1 μA Micropower CMOS Operational Amplifiers

AD8502/AD8504

FEATURES

Supply current: 1 μA maximum/amplifier
Offset voltage: 3 mV maximum
Single-supply or dual-supply operation
Rail-to-rail input and output
No phase reversal
Unity gain stable

APPLICATIONS

Portable equipment
Remote sensors
Low power filters
Threshold detectors
Current sensing

PIN CONFIGURATIONS

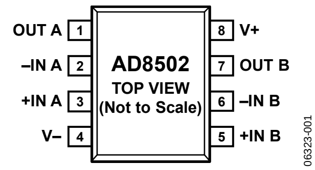

Figure 1. 8-Lead SOT-23

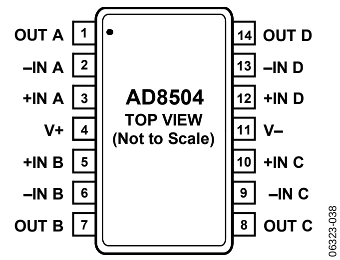

Figure 2. 14-Lead TSSOP (RU-14)

GENERAL DESCRIPTION

The AD8502/AD8504 are low power, precision CMOS operational amplifiers featuring a maximum supply current of 1 μA per amplifier. The AD8502/AD8504 have a maximum offset voltage of 3 mV and a typical input bias current of 1 pA operating rail-to-rail on both the input and output. The AD8502/AD8504 can operate from a single-supply voltage of +1.8 V to +5.5 V or a dual-supply voltage of ±0.9 V to ±2.75 V.

With its low power consumption, low input bias current, and rail-to-rail input and output, the AD8502/AD8504 are ideally suited for a variety of battery-powered portable applications. Potential applications include bedside monitors, pulse monitors, glucose meters, smoke and fire detectors, vibration monitors, and backup battery sensors.

The ability to swing rail-to-rail at both the input and output helps maximize dynamic range and signal-to-noise ratio in systems that operate at very low voltages. The low offset voltage allows use of the AD8502/AD8504 in systems with high gain without creating excessively large output offset errors. The AD8502 and AD8504 offer an additional benefit by providing high accuracy without the need for system calibration.

The AD8502/AD8504 are fully specified over the industrial temperature range (−40°C to +85°C) and the extended industrial temperature range (−40°C to +125°C). The AD8502 is available in an 8-lead, SOT-23 surface-mount package. The AD8504 is available in a 14-lead TSSOP surface-mount package.

Table 1. Low Supply Current Op Amps

Supply Current	1 μA	10 μA	20 μA
Single	AD8500		
Dual	AD8502	ADA4505-2	AD8506
Quad	AD8504	ADA4505-4	AD8508

Rev. A

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REVISION HISTORY

2/09—Rev. 0 to Rev. A

Changes to General Description Section 1
Added Table 1; Renumbered Sequentially 1
Changes to Typical Performance Characteristics Section 7
Updated Outline Dimensions 14

1/07—Revision 0: Initial Version

SPECIFICATIONS

ELECTRICAL CHARACTERISTICS

@ V_S = 5 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}	0 V < V_{CM} < 5 V		0.5	3	mV
		−40°C < T_A < +85°C			5	mV
		−40°C < T_A < +125°C			5.5	mV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	−40°C < T_A < +85°C		7		µV/°C
		−40°C < T_A < +125°C		5		µV/°C
Input Bias Current	I_B	0 V < V_{CM} < 5 V		1	10	pA
		−40°C < T_A < +85°C			100	pA
		−40°C < T_A < +125°C			600	pA
Input Offset Current	I_{OS}	0 V < V_{CM} < 5 V		0.5	5	pA
		−40°C < T_A < +85°C			50	pA
		−40°C < T_A < +125°C			100	pA
Input Voltage Range	IVR		0		5.0	V
Common-Mode Rejection Ratio	CMRR	0 V < V_{CM} < 5 V	67	76		dB
		−40°C < T_A < +85°C	65			dB
		−40°C to +125°C	65			dB
Large Signal Voltage Gain	A_{VO}	0.1 V < V_{OUT} < 4.9 V; R_{LOAD} = 1 MΩ	98	120		dB
		0.1 V < V_{OUT} < 4.9 V; −40°C < T_A < +85°C	93			dB
		0.1 V < V_{OUT} < 4.9 V; −40°C < T_A < +125°C	75			dB
Input Capacitance	C_{DIFF}			2		pF
	C_{CM}			4.5		pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	R_{LOAD} = 100 kΩ to GND	4.970	4.990		V
		−40°C < T_A < +85°C	4.960			V
		−40°C to +125°C	4.950			V
		R_{LOAD} = 10 kΩ to GND	4.900	4.930		V
		−40°C < T_A < +85°C	4.810			V
		−40°C to +125°C	4.650			V
Output Voltage Low	V_{OL}	R_{LOAD} = 100 kΩ to V_S		1.6	5	mV
		−40°C < T_A < +85°C			7	mV
		−40°C to +125°C			7	mV
		R_{LOAD} = 10 kΩ to V_S		15	20	mV
		−40°C < T_A < +85°C			37	mV
		−40°C to +125°C			40	mV
Short-Circuit Current	I_{SC}	V_{OUT} = GND		±5		mA
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	1.8 V < V_S < 5 V	85	105		dB
		−40°C < T_A < +85°C	66			dB
		−40°C < T_A < +125°C	66			dB
Supply Current/Amplifier	I_{SY}	V_O = V_S/2		0.75	1	µA
		−40°C < T_A < +85°C			1.5	µA
		−40°C < T_A < +125°C			2	µA
DYNAMIC PERFORMANCE						
Slew Rate	SR	R_{LOAD} = 1 MΩ		0.004		V/µs
Gain Bandwidth Product	GBP			7		kHz
Phase Margin	$Ø_O$			60		Degrees

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
NOISE PERFORMANCE						
Peak-to-Peak Noise		0.1 Hz to 10 Hz		6		μV p-p
Voltage Noise Density	e_n	f = 1 kHz		190		nV/√Hz
Current Noise Density	i_n	f = 1 kHz		0.1		pA/√Hz

@ V_S = 1.8 V, $V_{CM} = V_S/2$, T_A = 25°C, unless otherwise noted.

