

1. 特性

- 纳安级静态电流：570nA/通道
- 失调电压：210 μ V (max)
- 失调电压漂移 $TcVos$ ：2 μ V/ $^{\circ}$ C
- 增益带宽积：11kHz
- 供电电压：1.6V to 5.5V
- 低输入偏置电流：0.1pA
- 单位增益稳定
- 轨到轨输入输出
- EMI 保护
- 关断

2. 应用

- CO 和 O₂ 气体检测
- PIR 动作检测
- 烟雾报警
- 温度测量
- IoT 远程传感器
- 有源 RFID 标签接受器
- 手持医疗器件
- 检测和报警
- 可穿戴器件

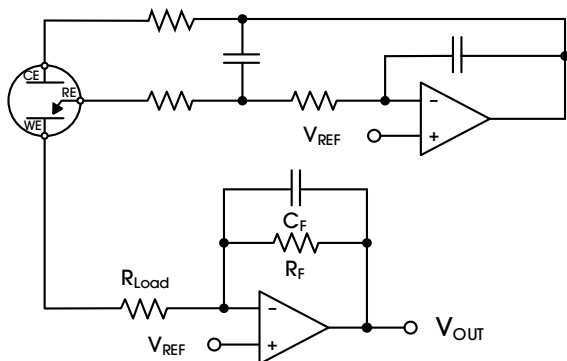
3. 说明

OPA503/OPA504 是类比提供的超低功耗系列运算放大器之一。

OPA503/OPA504 运算放大器的静态电流仅为 570nA，工作电压介于 1.6V 和 5.5V 之间，适用于大多数电池供电环境，即使没有额外的升压拓扑也能保持稳定。OPA503/OPA504 器件保持低功耗和 11kHz 带宽，与 CO 探测器、烟雾探测器和 PIR 运动探测器等器件配合得很好。此外，OPA503/OPA504 运算放大器具有 CMOS 输入级，偏置电流通常为飞安级。EMI 保护被纳入 OPA503/OPA504 设计，以降低系统对来自移动电话、Wi-Fi、无线电发射器和标签接收器的不良射频信号的敏感度来增强整体系统可靠性。在低功耗应用中，EN 引脚可以帮助节省功耗。

OPA503/OPA504 运算放大器分别采用 SOT23-5 和 SOT23-6 封装，额定温度范围为 -40 $^{\circ}$ C 至 125 $^{\circ}$ C，适用于各种恶劣环境。有关订购信息，请参见 Table 1。

Nanopower Amplifier in Electrochemical Sensor



Nanopower Amplifier in PIR Motion Detector

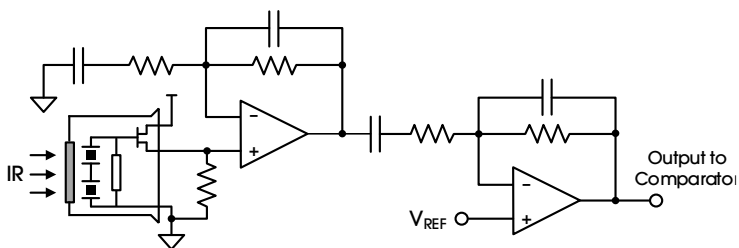


Table 1 lists the order information.

Table 1. Order Information

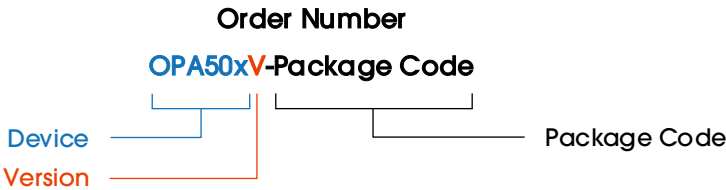
ORDER NUMBER ⁽¹⁾	CH (#)	PACKAGE	MARK	I _Q PER CH (TYP) (nA)	GBW (kHz)	SLEW RATE (TYP) (V/ms)	NOISE nV/√Hz (100Hz)	OPERATING TEMP (°C)	PACKAGE OPTION
OPA503ASOT235	1	SOT23-5	OPA503	570	11	3	214	−40-125	T/R-3000
OPA504ASOT236	1	SOT23-6	OPA504	570	11	3	214	−40-125	T/R-3000

Table 2. Family Selection Guide

ORDER NUMBER ⁽¹⁾	CH (#)	PACKAGE	MARK	I _Q PER CH (TYP) (nA)	GBW (kHz)	SLEW RATE (TYP) (V/ms)	NOISE nV/√Hz (100Hz)	OPERATING TEMP (°C)	PACKAGE OPTION
OPA501BSOT235	1	SOT23-5	OPA501	240	4.2	1.3	347	−40-125	T/R-3000
OPA505ASOT235	1	SOT23-5	OPA505	3200	65	20	100	−40-125	T/R-3000
OPA506ASOT236	1	SOT23-6	OPA506	3200	65	20	100	−40-125	T/R-3000

- Devices can be ordered via the following two ways:
1. Place orders directly on our website (www.analogyssemi.com), or;
 2. Contact our sales team by mailing to sales@analogyssemi.com.

Note:



4. PIN CONFIGURATION AND FUNCTIONS

Figure 1 illustrates the pin configuration.

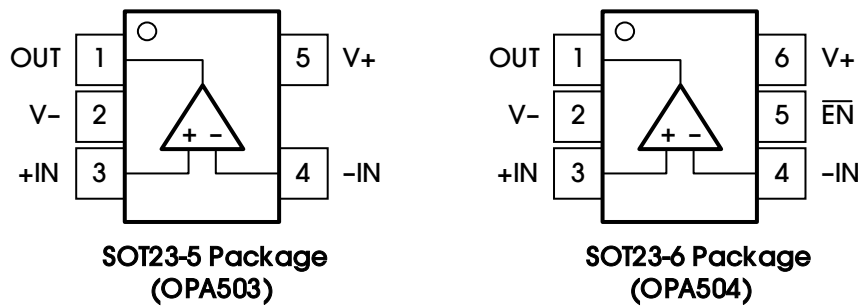


Figure 1. Pin Configuration

Table 3 lists the pin functions.

Table 3. Pin Functions

POSITION		NAME	TYPE	DESCRIPTION
SOT23-5 (OPA503)	SOT23-6 (OPA504)			
1	1	OUT	Output	Output
2	2	V-	Power	Negative (lowest) power supply
3	3	+IN	Input	Positive (non-inverting) input
4	4	-IN	Input	Negative (inverting) input
5	6	V+	Power	Positive (highest) power supply
—	5	EN	Input	Pull to V- to enable operation

5. SPECIFICATIONS

5.1 ABSOLUTE MAXIMUM RATINGS

Table 4 lists the absolute maximum ratings of the OPA503/OPA504.

