OPAx486 48V, Zero-Drift, Low-Power, Low-Noise, Op Amp with Mux-Friendly Inputs

1 Features

- Wide operating supply range: 4.5V to 48V
- Zero-drift precision:
  - Input offset voltage: 5µV, max
  - Input offset voltage drift: 0.025µV/°C, max
  - High PSRR: 144dB, min
  - High CMRR: 144dB, min
- Ac performance:
  - Gain bandwidth: 5.6MHz
  - Slew rate: 15V/µs
  - Low noise: 9.2nV/$\sqrt{Hz}$
  - Near zero flicker noise: 0.3μV_{PP}
- Input to the negative rail, rail-to-rail output
- Low quiescent current: 650µA, max
- Temperature: –40°C to +125°C

2 Applications

- Battery backup unit (BBU)-12V DC/48V DC
- Common redundant power supply (CRPS)
- Analog input module
- Flow transmitter
- Pressure transmitter
- Merchant battery charger
- Weigh Scale

3 Description

The OPA486, OPA2486, and OPA4486 (OPAx486) are a family of 48V, low noise, wide-bandwidth, low power, zero-drift operational amplifiers (op amps). The OPAx486 are a pin compatible replacement to many industry standard amplifiers that can benefit from higher operating voltage. The 48V operating voltage and the 60V absolute maximum supply voltage rating enable robust circuit designs.

These op amps feature a 5µV of input offset voltage (max) and 0.025µV/°C of input offset voltage drift (max) over a wide temperature range. The OPAx486 also provide common-mode and power supply rejection to enable high precision measurements under a variety of operating conditions.

These devices are designed for both dc and ac applications with near-zero flicker noise, very low broadband noise, wide bandwidth, and high slew. The ac performance is achieved with relatively low quiescent current of 650µA (max) to maintain system power budget limits.

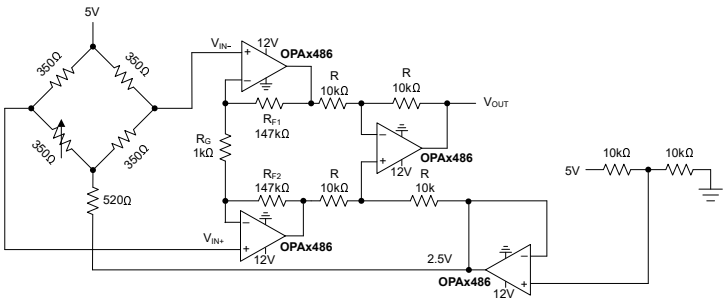
The combination of ac and dc performance make the OPAx486 appropriate for a wide range of high precision end equipment like analog input modules, battery testers, precision instrumentation, and process control. This family of devices are equipped with a proprietary MUX-friendly input architecture to enhance performance in multichannel, multiplexed applications.

The OPAx486 are available in industry standard packages as well as micro-size packages to fit even the most space-constrained applications. The devices are specified for operation from –40°C to +125°C.

Package Information

PART NUMBER	CHANNEL COUNT	PACKAGE(1)	PACKAGE SIZE(2)
OPA486	Single	D (SOIC, 8)(3)	4.90mm × 6.00mm
		DBV (SOT-23, 5)(3)	2.90mm × 2.80mm
		DRL (SOT, 5)(3)	1.60mm × 1.60mm
OPA2486	Dual	D (SOIC, 8)	4.90mm × 6.00mm
		DGK (VSSOP-8)(3)	3.00mm × 4.90mm
		DSG (WSON-8)(3)	2.00mm × 2.00mm
OPA4486	Quad	D (SOIC, 14)(3)	8.65mm × 6.00mm
		PW (TSSOP-14)(3)	5.00mm × 6.40mm

(1) For more information, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.
(3) Preview information (not Production Data).



Instrumentation Amplifier

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4 Pin Configuration and Functions

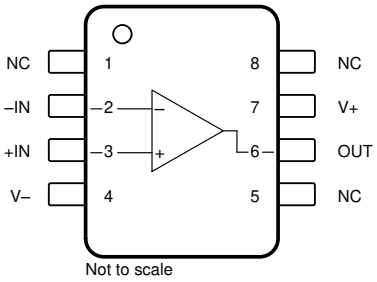


Figure 4-1. OPA486: D Package, 8-Pin SOIC (Top View)

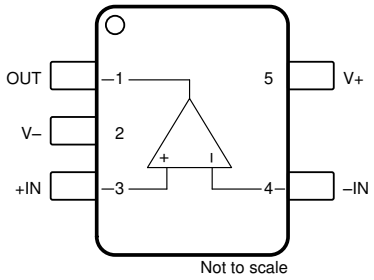


Figure 4-2. OPA486: DBV Package, 5-Pin SOT-23 (Top View)

Table 4-1. Pin Functions: OPA486

PIN			TYPE	DESCRIPTION
NAME	NO.			
	D	DBV		
–IN	2	4	Input	Inverting input
+IN	3	3	Input	Noninverting input
NC	1, 8, 5	–	_	No connection (can be left floating)
OUT	6	1	Output	Output
V–	4	2	Power	Negative (lowest) power supply
V+	7	5	Power	Positive (highest) power supply

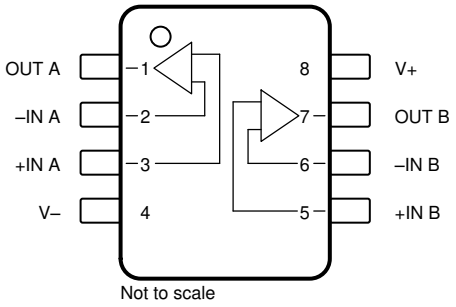


Figure 4-3. OPA2486: D Package, 8-Pin SOIC and DGK Package, 8-pin VSSOP (Top View)

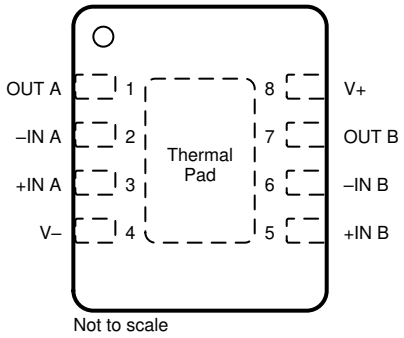


Figure 4-4. DSG Package, 8-Pin WSON With Exposed Thermal Pad (Top View)

Table 4-2. Pin Functions: OPA2486

PIN		TYPE	DESCRIPTION
NAME	NO.		
–IN A	2	Input	Inverting input channel A
–IN B	6	Input	Inverting input channel B
+IN A	3	Input	Noninverting input channel A
+IN B	5	Input	Noninverting input channel B
OUT A	1	Output	Output channel A
OUT B	7	Output	Output channel B
V–	4	Power	Negative supply
V+	8	Power	Positive supply
Thermal Pad(1)	-	-	Connect thermal pad to the negative supply (V–). See also *Packages with an Exposed Thermal Pad* for more information.

(1) For DSG package only

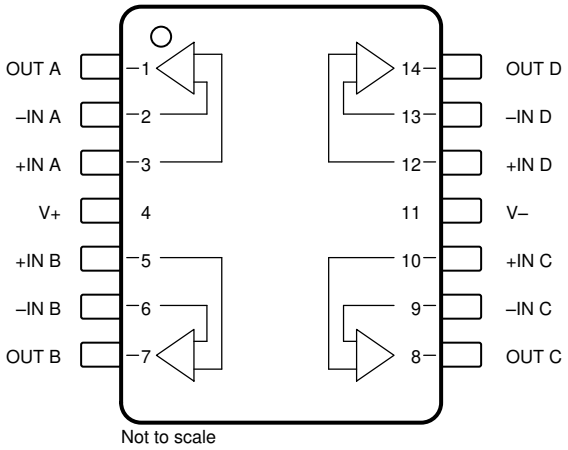


Figure 4-5. OPA4486: D Package, 14-Pin SOIC and PW Package, 14-Pin TSSOP (Top View)

Table 4-3. Pin Functions: OPA4486

PIN		TYPE	DESCRIPTION
NAME	NO.		
–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
+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
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–	11	Power	Negative supply
V+	4	Power	Positive 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			60	V
	Signal input voltage	Common-mode	(V–) – 0.5	(V+) + 0.5	V
		Differential		(V+) – (V–)	
	Current			±10	mA
	Output short circuit(2)		Continuous		
T_A	Operating temperature		–55	150	°C
T_J	Junction temperature			150	°C
T_{stg}	Storage temperature		–65	150	°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) Short-circuit to ground, one amplifier per package. This device has been designed to limit electrical damage due to excessive output current, but extended short-circuit current, especially with higher supply voltage, can cause excessive heating and eventual thermal destruction.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±3000	V
		Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002(2)	±250	

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
V_S	Supply voltage, (V+) – (V–)	Single supply	4.5		48	V
		Dual supply	±2.25		±24	
T_A	Operating temperature		–40		125	°C

5.4 Thermal Information for OPA486

THERMAL METRIC[1]		OPA486		UNIT
		DBV (SOT23-5)	D (SOIC)	
		5 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	197.9	149.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	110.3	88.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	62.6	93.6	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	36.3	36.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	62.4	92.9	°C/W
$R_{\theta JC(bot)}$	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 note.

5.5 Thermal Information for OPA2486

THERMAL METRIC[1]		OPA2486		UNIT
		D (SOIC)	DGK (VSSOP)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	138.4	159	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	77.7	53	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	82.3	93	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	27.7	3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	81.7	92	°C/W
$R_{\theta JC(bot)}$	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 note.

5.6 Thermal Information for OPA4486

THERMAL METRIC[1]		OPA4486		UNIT
		D (SOIC)	PW (TSSOP)	
		14 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	95	103	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	56	37	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	54	61	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	18	9	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	54	60	°C/W
$R_{\theta JC(bot)}$	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 note.

5.7 Electrical Characteristics

at T_A = 25°C, V_S = 4.5V (±2.25V) to 48V (±24V), V_{CM} = V_{OUT} = V_S / 2, and R_{LOAD} = 10kΩ connected to V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V_{OS}	Input offset voltage(1)				±1	±5	µV
		T_A = –40°C to +125°C				±10	
dV_{OS}/dT	Input offset voltage drift(1)	T_A = –40°C to +125°C			±0.005	±0.025	µV/°C
PSRR	Power-supply rejection ratio(1)	T_A = –40°C to +125°C			±0.01	±0.06	µV/V
INPUT BIAS CURRENT							
I_B	Input bias current(1)				±50	±250	pA
		T_A = –40°C to +125°C				±3	nA
I_{OS}	Input offset current(1)				±100	±500	pA
		T_A = –40°C to +125°C				±6	nA
NOISE							
E_n	Input voltage noise	f = 0.1Hz to 10Hz			0.30		$µV_{PP}$
e_n	Input voltage noise density	f = 10Hz			9.2		$nV/\sqrt{Hz}$
		f = 100Hz			9.2		
		f = 1kHz			9.2		
i_n	Input current noise density	f = 1kHz			200		$fA/\sqrt{Hz}$
INPUT VOLTAGE							
V_{CM}	Common-mode voltage			(V–) – 0.1		(V+) – 2	V
CMRR	Common-mode rejection ratio	(V–) – 0.1V ≤ V_{CM} ≤ (V+) – 2V	V_S = ±2.25V	120	144		dB
			V_S = ±24V	144	160		
		(V–) – 0.1V ≤ V_{CM} ≤ (V+) – 2V, T_A = –40°C to +125°C(1)	V_S = ±2.25V	120	144		
			V_S = ±24V	144	160		
INPUT IMPEDANCE							
z_{id}	Differential input impedance				100 || 2.2		MΩ || pF
z_{ic}	Common-mode input impedance				1 || 1.2		TΩ || pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain	V_S = ±24V, (V–) + 0.6V < V_O < (V+) – 0.6V, R_{LOAD} = 10kΩ		130	160		dB
			T_A = –40°C to +125°C(1)	130			
		V_S = ±24V, (V–) + 1.7V < V_O < (V+) – 1.7V, R_{LOAD} = 2kΩ		130	160		
			T_A = –40°C to +125°C(1)	130			

