

OPAx241、OPAx251 单电源低功耗运算放大器

1 特性

- OPAx241 系列经优化采用 5V 电源供电
- OPAx251 系列经优化采用 $\pm 15V$ 电源供电
- 低功耗： $I_Q = 25 \mu A$
- 单电源供电
- 轨到轨输出（在 50mV 以内）
- 宽电源电压范围
 - 单电源：2.7V 至 36V
 - 双电源： $\pm 1.35V$ 至 $\pm 18V$
- 低失调电压：最大 $\pm 250 \mu V$
- 高共模抑制：124dB
- 高开环增益：128dB
- 单通道、双通道和四通道

2 应用

- 电池供电型仪表
- 便携式器件
- 医疗仪器
- 测试设备

3 说明

OPA241、OPA2241、OPA4241 (OPAx241) 和 OPA251、OPA2251、OPA4251 (OPAx251) 器件专为电池供电的便携式应用而设计。除了极低的功耗 ($25 \mu A$) 之外，这些放大器还具有低失调电压、轨到轨输出摆幅、高共模抑制和高开环增益。

OPAx241 系列由低电源电压供电，而 OPAx251 系列由高电源电压供电。这两个系列均可采用单电源

(2.7V 至 36V) 或双电源 ($\pm 1.35V$ 至 $\pm 18V$)。输入共模电压范围比负电源电压低 200mV，因此是单电源应用的理想选择。

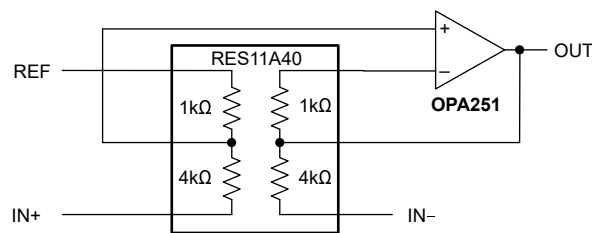
OPAx241 和 OPAx251 具有单位增益稳定特性，可驱动大容量负载。特殊的设计注意事项可确保这些产品易于使用。在放大器的摆幅接近额定限值时，仍可保持高性能。由于初始失调电压非常低（最高 $\pm 250 \mu V$ ），因此通常无需用户调整。但是，仍然为特殊应用提供了外部修整引脚（仅限单通道版本）。

OPAx241 和 OPAx251 的额定温度范围为 $-40^\circ C$ 至 $+85^\circ C$ ，工作温度范围为 $-55^\circ C$ 至 $+125^\circ C$ 。

器件信息

器件型号	通道数	封装 ⁽¹⁾
OPA241	单	D (SOIC, 8)
		P (PDIP, 8)
OPA2241	双	D (SOIC, 8)
		P (PDIP, 8)
OPA4241	四通道	N (PDIP, 14)
		D (SOIC, 14)
OPA251	单	D (SOIC, 8)
OPA2251	双	P (PDIP, 8)
		D (SOIC, 8)
OPA4251	四通道	D (SOIC, 14)

(1) 有关更多信息，请参阅节 9。



高共模、低功耗差分放大器



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4 Pin Configuration and Functions

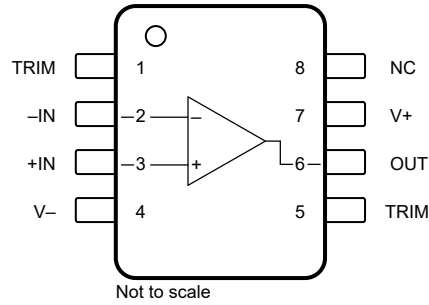


图 4-1. OPA241 and OPA251: D Package, 8-Pin SOIC and P Package, 8-Pin PDIP (Top View)

表 4-1. Pin Functions: OPA241 and OPA251

PIN		TYPE	DESCRIPTION
NAME	NO.		
+IN	3	Input	Noninverting input
-IN	2	Input	Inverting input
NC	8	—	No internal connection (can be left floating)
OUT	6	Output	Output
TRIM	1, 5	—	External offset voltage adjustment. See 节 6.1.2.
V+	7	Power	Positive (highest) power supply
V-	4	Power	Negative (lowest) power supply

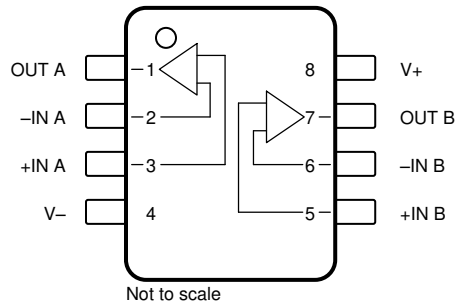


图 4-2. OPA2241 and OPA2251: D Package, 8-Pin SOIC, and P Package, 8-Pin PDIP (Top View)

表 4-2. Pin Functions: OPA2241 and OPA2251

PIN		TYPE	DESCRIPTION
NAME	NO.		
+IN A	3	Input	Noninverting input, channel A
+IN B	5	Input	Noninverting input, channel B
-IN A	2	Input	Inverting input, channel A
-IN B	6	Input	Inverting input, channel B
OUT A	1	Output	Output, channel A
OUT B	7	Output	Output, channel B
V+	8	Power	Positive (highest) power supply
V-	4	Power	Negative (lowest) power supply

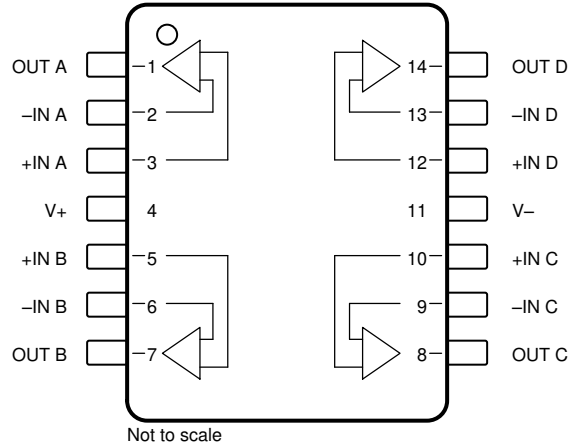


图 4-3. OPA4241 and OPA4251: D Package, 14-Pin SOIC (Top View)

Pin Functions: OPA4241 and OPA4251

PIN		TYPE	DESCRIPTION
NAME	NO.		
+IN A	3	Input	Noninverting input, channel A
+IN B	5	Input	Noninverting input, channel B
+IN C	10	Input	Noninverting input, channel C
+IN D	12	Input	Noninverting input, channel D
- IN A	2	Input	Inverting input, channel A
- IN B	6	Input	Inverting input, channel B
- IN C	9	Input	Inverting input, channel C
- IN D	13	Input	Inverting input, channel D
OUT A	1	Output	Output, channel A
OUT B	7	Output	Output, channel B
OUT C	8	Output	Output, channel C
OUT D	14	Output	Output, channel D
V+	4	Power	Positive (highest) power supply
V-	11	Power	Negative (lowest) power supply

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

			MIN	MAX	UNIT
V _S	Supply voltage, V _S = (V+) - (V-)	Single supply		36	V
		Dual supply		±18	
	Signal input pin voltage	Common-mode ⁽²⁾	(V-) - 0.5	(V+) + 0.5	V
		Differential ⁽³⁾		±0.5	
	Output short-circuit ⁽⁴⁾		Continuous		
T _A	Operating temperature		- 55	125	°C
T _J	Junction temperature			150	°C
T _{stg}	Storage temperature		- 55	125	°C
	Lead temperature (soldering, 10s)			300	°C

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) Input terminals are diode-clamped to the power supply rails. Current-limit input signals that can swing more than 0.5V beyond the supply rails to 5mA or less.
- (3) Input terminals are anti-parallel diode-clamped to each other. Current-limit input signals that cause differential voltage swings of more than ±0.5V to 5mA or less.
- (4) Short-circuit to ground, one amplifier per package.