Table 4. Absolute Maximum Ratings

PARAMETER	DESCRIPTION		MIN	MAX	UNITS
Voltage	Supply		-0.3	6	V
	Signal input pins ⁽²⁾⁽³⁾	Common-mode	(V-) - 0.3	(V+) + 0.3	
		Differential	(V-) - 0.3	(V+) + 0.3	
Current	Signal input pins		-10	10	mA
	Output short-circuit ⁽⁴⁾		Continuous		
Temperature	Operating, T _A		-40	125	°C
	Junction, T _J			150	
	Storage, T _{sta}		-65	150	

Note 1: Stresses beyond those listed under Table 4 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 Table 6. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Note 2: Not to exceed -0.3V or +6.0V on ANY pin, referred to V-.

Note 3: Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond the supply rails should be current-limited to 10mA or less.

Note 4: Short-circuit to V_S / 2, one amplifier per package. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.

5.2 ESD RATINGS

Table 5 lists the ESD ratings of the OPA503/OPA504.

Table 5. ESD Ratings

PARAMETER	SYMBOL	DESCRIPTION	VALUE	UNITS
Electrostatic Discharge	V _(ESD)	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±6000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±2000	

Note 1: The JEDEC document JEP155 indicates that 500V HBM allows safe manufacturing with a standard ESD control process.

Note 2: The JEDEC document JEP157 indicates that 250V CDM allows safe manufacturing with a standard ESD control process.

5.3 RECOMMENDED OPERATING CONDITIONS

Table 6 lists the recommended operating conditions for the OPA503/OPA504.

Table 6. Recommended Operating Conditions

PARAMETER	MIN	NOM	MAX	UNITS
Operating Voltage Range	1.6		5.5	V
Specified Temperature Range	-40		125	°C

5.4 THERMAL INFORMATION

Table 7 lists the thermal information for the OPA503/OPA504.

Table 7. Thermal Information

PARAMETER	SYMBOL	SOT23-5	SOT23-6	UNITS
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	168	169	°C/W
Junction-to-Board Thermal Resistance	$R_{\theta JB}$	39	28	°C/W
Junction-to-Top Characterization Parameter	ψ_{JT}	10	11	°C/W
Junction-to-Board Characterization Parameter	ψ_{JB}	36	28	°C/W
Junction-to-Case (Top) Thermal Resistance	$R_{\theta JC(top)}$	103	109	°C/W
Junction-to-Case (Bottom) Thermal Resistance	$R_{\theta JC(bot)}$	66	59	°C/W

5.5 ELECTRICAL CHARACTERISTICS

Table 8 lists the electrical characteristics of OPA503/OPA504. $T_A = 25^\circ\text{C}$, $V_S = 1.8\text{V}$ to 5V , $V_{CM} = V_{OUT} = V_S / 2$, and $R_L \geq 10\text{M}\Omega$ to $V_S / 2$, unless otherwise noted.

Table 8. Electrical Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OFFSET VOLTAGE						
Input Offset Voltage	V _{OS}	V _S = 1.8V, 3.3V, and 5V, V _{CM} = V _S / 2 or V _{CM} = (V ₊) - 0.9V		±52	±210	μV
Input Offset Drift	ΔV _{OS} /ΔT	V _{CM} = V ₋ , T _A = -40°C to 125°C		1.2		μV/°C
Power-Supply Rejection Ratio	PSRR	V _S = 1.8V to 5V, V _{CM} = V _{DD} /2		15	93	μV/V
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V _{CM}		0		V _{DD}	V
Common-Mode Rejection Ratio	CMRR	(V ₋) ≤ V _{CM} ≤ (V ₊), V _S = 5V	77	94		dB
INPUT BIAS CURRENT						
Input Bias Current	I _B	V _S = 1.8V, V _{CM} = V _S / 2		±100		fA
Input Offset Current	I _{OS}	V _S = 1.8V, V _{CM} = V _S / 2		±100		
INPUT IMPEDANCE						
Differential ⁽¹⁾				3.3		pF
Common Mode ⁽¹⁾				7.2		
NOISE						
Input Voltage Noise	E _n	f = 0.1Hz to 10Hz		9.1		μV _{pp}
Input Voltage Noise Density	e _n	f = 100Hz		214		nV/√Hz
		f = 1kHz		238		
OPEN-LOOP GAIN						
Open-Loop Voltage Gain	A _{OL}	(V ₋) + 0.3V ≤ V _O ≤ (V ₊) - 0.3V, R _L = 100kΩ		120		dB
OUTPUT						
Voltage Output Swing from Positive Rail	V _{OH}	V _S = 1.8V, R _L = 100kΩ to (V ₊) / 2		2	10	mV
Voltage Output Swing from Negative Rail	V _{OL}	V _S = 1.8V, R _L = 100kΩ to (V ₊) / 2		1.5	10	
Short-Circuit Current	I _{SC}	V _S = 3.3V, short to V _S / 2		10		mA
FREQUENCY RESPONSE						
Gain-Bandwidth Product	GBP	C _L = 20pF, R _L = 10MΩ, V _S = 5V		11		kHz
Slew Rate (10% to 90%)	SR	G = 1, Rising Edge, C _L = 20pF, V _S = 5V		3		V/ms
		G = 1, Falling Edge, C _L = 20pF, V _S = 5V		6		
POWER SUPPLY						
Quiescent Current		V _{CM} = V ₋ , I _O = 0, V _S = 3.3V		570	705	nA
Shutdown Current		V _{CM} = V ₋ , I _O = 0, V _S = 3.3V, $\overline{\text{EN}}$ = V _{DD} , OPA504		40	100	nA
LOGIC INPUT						
Enable Input High	V _{IH}		V ₊	V ₊		V
Enable Input Low	V _{IL}			V ₋	V ₋	V

Note: Guaranteed by design.

6. TYPICAL CHARACTERISTICS

$T_A = 25^\circ\text{C}$, $V_S = 3.3\text{V}$, $R_L = 10\text{M}\Omega$ to $V_S / 2$, $C_L = 20\text{pF}$, $V_{CM} = V_S / 2$, unless otherwise specified.