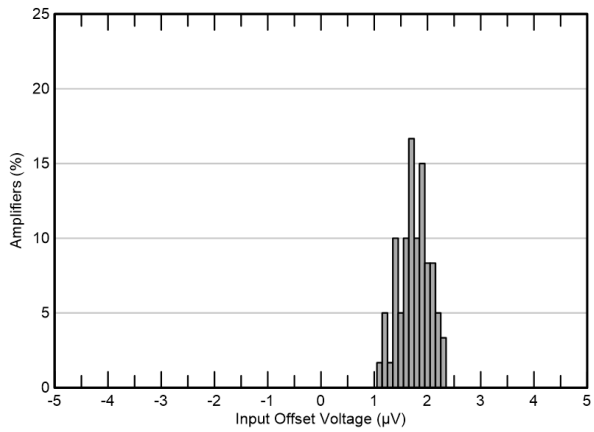
at T_A = 25°C, V_S = 4.5V (±2.25V) to 48V (±24V), V_{CM} = V_{OUT} = V_S / 2, and R_{LOAD} = 10kΩ connected to V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product				5.6		MHz
SR	Slew rate	Gain = 1, 10V step			15		V/µs
THD+N	Total harmonic distortion + noise	Gain = 1, f = 1kHz, V_{OUT} = 4V_{RMS}			0.00012%		
	Crosstalk	f = 100kHz, V_{IN} = 200mV_{PP}			110		dB
t_S	Settling time	V_S = ±24V, gain = 1, 10V step	To 0.1%		1.25		µs
			To 0.01%		12		
t_{OR}	Overload recovery time	V_{IN} × gain = V_S = ±24V			950		ns
OUTPUT							
f_{CHOP}	Chopping frequency				200		Hz
V_O	Voltage output swing from rail	Positive rail, V_S = 48V	No load[1]		6	20	mV
			R_{LOAD} = 10kΩ		175	200	
			R_{LOAD} = 2kΩ		860	900	
		Negative rail, V_S = 48V	No load[1]		6	20	
			R_{LOAD} = 10kΩ		165	200	
			R_{LOAD} = 2kΩ		860	900	
		R_{LOAD} = 10kΩ, T_A = –40°C to +125°C, both rails[1]				300	
I_{SC}	Short-circuit current	Sourcing			38		mA
		Sinking			–52		
C_{LOAD}	Capacitive load drive				See *Typical Characteristics*		pF
Z_O	Open-loop output impedance	f = 1MHz			460		Ω
POWER SUPPLY							
I_Q	Quiescent current per amplifier	OPA486, I_O = 0A			670	795	µA
			T_A = –40°C to +125°C[1]		670	800	
		OPA2486 and OPA4486, I_O = 0A			570	650	
			T_A = –40°C to +125°C[1]		570	655	

(1) Specification established from device population bench system measurements across multiple lots.

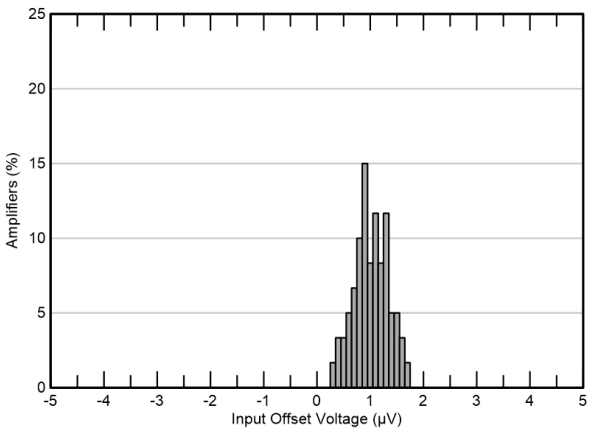
5.8 Typical Characteristics

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)



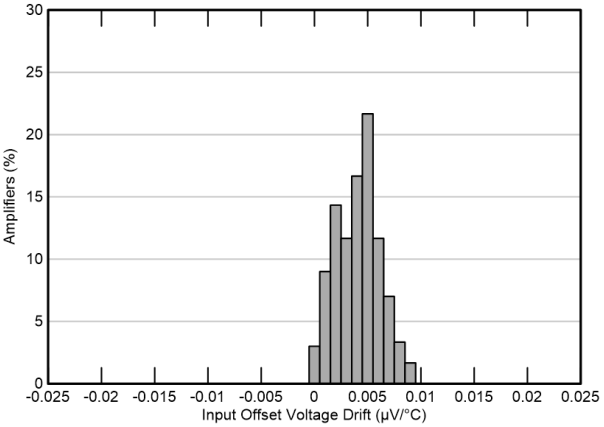
60 units

Figure 5-1. Offset Voltage Distribution



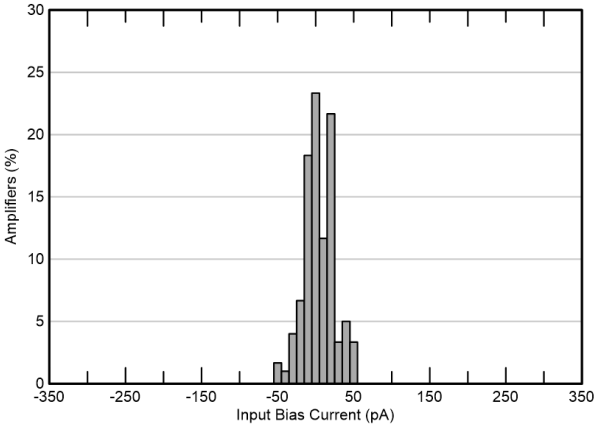
T_A = 125°C, 60 units

Figure 5-2. Offset Voltage Distribution



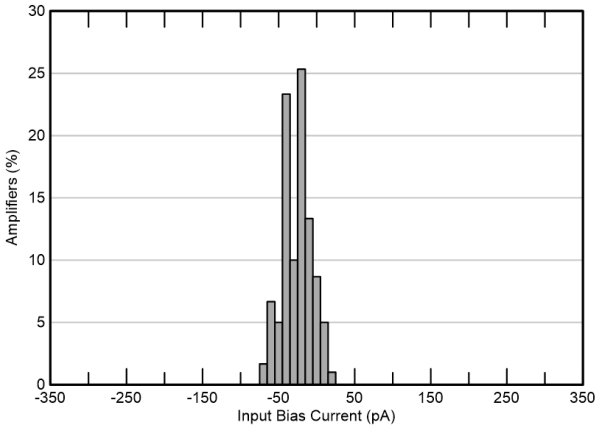
T_A = –40°C to +125°C, 60 units

Figure 5-3. Offset Voltage Drift



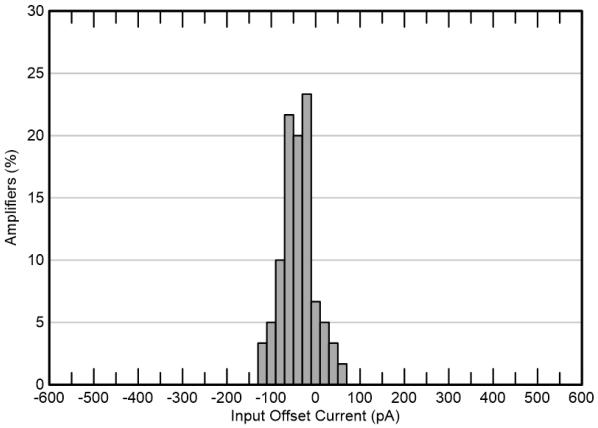
60 units

Figure 5-4. Input Bias Current Distribution, I_{BN}



60 units

Figure 5-5. Input Bias Current Distribution, I_{BP}

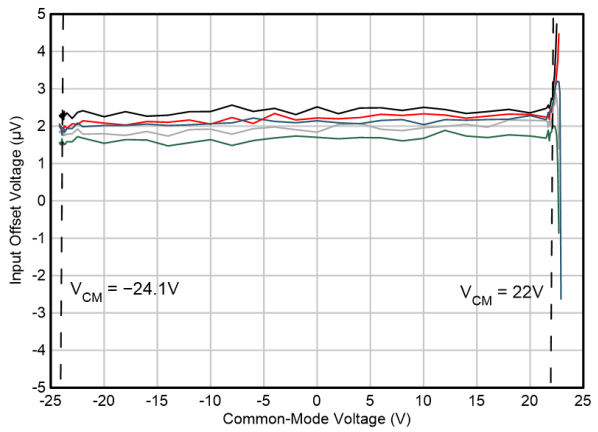


70 units

Figure 5-6. Input Offset Current Distribution

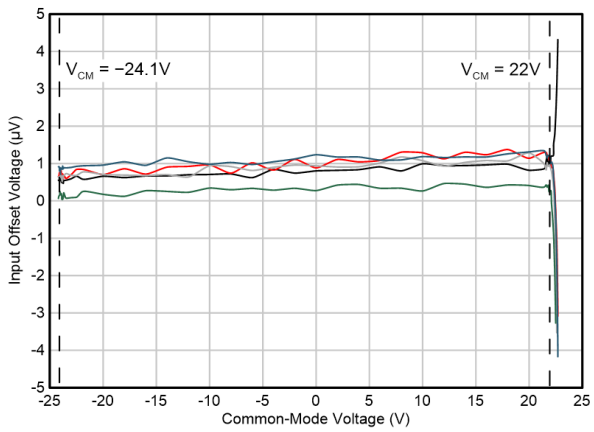
5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)



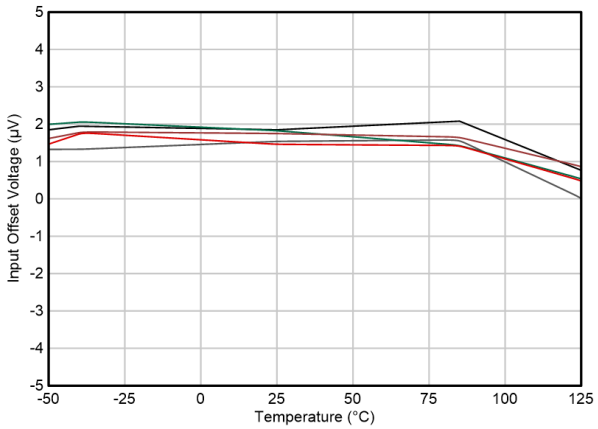
5 typical units

Figure 5-7. Offset Voltage vs Common-Mode Voltage



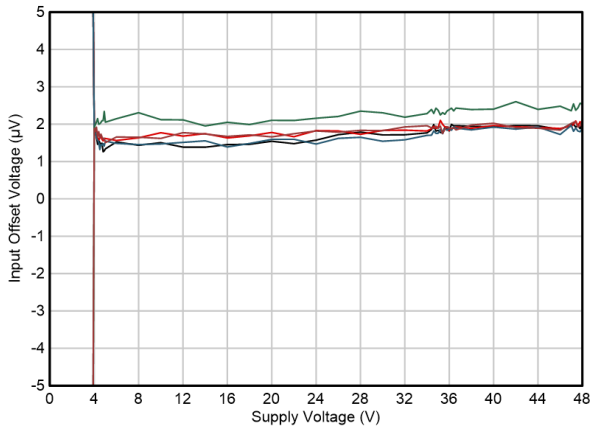
T_A = 125°C, 5 typical units

Figure 5-8. Offset Voltage vs Common-Mode Voltage



5 typical units

Figure 5-9. Offset Voltage vs Temperature



5 typical units

Figure 5-10. Offset Voltage vs Supply Voltage

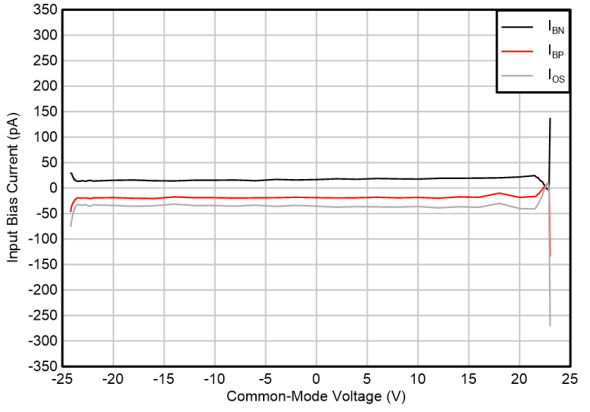


Figure 5-11. Input Bias Current vs Common-Mode Voltage

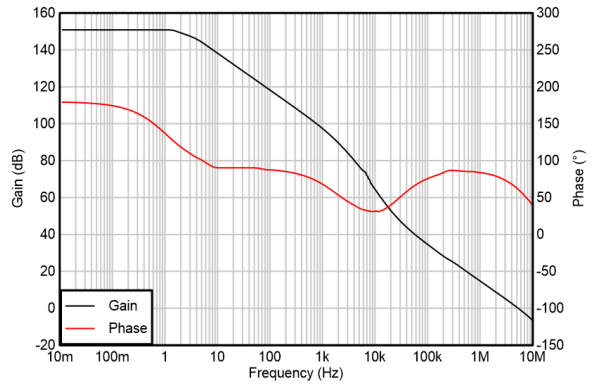


Figure 5-12. Open-Loop Gain and Phase vs Frequency

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)