Table 3.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}	0 V < V_{CM} < 1.8 V		0.5	3	mV
		−40°C < T_A < +85°C			5	mV
		−40°C < T_A < +125°C			5.5	mV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	−40°C < T_A < +85°C		7		μV/°C
		−40°C < T_A < +125°C		5		μV/°C
Input Bias Current	I_B	0 V < V_{CM} < 1.8 V		1	10	pA
		−40°C < T_A < +85°C			100	pA
		−40°C < T_A < +125°C			600	pA
Input Offset Current	I_{OS}	0 V < V_{CM} < 1.8 V		0.5	5	pA
		−40°C < T_A < +85°C			50	pA
		−40°C < T_A < +125°C			100	pA
Input Voltage Range	IVR		0		1.8	V
Common-Mode Rejection Ratio	CMRR	0 V < V_{CM} < 1.8 V	59	75		dB
		−40°C < T_A < +85°C	56			dB
		−40°C < T_A < +125°C	55			dB
Large Signal Voltage Gain	A_{VO}	0.1 V < V_{OUT} < 1.7 V; R_{LOAD} = 1 MΩ	88	110		dB
		0.1 V < V_{OUT} < 1.7 V; −40°C < T_A < +85°C	80			dB
		0.1 V < V_{OUT} < 1.7 V; −40°C < T_A < +125°C	65			dB
Input Capacitance	C_{DIFF}			2		pF
	C_{CM}			4.5		pF
OUTPUT CHARACTERISTICS						
Output Voltage High	V_{OH}	R_{LOAD} = 100 kΩ to GND	1.79	1.795		V
		−40°C < T_A < +85°C	1.78			V
		−40°C to +125°C	1.77			V
		R_{LOAD} = 10 kΩ to GND	1.75	1.764		V
		−40°C < T_A < +85°C	1.70			V
		−40°C to +125°C	1.65			V
Output Voltage Low	V_{OL}	R_{LOAD} = 100 kΩ to V_S		1.0	5	mV
		−40°C < T_A < +85°C			6	mV
		−40°C to +125°C			7	mV
		R_{LOAD} = 10 kΩ to V_S		10	20	mV
		−40°C < T_A < +85°C			28	mV
		−40°C to +125°C			29	mV
Short-Circuit Current	I_{SC}			±5		mA
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	1.8 V < V_S < 5 V	85	105		dB
		−40°C < T_A < +85°C	66			dB
		−40°C < T_A < +125°C	66			dB
Supply Current/Amplifier	I_{SY}	$V_O = V_S/2$		0.65	1	μA
		−40°C < T_A < +85°C			1.5	μA
		−40°C < T_A < +125°C			2	μA

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE						
Slew Rate	SR	R_{LOAD} = 1 MΩ		0.004		V/µs
Gain Bandwidth Product	GBP			7		kHz
Phase Margin	$Ø_O$			60		Degrees
NOISE PERFORMANCE						
Peak-to-Peak Noise		0.1 Hz to 10 Hz		6		µV p-p
Voltage Noise Density	e_n	f = 1 kHz		190		nV/√Hz
Current Noise Density	i_n	f = 1 kHz		0.1		pA/√Hz

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C, unless otherwise noted.

Table 4.

Parameter	Rating
Supply Voltage	6 V
Input Voltage	V_{SS} − 0.3 V to V_{DD} + 0.3 V
Differential Input Voltage	±6 V
Output Short-Circuit Duration to GND	Indefinite
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	−40°C to +125°C
Junction Temperature Range	−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.

Absolute maximum ratings apply at 25°C, unless otherwise noted.

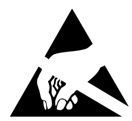
THERMAL RESISTANCE

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

Table 5. Thermal Characteristics

Package Type	θ_{JA}	θ_{JC}	Unit
8-Lead SOT-23 (RJ-8)	376	126	°C/W
14-Lead TSSOP (RU-14)	180	35	°C/W

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.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, unless otherwise noted.

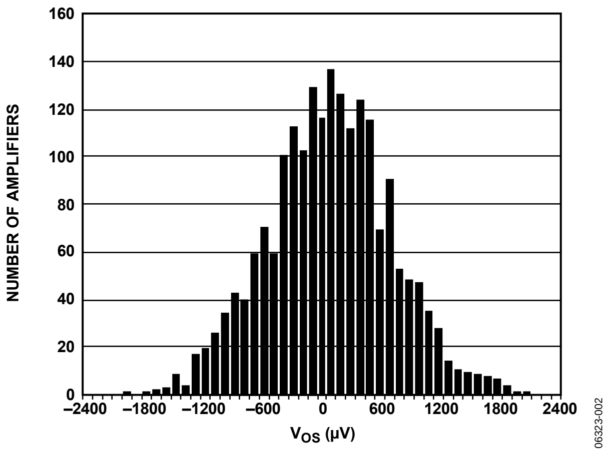


Figure 3. Input Offset Voltage Distribution (0 V < V_{CM} < 5.0 V), V_S = 5 V

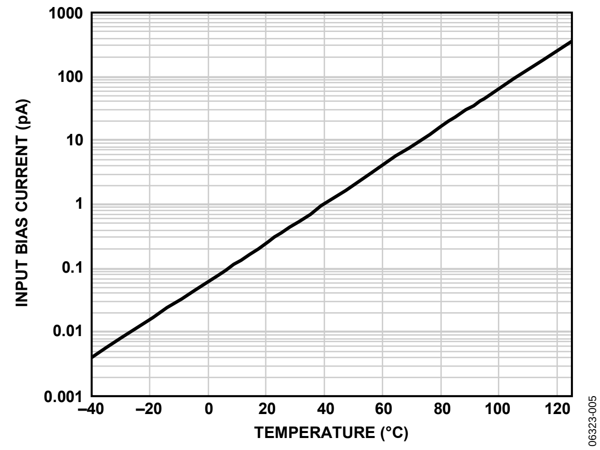


Figure 6. Input Bias Current vs. Temperature (V_S = 1.8 V and 5.0 V)