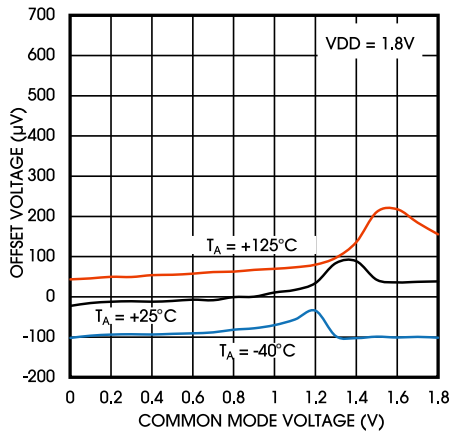


Figure 2. Typical Offset Voltage vs. Common Mode Voltage, 1.8V

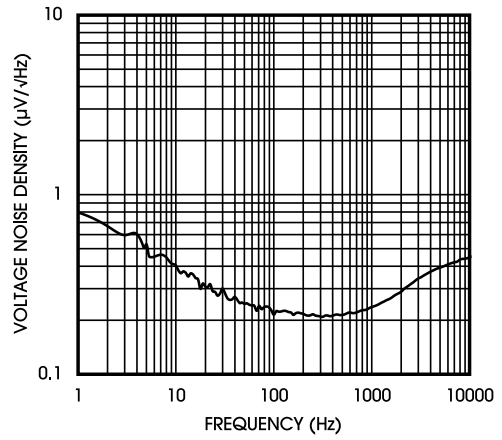


Figure 3. Input Voltage Noise vs. Frequency

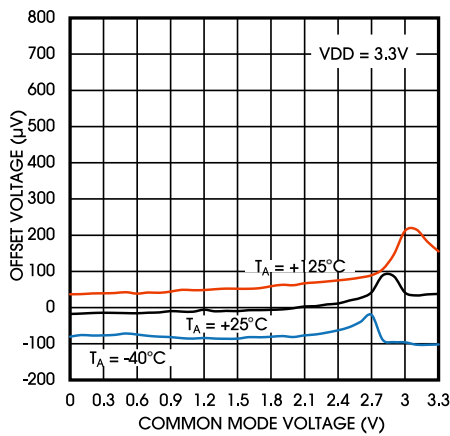


Figure 4. Typical Offset Voltage vs. Common Mode Voltage, 3.3V

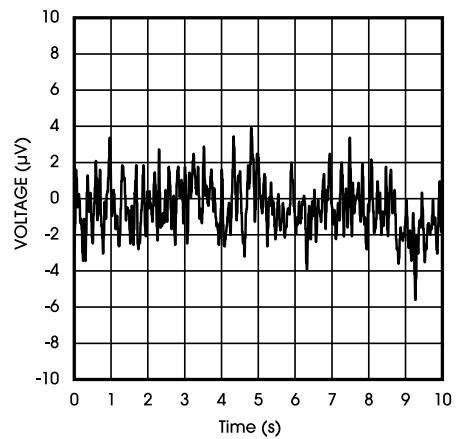


Figure 5. Integrated Noise

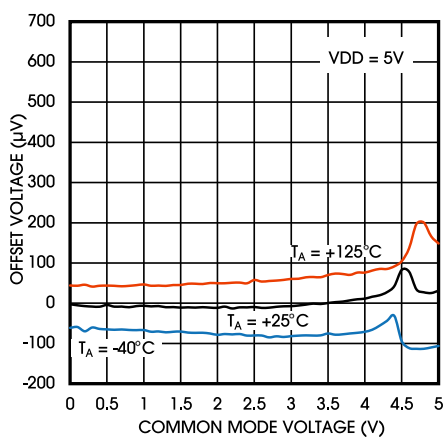


Figure 6. Typical Offset Voltage vs. Common Mode Voltage, 5V

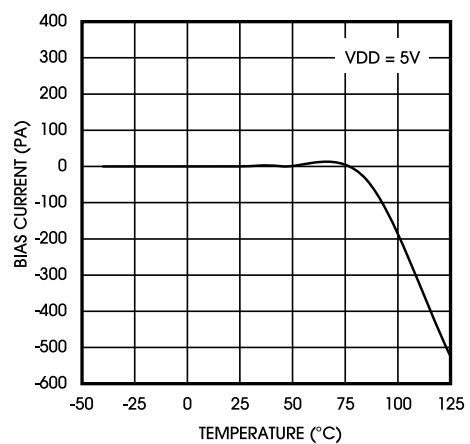


Figure 7. Input Bias Current vs. Temperature

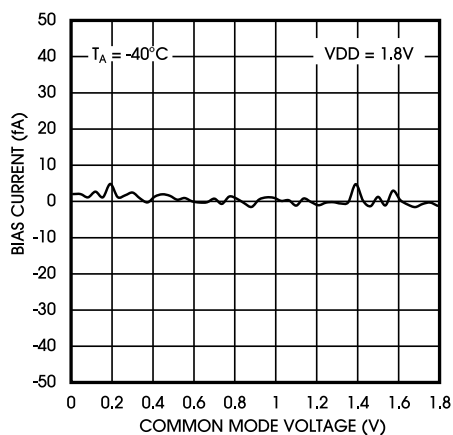


Figure 8. Input Bias Current vs. Common Mode Voltage

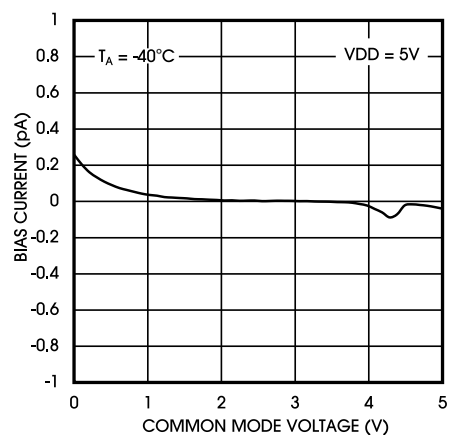


Figure 9. Input Bias Current vs. Common Mode Voltage

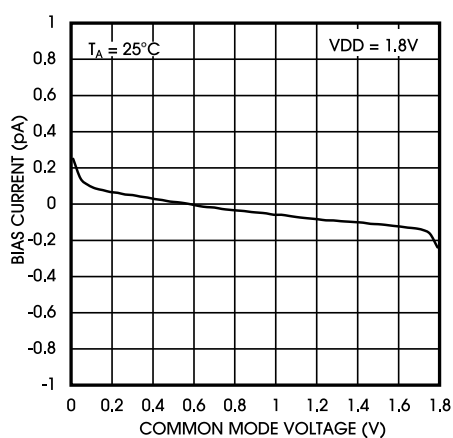


Figure 10. Input Bias Current vs. Common Mode Voltage

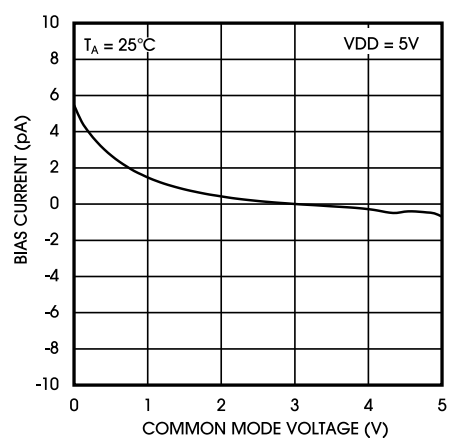


Figure 11. Input Bias Current vs. Common Mode Voltage

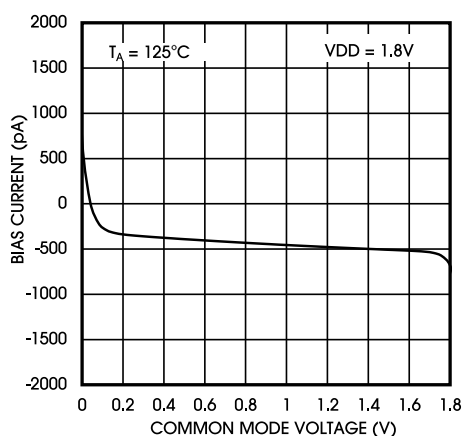


Figure 12. Input Bias Current vs. Common Mode Voltage