5.2 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
V _S	Supply voltage, V _S = (V+) - (V-)	Single supply	2.7	30	36	V
		Dual supply	±1.35	±15	±18	
T _A	Operating temperature		- 40		+85	°C

5.3 Thermal Information for OPA241 and OPA251

THERMAL METRIC ⁽¹⁾		OPA241 AND OPA251		UNIT
		D (SOIC)	P (PDIP)	
		8 PINS	8 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	150	100	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	67.6	N/A	°C/W
R _{θJB}	Junction-to-board thermal resistance	75.4	N/A	°C/W
ψ _{JT}	Junction-to-top characterization parameter	15.1	N/A	°C/W
ψ _{JB}	Junction-to-board characterization parameter	74.2	N/A	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

5.4 Thermal Information for OPA2241 and OPA2251

THERMAL METRIC ⁽¹⁾		OPA2241 AND OPA2251		UNIT
		D (SOIC)	P (PDIP)	
		8 PINS	8 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	150	100	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	61.0	N/A	°C/W
R _{θJB}	Junction-to-board thermal resistance	68.3	N/A	°C/W
ψ _{JT}	Junction-to-top characterization parameter	10.8	N/A	°C/W
ψ _{JB}	Junction-to-board characterization parameter	67.4	N/A	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

5.5 Thermal Information for OPA4241 and OPA4251

THERMAL METRIC ⁽¹⁾		OPA4241 AND OPA4251		UNIT
		D (SOIC)	P (PDIP)	
		14 PINS	14 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	100	80	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	N/A	N/A	°C/W
R _{θJB}	Junction-to-board thermal resistance	N/A	N/A	°C/W
ψ _{JT}	Junction-to-top characterization parameter	N/A	N/A	°C/W
ψ _{JB}	Junction-to-board characterization parameter	N/A	N/A	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

5.6 Electrical Characteristics for $V_S = 2.7V$ to $5V$

at $T_A = 25^\circ\text{C}$, $V_{CM} = V_{OUT} = \text{midsupply}$, and $R_L = 100\text{k}\Omega$ connected to $V_S / 2$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
OFFSET VOLTAGE								
V_{OS}	Input offset voltage	OPAx241			± 50	± 250	μV	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		± 100	± 400		
		OPAx251			± 100			
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		± 130			
dV_{OS}/dT	Input offset voltage drift	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	OPAx241		± 0.4		$\mu\text{V}/^\circ\text{C}$	
			OPAx251		± 0.6			
PSRR	Power supply rejection ratio	$V_S = 2.7V$ to $36V$			± 3	± 30	$\mu\text{V}/V$	
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$					± 30
	Channel separation, (dual, quad)				0.3		$\mu\text{V}/V$	
INPUT BIAS CURRENT								
I_B	Input bias current ⁽¹⁾				-4	-20	nA	
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$						-25
I_{OS}	Input offset current				± 0.1	± 2	nA	
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$						± 2
NOISE								
	Input voltage noise	$f = 0.1\text{Hz}$ to 10Hz			1.7		μV_{PP}	
e_n	Input voltage noise density	$f = 1\text{kHz}$			65		$\text{nV}/\sqrt{\text{Hz}}$	
i_n	Input current noise density	$f = 1\text{kHz}$			40		$\text{fA}/\sqrt{\text{Hz}}$	
INPUT VOLTAGE								
V_{CM}	Common-mode voltage			-0.2		$(V+) - 0.8$	V	
CMRR	Common-mode rejection ratio	$-0.2V < V_{CM} < (V+) - 0.8V$		80	106		dB	
		$0V < V_{CM} < (V+) - 0.8V$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$		80				
INPUT IMPEDANCE								
Z_{IN}	Input impedance	Differential			$10 \parallel 3.75$		$\text{M}\Omega \parallel \text{pF}$	
		Common-mode			$1 \parallel 4$		$\text{G}\Omega \parallel \text{pF}$	
OPEN-LOOP GAIN								
A_{OL}	Open-loop voltage gain	$(V-) + 100\text{mV} < V_O < (V+) - 100\text{mV}$			100	120	dB	
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		100			
		$(V-) + 200\text{mV} < V_O < (V+) - 200\text{mV}$, $R_L = 10\text{k}\Omega$			100	120		
			$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		100			
FREQUENCY RESPONSE								
GBW	Gain-bandwidth product				35		kHz	
SR	Slew rate	$V_S = 5V$, $G = 1V/V$			0.01		$V/\mu\text{s}$	
	Overload recovery time	$V_S = V_{IN} \times G$			80		μs	

5.6 Electrical Characteristics for $V_S = 2.7V$ to $5V$ (续)

at $T_A = 25^\circ C$, $V_{CM} = V_{OUT} = \text{mid supply}$, and $R_L = 100k\Omega$ connected to $V_S / 2$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT	
OUTPUT							
Voltage output swing from rail ⁽²⁾	$A_{OL} > 70dB$			50		mV	
				75	100		
	$A_{OL} > 100dB$	$T_A = -40^\circ C$ to $+85^\circ C$			100		
				100	200		
$A_{OL} > 100dB, R_L = 10k\Omega,$	$T_A = -40^\circ C$ to $+85^\circ C$			200			
				200			
I_{SC}	Short-circuit current	Source, $V_S = 5V$	Single	4		mA	
			Dual and Quad	4			
	Sink, $V_S = 5V$	Single	-24				
		Dual and Quad	-24				
C_{LOAD}	Capacitive load drive		See Typical Characteristics				
POWER SUPPLY							
I_Q	Quiescent current per amplifier	$I_O = 0mA$		± 25	± 30	μA	
			$T_A = -40^\circ C$ to $+85^\circ C$		± 36		

- (1) The negative sign indicates input bias current flows out of the input terminals.
- (2) Output voltage swings are measured between the output and power supply rails.