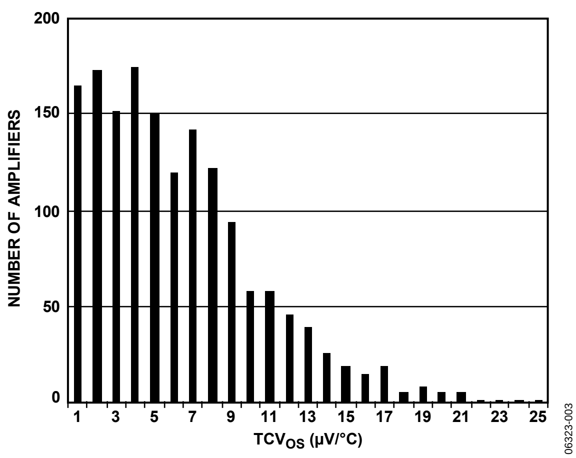


Figure 4. Input Offset Voltage Temperature Drift Distribution (–40°C < T_A < +85°C), V_S = 5 V

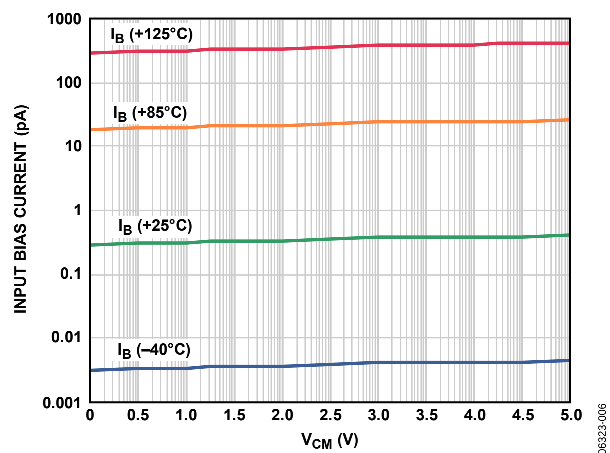


Figure 7. Input Bias Current vs. Common-Mode Voltage, V_S = 5 V

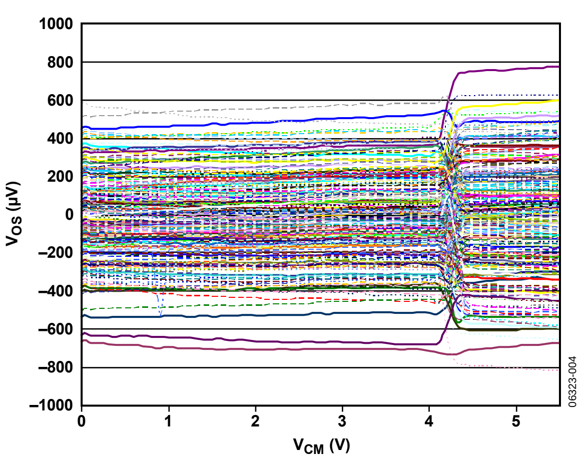


Figure 5. Input Offset Voltage vs. Common-Mode Voltage, V_S = 5 V

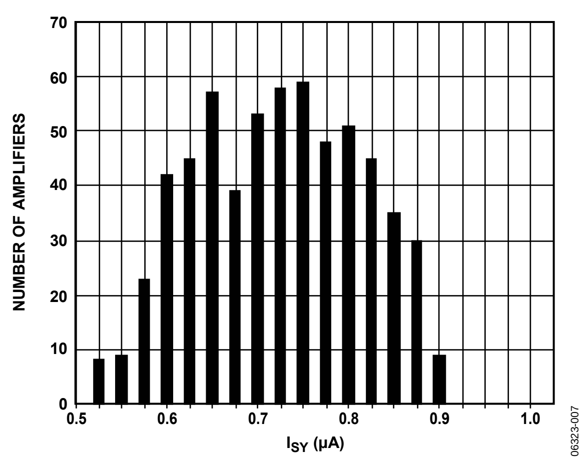


Figure 8. Supply Current Distribution, V_S = 5 V

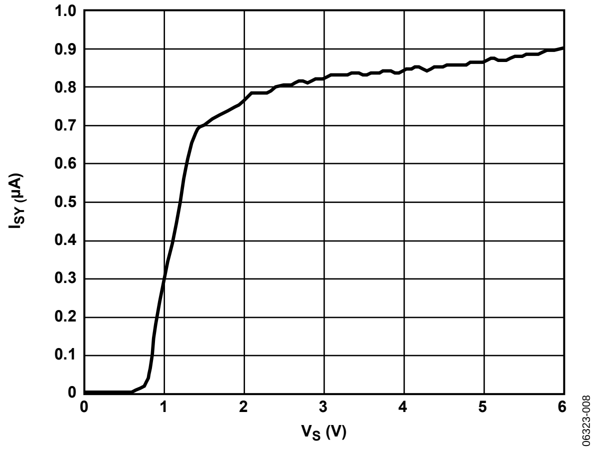


Figure 9. Supply Current vs. Supply Voltage

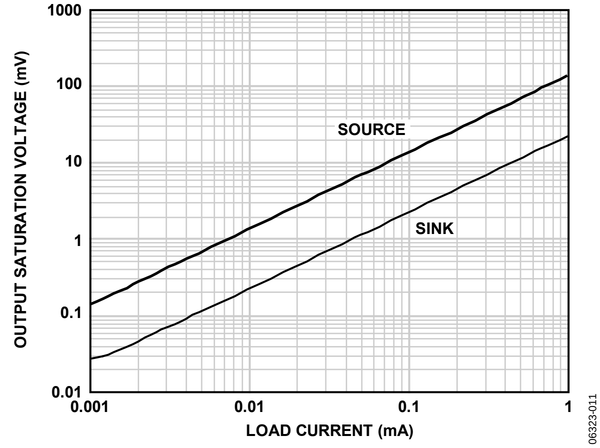


Figure 12. Output Saturation Voltage vs. Load Current, V_S = 5 V

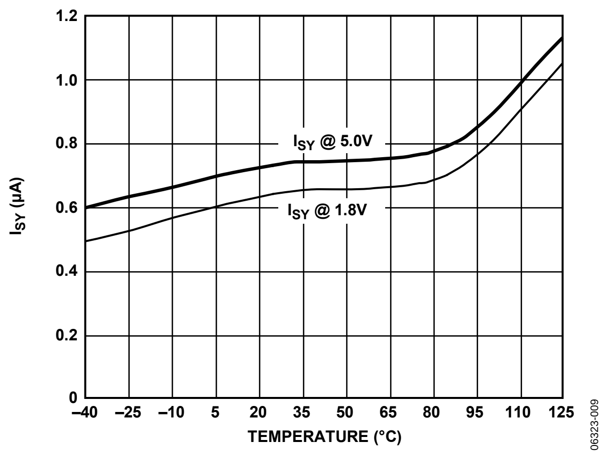


Figure 10. Supply Current vs. Temperature