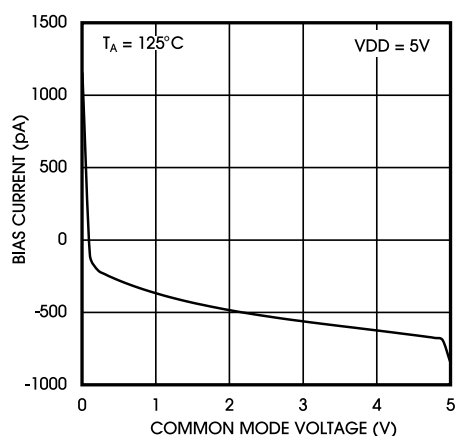


Figure 13. Input Bias Current vs. Common Mode Voltage

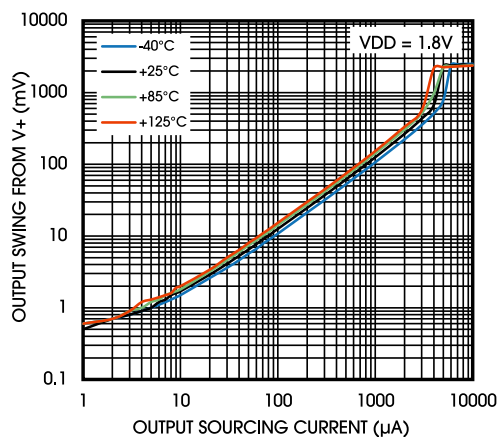


Figure 14. Output Swing vs. Sourcing Current, 1.8V

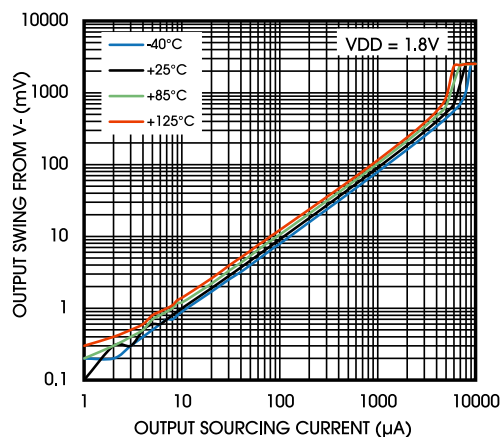


Figure 15. Output Swing vs. Sinking Current, 1.8V

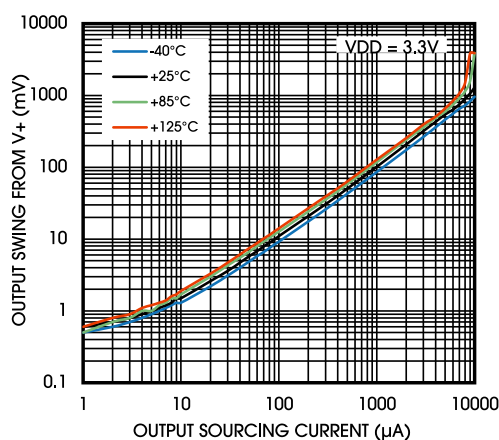


Figure 16. Output Swing vs. Sourcing Current, 3.3V

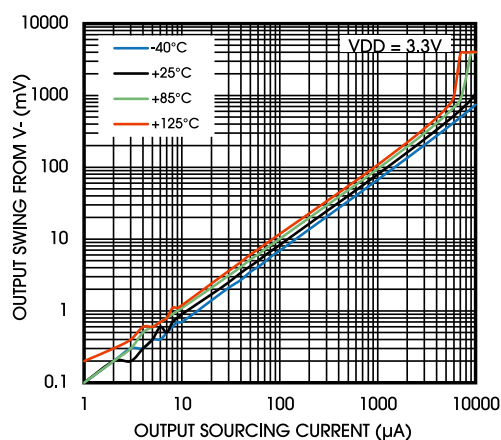


Figure 17. Output Swing vs. Sinking Current, 3.3V

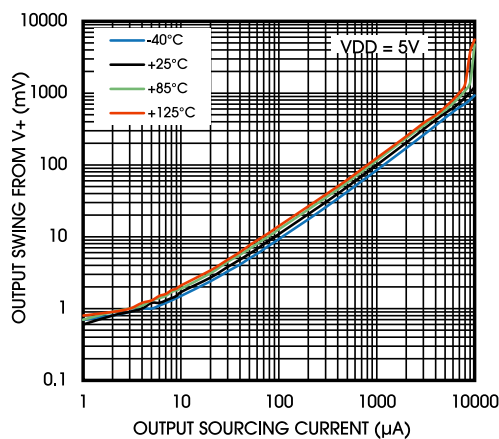


Figure 18. Output Swing vs. Sourcing Current, 5V

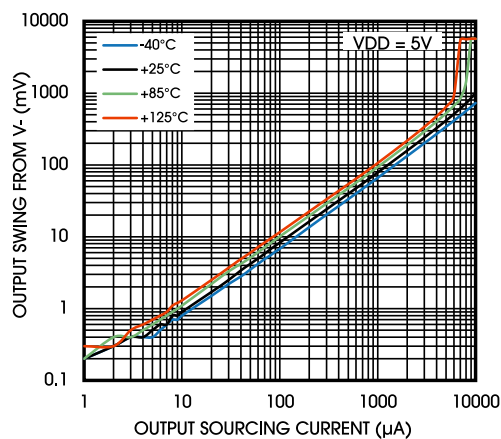


Figure 19. Output Swing vs. Sinking Current, 5V

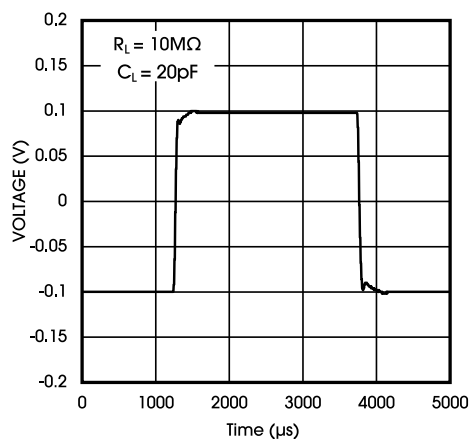


Figure 20. Small Signal Pulse Response, 1.8V

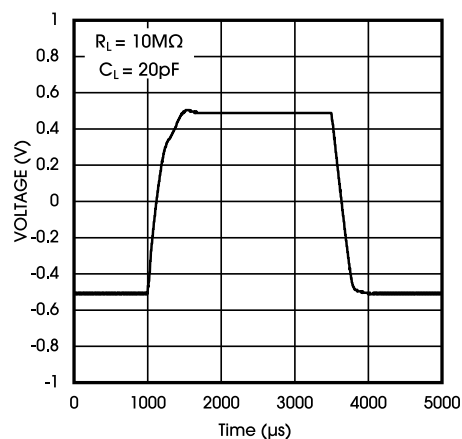


Figure 21. Large Signal Pulse Response, 1.8V

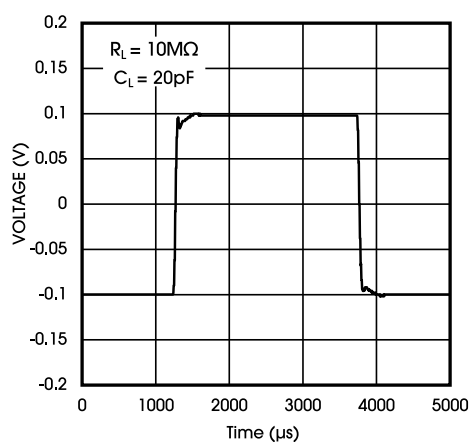


Figure 22. Small Signal Pulse Response, 3.3V

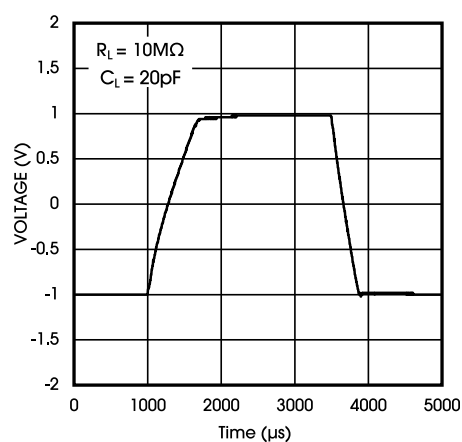


Figure 23. Large Signal Pulse Response, 3.3V

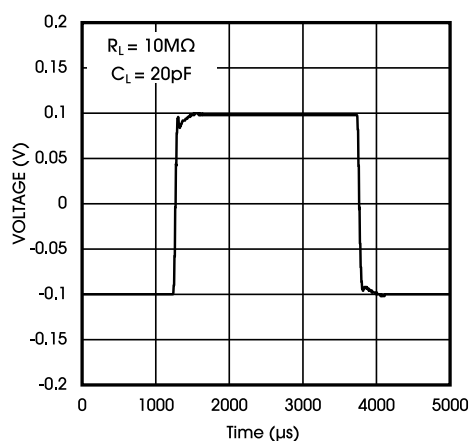