5.7 Electrical Characteristics for $V_S = \pm 15V$

at $T_A = 25^\circ C$, $V_{CM} = V_{OUT} = \text{midsupply}$, and $R_L = 100k\Omega$ connected to $V_S / 2$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
OFFSET VOLTAGE								
V_{OS}	Input offset voltage	OPAx241			± 100		μV	
			$T_A = -40^\circ C \text{ to } +85^\circ C$		± 150			
		OPAx251			± 50	± 250		
			$T_A = -40^\circ C \text{ to } +85^\circ C$		± 100	± 300		
dV_{OS}/dT	Input offset voltage drift	$T_A = -40^\circ C \text{ to } +85^\circ C$	OPAx241		± 0.6		$\mu V/^\circ C$	
			OPAx251		± 0.5			
PSRR	Power supply rejection ratio	$V_S = 2.7V \text{ to } 36V$			± 3	± 30	$\mu V/V$	
			$T_A = -40^\circ C \text{ to } +85^\circ C$					± 30
	Channel separation, (dual, quad)				0.3		$\mu V/V$	
INPUT BIAS CURRENT								
I_B	Input bias current ⁽¹⁾				-4	-20	nA	
		$T_A = -40^\circ C \text{ to } +85^\circ C$				-25		
I_{OS}	Input offset current				± 0.1	± 2	nA	
		$T_A = -40^\circ C \text{ to } +85^\circ C$						± 2
NOISE								
	Input voltage noise	$f = 0.1Hz \text{ to } 10Hz$			1.7		μV_{PP}	
e_n	Input voltage noise density	$f = 1kHz$			65		nV/\sqrt{Hz}	
i_n	Input current noise density	$f = 1kHz$			40		fA/\sqrt{Hz}	
INPUT VOLTAGE								
V_{CM}	Common-mode voltage			$(V_-) - 0.2$		$(V_+) - 0.8$	V	
CMRR	Common-mode rejection ratio	$-15.2V < V_{CM} < (V_+) - 14.2V$		100	124		dB	
		$-15V < V_{CM} < (V_+) - 14.2V$	$T_A = -40^\circ C \text{ to } +85^\circ C$	100				
INPUT IMPEDANCE								
Z_{IN}	Input impedance	Differential			$10 \parallel 3.75$		$M\Omega \parallel pF$	
		Common-mode			$1 \parallel 4$		$G\Omega \parallel pF$	
OPEN-LOOP GAIN								
A_{OL}	Open-loop voltage gain	$(V_-) + 250mV < V_O < (V_+) - 250mV$		100	128		dB	
			$T_A = -40^\circ C \text{ to } +85^\circ C$		100			
		$(V_-) + 300mV < V_O < (V_+) - 300mV, R_L = 20k\Omega$		100	128			
			$T_A = -40^\circ C \text{ to } +85^\circ C$		100			
FREQUENCY RESPONSE								
GBW	Gain-bandwidth product				30		kHz	
SR	Slew rate	$V_S = 5V, G = 1V/V$			0.01		$V/\mu s$	
	Overload recovery time	$V_S = V_{IN} \times G$			75		μs	

5.7 Electrical Characteristics for $V_S = \pm 15V$ (续)

at $T_A = 25^\circ C$, $V_{CM} = V_{OUT} = \text{mid supply}$, and $R_L = 100k\Omega$ connected to $V_S / 2$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT	
OUTPUT							
Voltage output swing from rail ⁽²⁾	$A_{OL} > 100dB$			50		mV	
				75	250		
	$A_{OL} > 100dB$	$T_A = -40^\circ C \text{ to } +85^\circ C$			250		
				100	300		
$A_{OL} > 100dB, R_L = 20k\Omega,$	$T_A = -40^\circ C \text{ to } +85^\circ C$				300		
					300		
I_{SC}	Short-circuit current	Source	Single		4	mA	
			Dual		4		
	Sink	Single		- 21			
		Dual		- 27			
C_{LOAD}	Capacitive load drive		See Typical Characteristics				
POWER SUPPLY							
I_Q	Quiescent current per amplifier	$I_O = 0mA$		± 27	± 38	μA	
			$T_A = -40^\circ C \text{ to } +85^\circ C$		± 45		

- (1) The negative sign indicates input bias current flows out of the input terminals.
- (2) Output voltage swings are measured between the output and power supply rails.

5.8 Typical Characteristics

at $T_A = +25^\circ\text{C}$, $R_L = 100\text{k}\Omega$ connected to $V_S/2$ (ground for $V_S = \pm 15\text{V}$), and curves apply to OPA241 and OPA251 (unless otherwise specified)