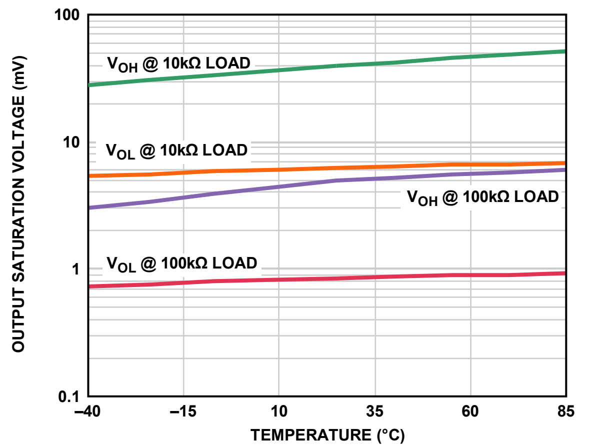


Figure 13. Output Saturation Voltage vs. Temperature, V_S = 5 V

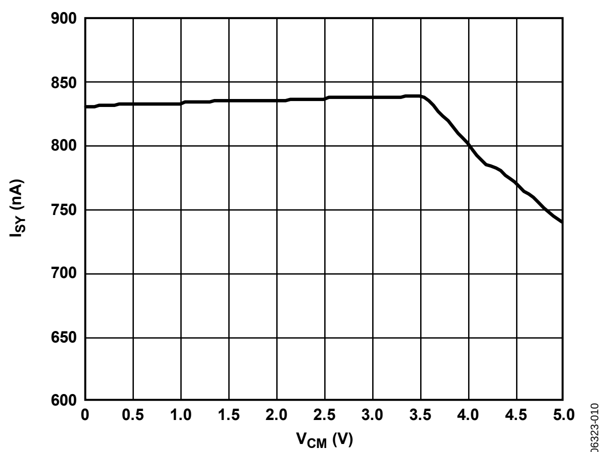


Figure 11. Supply Current vs. Input Common-Mode Voltage, V_S = 5 V

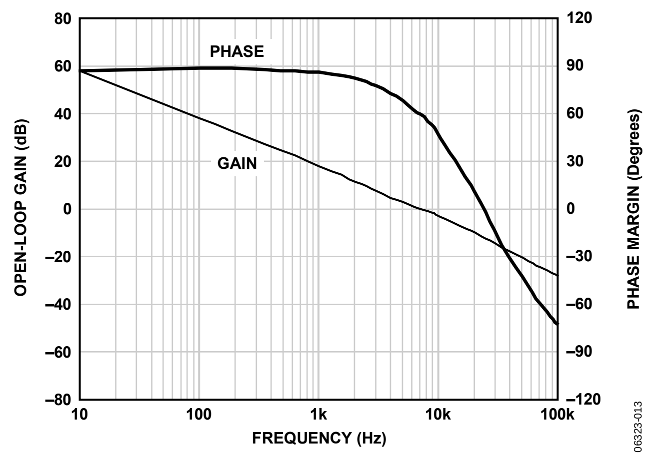


Figure 14. Open-Loop Gain and Phase vs. Frequency, V_S = 5 V

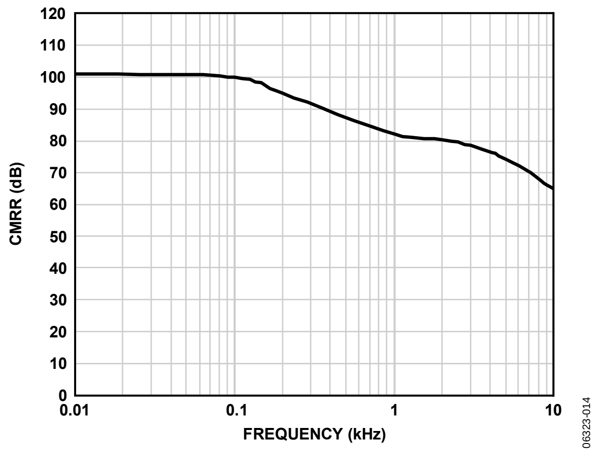


Figure 15. CMRR vs. Frequency, $V_S = 5$ V

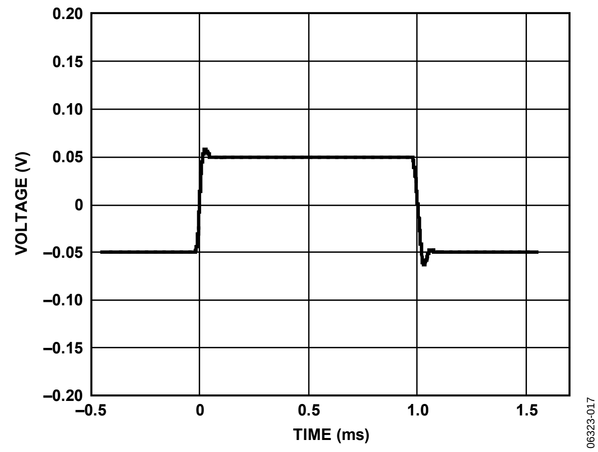


Figure 18. Small Signal Transient Response (No Load), $V_S = 5$ V

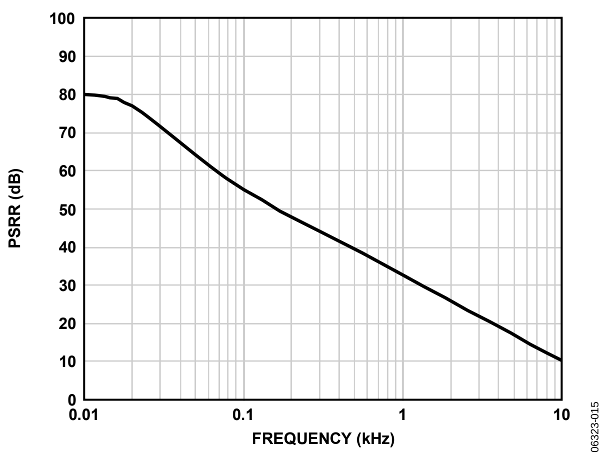


Figure 16. PSRR vs. Frequency, $V_S = 5$ V

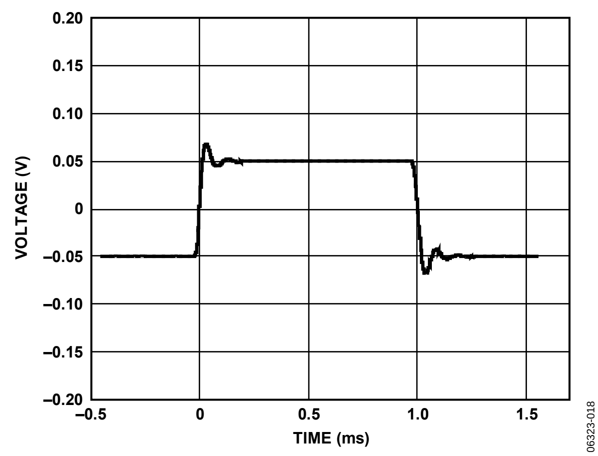


Figure 19. Small Signal Transient Response
(100 pF Load Capacitance, $V_S = 5$ V)