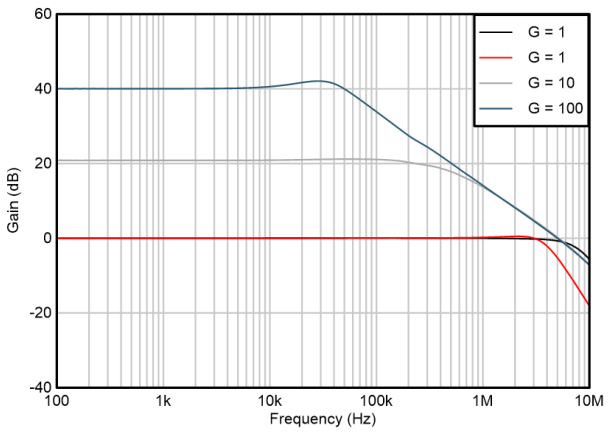


Figure 5-13. Closed-Loop Gain vs Frequency

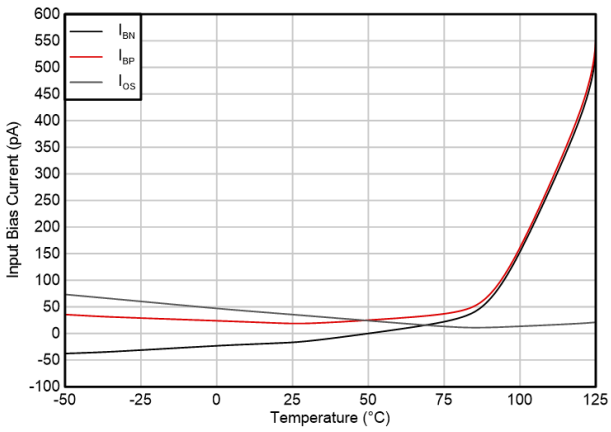


Figure 5-14. Input Bias Current and Offset Current vs Temperature

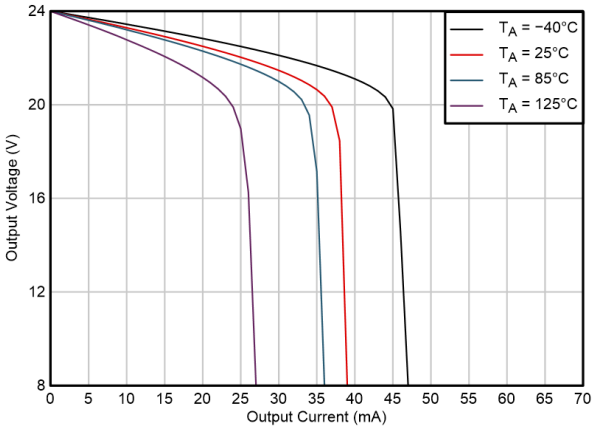


Figure 5-15. Output Voltage Swing vs Output Current (Sourcing)

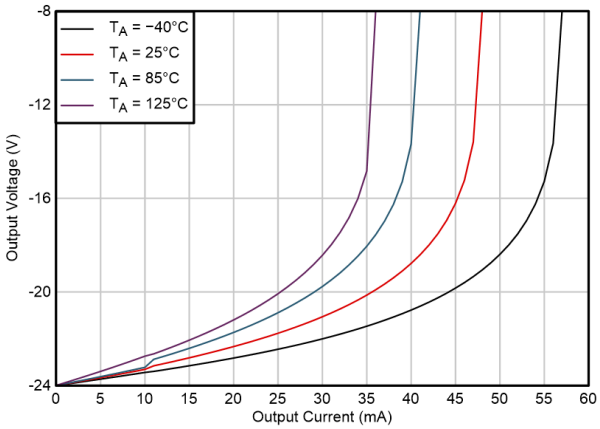


Figure 5-16. Output Voltage Swing vs Output Current (Sinking)

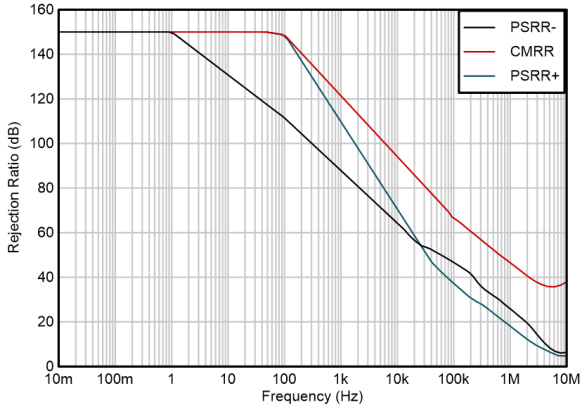
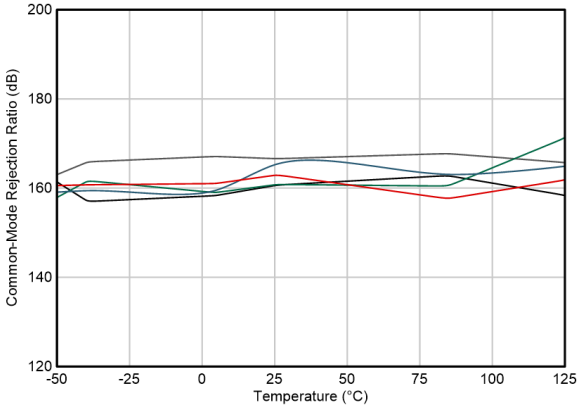


Figure 5-17. CMRR and PSRR vs Frequency

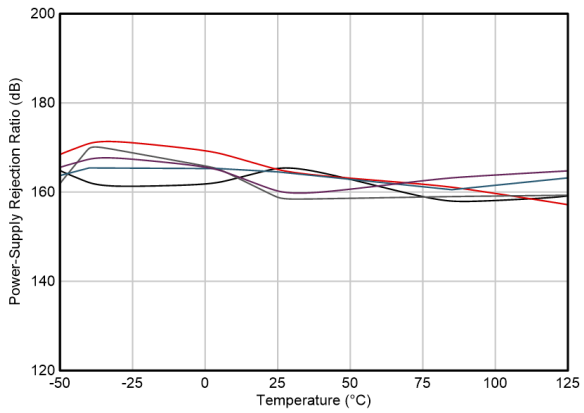


5 typical units

Figure 5-18. CMRR vs Temperature

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)



5 typical units

Figure 5-19. PSRR vs Temperature

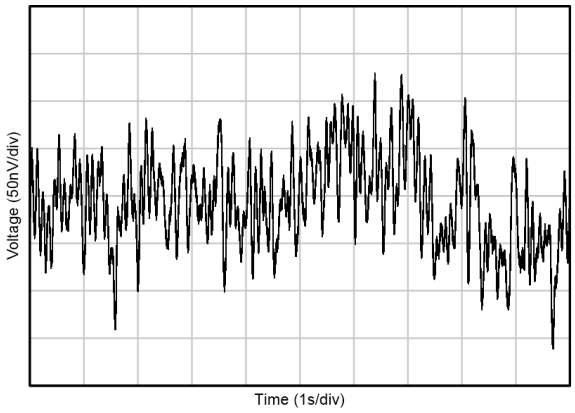


Figure 5-20. 0.1Hz to 10Hz Voltage Noise

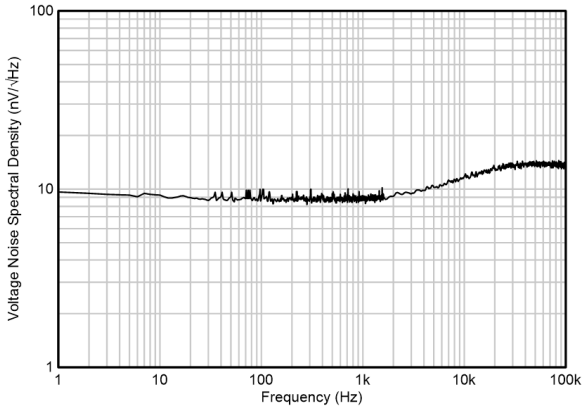


Figure 5-21. Input Voltage Noise Spectral Density vs Frequency

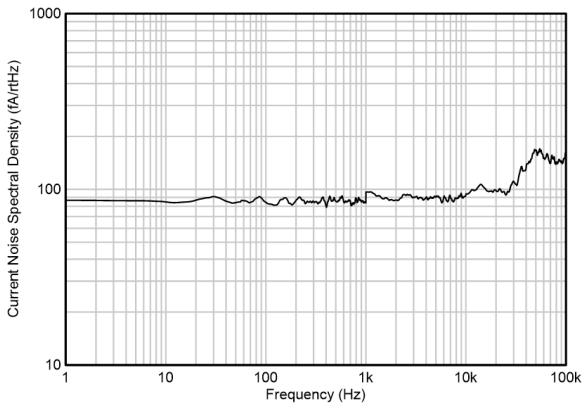
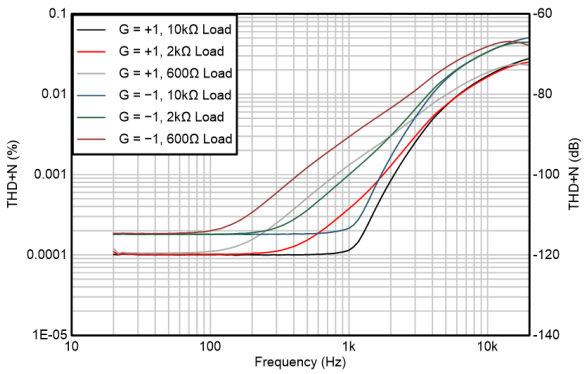
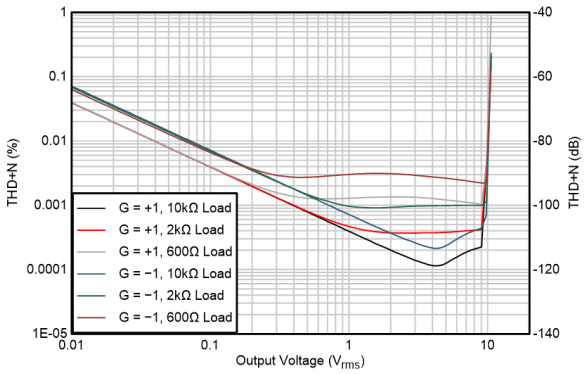


Figure 5-22. Input Current Noise Spectral Density vs Frequency



V_{OUT} = 4V_{RMS}, 80kHz bandwidth

Figure 5-23. THD+N vs Frequency

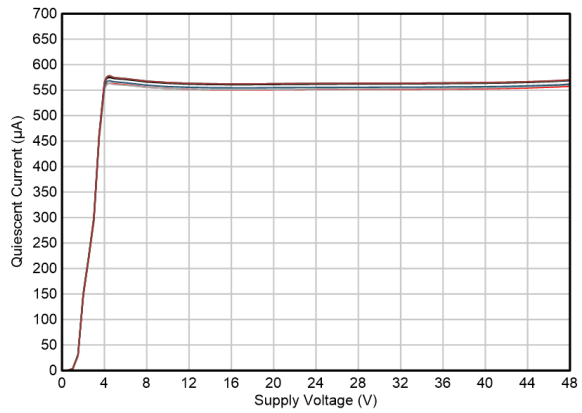


f = 1kHz

Figure 5-24. THD+N vs Output Amplitude

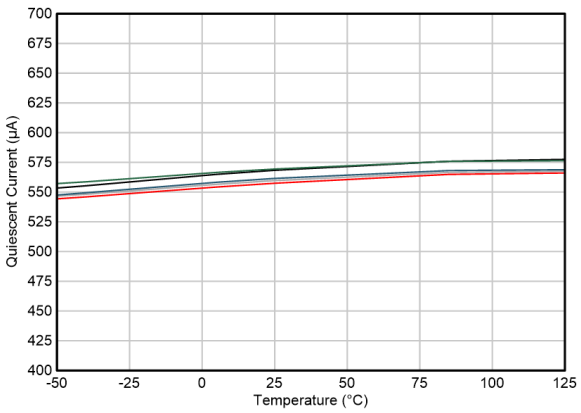
5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)



5 typical units

Figure 5-25. Quiescent Current vs Supply Voltage



5 typical units

Figure 5-26. Quiescent Current vs Temperature

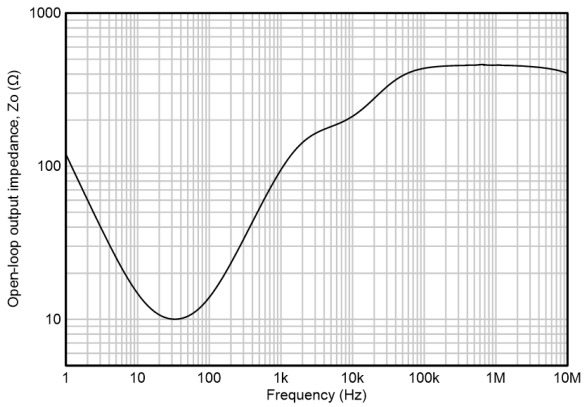
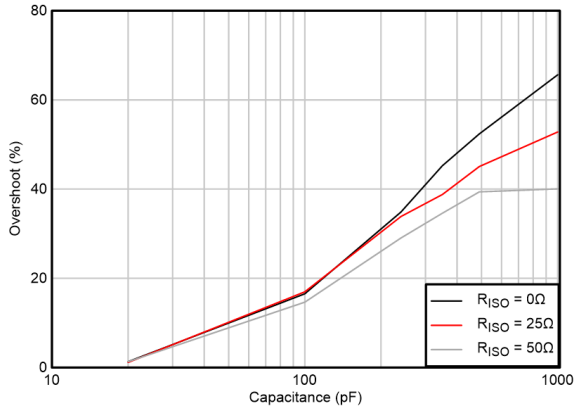
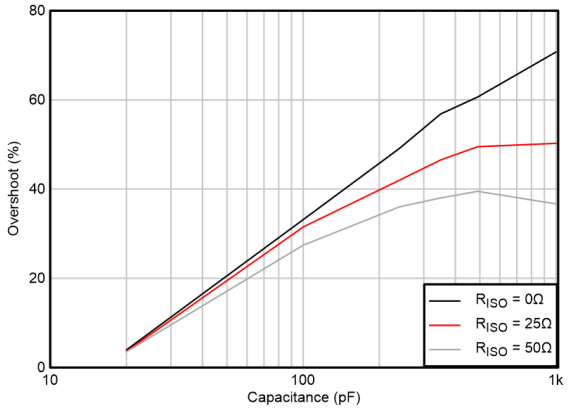