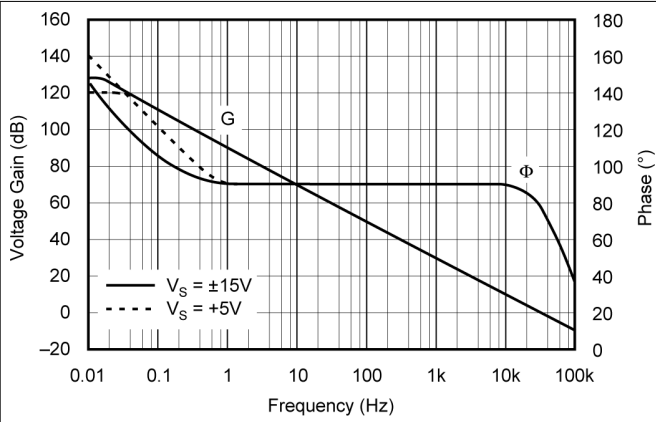


图 5-1. Open-Loop Gain and Phase vs Frequency

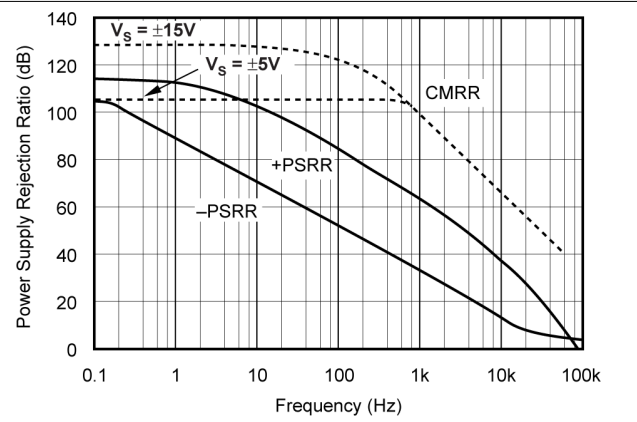


图 5-2. Power Supply and Common-mode Rejection Ratio vs Frequency

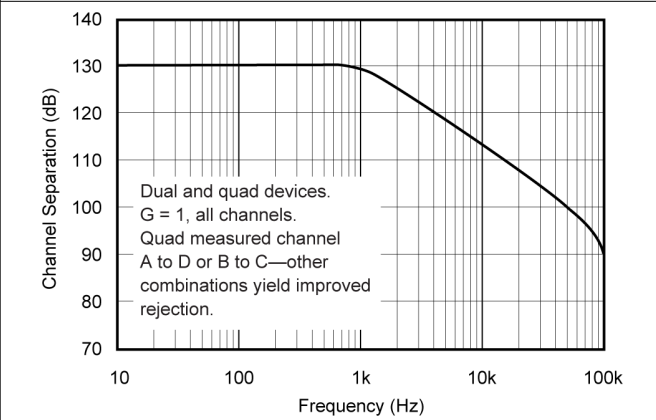


图 5-3. Channel Separation vs Frequency

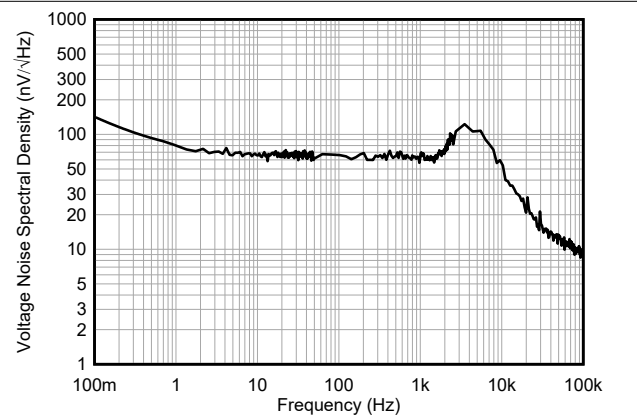


图 5-4. Input Voltage Noise Spectral Density vs Frequency

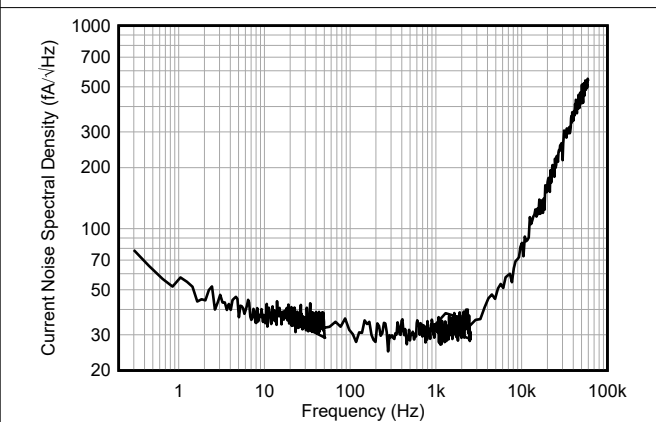


图 5-5. Input Current Noise Spectral Density vs Frequency

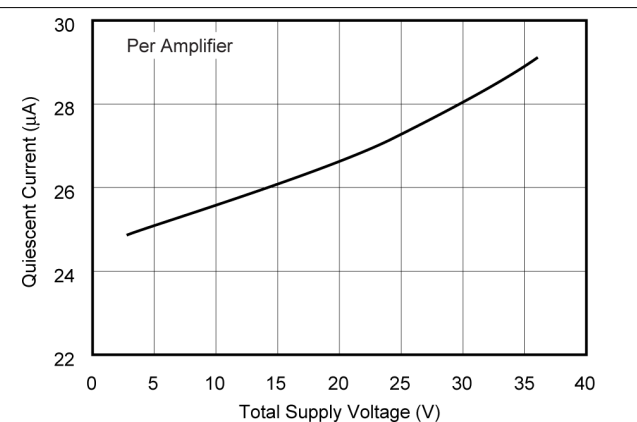


图 5-6. Quiescent Current vs Supply Voltage

5.8 Typical Characteristics (continued)

at $T_A = +25^\circ\text{C}$, $R_L = 100\text{k}\Omega$ connected to $V_S/2$ (ground for $V_S = \pm 15\text{V}$), and curves apply to OPA241 and OPA251 (unless otherwise specified)