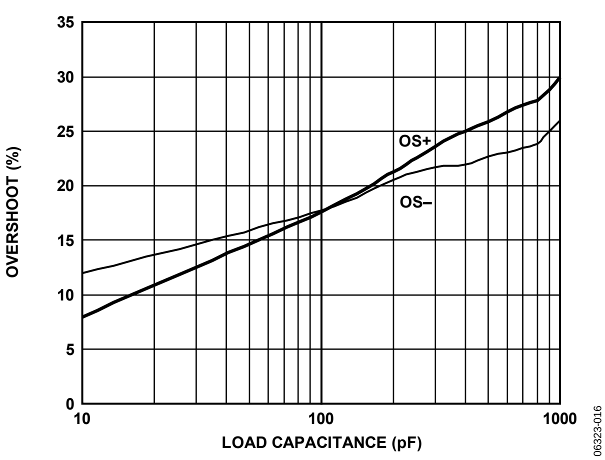


Figure 17. Small Signal Overshoot vs. Load Capacitance, $V_S = 5$ V

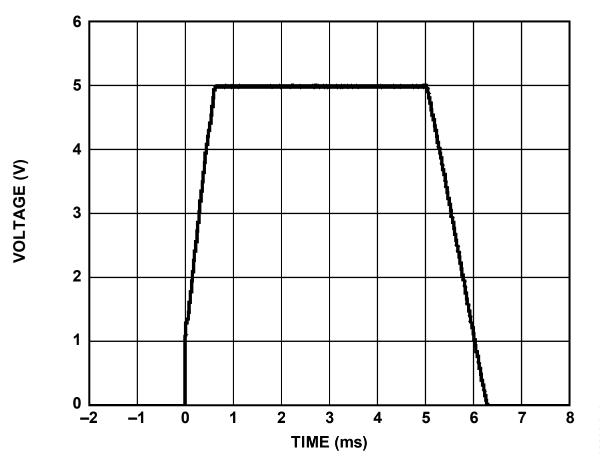


Figure 20. Large Signal Transient Response No Load), $V_S = 5$ V

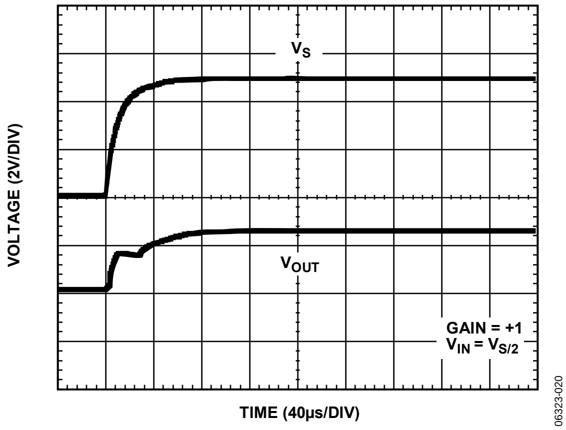


Figure 21. Turn-On Transient Response, $V_S = 5$ V

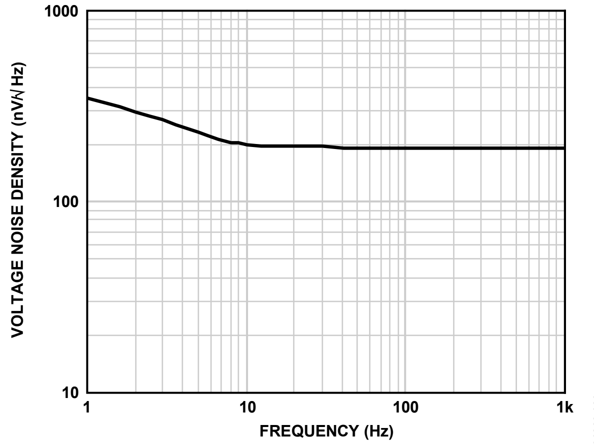


Figure 24. Input Voltage Noise ($V_S = 5$ V and 1.8 V)

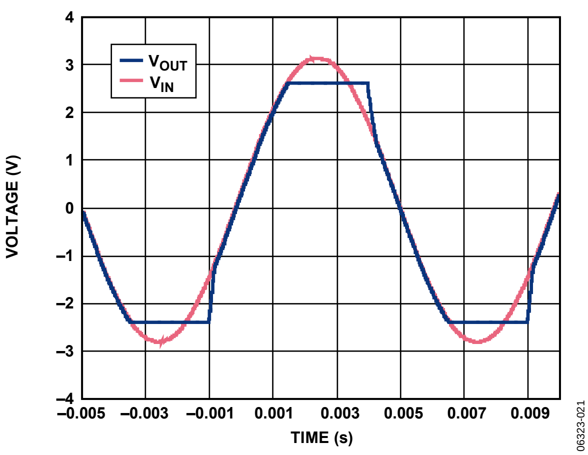


Figure 22. No Phase Reversal, $V_S = 5$ V

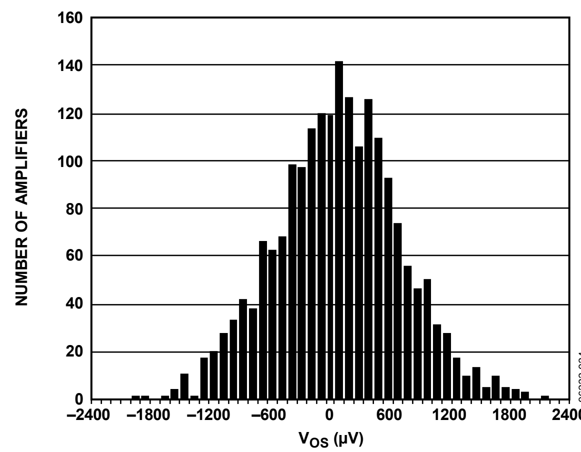


Figure 25. Input Offset Voltage Distribution (0 V < V_{CM} < 1.8 V), $V_S = 1.8$ V

