TEXAS INSTRUMENTS

OPA187, OPA2187, OPA4187

SBOS807A –DECEMBER 2016–REVISED JULY 2017

OPAx187 0.005-µV/°C Drift, Low Power, Rail-to-Rail Output 36-V Operational Amplifiers Zero-Drift Series

1 Features

- Low Offset Voltage: 10 µV (maximum)
- Zero Drift: 0.005 µV/°C
- Low Noise: 20 nV/√Hz
- PSRR: 160 dB
- CMRR: 140 dB
- AOL: 160 dB
- Quiescent Current: 100 µA
- Wide Supply Voltage: ±2.25 V to ±18 V
- Rail-to-Rail Output Operation
- Input Includes Negative Rail
- Low Bias Current: 100 pA (typical)
- EMI Filtered Inputs
- Microsize Packages

2 Applications

- Bridge Amplifier
- Strain Gauge
- Test and Measurement Equipment
- Transducer Application
- Temperature Measurement
- Electronic Scales
- Medical Instrumentation
- RTD Amplifier
- Precision Active Filters
- Low-Side Current Monitoring

3 Description

The OPAx187 series operational amplifiers use auto-zeroing techniques to simultaneously provide low-offset voltage (1 µV), and near zero drift over time and temperature. These miniature, high-precision, low-quiescent current amplifiers offer high-input impedance and rail-to-rail output swing within 5 mV of the rails into high-impedance loads. The input common-mode range includes the negative rail. Either single or dual supplies can be used in the range of 4.5 V to 36 V (±2.25 V to ±18 V).
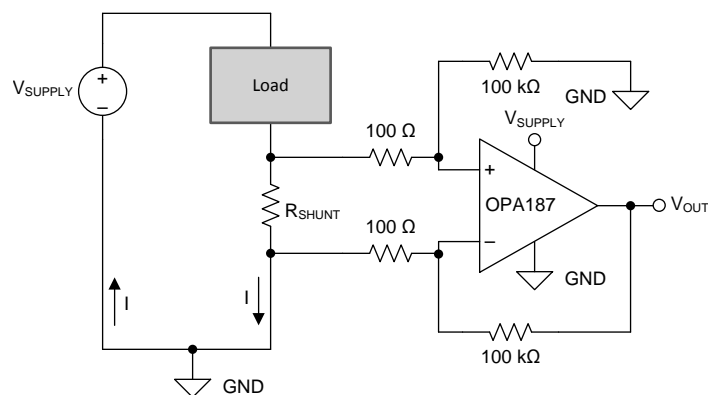
The single version of the OPAx187 device is available in Microsize 8-pin VSSOP, 5-pin SOT-23, and 8-pin SOIC packages. The dual version is offered in 8-pin VSSOP and 8-pin SOIC packages. The quad version is offered in 14-pin SOIC, 14-pin TSSOP, and 16-pin WQFN packages. All versions are specified for operation from –40°C to +125°C.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA187	SOIC (8)	4.90 mm × 3.91 mm
	SOT-23 (5)	2.90 mm × 1.60 mm
	VSSOP (8)	3.00 mm × 3.00 mm
OPA2187	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm
OPA4187	SOIC (14)	8.70 mm × 3.90 mm
	TSSOP (14)	5.00 mm × 4.40 mm
	WQFN (16)	4.00 mm x 4.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

OPAx187 Offers Precision Low-Side Current Measurement Capability
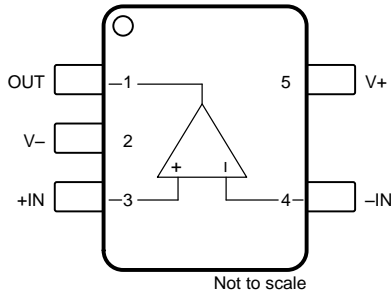

$$G = 1000 \cdot R_{SHUNT} \cdot I$$

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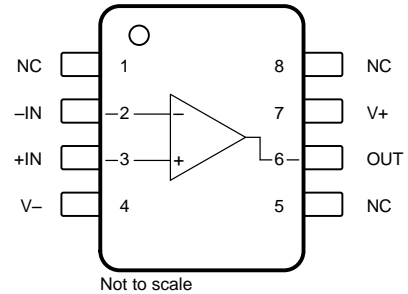
OPA187: DBV Package
5-Pin SOT-23
Top View

Not to scale

OPA187: D and DGK Packages
8-Pin SOIC and 8-pin VSSOP
Top View

Not to scale

(1)   NC denotes no internal connection.