Figure 24. Small Signal Pulse Response, 5V

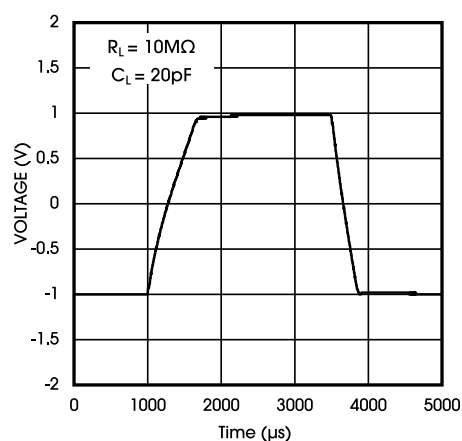


Figure 25. Large Signal Pulse Response, 5V

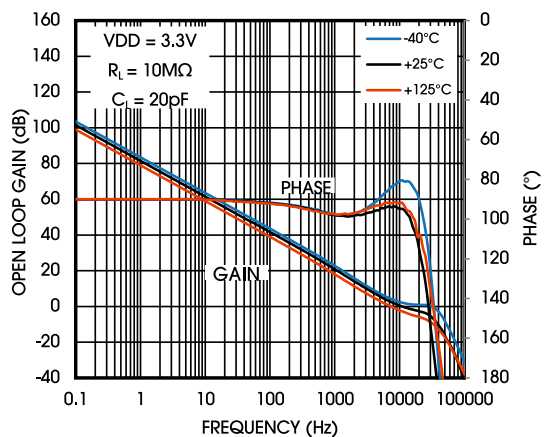


Figure 26. Open Loop Gain and Phase, 3.3V, 10MΩ Load

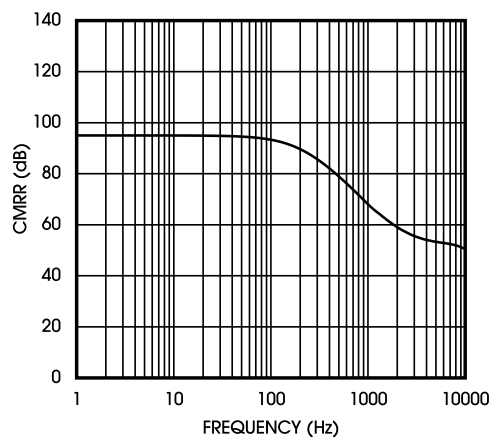


Figure 27. CMRR vs. Frequency

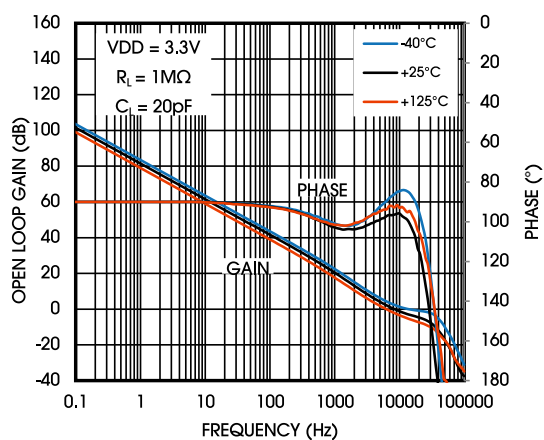


Figure 28. Open Loop Gain and Phase, 3.3V, 1MΩ Load

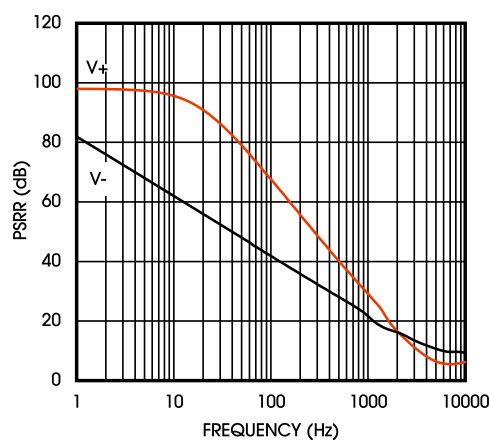


Figure 29. PSRR vs. Frequency

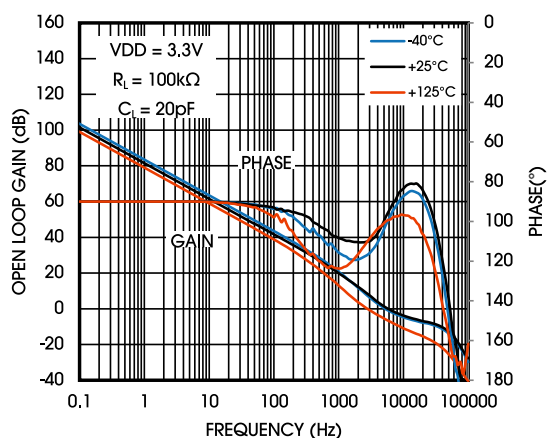


Figure 30. Open Loop Gain and Phase, 3.3V, 100kΩ Load

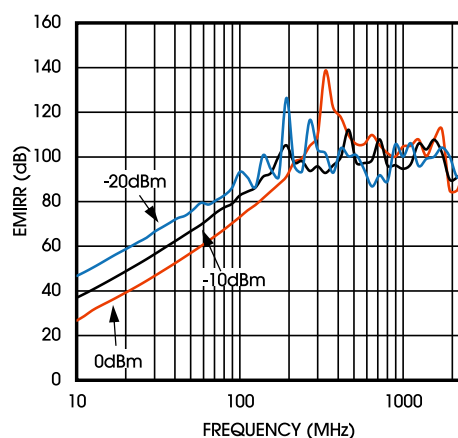


Figure 31. EMIRR Performance

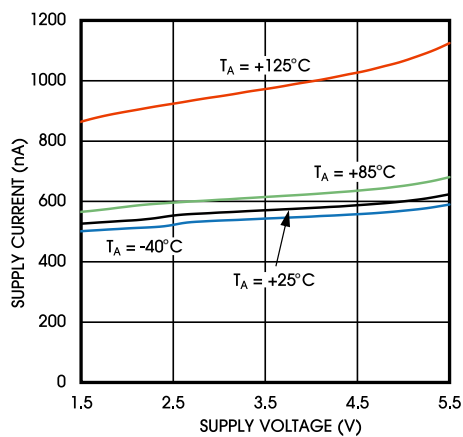


Figure 32. Supply Current vs. Supply Voltage

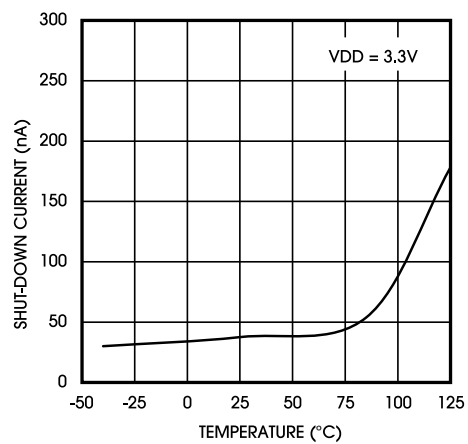


Figure 33. Shut-Down Current vs. Temperature

7. 详细说明

7.1 概述

OPA503/OPA504 毫微功耗 CMOS 运算放大器专为长寿命电池供电和能量收集应用而设计。它们可以采用低至 1.6V 的单电源供电。低输入偏置电流使其成为传感器接口的理想选择，特别是对于以低电压和低频率工作的传感器。共模范围扩展到电源，使其成为单电源应用的理想选择。EMI 保护已在内部采用，以减少 EMI 的影响。

7.2 特性描述

7.2.1 轨到轨输入

