Precision, Low Noise, CMOS, Rail-to-Rail, Input/Output Operational Amplifiers

AD8605/AD8606/AD8608

FEATURES

Low offset voltage: 65 µV maximum
Low input bias currents: 1 pA maximum
Low noise: 8 nV/√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[1] 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® 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°C to +125°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 WLSCP, 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.

[1] Protected by U.S. Patent No. 5,969,657; other patents pending.

FUNCTIONAL BLOCK DIAGRAMS

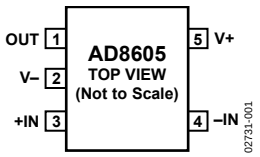


Figure 1. 5-Lead SOT-23 (RJ Suffix)

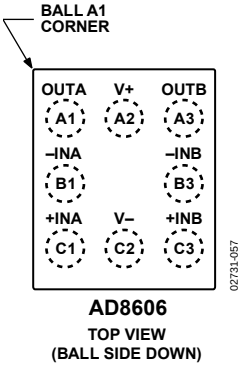


Figure 2. 8-Ball WLCSP (CB Suffix)

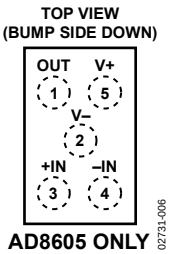


Figure 3. 5-Ball WLCSP (CB Suffix)

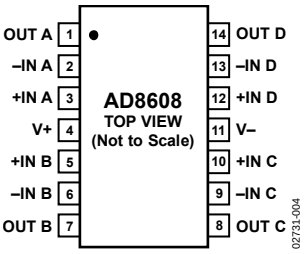


Figure 4. 14-Lead SOIC_N (R Suffix)

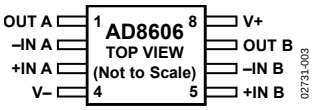


Figure 5. 8-Lead MSOP (RM Suffix), 8-Lead SOIC_N (R Suffix)

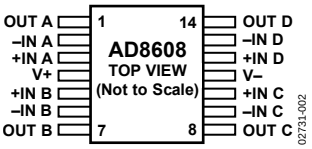


Figure 6. 14-Lead TSSOP (RU Suffix)

5 V ELECTRICAL SPECIFICATIONS

V_S = 5 V, V_{CM} = V_S/2, T_A = 25°C, unless otherwise noted.

Table 1.

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

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
NOISE PERFORMANCE						
Peak-to-Peak Noise	e_n p-p	f = 0.1 Hz to 10 Hz		2.3	3.5	μV p-p
Voltage Noise Density	e_n	f = 1 kHz		8	12	nV/√Hz
	e_n	f = 10 kHz		6.5		nV/√Hz
Current Noise Density	i_n	f = 1 kHz		0.01		pA/√Hz

2.7 V ELECTRICAL SPECIFICATIONS

V_S = 2.7 V, V_{CM} = V_S/2, T_A = 25°C, unless otherwise noted.

Table 2.

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

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
NOISE PERFORMANCE						
Peak-to-Peak Noise	e_n p-p	f = 0.1 Hz to 10 Hz		2.3	3.5	μV p-p
Voltage Noise Density	e_n	f = 1 kHz		8	12	nV/√Hz
	e_n	f = 10 kHz		6.5		nV/√Hz
Current Noise Density	i_n	f = 1 kHz		0.01		pA/√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.

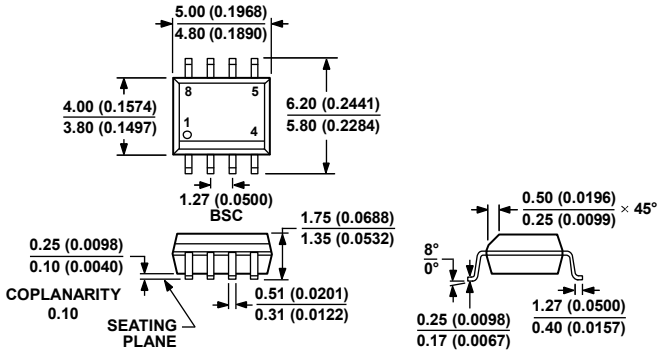
Table 4.