Pin Functions: OPA187

PIN			I/O	DESCRIPTION
NAME	DBV	D and DGK		
+IN	3	3	I	Non-inverting input
–IN	4	2	I	Inverting input
NC	—	1, 5, 8	—	No connection (can be left floating)
OUT	1	6	O	Output signal
V+	5	7	—	Positive (highest) supply voltage
V–	2	4	—	Negative (lowest) supply voltage

OPA2187: D and DGK Packages
8-Pin SOIC and 8-Pin VSSOP
Top View

Not to scale
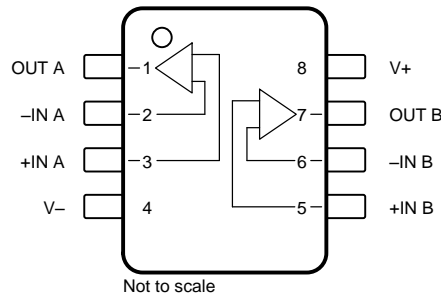
Pin Functions: OPA2187

PIN		I/O	DESCRIPTION
NAME	D and DGK		
+IN A	3	I	Non-inverting input, channel A
–IN A	2	I	Inverting input, channel A
+IN B	5	I	Non-inverting input, channel B
–IN B	6	I	Inverting input, channel B
OUT A	1	O	Output, channel A
OUT B	7	O	Output, channel B
V+	8	—	Positive (highest) supply voltage
V–	4	—	Negative (lowest) supply voltage

**OPA4187: D and PW Packages
14-pin SOIC and 14-Pin TSSOP
Top View**
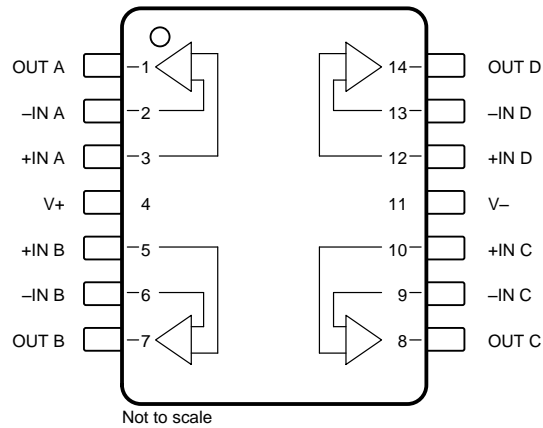
**OPA4187: RUM Package
16-pin WQFN
Top View**