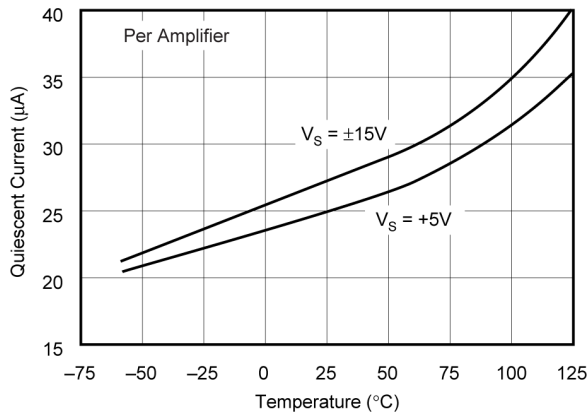


图 5-7. Quiescent Current vs Temperature

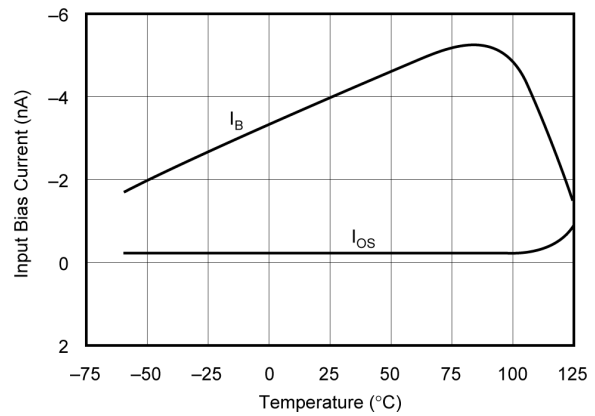


图 5-8. Input Bias Current vs Temperature

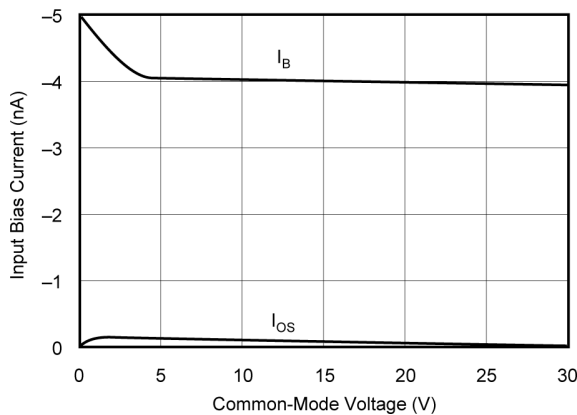


图 5-9. Input Bias Current vs Input Common-mode Voltage

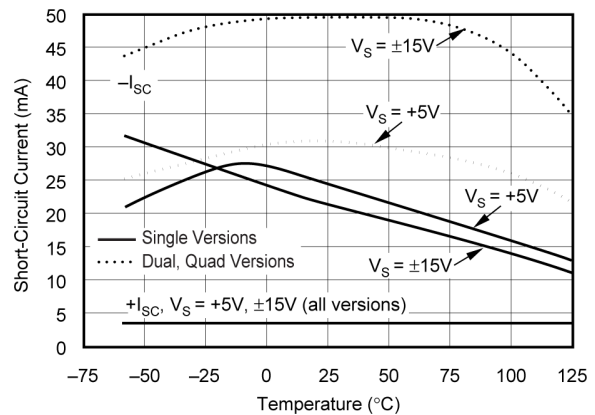


图 5-10. Short-circuit Current vs Temperature

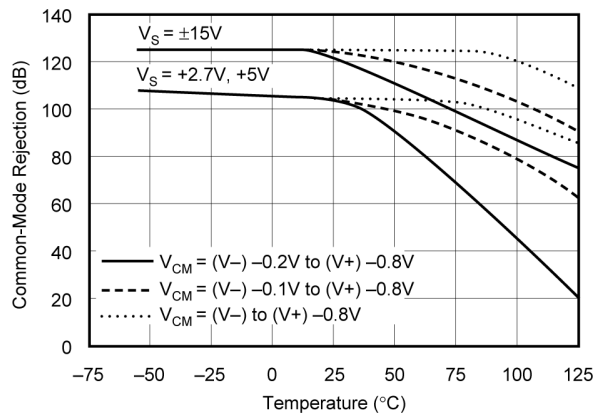


图 5-11. Common-mode Rejection vs Temperature

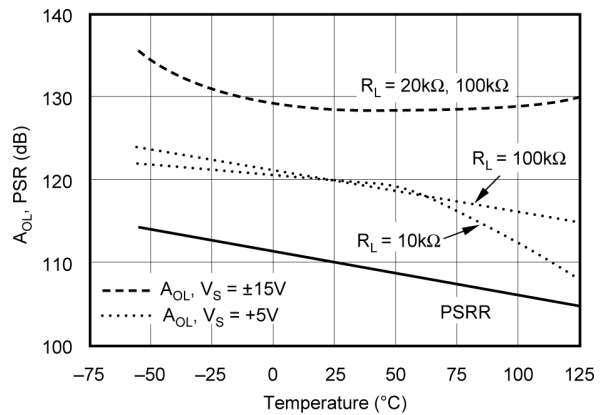


图 5-12. Open-loop Gain and Power Supply Rejection vs Temperature

5.8 Typical Characteristics (continued)

at $T_A = +25^\circ\text{C}$, $R_L = 100\text{k}\Omega$ connected to $V_S/2$ (ground for $V_S = \pm 15\text{V}$), and curves apply to OPA241 and OPA251 (unless otherwise specified)

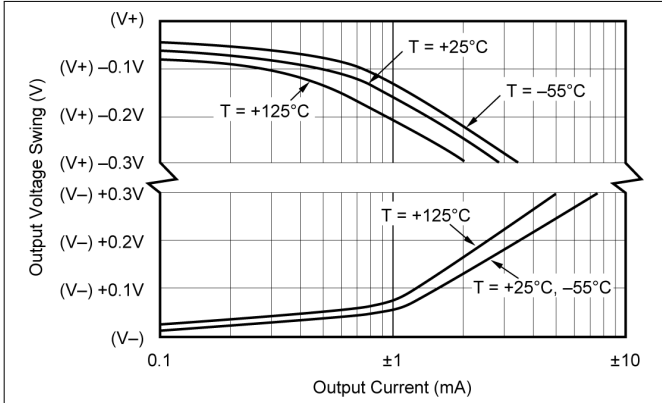


图 5-13. Output Voltage Swing vs Output Current

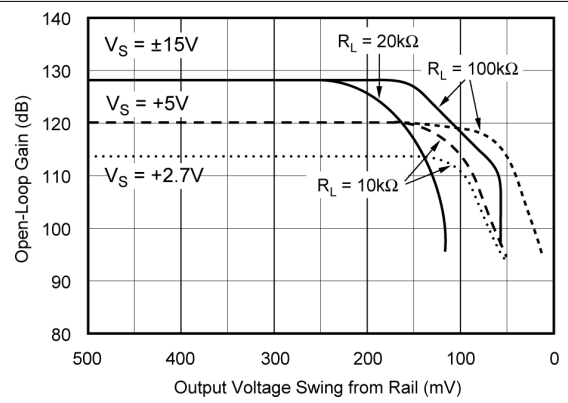


图 5-14. Open-loop Gain vs Output Voltage Swing

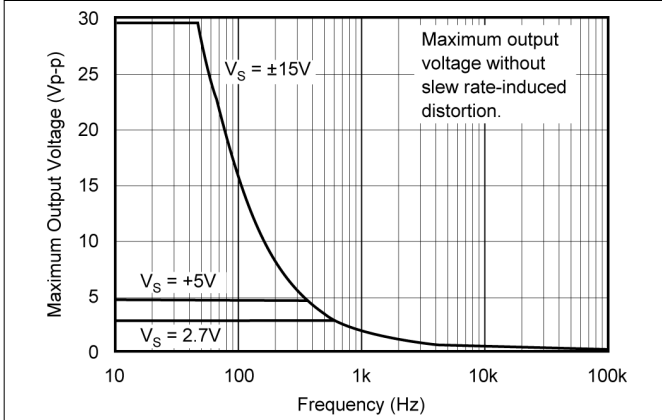


图 5-15. Maximum Output Voltage vs Frequency

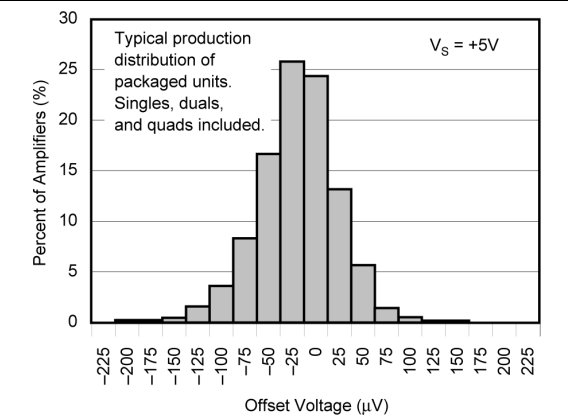


图 5-16. OPA241 Series Offset Voltage Production Distribution

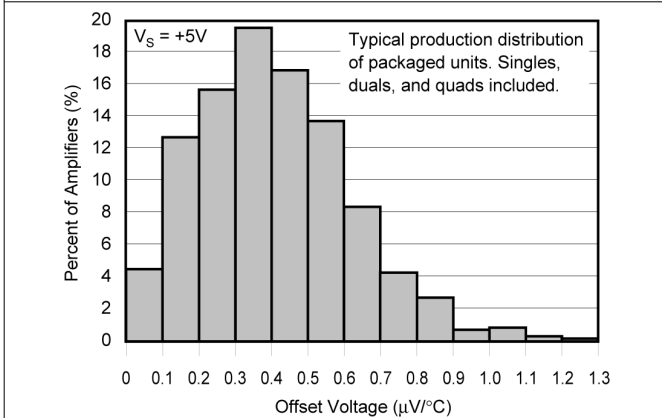


图 5-17. OPA241 Series Offset Voltage Drift Production Distribution

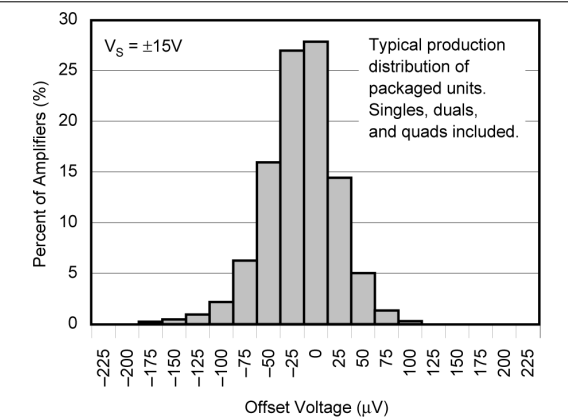


图 5-18. OPA251 Series Offset Voltage Production Distribution

5.8 Typical Characteristics (continued)

at $T_A = +25^\circ\text{C}$, $R_L = 100\text{k}\Omega$ connected to $V_S/2$ (ground for $V_S = \pm 15\text{V}$), and curves apply to OPA241 and OPA251 (unless otherwise specified)