Figure 5-27. Open-Loop Output Impedance vs Frequency



Gain = –1, 10mV step

Figure 5-28. Small-Signal Overshoot vs Capacitive Load



Gain = 1, 10mV step

Figure 5-29. Small-Signal Overshoot vs Capacitive Load

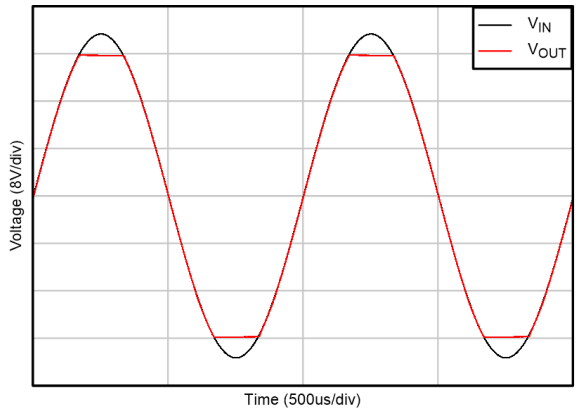


Figure 5-30. No Phase Reversal

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)

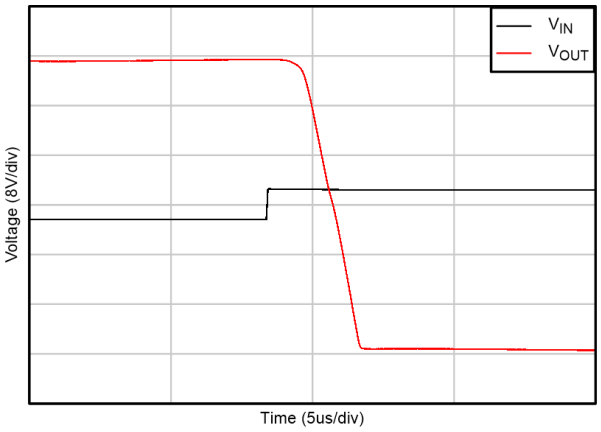


Figure 5-31. Positive Overload Recovery

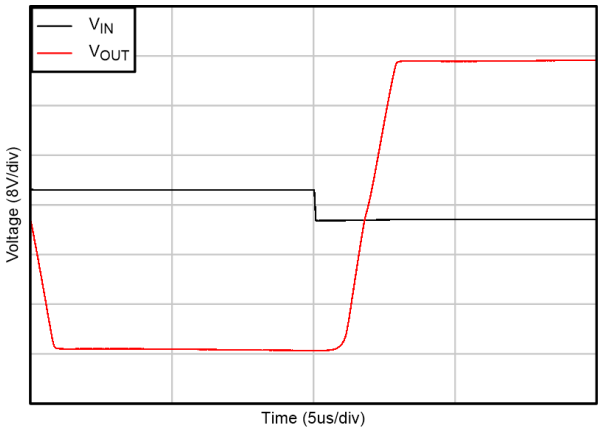
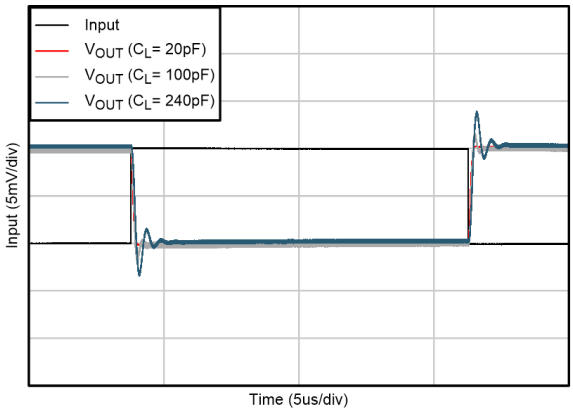
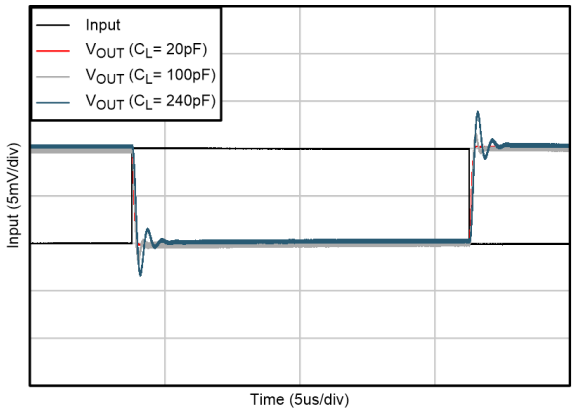


Figure 5-32. Negative Overload Recovery



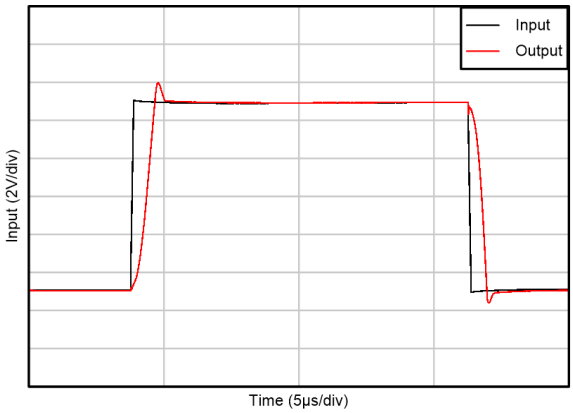
Gain = 1, 10mV step

Figure 5-33. Small-Signal Step Response



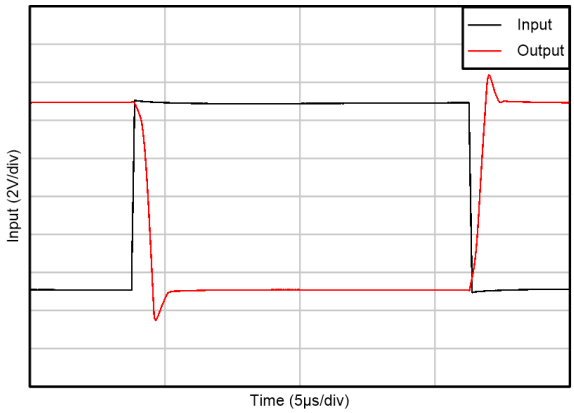
Gain = –1, 10mV step

Figure 5-34. Small-Signal Step Response



Gain = 1, 10V step

Figure 5-35. Large-Signal Step Response



Gain = –1, 10V step

Figure 5-36. Large-Signal Step Response

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = ±24V, V_{CM} = V_S / 2, and R_L = 10kΩ (unless otherwise noted)

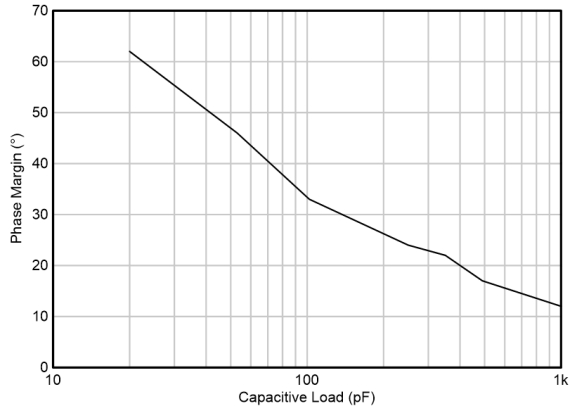
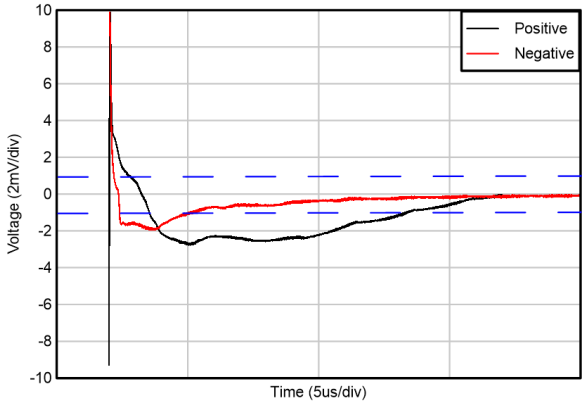