Not to scale

Not to scale
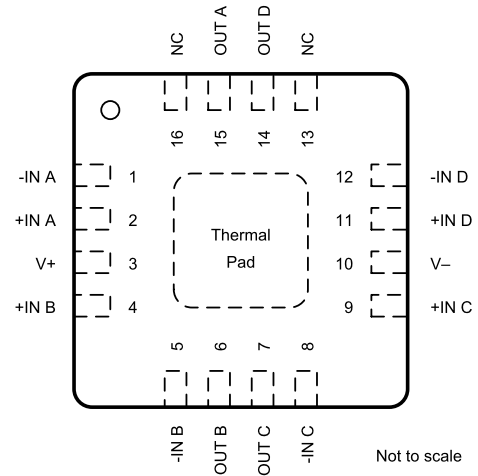
Pin Functions: OPA4187

PIN			I/O	DESCRIPTION
NAME	D and PW	RUM		
+IN A	3	2	I	Non-inverting input, channel A
–IN A	2	1	I	Inverting input, channel A
+IN B	5	4	I	Non-inverting input, channel B
–IN B	6	5	I	Inverting input, channel B
+IN C	10	9	I	Non-inverting input, channel C
–IN C	9	8	I	Inverting input, channel C
+IN D	12	11	I	Non-inverting input, channel D
–IN D	13	12	I	Inverting input, channel D
OUT A	1	15	O	Output, channel A
OUT B	7	6	O	Output, channel B
OUT C	8	7	O	Output, channel C
OUT D	14	14	O	Output, channel D
V+	4	3	—	Positive (highest) supply voltage
V–	11	10	—	Negative (lowest) supply voltage
NC	—	13, 16	—	No internal connection (can be left floating)

Product Folder Links: *OPA187 OPA2187 OPA4187*

6 Specifications

6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
Voltage	Supply, $V_S = (V^+) - (V^-)$			40	V
	Signal input pin[2]	Common-mode	$(V^-) - 0.5$	$(V^+) + 0.5$	
		Differential[3]		±0.5	
	Signal output pin[4]		$(V^-) - 0.5$	$(V^+) + 0.5$	
Current	Signal input pin[2]		−10	10	mA
	Signal output pin[4]		−55	55	mA
	Output short-circuit[5]		Continuous		
Temperature	Operating, T_A		−55	150	°C
	Junction, T_J			150	
	Storage, T_{stg}		−65	150	

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5 V beyond the supply rails should be current limited to ±10 mA or less.
(3) Refer to the *Electrical Overstress* section for more information.
(4) Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.5 V beyond the supply rails should be current limited to ±55 mA or less.
(5) Short-circuit to ground, one amplifier per package.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±4000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±1500	

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

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
$(V^+) - (V^-)$	Supply voltage	4.5 (±2.25)		36 (±18)	V
T_A	Specified temperature	−40		125	°C

6.4 Thermal Information: OPA187

THERMAL METRIC[1]		OPA187			UNIT
		5 PINS	8 PINS		
		DBV (SOT-23)	DGK (VSSOP)	D (SOIC)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	273.8	159	100.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	126.8	37	42.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	85.9	49	41.0	°C/W
ψ_{JT}	Junction-to-top characterization parameter	10.9	1.2	4.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	84.9	77.1	40.3	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a	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.

6.5 Thermal Information: OPA2187

THERMAL METRIC[1]		OPA2187		UNIT
		8 PINS		
		DGK (VSSOP)	D (SOIC)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	159	100.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	37	42.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	49	41.0	°C/W
ψ_{JT}	Junction-to-top characterization parameter	1.2	4.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	77.1	40.3	°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 report.

6.6 Thermal Information: OPA4187

THERMAL METRIC[1]		OPA4187			UNIT
		14 PINS		16 PINS	
		PW (TSSOP)	D (SOIC)	RUM (WQFN)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	107.8	83.8	35.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	29.6	70.7	32.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	52.6	59.5	12.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	1.5	11.6	0.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	51.6	37.7	12.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a	n/a	3.3	°C/W

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

Product Folder Links: *OPA187 OPA2187 OPA4187*

6.7 Electrical Characteristics: High-Voltage Operation

at T_A = 25°C, V_S = ±4 V to ±18 V (V_S = 8 V to 36 V), R_L = 10 kΩ connected to V_S / 2[(1)], and V_{CM} = V_{OUT} = V_S / 2[(1)] (unless otherwise noted)

	PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V_{OS}	Input offset voltage				±1	±10	µV
			T_A = −40°C to +125°C		±0.005	±0.05	µV/°C
PSRR	Power-supply rejection ratio		V_S = 4.5 V to 36 V, T_A = −40°C to +125°C		±0.01	±1	µV/V
INPUT BIAS CURRENT							
I_B	Input bias current		V_{CM} = V_S / 2		±100	±350	pA
			T_A = −40°C to +125°C			±5	nA
I_{OS}	Input offset current				±100	±500	pA
			T_A = −40°C to +125°C			±5	nA
NOISE							
e_n	Input voltage noise		f = 0.1 Hz to 10 Hz		0.4		µV$_{PP}$
			f = 0.1 Hz to 10 Hz		60		nVrms
	Input voltage noise density		f = 1 kHz		20		nV/√Hz
i_n	Input current noise density		f = 1 kHz		160		fA/√Hz
INPUT VOLTAGE RANGE							
V_{CM}	Common-mode voltage range			(V−) − 0.1		(V+) − 2	V
CMRR	Common-mode rejection ratio		(V−) − 0.1 V < V_{CM} < (V+) − 2 V, V_S = ±18 V	126	140		dB
			(V−) < V_{CM} < (V+) − 2 V, V_S = ±18 V, T_A = −40°C to +125°C	130	145		dB
INPUT IMPEDANCE							
Z_{ID}	Differential				100 ‖ 6		MΩ ‖ pF
Z_{IC}	Common-mode				6 ‖ 4.2		10^{12} Ω ‖ pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain		T_A = −40°C to +125°C, V_S = ±4 V to ±18 V, (V−) + 0.3 V < V_O < (V+) − 0.3 V, R_L = 10 kΩ	132	160		dB
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product				550		kHz
SR	Slew rate		V_O = 10-V step, G = 1		0.2		V/µs
t_S	Settling time	0.1%	V_S = ±18 V, G = 1, 10-V step		46		µs
		0.01%	V_S = ±18 V, G = 1, 10-V step		48		µs
t_{OR}	Overload recovery time		V_{IN} × G = V_S		8		µs
THD+N	Total harmonic distortion + noise		1 kHz, G = 1, V_{OUT} = 3.5 V_{RMS}, No Load		0.035%		
OUTPUT							
	Voltage output swing from rail		V_S = ±4 V to ±18 V, No Load		5	15	mV
			V_S = ±4 V to ±18 V, R_L = 10 kΩ		75	100	
			V_S = ±4 V to ±18 V, R_L = 10 kΩ, T_A = −40°C to +125°C		100	125	
I_{SC}	Short-circuit current		V_S = ±18 V, Sinking		−30		mA
			V_S = ±18 V, Sourcing		+30		mA
R_O	Open-loop output resistance		f = 550 kHz, I_O = 0, See Figure 21		1.4		kΩ
C_{LOAD}	Capacitive load drive				See *Typical Characteristics*		
POWER SUPPLY							
I_Q	Quiescent current (per amplifier)		V_S = ±4 V to V_S = ±18 V		100	145	µA
			I_O = 0 mA, T_A = −40°C to +125°C			150	µA

(1) V_S / 2 = midsupply.

Product Folder Links: *OPA187 OPA2187 OPA4187*

6.8 Electrical Characteristics: Low-Voltage Operation

at T_A = +25°C, V_S = ±2.25 V to < ±4 V (V_S = +4.5 V to < 8 V), R_L = 10 kΩ connected to V_S / 2[(1)], and V_{CM} = V_{OUT} = V_S / 2[(1)] (unless otherwise noted)