OPA503/OPA504 具有轨到轨输入和 100fA 偏置电流，使其成为 CO 和 O₂ 气体检测器等传感器的理想选择。低输入偏置电流有助于减少传感器的误差。有关典型输入偏置电流的信息，请参见 Figure 7 至 Figure 13。

7.2.2 轨到轨输出级

OPA503/OPA504 输出电压在 1.8V 电源下从轨摆动 2mV，从而在输出端提供最大可能的动态范围。这在低电源电压下运行时尤为重要。最大输出电压摆幅图定义了特定输出负载下可能的最大摆幅。请参见 Figure 14 至 Figure 19。

7.2.3 电源

连接一个 100nF 电容尽可能靠近 V₊/V₋引脚，以减少电源纹波。电容的选择需要注意，OPA503/OPA504 是毫微功率器件，在小功率应用中，陶瓷电容的静态漏电流不容忽视，尤其是在高温下。通常高压陶瓷电容的静态漏电流较小，当静态漏电流很重要时使用高压陶瓷电容或薄膜电容。

在针对超低功耗进行设计时，请谨慎选择系统反馈组件。要最大限度地减少静态电流消耗，请选择大值反馈电阻器。任何大电阻都会与电路中的杂散电容和运算放大器的输入电容发生反应。这些寄生 RC 组合会影响整个系统的稳定性。可能需要一个反馈电容器来确保稳定性并限制过冲或增益峰值。如果可能，使用交流耦合和交流反馈来减少通过反馈元件的静态电流消耗。使用薄膜或陶瓷电容器，因为大的电解电容器可能具有纳安级的大静态漏电流。

7.2.4 关断操作

该器件具有低电平有效启用模式，将 $\overline{\text{EN}}$ 引脚拉至 V₋以实现正常操作。要关断器件，请将 $\overline{\text{EN}}$ 引脚拉至 V₊。在关断模式下，静态电流仅为 40nA，功耗显著减低。

强烈建议将 $\overline{\text{EN}}$ 引脚连接到 V₊或 V₋以启用高(V_{IH})或低(V_{IL})阈值电压。将 $\overline{\text{EN}}$ 引脚置于 V₊和 V₋中间可能会导致高电源电流。

7.2.5 驱动容性负载

OPA503/OPA504 针对稳定的单位增益操作进行了内部补偿，具有 11kHz 的典型增益带宽。然而，单位增益跟随器是对容性负载最敏感的配置。直接放置在放大器输出端的容性负载与放大器的输出阻抗相结合会产生相位滞后，从而降低放大器的相位裕度。如果相位裕度显著降低，则响应将欠阻尼，这会导致传输出现峰值，并且当峰值过多时，运算放大器可能会开始振荡。