Figure 5-37. Phase Margin vs Capacitive Load



10V step, 0.01% settling

Figure 5-38. Settling Time

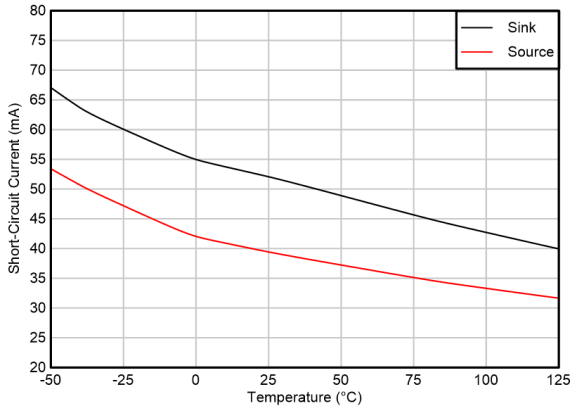


Figure 5-39. Short Circuit Current vs Temperature

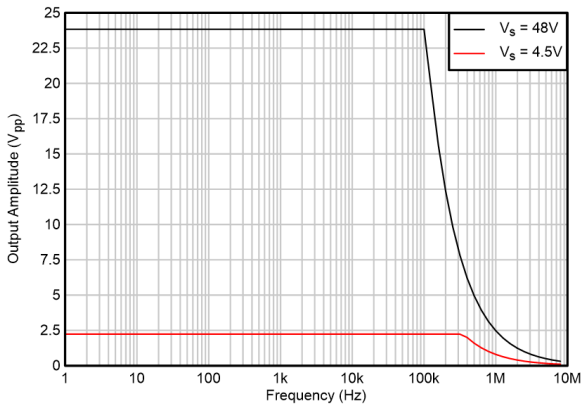


Figure 5-40. Maximum Output Voltage vs Frequency

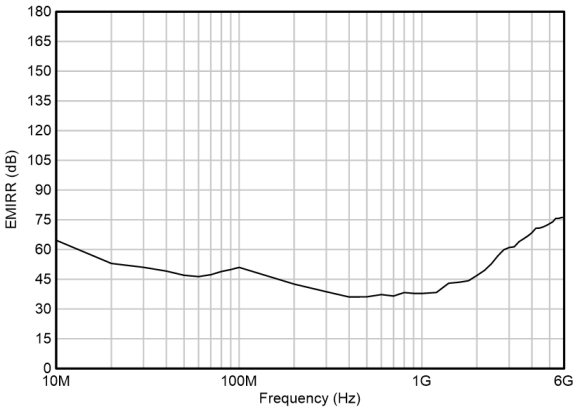


Figure 5-41. EMIRR vs Frequency

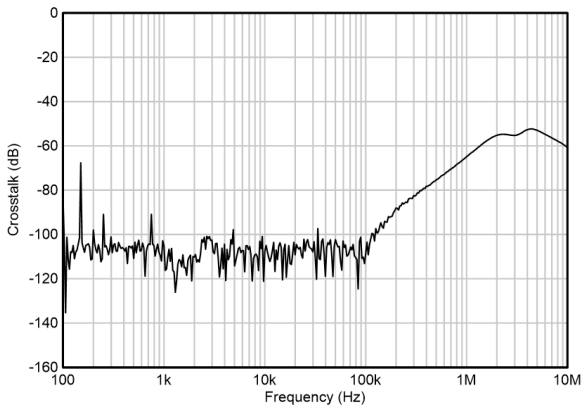


Figure 5-42. Channel Separation

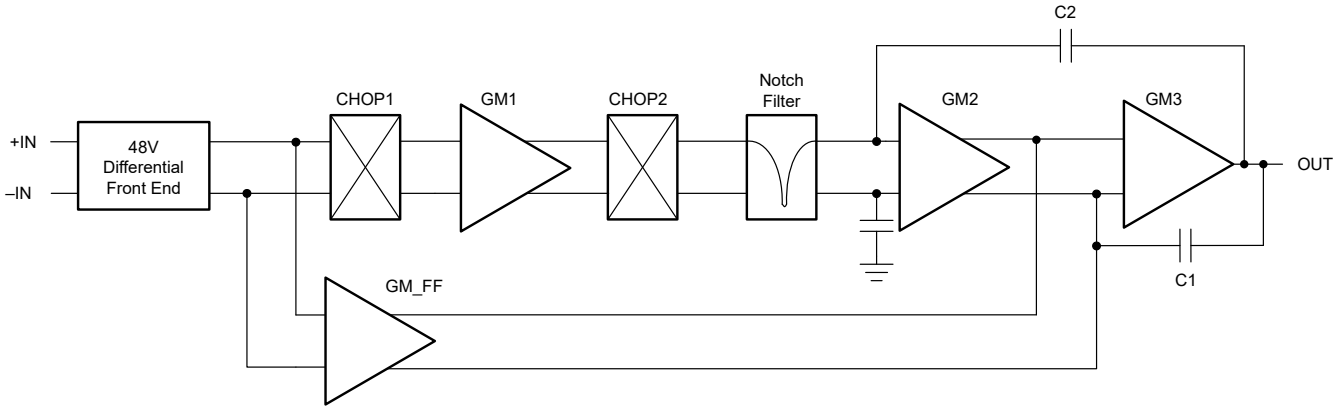
6 Detailed Description

6.1 Overview

The OPAx486 are next generation operational amplifiers that provide 48V operating voltage and precision. The combination of ultra-low offset and drift with dynamic performance make these devices an appropriate choice for a wide variety of precision applications. The precision maximum offset drift of only 0.025µV/°C provides stability over the entire operating temperature range of –40°C to +125°C. In addition, this device offers linear performance with high CMRR, PSRR, and AOL. The OPAx486 provide a balanced combination of bandwidth, noise, and quiescent current consumption to support most precision signal conditioning designs.

Additionally, the unity-gain stable OPAx486 are equipped with other features to enhance the signal conditioning performance. The devices feature MUX-friendly inputs, a patented technology that improves settling behavior and enables high precision multiplexed systems. The zero-drift architecture provides an additional benefit to the near-zero input offset voltage drift over temperature and time, as the architecture also eliminates the flicker noise of the amplifier.

6.2 Functional Block Diagram



6.3 Feature Description

The OPAx486 operational amplifiers use a proprietary, periodic autocalibration technique to provide extremely low input offset voltage and input offset voltage drift over time and temperature. The devices have several integrated features to help maintain a high level of precision through a variety of applications. These include a phase-reversal protection, electrical overstress protection, and MUX-friendly inputs.

Several design techniques and considerations to maintain the specified performance of the OPAx486 are detailed in the *Optimizing Chopper Amplifier Accuracy* and *Op Amp Offset Voltage and Bias Current Limitations* application notes.

6.3.1 Input Common-Mode Range

The OPAx486 are specified for operation from 4.5V to 48V (±2.25V to ±24V). The OPAx486 provide a wide input common-mode voltage (V_{CM}) range that includes the negative rail making them an appropriate choice for single supply operation. The input common-mode voltage to the positive rail is limited to (V+) − 2V. Limit the input common mode voltage to (V–) – 0.1V ≤ V_{CM} ≤ (V+) – 2V to maintain specified performance.

6.3.2 Phase-Reversal Protection

The OPAx486 have internal phase-reversal protection. Some op amps exhibit a phase reversal when the input is driven beyond the linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The OPAx486 input prevents phase reversal with excessive common-mode voltage. Instead, the output is limited to the appropriate rail.

6.3.3 Chopping Transients

Zero-drift amplifiers such as the OPAx486 use a switching architecture on the inputs to correct for the intrinsic offset and drift of the amplifier. Charge injection from the integrated switches on the inputs can introduce short transients in the input bias current of the amplifier. The extremely short duration of these pulses prevents the pulses from amplifying; however, the pulses can be coupled to the output of the amplifier through the feedback network. Use low value resistors to minimize the input transient effects at the output of the amplifier. Use a low-pass filter, such as an RC network, to minimize any additional noise attributed to the transients. The chopping frequency of the OPAx486 is typically 200kHz. Include a simple low pass, RC filter at the output of the amplifier to attenuate any chopping noise.

6.3.4 EMI Rejection

The OPAx486 provides good electromagnetic interference (EMI) rejection performance to reduce the effects of EMI interference from sources such as wireless communications and densely-populated boards with a mix of analog signal chain and digital components. EMI immunity can be improved with circuit design techniques; the OPAx486 benefits from these design improvements.

High-frequency signals conducted or radiated to any pin of the operational amplifier can result in adverse effects, as there is insufficient amplifier loop gain to correct for signals with spectral content outside the bandwidth. Conducted or radiated EMI on inputs, power supply, or output can result in unexpected dc offsets, transient voltages, or other unknown behavior. Take care to properly shield and isolate sensitive analog nodes from noisy radio signals and digital clocks and interfaces.

6.3.5 Electrical Overstress

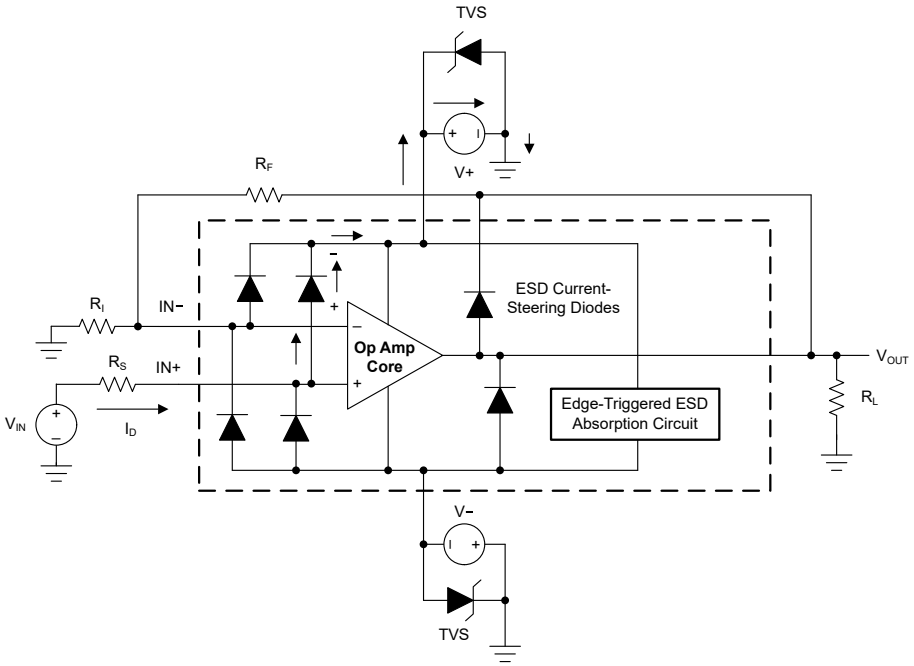
Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but can involve the supply voltage pins or even the output pin. Each of these different pin functions have electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect from accidental ESD events both before and during product assembly.

A good understanding of this basic ESD circuitry and the relevance to an electrical overstress event is helpful. Figure 6-1 shows an illustration of the ESD circuits contained in the OPAx486 (shows as the dashed line area). The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power-supply lines, where the diodes meet at an absorption device internal to the op amp. This protection circuitry is intended to remain inactive during normal circuit operation.

An ESD event produces a short-duration, high-voltage pulse that is transformed into a short-duration, high-current pulse while discharging through a semiconductor device. The ESD protection circuits are designed to provide a current path around the operational amplifier core to prevent damage. The energy absorbed by the protection circuitry is then dissipated as heat.

When an ESD voltage develops across two or more amplifier device pins, current flows through one or more steering diodes. Depending on the path that the current takes, the absorption device can activate. The absorption device has a trigger or threshold voltage that is greater than the normal operating voltage of the OPAx486, but less than the device breakdown voltage level. When this threshold is exceeded, the absorption device quickly activates and clamps the voltage across the supply rails to a safe level.

Figure 6-1 shows that when the operational amplifier connects into a circuit, the ESD protection components are intended to remain inactive, and do not become involved in the application circuit operation. However, circumstances can arise where an applied voltage exceeds the operating voltage range of a given pin. If this condition occurs, there is a risk that some internal ESD protection circuits are biased on and conduct current. Any such current flow occurs through steering-diode paths and rarely involves the absorption device.



Notes: V_{IN} = (V+) + 500mV.
TVS: V+ < $V_{TVSBR\ (min)}$ < 60V, where $V_{TVSBR\ (min)}$ is the minimum specified value for the TVS breakdown voltage.
Suggested value for R_S is approximately 5kΩ in an overvoltage condition.

Figure 6-1. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

Figure 6-1 shows a specific example where the input voltage (V_{IN}) exceeds the positive supply voltage (V+) by 500mV or more. Much of what happens in the circuit depends on the supply characteristics. If V+ can sink the current, one of the upper input steering diodes conducts and directs current to $+V_S$. Excessively high current levels can flow with increasingly higher V_{IN}. As a result, the data sheet specifications recommend that applications limit the input current to 10mA.

If the supply is not capable of sinking the current, V_{IN} can begin sourcing current to the operational amplifier, and then take over as the source of positive supply voltage. The danger in this case is that the voltage can rise to levels that exceed the operational amplifier absolute maximum ratings.

Another common question involves what happens to the amplifier if an input signal is applied to the input while the power supplies V+ or V– are at 0V. Again, this question depends on the supply characteristic while at 0V, or at a level below the input signal amplitude. If the supplies appear as high impedance, then the operational amplifier supply current can be supplied by the input source through the current-steering diodes. This state is not a normal biasing condition for the amplifier and can result in specification degradation or abnormal operation. If the supplies are low impedance, then the current through the steering diodes can become quite high. The current level depends on the ability of the input source to deliver current, and any resistance in the input path.

If there is any uncertainty about the ability of the supply to absorb this current, add external transient voltage suppressor (TVS) diodes to the supply pins; see also Figure 6-1. The breakdown voltage must be selected such that the diode does not turn on during normal operation. However, the breakdown voltage must be low enough so that the TVS diode conducts if the supply pin begins to rise above the safe operating supply voltage level.

6.3.6 MUX-Friendly Inputs

The OPAx486 features a proprietary input stage design that allows an input differential voltage to be applied while maintaining high input impedance. Typically, high-voltage CMOS or bipolar-junction input amplifiers feature antiparallel diodes that protect input transistors from large gate to source (V_{GS}) voltages that can exceed the semiconductor process maximum and permanently damage the device. Large V_{GS} voltages can be forced when applying a large input step, switching between channels, or attempting to use the amplifier as a comparator.

The OPAx486 solves these problems with a switched-input technique that prevents large input bias currents when large differential voltages are applied. This input architecture addresses many issues seen in switched or multiplexed applications, where large disruptions to RC filtering networks are caused by fast switching between large potentials.Figure 6-2 shows a typical application where MUX-Friendly inputs can improve settling time performance. The OPAx486 offers outstanding settling performance as a result of these design innovations and built-in slew-rate boost and wide bandwidth. The OPAx486 can also be used as a comparator. Differential and common-mode input ranges still apply.

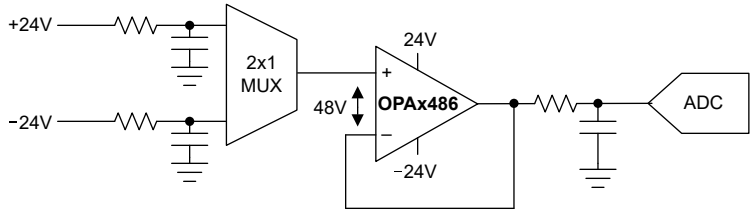


Figure 6-2. Multiplexed Application

6.4 Device Functional Modes

The OPAx486 has a single functional mode, and is operational when the power-supply voltage is greater than 4.5V (±2.25V). The recommended power supply voltage for the OPAx486 is 48V (±24V).

7 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

The OPAx486 operational amplifiers provide a good trade-off between gain-bandwidth, noise, and current consumption. The OPAx486 excel in applications that require signal conditioning for very low level signals like current sensing, Wheatstone bridges, thermocouples, resistance temperature detectors (RTDs), and electrocardiograms (ECG). The low offset and wide bandwidth enable very high gain configurations, while the low broadband noise and near zero flicker noise help maintain signal fidelity. The 48V operating voltage enable additional applications that require high input common-mode voltage or wide output swing capability.