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage			±1	±15	μV
		T_A = −40°C to +125°C		±0.005	±0.05	μV/°C
PSRR	Power-supply rejection ratio	V_S = 4.5 V to 36 V, T_A = −40°C to +125°C		±0.01	±1	μV/V
INPUT BIAS CURRENT						
I_B	Input bias current	V_{CM} = V_S / 2		±100	±350	pA
		T_A = −40°C to +125°C			±5	nA
I_{OS}	Input offset current			±100	±500	pA
		T_A = −40°C to +125°C			±5	nA
NOISE						
e_n	Input voltage noise	f = 0.1 Hz to 10 Hz		0.4		μV$_{PP}$
		f = 0.1 Hz to 10 Hz		60		nVrms
	Input voltage noise density	f = 1 kHz		20		nV/$\sqrt{Hz}$
i_n	Input current noise density	f = 1 kHz		160		fA/$\sqrt{Hz}$
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range		(V−) − 0.1		(V+) − 2	V
CMRR	Common-mode rejection ratio	(V−) − 0.1 V < V_{CM} < (V+) − 2 V, V_S = ±2.25 V	114	130		dB
		(V−) < V_{CM} < (V+) − 2 V, V_S = ±2.25 V, T_A = −40°C to +125°C	120	137		dB
INPUT IMPEDANCE						
Z_{ID}	Differential			100 ‖ 6		MΩ ‖ pF
Z_{IC}	Common-mode			6 ‖ 4.2		10^{12} Ω ‖ pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	T_A = −40°C to +125°C, V_S = ±2.25 V to ±4 V, (V−) + 0.3 V < V_O < (V+) − 0.3 V, R_L = 10 kΩ	120	140		dB
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product			550		kHz
SR	Slew rate	V_O = 1-V step, G = 1		0.2		V/μs
t_{OR}	Overload recovery time	V_{IN} × G = V_S		8		μs
THD+N	Total harmonic distortion + noise	1 kHz, G = 1, V_{OUT} = 1 Vrms, No Load		0.05%		
OUTPUT						
	Voltage output swing from rail	V_S = ±2.25 V to ±4 V, No Load		5	15	mV
		V_S = ±2.25 V to ±4 V, R_L = 10 kΩ		15	25	
		V_S = ±2.25 V to ±4 V, R_L = 10 kΩ, T_A = −40°C to +125°C		15	30	
I_{SC}	Short-circuit current	V_S = ±2.25, Sinking		−20		mA
		V_S = ±2.25, Sourcing		+20		mA
R_O	Open-loop output resistance	f = 550 kHz, I_O = 0, See Figure 21		1.4		kΩ
C_{LOAD}	Capacitive load drive			See *Typical Characteristics*		
POWER SUPPLY						
I_Q	Quiescent current (per amplifier)	V_S = ±2.25 V to V_S = ±4 V		100	145	μA
		I_O = 0 mA, T_A = −40°C to +125°C			150	μA

(1) V_S / 2 = midsupply.

Product Folder Links: *OPA187 OPA2187 OPA4187*

6.9 Typical Characteristics

Table 1. Typical Characteristic Graphs
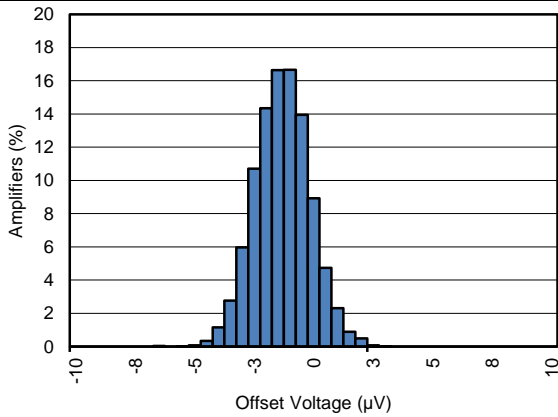
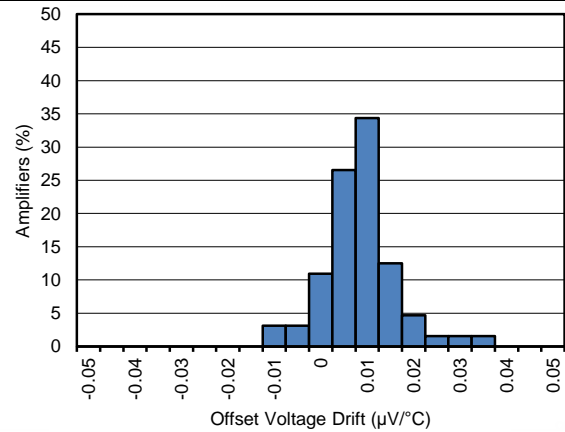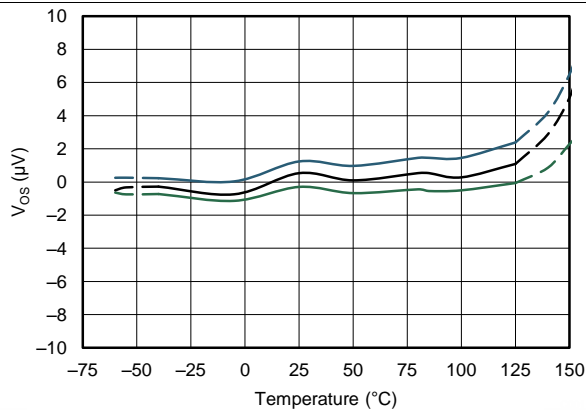| DESCRIPTION	FIGURE
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at V_S = ±18 V, V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 100 pF (unless otherwise noted)