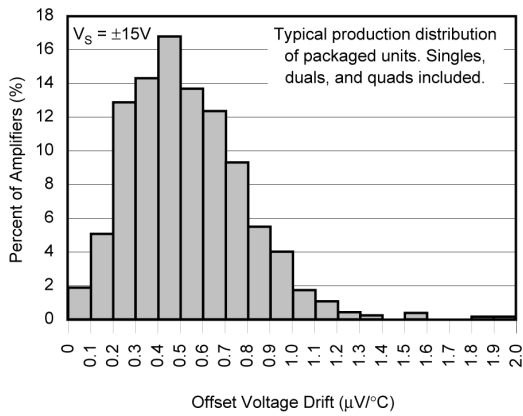


图 5-19. OPA251 Series Offset Voltage Drift Production Distribution

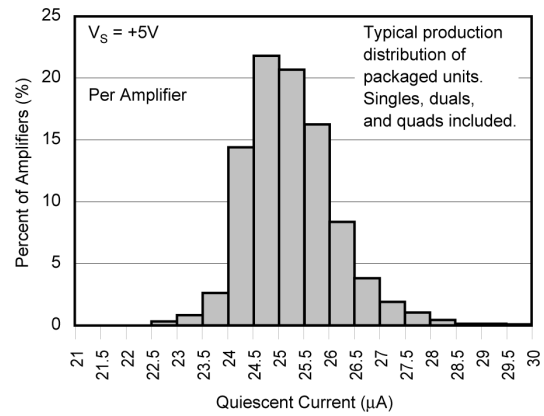


图 5-20. Quiescent Current Product Distribution

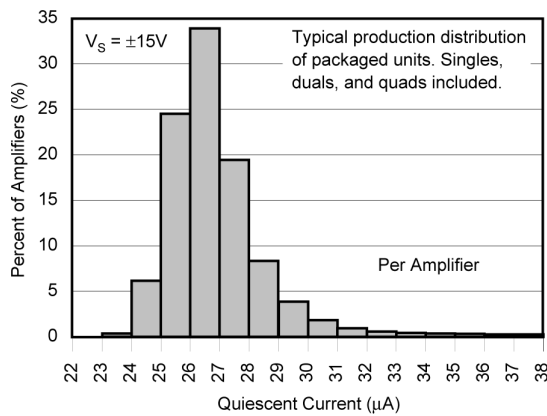
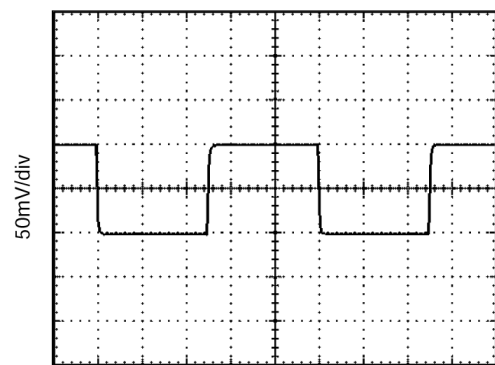
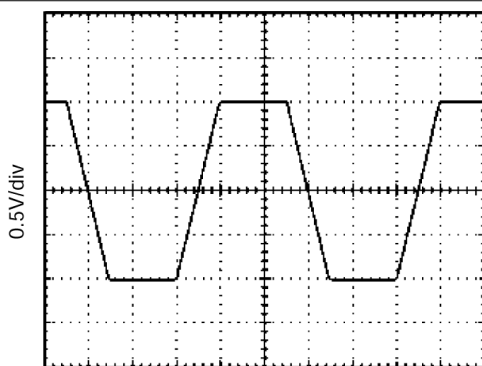


图 5-21. Quiescent Current Production Distribution



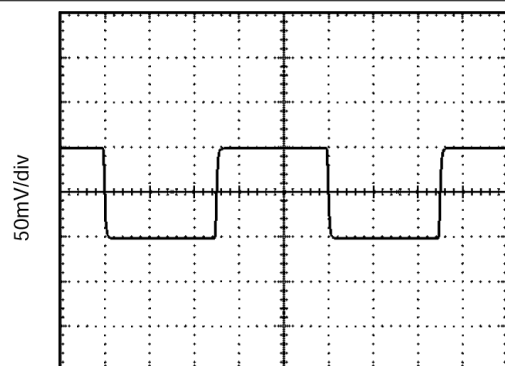
$V_S = 5\text{V}$, $G = +1$, $R_L = 100\text{k}\Omega$, $C_L = 100\text{pF}$

图 5-22. OPA241 Small-Signal Step Response



$V_S = 5\text{V}$, $G = +1$, $R_L = 100\text{k}\Omega$, $C_L = 100\text{pF}$

图 5-23. OPA241 Large-Signal Step Response

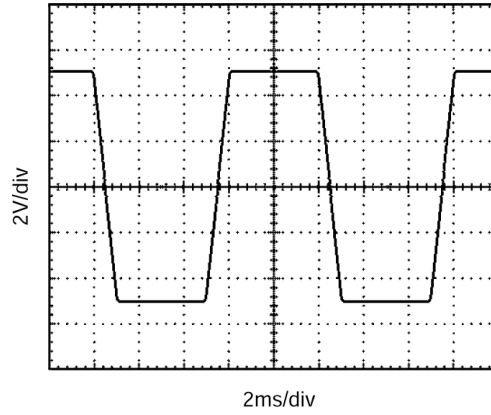


$V_S = \pm 15\text{V}$, $G = +1$, $R_L = 100\text{k}\Omega$, $C_L = 500\text{pF}$

图 5-24. OPA251 Small-Signal Step Response

5.8 Typical Characteristics (continued)

at $T_A = +25^\circ\text{C}$, $R_L = 100\text{k}\Omega$ connected to $V_S/2$ (ground for $V_S = \pm 15\text{V}$), and curves apply to OPA241 and OPA251 (unless otherwise specified)



$V_S = \pm 15\text{V}$, $G = +1$, $R_L = 100\text{k}\Omega$, $C_L = 500\text{pF}$

图 5-25. OPA251 Large-Signal Step Response

6 Application and Implementation

备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

6.1 Applications Information

The OPAX241 and OPAX251 series are unity-gain stable and designed for a wide range of general-purpose applications. Bypass power-supply pins with $0.01\ \mu\text{F}$ ceramic capacitors.

6.1.1 Operating Voltage

The OPAX241 series is laser-trimmed for low offset voltage and drift at a low supply voltage ($V_S = 5\text{V}$). The OPAX251 series is trimmed for $\pm 15\text{V}$ operation. Both series operate over the full voltage range (2.7V to 36V or $\pm 1.35\text{V}$ to $\pm 18\text{V}$) with some compromises in offset voltage and drift performance. However, all other parameters have similar performance. Key parameters are production tested over the specified temperature range of -40°C to $+85^\circ\text{C}$. Most behavior remains unchanged throughout the full operating voltage range. The typical characteristics curves show parameters that vary significantly with operating voltage or temperature.