7.1.1 Basic Noise Calculations

Low-noise circuit design requires careful analysis of all noise sources. In many cases, external noise sources can dominate; consider the effect of source resistance on overall op-amp noise performance. Total noise of the circuit is the root-sum-square combination of all noise components.

The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. The source impedance is typically fixed; consequently, select op amp and the feedback resistors that minimize the respective contributions to the total noise.

Figure 7-1 shows the noninverting op-amp circuit configurations with gain. Figure 7-2 shows the inverting op-amp circuit configurations with gain. In circuit configurations with gain, the feedback network resistors also contribute noise. In general, the current noise of the op amp reacts with the feedback resistors to create additional noise components. However, the low current noise of the OPAx486 means that the current noise contribution can be ignored.

The feedback resistor values can generally be chosen to make these noise sources negligible. Low impedance feedback resistors load the output of the amplifier. The equations for total noise are shown for both configurations.

For additional resources on noise calculations, visit *TI Precision Labs*.

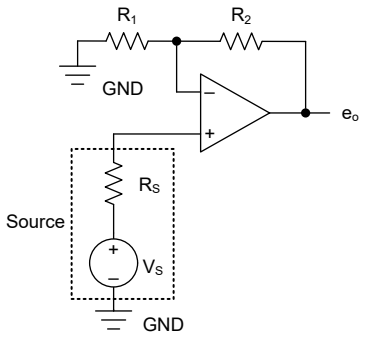


Figure 7-1. Noise Calculation in Noninverting Gain Configurations

$$E_o = e_o\sqrt{BW_N}\ [V_{RMS}] \quad (1)$$

$$e_o = \left(1 + \frac{R_2}{R_1}\right)\sqrt{e_S{}^2 + e_N{}^2 + \left(e_{R_1||R_2}\right)^2 + \left(i_N R_S\right)^2 + \left(i_N \frac{R_1 R_2}{R_1 + R_2}\right)^2}\left[\frac{V}{\sqrt{Hz}}\right] \quad (2)$$

$$e_S = \sqrt{4k_B T(K) R_S}\left[\frac{V}{\sqrt{Hz}}\right] \quad (3)$$

$$e_{R_1||R_2} = \sqrt{4k_B T(K)\left(\frac{R_1 R_2}{R_1 + R_2}\right)}\left[\frac{V}{\sqrt{Hz}}\right] \quad (4)$$

$$k_B = 1.38065 \times 10^{-23}\left[\frac{J}{K}\right] \quad (5)$$

$$T(K) = 2.37.15 + T(°C)\ [K] \quad (6)$$

where

- e_N is the voltage noise spectral density of the amplifier. For the OPAx486, e_n = 9.2nV/$\sqrt{Hz}$ at 1kHz)
- i_N is the current noise spectral density of the amplifier. For the OPAx486, i_n = 200fA/$\sqrt{Hz}$ at 1kHz)
- e_o is the total noise density
- e_S is the thermal noise of R_S
- $e_{R_1 \,||\, R_2}$ is the thermal noise of R_1 || R_2
- k_B is the Boltzmann constant
- T(K) is the temperature in kelvins

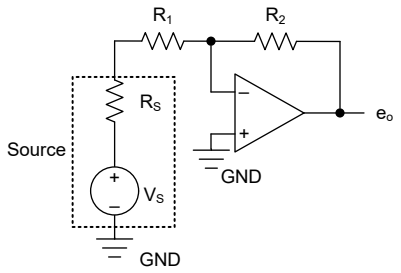


Figure 7-2. Noise Calculation in Inverting Gain Configurations

$$E_o = e_o\sqrt{BW_N}\ [V_{RMS}] \tag{7}$$

$$e_o = \left(1 + \frac{R_2}{R_S + R_1}\right)\sqrt{{e_N}^2 + \left(e_{R_1 + R_S||R_2}\right)^2 + \left(i_N\frac{(R_S + R_1)R_2}{R_S + R_1 + R_2}\right)^2}\left[\frac{V}{\sqrt{Hz}}\right] \tag{8}$$

$$e_{R_1 + R_S||R_2} = \sqrt{4k_BT(K)\left(\frac{(R_S + R_1)R_2}{R_S + R_1 + R_2}\right)}\left[\frac{V}{\sqrt{Hz}}\right] \tag{9}$$

$$k_B = 1.38065\ \times 10^{-23}\left[\frac{J}{K}\right] \tag{10}$$

$$T(K) = 2.37.15 + T(°C)\ [K] \tag{11}$$

where

- See

- e_N is the voltage noise spectral density of the amplifier. For the OPAx486, e_n = 9.2nV/$\sqrt{Hz}$ at 1kHz)
- i_N is the current noise spectral density of the amplifier. For the OPAx486, i_n = 200fA/$\sqrt{Hz}$ at 1kHz)
- e_o is the total noise density
- e_S is the thermal noise of R_S
- $e_{(R_1 + R_S)\ ||\ R_2}$ is the thermal noise of (R_1 + R_S) || R_2
- k_B is the Boltzmann constant
- T(K) is the temperature in kelvins

7.2 Typical Applications

7.2.1 Instrumentation Amplifier

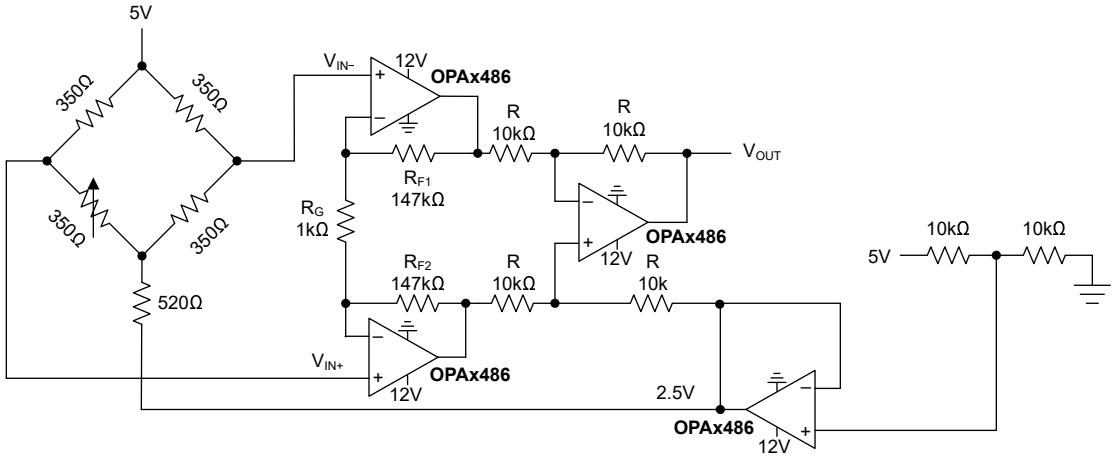


Figure 7-3. Instrumentation Amplifier For Strain Gauge

7.2.1.1 Design Requirements

Effective process control is critical for the safe and reliable manufacture of goods. An important requirement in process control is the accurate measurement of pressure. The classic strain gauge remains a popular choice for designers due to the low cost and high reliability of the material.

The working principle of a strain gauge is straightforward. When a force is applied to a strain gauge, the physical structure is altered and a proportional change in resistance occurs. A Wheatstone bridge can be used to measure this change in resistance with high precision.

The gauge factor of a strain gauge is a measure of the sensitivity of the sensor and expresses the relative resistance change under a given force. The change in resistance can be incredibly small, and a change of only 0.1% of the nominal resistance value of the strain gauge is not uncommon. This change results in a very small signal that needs significant gain to be accurately digitized. OPAx486 devices offer exceptional precision and wide gain bandwidth product to accommodate for very high gain configurations.

The OPAx486 can be configured as a three op amp instrumentation amplifier to provide high gain, high common-mode rejection ratio, and differential to single ended conversion.

Use the following parameters for this design example:

- Single supply: 12V
- Linear output voltage range target: 0V to 5V
- Bridge excitation: 5V
- Strain gauge resistance variation: ±6%
- Nominal strain gauge resistance: 350

The following design details and equations can be used to reconfigure this design for different output voltage ranges and current loads.

7.2.1.2 Detailed Design Procedure

Designing an instrumentation amplifier with high gain and high common-mode rejection requires the use of three channels of OPAx486, and a precision matched resistor network. The instrumentation amplifier configuration is illustrated in Figure 7-3.

The strain gauge in this example is set to have a nominal resistance of 350Ω and assumed to vary up to ±6% of the nominal resistance. The variation amounts to a resistance change of about 21Ω from the nominal value. The change in resistance directly affects the full-scale output of the bridge. Using a high precision op amp with very low drift is crucial to preserve accuracy of the system. Note that bridge sensors are inherently nonlinear, but the linearity is acceptable across small changes. Figure 7-4 shows a simulated bridge output to illustrate the small nonlinearity.

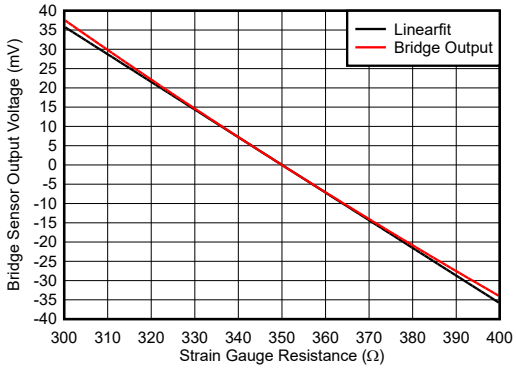


Figure 7-4. Bridge Sensor Linearity

The bridge excitation voltage also affects the full-scale output of the bridge with higher voltages producing a larger signal. The maximum voltage is limited by the manufacturer maximum rating for the bridge. Consider that an increasing voltage also leads to increased power loss across the bridge. Use a resistor to limit the current through the bridge to an acceptable level, but note that this resistor sets the common-mode voltage and reduces the overall output of the bridge. In this case, a 5V supply is readily available, and we add a resistor to limit the current through the bridge to about 3mA. The additional resistor sets the common-mode voltage of the signal to about 4.485V.

The common-mode voltage of the OPAx486 is (V−) to (V+) − 2V. To accommodate this limitation, the amplifiers are powered with a common 12V supply. The expected common-mode voltage of the bridge is within the 0V to 13V range in this application.

Equally important is consideration for the output swing voltage. In this application, there are two important considerations. The first is the output voltage limitations of the amplifiers interfacing with the bridge. Those two amplifiers need to be able to swing well above the common-mode voltage. The second consideration relates to the output amplifier. Keep the output of the amplifier within the linear output range. The OPAx486 maintains high linearity within (V−) + 0.6 to (V+) − 0.6V when driving a 10kΩ. This circuit is designed to swing from 600mV to 4.4V.

Next, determine the gain of the instrumentation amplifier using the expected output from the bridge and the output swing constraints discussed earlier. Equation 12 provides a calculation for the gain. Note that a slightly lower than calculated gain of 124V/V is chosen for this design.

$$G_{diff} = \frac{4.4V - 0.6V}{0.015V - (-0.015)} \approx 126\frac{V}{V} \quad (12)$$

This circuit provides excellent design flexibility when compared to monolithic instrumentation amplifiers. For this design, the gain is set in the first stage by resistors, R_G, and R_{F1}, and R_{F2}. Equation 13 provides the gain equation for this amplifier. Using the value for gain obtained in Equation 12, the appropriate resistors can be chosen. Always take into account the impact on noise and stability when choosing large resistors. Make sure that resistors are tightly matched to maintain high common-mode rejection, and low gain error.

$$G_{diff} = \left(1 + \frac{2R_F}{R_G}\right) \quad (13)$$

This design can be customized for any particular design taking into consideration the limitations posed in this section.

7.2.1.3 Application Curve

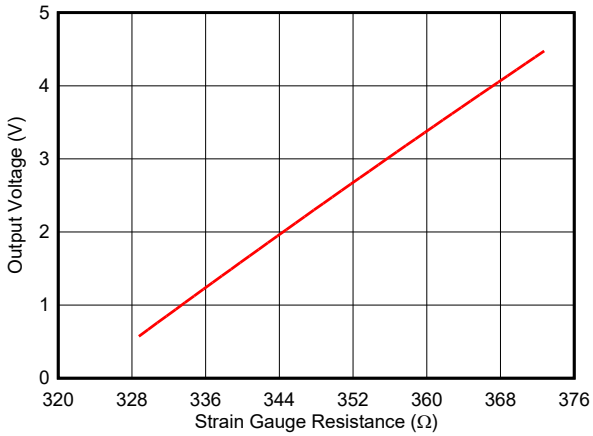


Figure 7-5. Instrumentation Amplifier Results

7.2.2 Low Power Instrumentation Amplifier

The previous section demonstrated how to design an instrumentation amplifier that provides high impedance inputs, high common-mode rejection, and differential to single ended conversion. As shown previously, the implementation requires the use of at least three channel counts of OPAx486. In many applications, power and space on the board is strictly limited and a smaller, lower power design is desirable. Figure 7-6 demonstrates an alternative configuration to the design discussed in detail in the previous section. This design provides a 33% reduction in quiescent current consumption and can be implemented using a dual channel package for significant size improvement. The trade-off for this power and size improvement is common-mode rejection (ac in particular) and a more limited input common-mode voltage.