Figure 1. Offset Voltage Production Distribution

Figure 2. Offset Voltage Drift Distribution
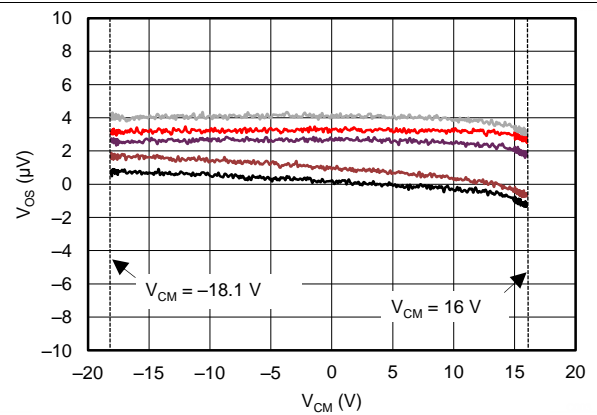

Figure 3. Offset Voltage vs Temperature

Figure 4. Offset Voltage vs Common-Mode Voltage

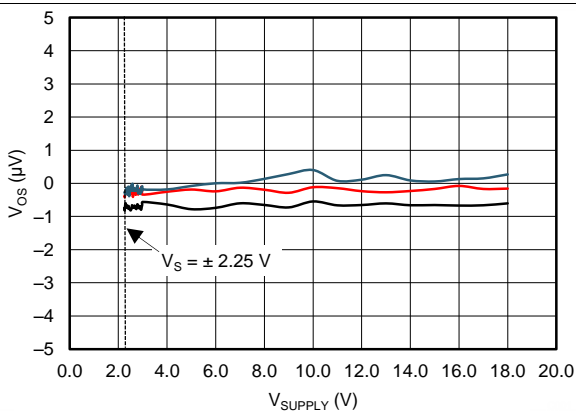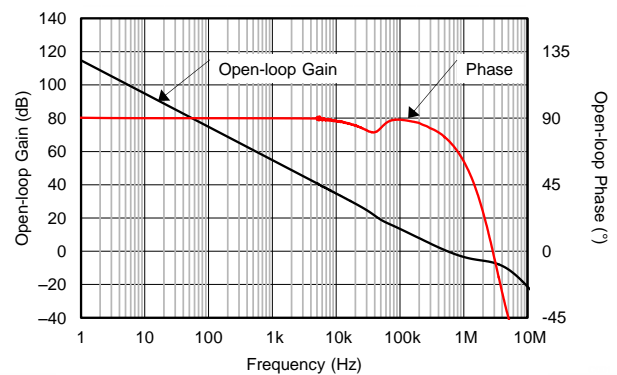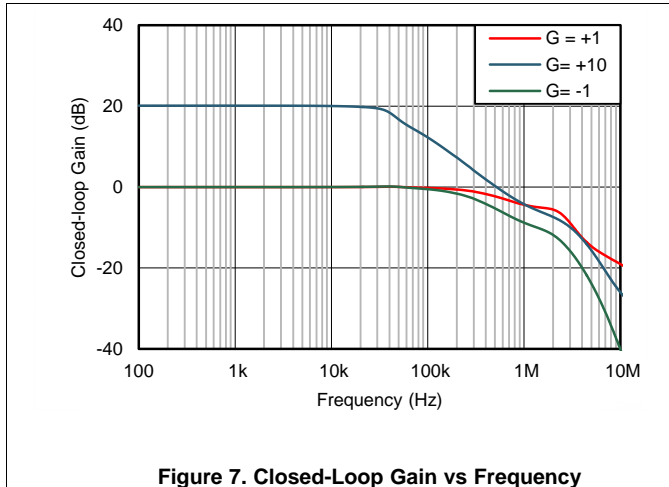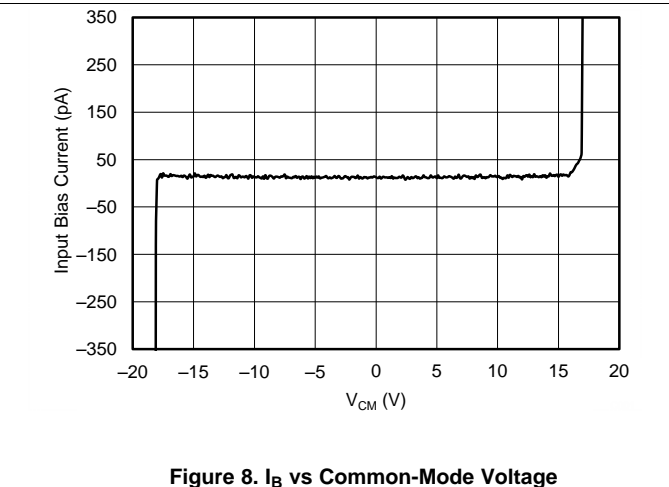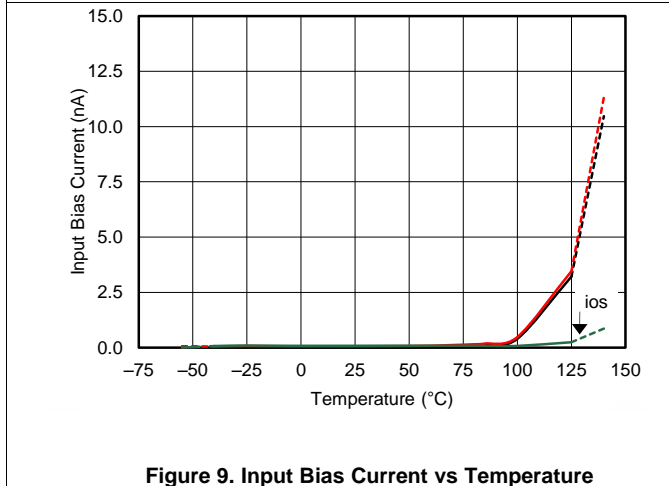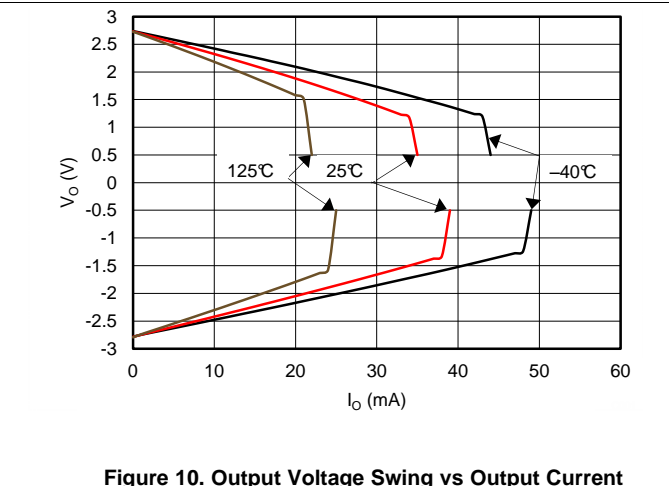Figure 5. Offset Voltage vs Power Supply