为了驱动重(> 50pF)容性负载，应使用隔离电阻器 R_{ISO} 。通过使用这个隔离电阻，容性负载与放大器的输出隔离开来。 R_{ISO} 的值越大，放大器越稳定。如果 R_{ISO} 的值足够大，则反馈回路将稳定，与 C_L 的值无关。然而，较大的 R_{ISO} 值会导致输出摆幅降低和输出电流驱动降低。 R_{ISO} 的推荐值为 30-50k Ω 。

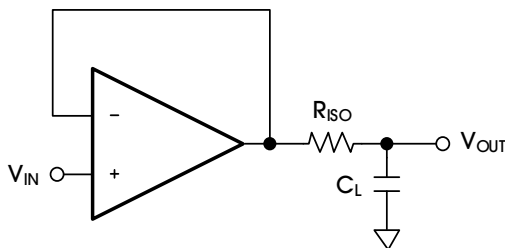


Figure 34. Resistive Isolation of Capacitive Load

7.2.6 PCB 布局建议

注意布局路由。输入和输出端的寄生电容会显著降低相位裕度和带宽。对于单位增益等应用，如果内层或底层有接地屏蔽，建议精细布线，或使用底层代替内层作为接地屏蔽。此外，输入和输出的路由应尽可能短。

8. PACKAGE INFORMATION

8.1 SOT23-5 PACKAGE

Figure 35 shows the SOT23-5 package view.

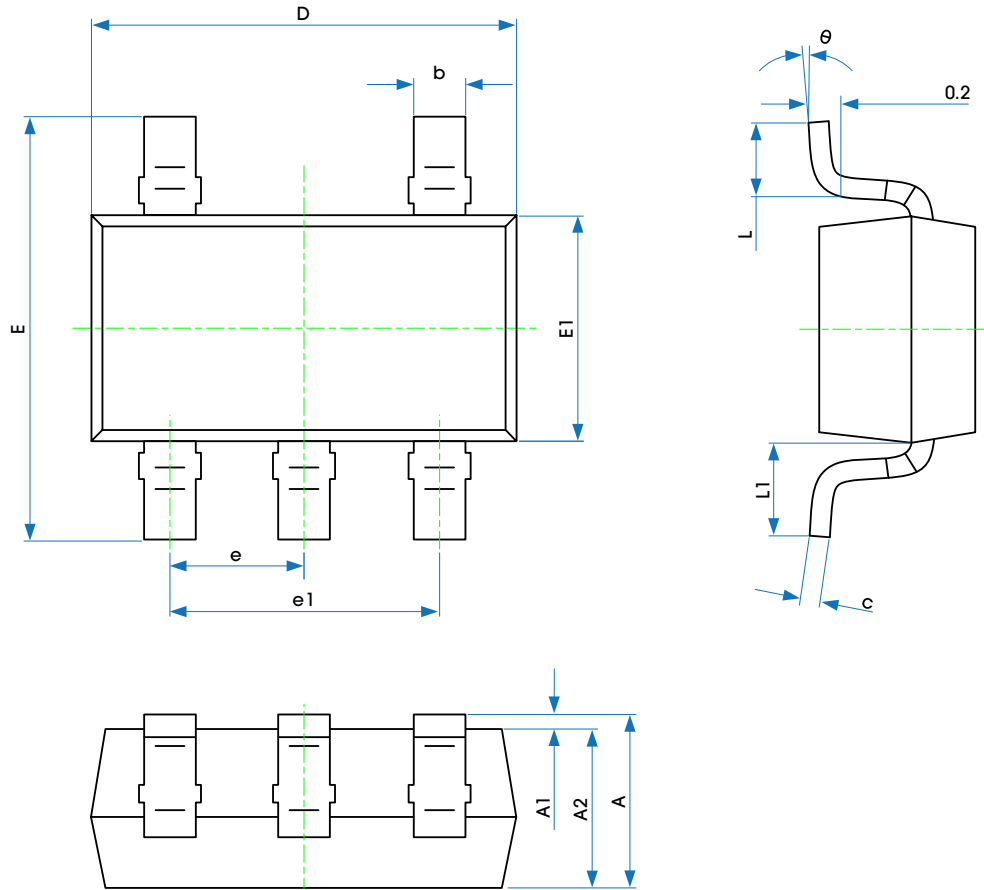


Figure 35. SOT23-5 Package View

Table 9 provides detailed information about the dimensions of the SOT23-5 package.

Table 9. Dimensions of the SOT23-5 Package

SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	2.650	2.950	0.104	0.116
E1	1.500	1.700	0.059	0.067
e	0.950 (BSC)		0.037 (BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
L1	0.600 REF.		0.024 REF.	
θ	0°	8°	0°	8°

8.2 SOT23-6 PACKAGE

Figure 36 shows the SOT23-6 package view.