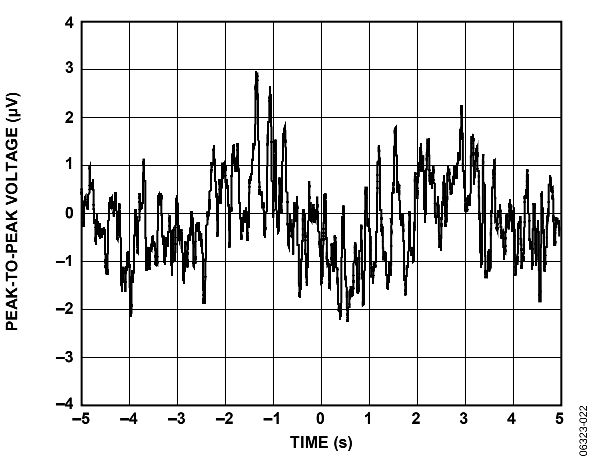


Figure 23. 0.1 Hz to 10 Hz Input Voltage Noise ($V_S = 5$ V and 1.8 V)

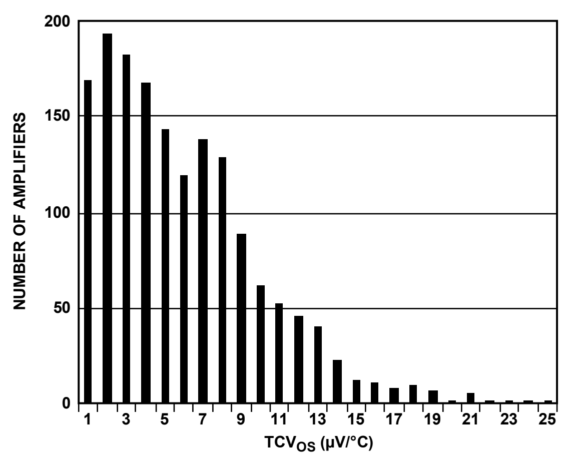


Figure 26. Input Offset Voltage Temperature Drift Distribution (−40°C < T_A < +85°C), $V_S = 1.8$ V