6.1.2 Offset Voltage Trim

As previously mentioned, the OPAX241 series offset voltage is laser-trimmed at 5V . The OPAX251 series is trimmed at $\pm 15\text{V}$. The initial offset is so low that user adjustment is usually not required. However, the OPA241 and OPA251 (single op-amp versions) provide offset voltage trim connections on pins 1 and 5. 图 6-1 shows how the offset voltage can be adjusted by connecting a potentiometer. Only use this adjustment to null the offset of the op amp, not to adjust system offset or offset produced by the signal source. Nulling offset can degrade the offset drift behavior of the op amp. While predicting the exact change in drift is not possible, the effect is usually small.

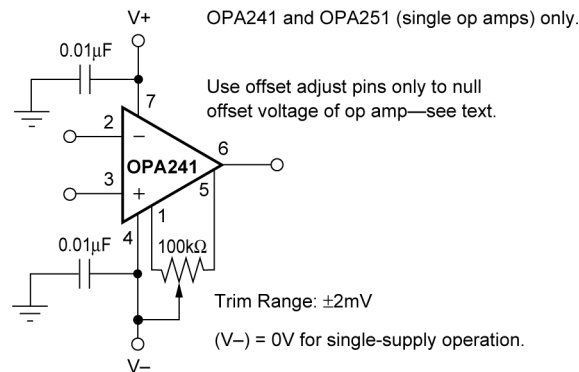


图 6-1. OPA241 and OPA251 Offset Voltage Trim Circuit

6.1.3 Capacitive Load and Stability

The OPAX241 series and OPAX251 series can drive a wide range of capacitive loads. However, all op amps under certain conditions can be unstable. Op amp configuration, gain, and load value are just a few of the factors to consider when determining stability.

图 6-2 和 图 6-3 show the regions where the OPAX241 series and OPAX251 series have the potential for instability. As shown, the unity gain configuration with low supplies is the most susceptible to the effects of capacitive load. With $V_S = 5\text{V}$, $G = 1$, and $I_{\text{OUT}} = 0$, operation remains stable with load capacitance up to approximately 200pF . Increasing a combination of supply voltage, output current, and gain significantly improves capacitive load drive. For example, increasing the supplies to $\pm 15\text{V}$ and gain to 10 drives approximately 2700pF .

图 6-4 显示了一种在单位增益配置中通过插入电阻器来改善电容负载驱动的方法。这可以减少大电容负载时的振铃，同时保持直流精度。例如，在 $V_S = \pm 1.35V$ 且 $R_S = 5k\Omega$ 的情况下，OPA241 系列和 OPA251 系列在大电容负载（超过 1000pF）的情况下表现良好。如果没有串联电阻器，电容负载驱动通常为 200pF。然而，这种方法会导致输出电压摆幅略有减小。

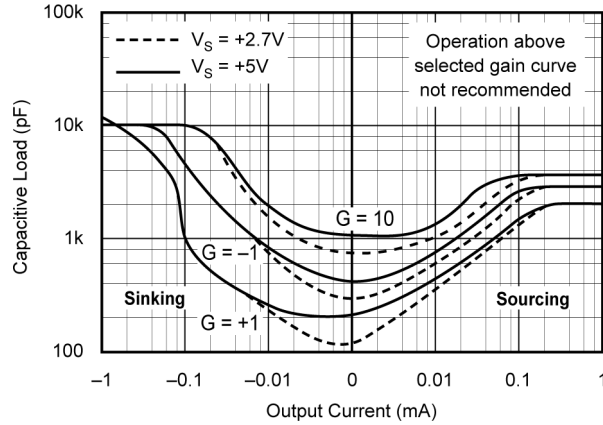


图 6-2. Stability—Capacitive Load vs Output Current for Low Supply Voltage

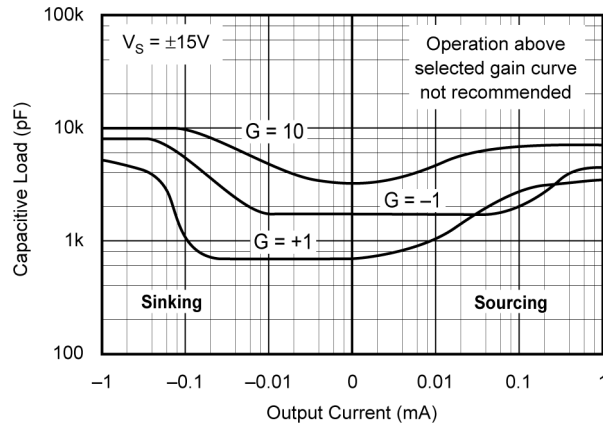


图 6-3. Stability—Capacitive Load vs Output Current for $\pm 15V$ Supplies

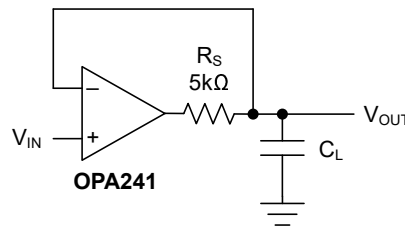
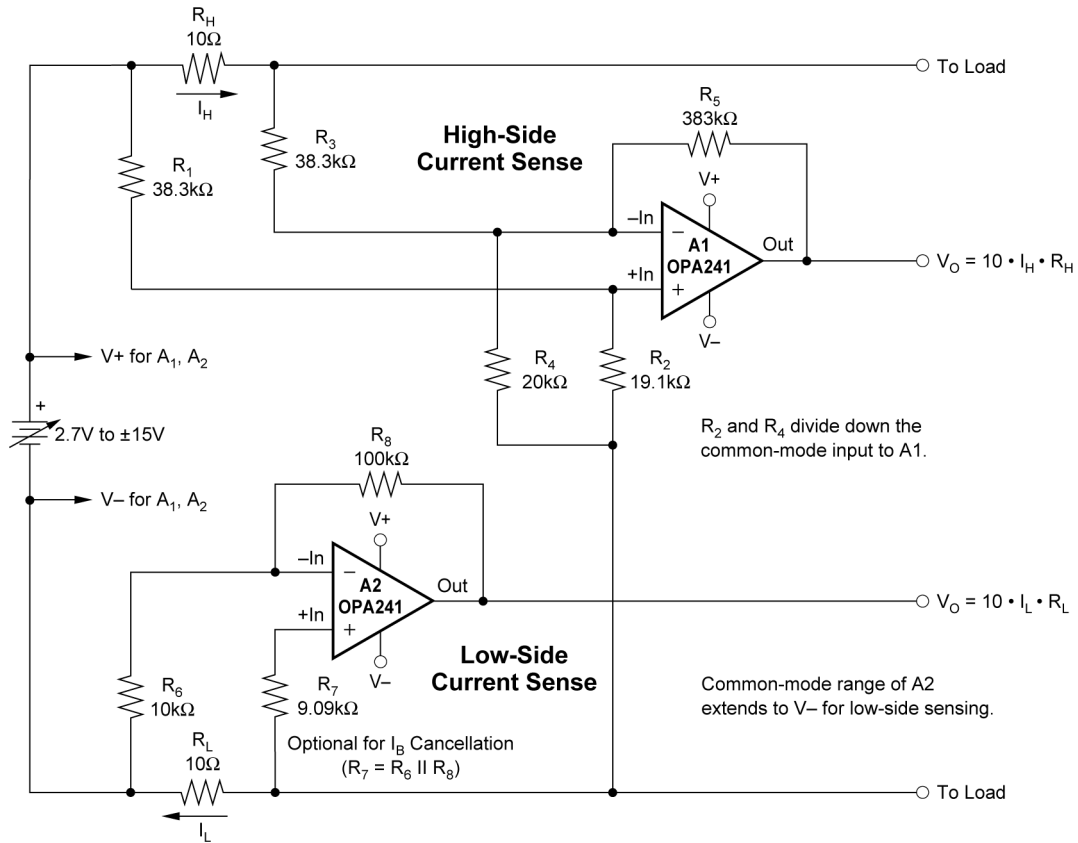


图 6-4. Series Resistor in Unity Gain Configuration Improves Capacitive Load Drive



NOTE: Low and high-side sensing circuits can be used independently.