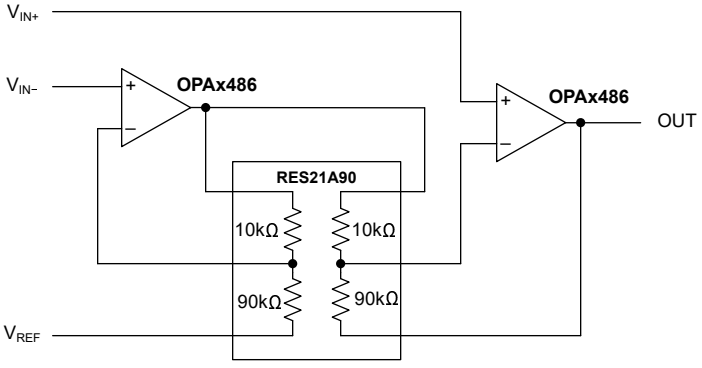


Figure 7-6. Two Op Amp Instrumentation Amplifier

7.2.3 Difference Amplifier

In some applications, a differential signal of interest exits on a high common-mode voltage and an amplifier with a high common-mode voltage is required. High side current sensing is one such case. Designers can use a difference amplifier configuration as shown in Figure 7-7 to solve this problem. The input common-mode voltage of this configuration is a function of the gain and the input common-mode voltage of the amplifier.

$$V_{IN}\left(\frac{G}{G+1}\right) + V_{REF}\left(\frac{1}{G+1}\right) \leq V_{+} - 2V \quad (14)$$

$$V_{IN}\left(\frac{G}{G+1}\right) + V_{REF}\left(\frac{1}{G+1}\right) \geq V_{-} - 0.1V \quad (15)$$

Where the gain (G) is given by Equation 16 and the input common-mode voltage is given in *Electrical Characteristics*.

$$G = \frac{R_G}{R_{IN}} \quad (16)$$

The OPAx486 provide a 48V operating supply voltage to enable very high common-mode voltage difference amplifiers. The very high precision of the OPAx486 makes high accuracy, and temperature stable measurements possible.

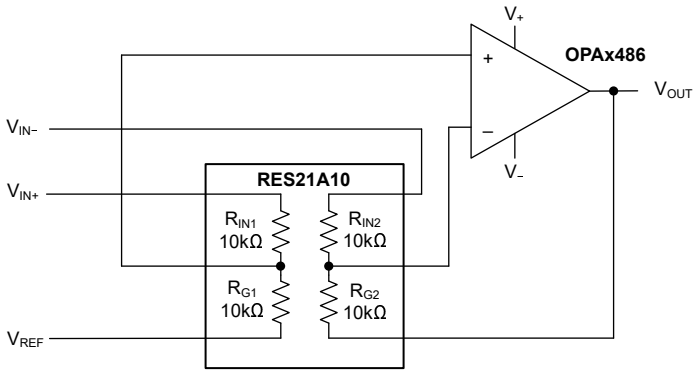


Figure 7-7. Difference Amplifier

7.2.4 Resistance Temperature Detector (RTD)

The OPAx486 is an excellent choice in a high precision RTD designs. RTDs are popular for high accuracy and wide temperature range applications. Unfortunately, the RTD resistance change with temperature is not totally linear and some kind of compensation is necessary to get the best results. Figure 7-8 shows a circuit that provides analog compensation for RTDs. Resistors R2, R4, and R3 set the noise gain of the circuit, while the ratio of R3 and R2 set the dc offset for the circuit. Resistor R1 sets the current excitation of the Pt100 RTD, and R5 provides the compensation. The choice of resistors depends on various variables that are discussed in detail in the Analog Linearization of Resistance Temperature Detectors report.

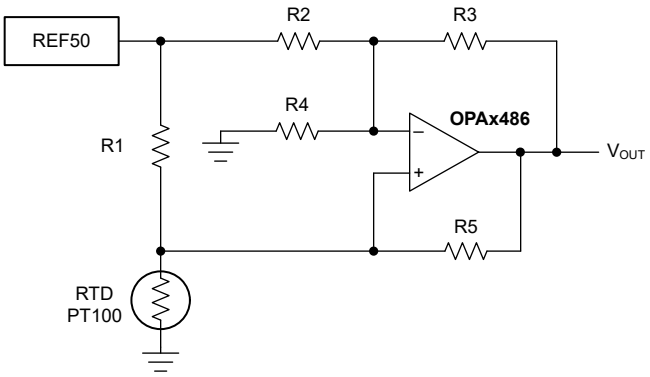


Figure 7-8. RTD Configuration With Linearization

7.3 Power Supply Recommendations

The OPAx486 are specified for operation from 4.5V to 48V (±2.25V to ±24V). The OPAx486 operates on both single and dual supplies. The OPAx486 do not require symmetrical supplies; the op amps only require a minimum voltage of 4.5V to operate.

CAUTION

Supply voltages larger than 60V can permanently damage the device (see the *Absolute Maximum Ratings* table).

Place 0.1µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see *Section 7.4*.

7.4 Layout

7.4.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices:

- For the lowest offset voltage, avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. Also:
  - Use low thermoelectric-coefficient conditions (avoid dissimilar metals).
  - Thermally isolate components from power supplies or other heat sources.
  - Shield operational amplifier and input circuitry from air currents, such as cooling fans.
- Noise can propagate into analog circuitry through the power pins of the op amp and the circuit as a whole. Bypass capacitors reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1µF ceramic bypass capacitors between each supply pin and ground, placed as close as possible to the device. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most effective methods of noise suppression. One or more layers on multilayer PCBs are typically devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Physically separate digital and analog grounds paying attention to the flow of the ground current. For more detailed information, see the *The PCB is a component of op amp design* analog application journal.
- To reduce parasitic coupling, run the input traces as far away as possible from the supply or output traces. If these traces cannot be separated, cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close as possible to the device. As Figure 7-10 shows, keep the feedback resistor (R3) and gain resistor (R4) close to the inverting input to minimize parasitic capacitance.
- Keep the length of input traces as short as possible. Short traces to the inverting input help to minimize parasitic capacitance on the inverting input. Always remember that the input traces are the most sensitive part of the circuit.
- For best performance, clean the PCB following board assembly.
- Any precision integrated circuit can experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, bake the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

7.4.2 Layout Example

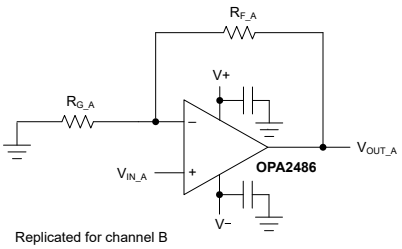


Figure 7-9. Schematic Representation

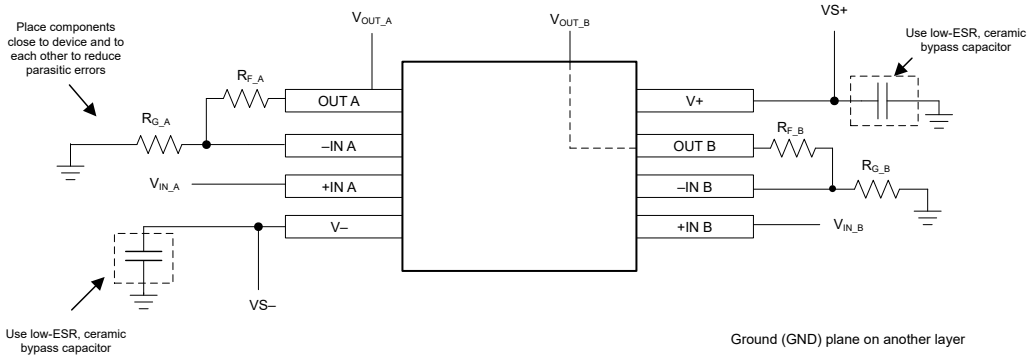


Figure 7-10. Operational Amplifier Board Layout for Noninverting Amplifier Configuration

8 Device and Documentation Support

8.1 Device Support

8.1.1 Development Support

8.1.1.1 PSpice® for TI

PSpice® for TI is a design and simulation environment that helps evaluate performance of analog circuits. Create subsystem designs and prototype designs before committing to layout and fabrication, reducing development cost and time to market.

8.1.1.2 TINA-TI™ Simulation Software (Free Download)

TINA-TI™ simulation software is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI simulation software is a free, fully-functional version of the TINA™ software, preloaded with a library of macromodels, in addition to a range of both passive and active models. TINA-TI simulation software provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a free download from the Design and simulation tools web page, TINA-TI simulation software offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

Note

These files require that either the TINA software or TINA-TI software be installed. Download the free TINA-TI simulation software from the TINA-TI™ software folder.

8.2 Documentation Support

8.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *Zero-drift Amplifiers: Features and Benefits* application brief
- Texas Instruments, *The PCB is a component of op amp design* application note
- Texas Instruments, *Operational amplifier gain stability, Part 3: AC gain-error analysis*
- Texas Instruments, *Operational amplifier gain stability, Part 2: DC gain-error analysis*
- Texas Instruments, *Using infinite-gain, MFB filter topology in fully differential active filters* application note
- Texas Instruments, *Op Amp Performance Analysis*
- Texas Instruments, *Single-Supply Operation of Operational Amplifiers* application note
- Texas Instruments, *Shelf-Life Evaluation of Lead-Free Component Finishes* application note
- Texas Instruments, *Feedback Plots Define Op Amp AC Performance* application note
- Texas Instruments, *EMI Rejection Ratio of Operational Amplifiers* application note
- Texas Instruments, *Analog Linearization of Resistance Temperature Detectors* application note
- Texas Instruments, *TI Precision Design TIPD102 High-Side Voltage-to-Current (V-I) Converter*

8.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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8.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.7 Glossary

TI Glossary — This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (January 2026) to Revision A (February 2026) **Page**

- Updated data sheet status from *Advanced Information* to *Production Data* 1
- Updated *Features*, *Feature Description*, *Thermal Information*, *Electrical Characteristics*, *ESD Ratings* and *Typical Characteristics* to the production data specifications..... 1
- Changed OPA2486D from *Preview* to *Production Data* 1

DATE	REVISION	NOTES
January 2026	*	Initial Release

10 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)
OPA2486DR	Active	Production	SOIC (D) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	OP2486
POPA486DBVR	Active	Preproduction	SOT-23 (DBV) | 5	3000 | LARGE T&R	-	Call TI	Call TI	-40 to 125	

(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.

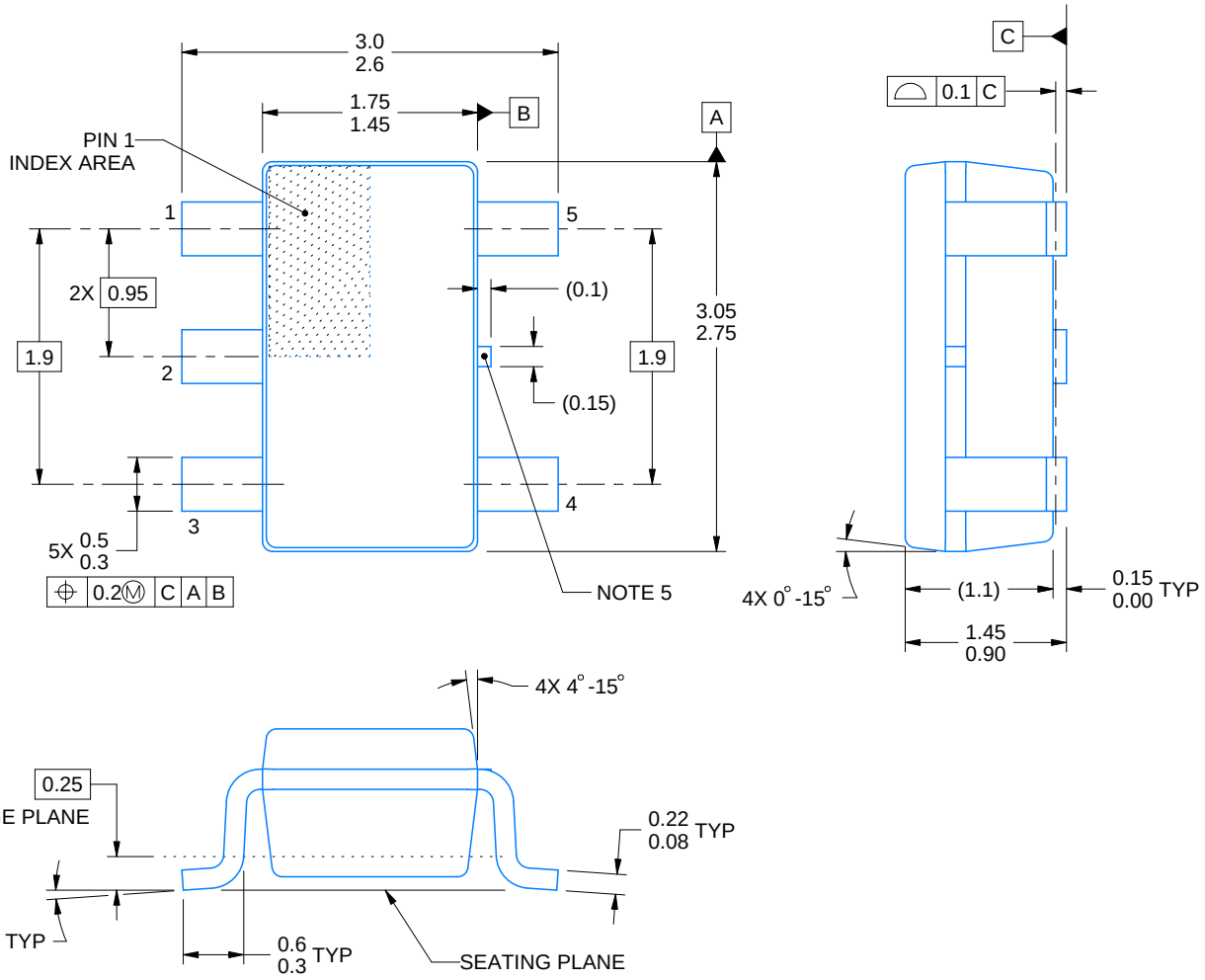
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