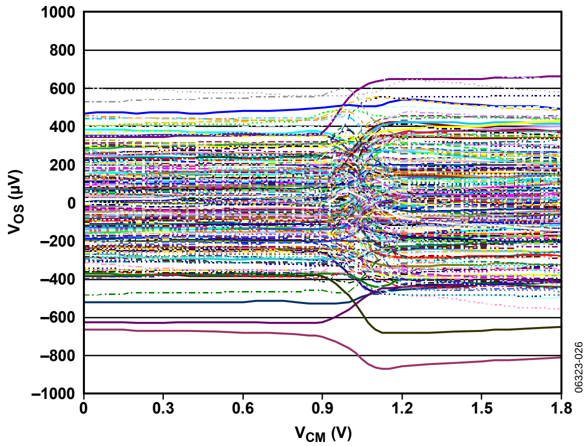


Figure 27. Input Offset Voltage vs. Input Common-Mode Voltage, V_S = 1.8 V

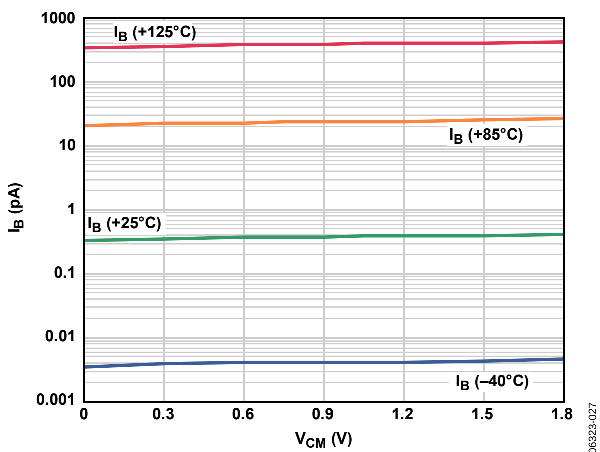


Figure 28. Input Bias Current vs. Input Common-Mode Voltage, V_S = 1.8 V

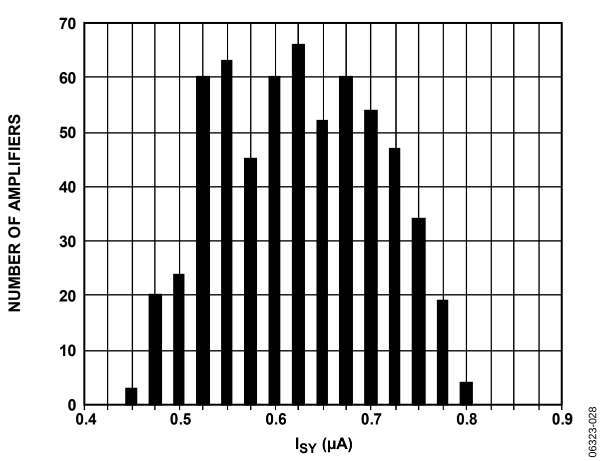


Figure 29. Supply Current Distribution, V_S = 1.8 V

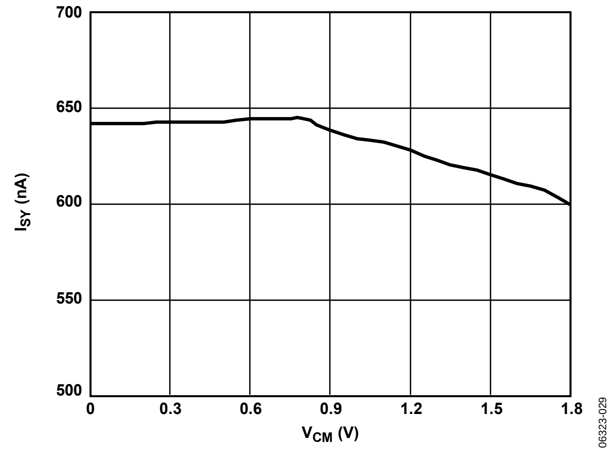


Figure 30. Supply Current vs. Input Common-Mode Voltage, V_S = 1.8 V

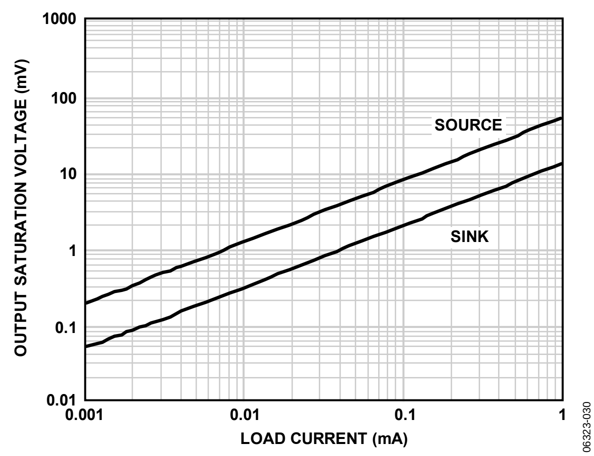


Figure 31. Output Saturation Voltage vs. Load Current V_S = 1.8 V

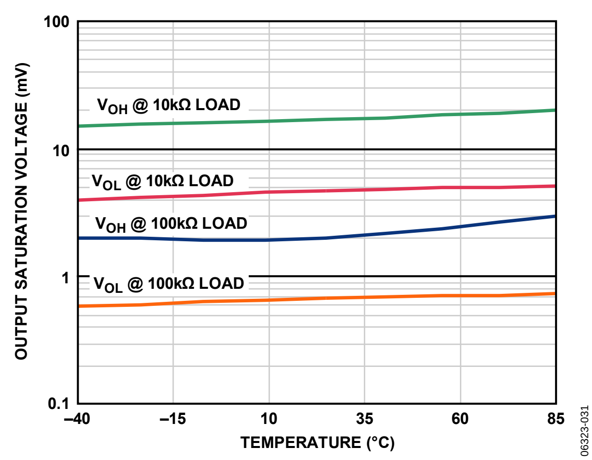


Figure 32. Output Saturation Voltage vs. Temperature, V_S = 1.8 V

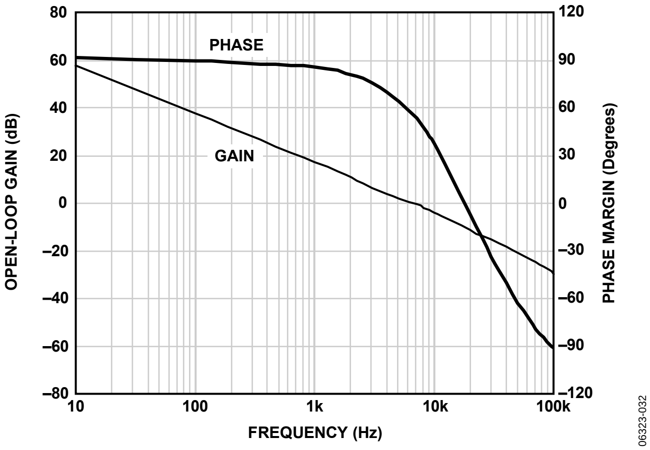


Figure 33. Open-Loop Gain and Phase vs. Frequency, $V_S = 1.8$ V

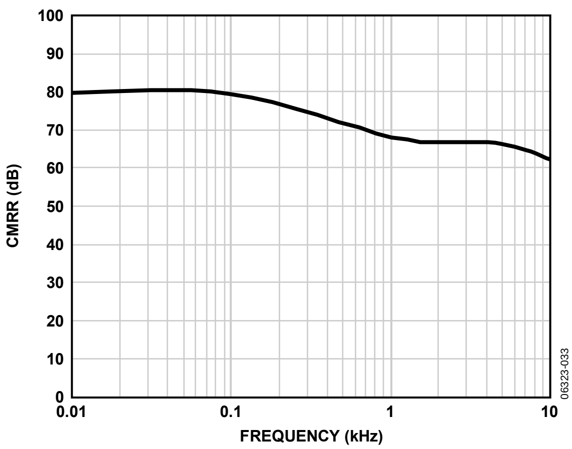


Figure 34. CMRR vs. Frequency, $V_S = 1.8$ V

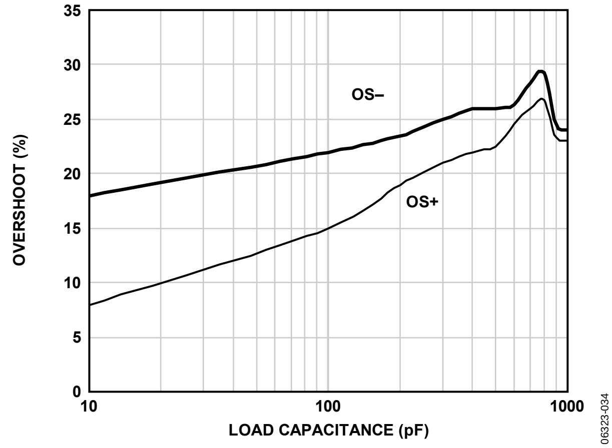


Figure 35. Small Signal Overshoot vs. Load Capacitance, $V_S = 1.8$ V

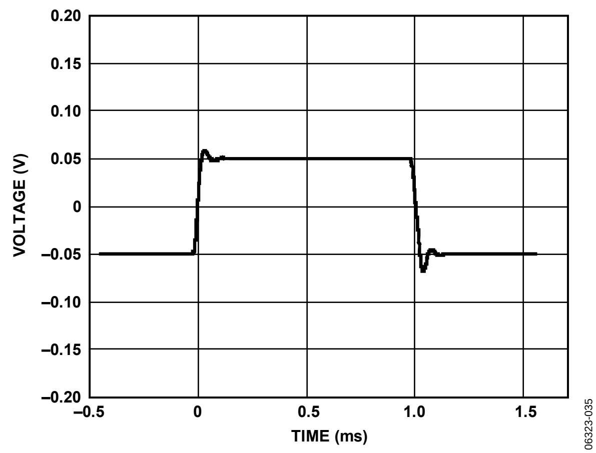


Figure 36. Small Signal Transient Response (No Load), $V_S = 1.8$ V