图 6-5. Low-Side and High-Side Battery Current Sensing

7 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

7.1 接收文档更新通知

要接收文档更新通知，请导航至 [ti.com](https://www.ti.com) 上的器件产品文件夹。点击 [通知](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

7.2 支持资源

TI E2E™ [中文支持论坛](#) 是工程师的重要参考资料，可直接从专家处获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题，获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 [使用条款](#)。

7.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.

所有商标均为其各自所有者的财产。

7.4 静电放电警告



静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

7.5 术语表

[TI 术语表](#) 本术语表列出并解释了术语、首字母缩略词和定义。

8 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision * (September 2000) to Revision A (June 2024)	Page
• 更新了整个文档中的表格、图和交叉参考的编号格式.....	1
• 添加了 器件信息表 、 引脚配置和功能 、 建议运行条件 、 热性能信息 、 电气特性 、 应用和实施 、 器件和文档支持 、 修订历史记录 以及 机械 、 封装和可订购信息 部分.....	1
• 向 说明 中添加了新图.....	1
• Updated pin names.....	3
• Changed input voltage noise from 1μV _{PP} to 1.7μV _{PP}	7
• Changed input voltage noise density from 45nV/√Hz to 65nV/√Hz	7
• Changed input impedance differential capacitance from 2pF to 3.75pF.....	7
• Changed overload recovery from 60μs to 80μs.....	7
• Changed short-circuit current from -30mA to -24mA for dual and quad.....	7
• Changed short-circuit current sink from -50mA to -27mA.....	9
• Deleted <i>Input Voltage and Current Noise Spectral Density vs Frequency</i> from <i>Typical Characteristics</i>	11
• Added Figure 5-4, <i>Input Voltage Noise Spectral Density vs Frequency</i> and Figure 5-5, <i>Input Current Noise Spectral Density vs Frequency</i>	11

9 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
OPA2241PA	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2241PA
OPA2241PA.A	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2241PA
OPA2241PAG4	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2241PA
OPA2241UA	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 85	OPA 2241UA
OPA2241UA/2K5	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2241UA
OPA2241UA/2K5.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2241UA
OPA2241UA/2K5.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2241UA
OPA2251PA	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2251PA
OPA2251PA.A	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2251PA
OPA2251PAG4	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA2251PA
OPA2251UA	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 85	OPA 2251UA
OPA2251UA/2K5	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2251UA
OPA2251UA/2K5.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2251UA
OPA2251UA/2K5.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 2251UA
OPA241PA	Last Time Buy	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-	OPA241PA
OPA241PA.A	Active	Production	PDIP (P) 8	50 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA241PA
OPA241UA	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 85	OPA 241UA
OPA241UA/2K5	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 241UA
OPA241UA/2K5.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 241UA

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
OPA241UA/2K5.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 241UA
OPA251UA	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 85	OPA 251UA
OPA251UA/2K5	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 251UA
OPA251UA/2K5.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 251UA
OPA251UA/2K5.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	OPA 251UA
OPA4241PA	Active	Production	PDIP (N) 14	25 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA4241PA
OPA4241PA.A	Active	Production	PDIP (N) 14	25 TUBE	Yes	NIPDAU	N/A for Pkg Type	-40 to 85	OPA4241PA
OPA4241UA	Active	Production	SOIC (D) 14	50 TUBE	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4241UA
OPA4241UA.A	Active	Production	SOIC (D) 14	50 TUBE	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4241UA
OPA4241UA/2K5	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4241UA
OPA4241UA/2K5.A	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4241UA
OPA4251UA	Active	Production	SOIC (D) 14	50 TUBE	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4251UA
OPA4251UA.A	Active	Production	SOIC (D) 14	50 TUBE	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4251UA
OPA4251UA/2K5	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4251UA
OPA4251UA/2K5.A	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAUAG	Level-3-260C-168 HR	-40 to 85	OPA4251UA

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

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
OPA2241UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA2251UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA241UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA251UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA4241UA/2K5	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
OPA4251UA/2K5	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA2241UA/2K5	SOIC	D	8	2500	353.0	353.0	32.0
OPA2251UA/2K5	SOIC	D	8	2500	353.0	353.0	32.0
OPA241UA/2K5	SOIC	D	8	2500	353.0	353.0	32.0
OPA251UA/2K5	SOIC	D	8	2500	353.0	353.0	32.0
OPA4241UA/2K5	SOIC	D	14	2500	353.0	353.0	32.0
OPA4251UA/2K5	SOIC	D	14	2500	353.0	353.0	32.0

TUBE


*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
OPA2241PA	P	PDIP	8	50	506	13.97	11230	4.32
OPA2241PA.A	P	PDIP	8	50	506	13.97	11230	4.32
OPA2241PAG4	P	PDIP	8	50	506	13.97	11230	4.32
OPA2251PA	P	PDIP	8	50	506	13.97	11230	4.32
OPA2251PA.A	P	PDIP	8	50	506	13.97	11230	4.32
OPA2251PAG4	P	PDIP	8	50	506	13.97	11230	4.32
OPA241PA	P	PDIP	8	50	506	13.97	11230	4.32
OPA241PA.A	P	PDIP	8	50	506	13.97	11230	4.32
OPA4241PA	N	PDIP	14	25	506	13.97	11230	4.32
OPA4241PA.A	N	PDIP	14	25	506	13.97	11230	4.32
OPA4241UA	D	SOIC	14	50	506.6	8	3940	4.32
OPA4241UA.A	D	SOIC	14	50	506.6	8	3940	4.32
OPA4251UA	D	SOIC	14	50	506.6	8	3940	4.32
OPA4251UA.A	D	SOIC	14	50	506.6	8	3940	4.32



D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

- Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed $.006$ [0.15] per side.
- This dimension does not include interlead flash.
- Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
 EXPOSED METAL SHOWN
 SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Falls within JEDEC MS-001 variation BA.

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - The 20 pin end lead shoulder width is a vendor option, either half or full width.



D0014A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4220718/A 09/2016

NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.

EXAMPLE BOARD LAYOUT

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
SCALE:8X



SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

4220718/A 09/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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