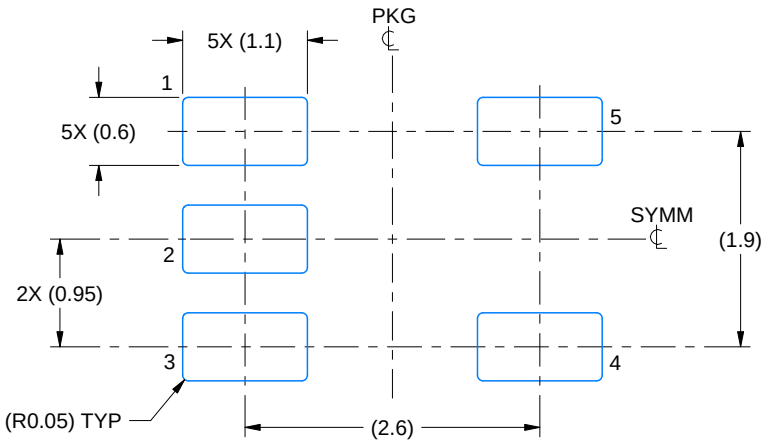
SMALL OUTLINE TRANSISTOR



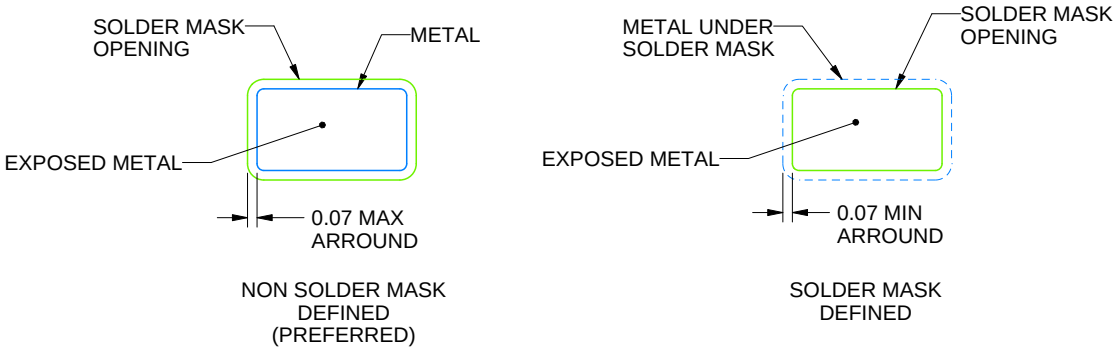
4214839/K 08/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

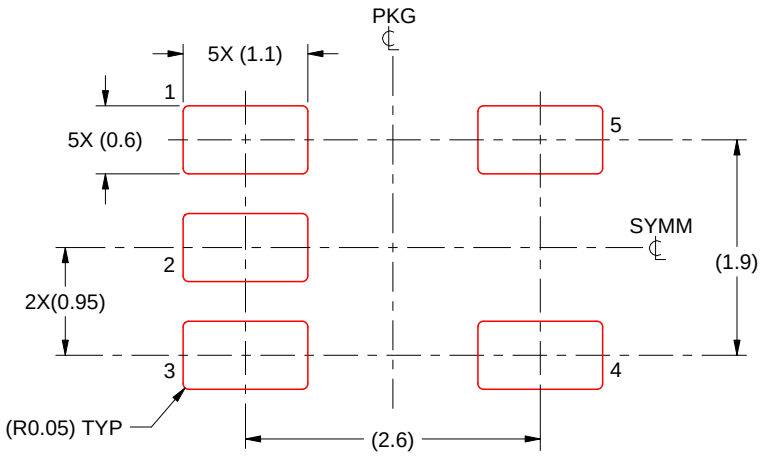


SOLDER MASK DETAILS

4214839/K 08/2024

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.

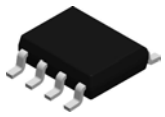


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/K 08/2024

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.

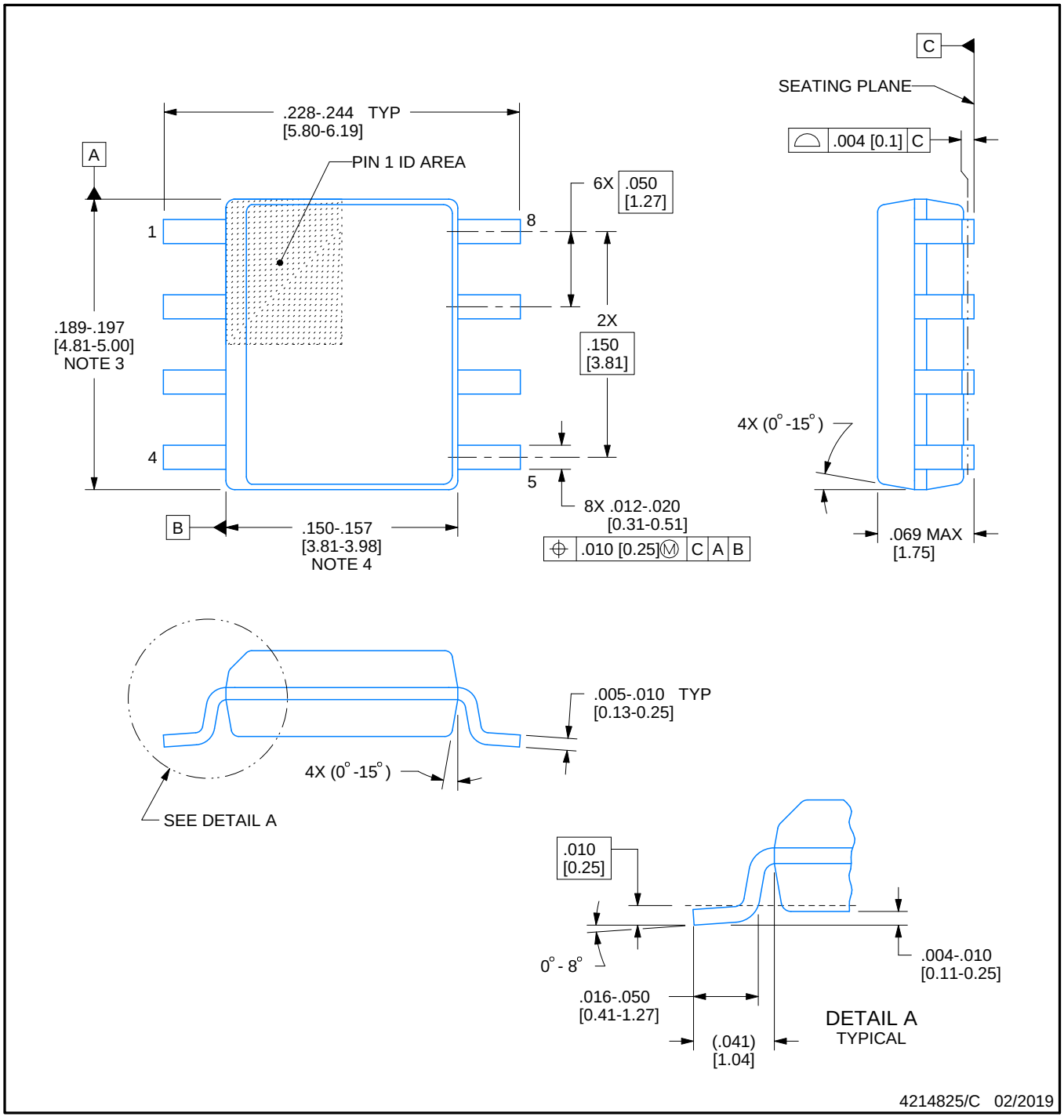


PACKAGE OUTLINE

D0008A

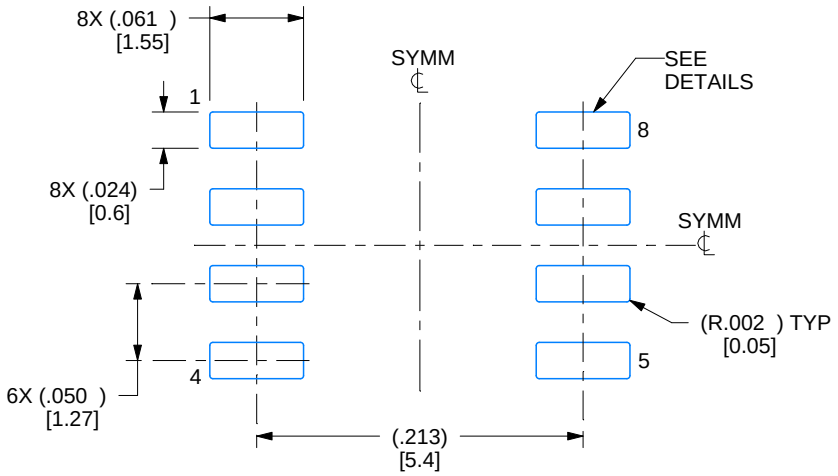
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

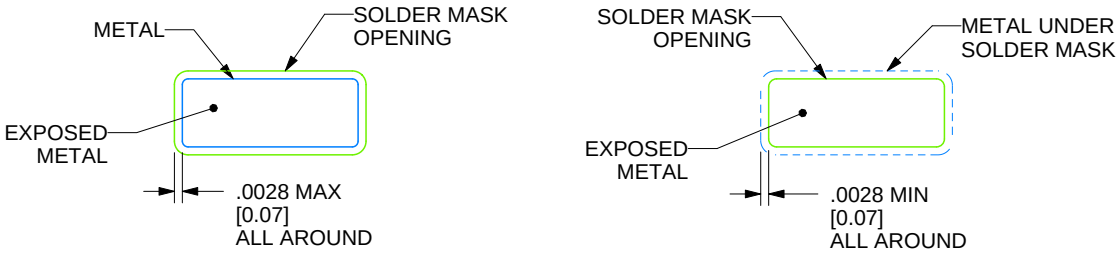


NOTES:

1. 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.
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 .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

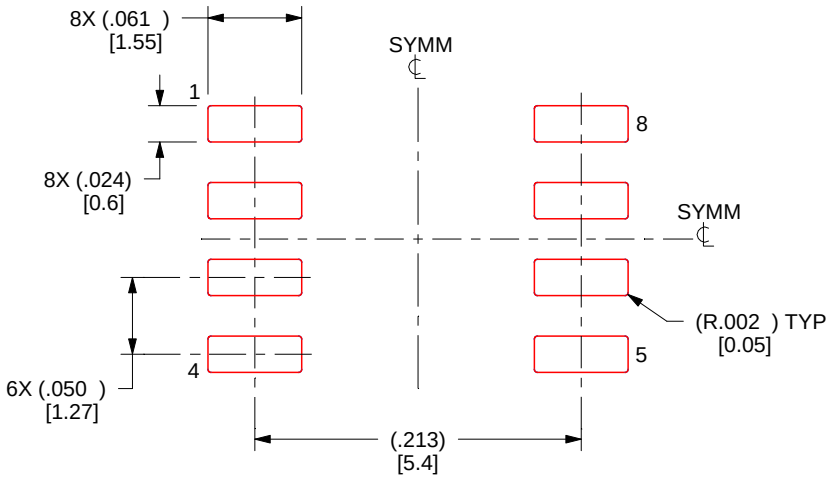
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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.

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Last updated 10/2025