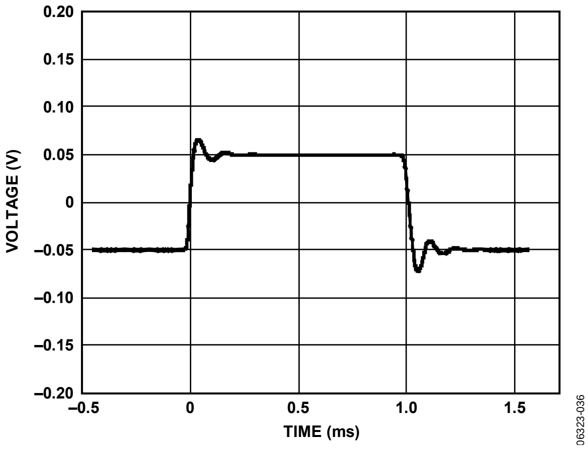


Figure 37. Small Signal Transient Response (100 pF Load Capacitance), V_S = 1.8 V

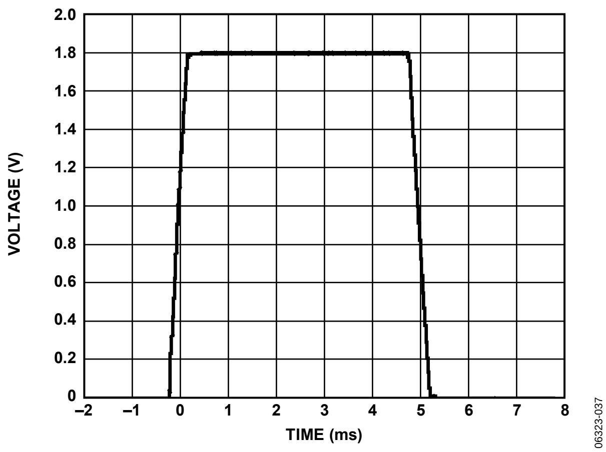


Figure 38. Large Signal Transient Response (No Load), V_S = 1.8 V

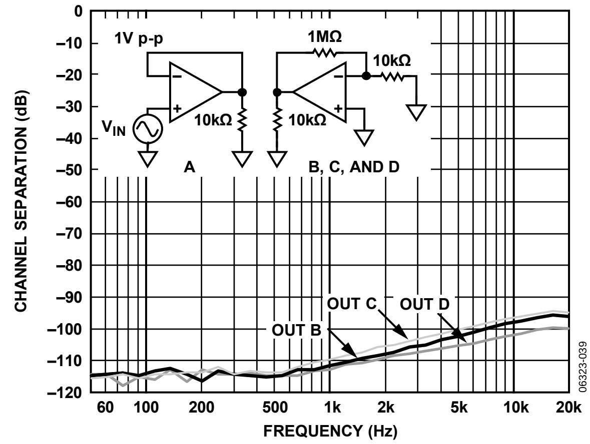


Figure 39. Channel Separation

OUTLINE DIMENSIONS

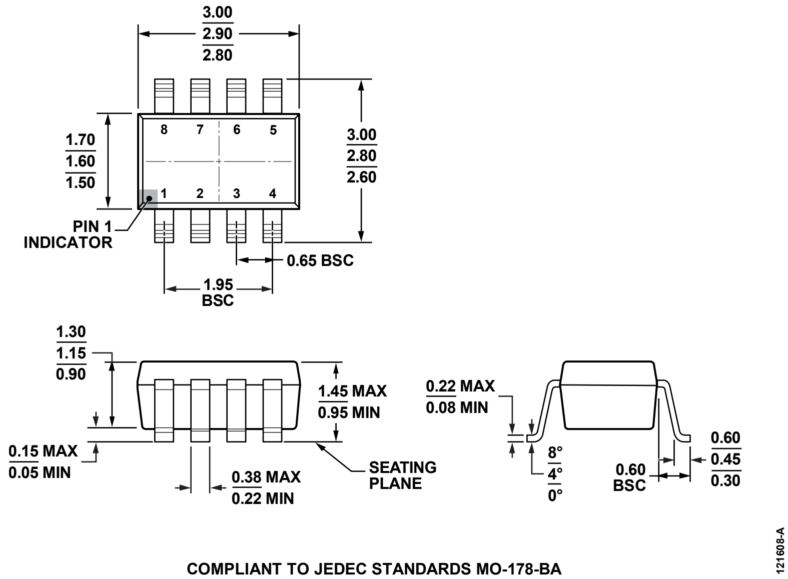


Figure 40. 8-Lead Small Outline Transistor Package [SOT-23]
(RJ-8)
Dimensions shown in millimeters

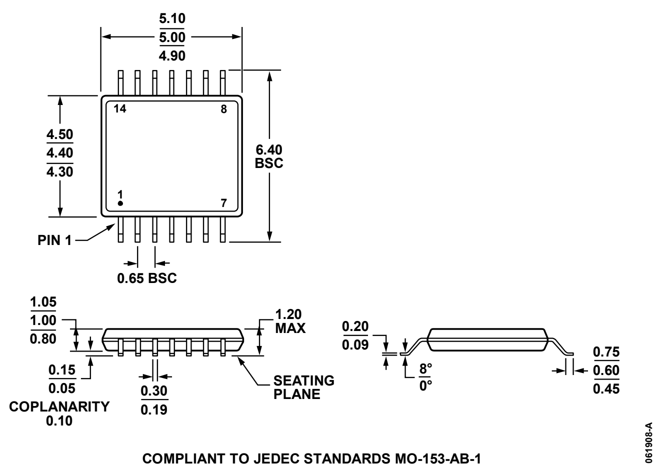


Figure 41. 14-Lead Thin Shrink Small Outline Package [TSSOP]
(RU-14)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option	Branding
AD8502ARJZ-R2[1]	−40°C to +125°C	8-Lead SOT-23	RJ-8	A1D
AD8502ARJZ-REEL[1]	−40°C to +125°C	8-Lead SOT-23	RJ-8	A1D
AD8502ARJZ-REEL7[1]	−40°C to +125°C	8-Lead SOT-23	RJ-8	A1D
AD8504ARUZ[1]	−40°C to +125°C	14-Lead TSSOP	RU-14	
AD8504ARUZ-REEL[1]	−40°C to +125°C	14-Lead TSSOP	RU-14	

[1] Z = RoHS Compliant Part.

NOTES

NOTES

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