to +125°C	14-Lead TSSOP	RU-14	

<sup>1</sup> Z = RoHS Compliant Part, # denotes RoHS compliant product (except for CB-5-1) may be top or bottom marked.