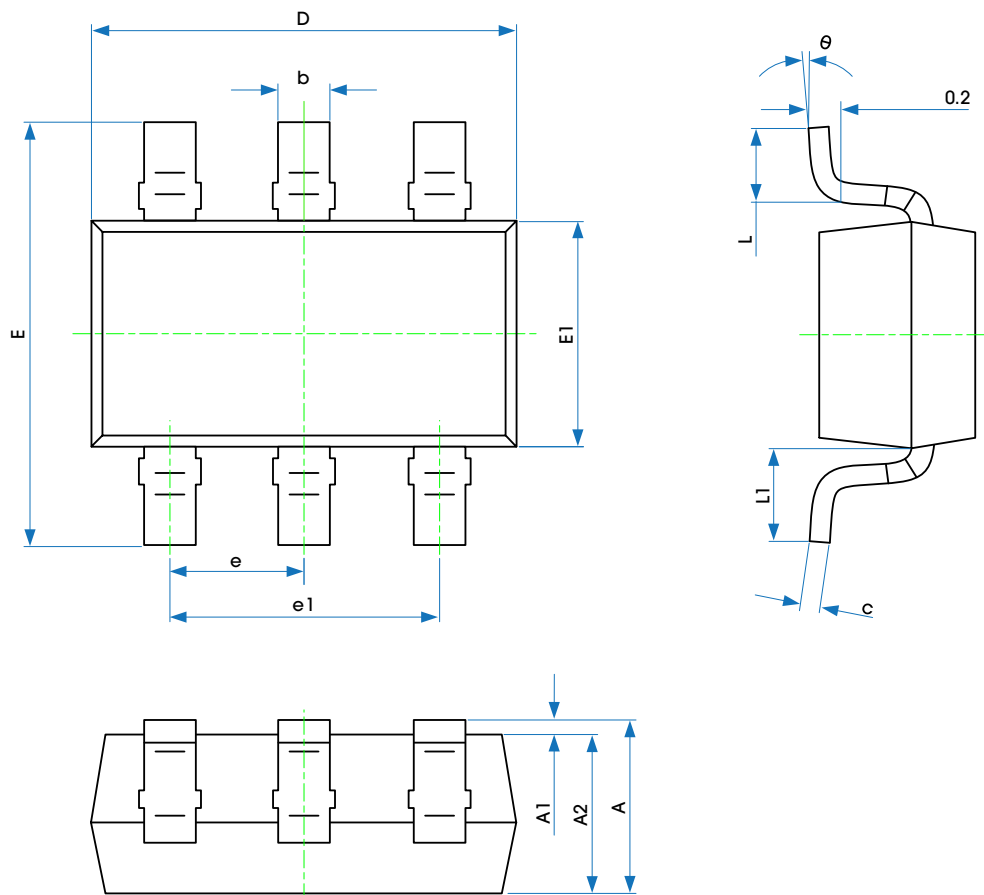


Figure 36. SOT23-6 Package View

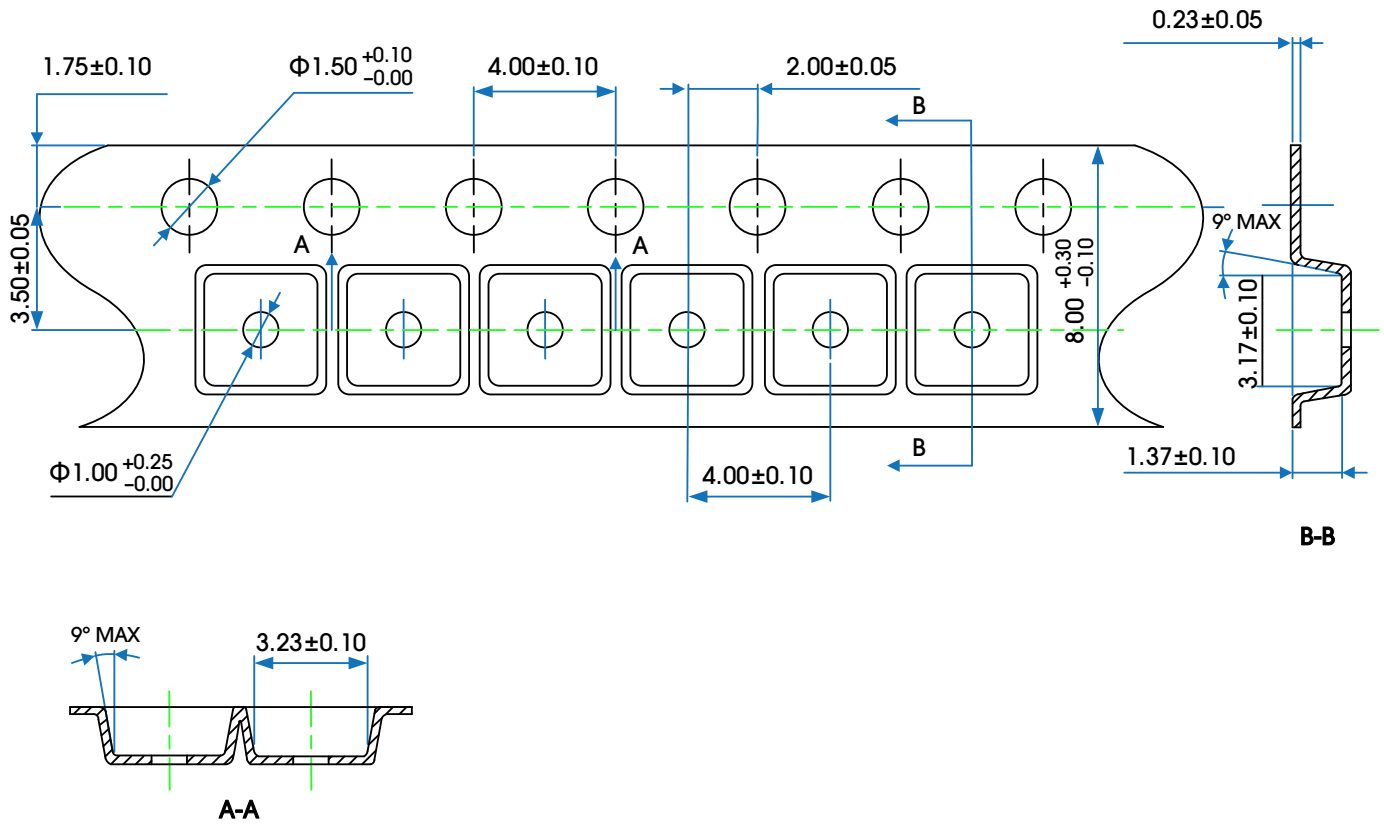
Table 10 provides detailed information about the dimensions of the SOT23-6 package.

Table 10. Dimensions of the SOT23-6 Package

SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	2.650	2.950	0.104	0.116
E1	1.500	1.700	0.059	0.067
e	0.950 (BSC)		0.037 (BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
L1	0.600 REF.		0.024 REF.	
θ	0°	8°	0°	8°

9. TAPE AND REEL INFORMATION

Figure 37 illustrates the carrier tape.



Notes:

1. Cover tape width: 5.50 ± 0.10 .
2. Cumulative tolerance of 10 sprocket hole pitch: ± 0.20 (max).
3. Camber: not to exceed 2mm in 250mm.
4. Mold#: SOT23-5/SOT23-6.
5. All dimensions: mm.
6. Direction of view:

Figure 37. Carrier Tape Drawing

Table 11 provides information about tape and reel.

Table 11. Tape and Reel Information

PACKAGE TYPE	REEL	QTY/REEL	REEL/ INNER BOX	INNER BOX/ CARTON	QTY/CARTON	INNER BOX SIZE (MM)	CARTON SIZE (MM)
SOT23-5 (OPA503)/ SOT23-6 (OPA504)	7"	3000	10	4	120000	210*208*203	440*440*230

Figure 38 shows the product loading orientation—pin 1 is assigned on the lower left corner.

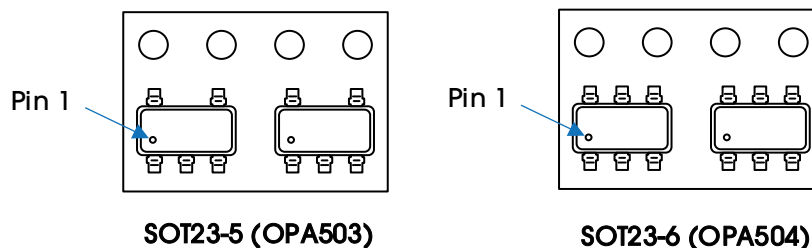


Figure 38. Product Loading Orientation

REVISION HISTORY

REVISION	DATE	DESCRIPTION
Rev B	04 August 2023	Rev B release.