Package Type	θ_{JA}[1]	θ_{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

[1] θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

ESD CAUTION

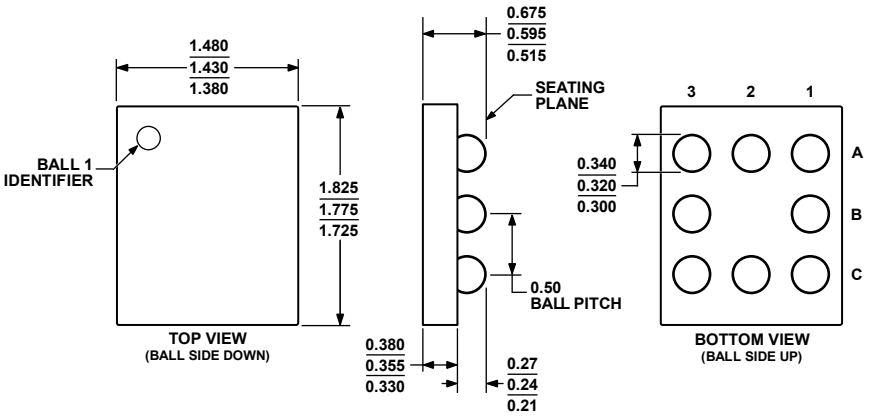
ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken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

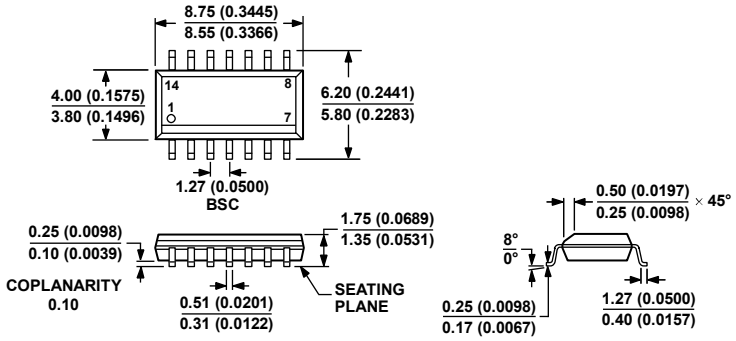
012407-A

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)

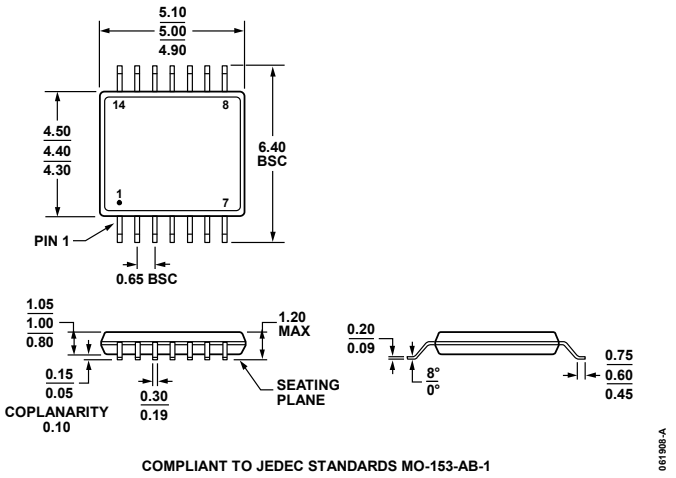


Figure 63. 14-Lead Thin Shrink Small Outline Package [TSSOP]
(RU-14)
Dimensions shown in millimeters

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[1]	−40°C to +125°C	5-Ball WLCSP	CB-5-1	A1J
AD8605ACBZ-REEL7[1]	−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[1]	−40°C to +125°C	5-Lead SOT-23	RJ-5	B3A#
AD8605ARTZ-REEL[1]	−40°C to +125°C	5-Lead SOT-23	RJ-5	B3A#
AD8605ARTZ-REEL7[1]	−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[1]	−40°C to +125°C	8-Lead MSOP	RM-8	B6A#
AD8606ARMZ-R2[1]	−40°C to +125°C	8-Lead MSOP	RM-8	B6A#
AD8606ARMZ-REEL[1]	−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[1]	−40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ARZ-REEL[1]	−40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ARZ-REEL7[1]	−40°C to +125°C	8-Lead SOIC_N	R-8	
AD8606ACBZ-REEL[1]	−40°C to +125°C	8-Ball WLCSP	CB-8-1	B6A#
AD8606ACBZ-REEL7[1]	−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[1]	−40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARZ-REEL[1]	−40°C to +125°C	14-Lead SOIC_N	R-14	
AD8608ARZ-REEL7[1]	−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[1]	−40°C to +125°C	14-Lead TSSOP	RU-14	
AD8608ARUZ-REEL[1]	−40°C to +125°C	14-Lead TSSOP	RU-14	

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