Figure 6. Open-Loop Gain and Phase vs Frequency

Product Folder Links: *OPA187 OPA2187 OPA4187*

at V_S = ±18 V, V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 100 pF (unless otherwise noted)

Figure 7. Closed-Loop Gain vs Frequency

Figure 8. I_B vs Common-Mode Voltage

Figure 9. Input Bias Current vs Temperature

Figure 10. Output Voltage Swing vs Output Current
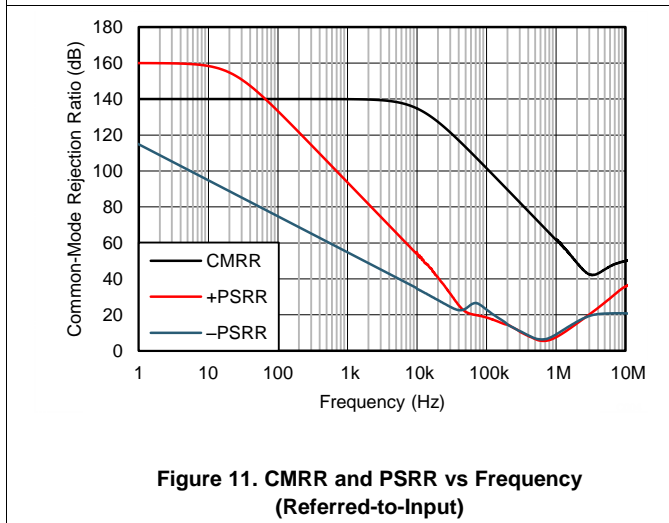
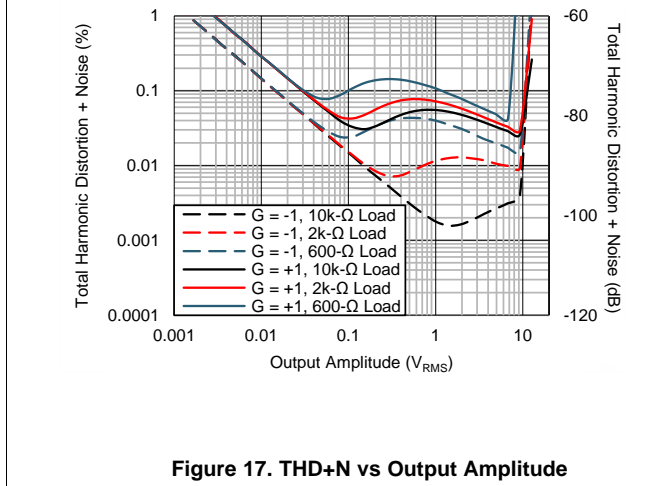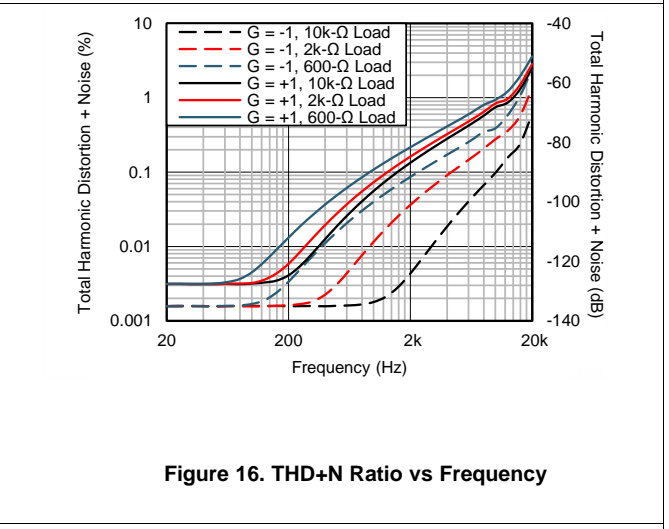**Figure 11. CMRR and PSRR vs Frequency (Referred-to-Input)**
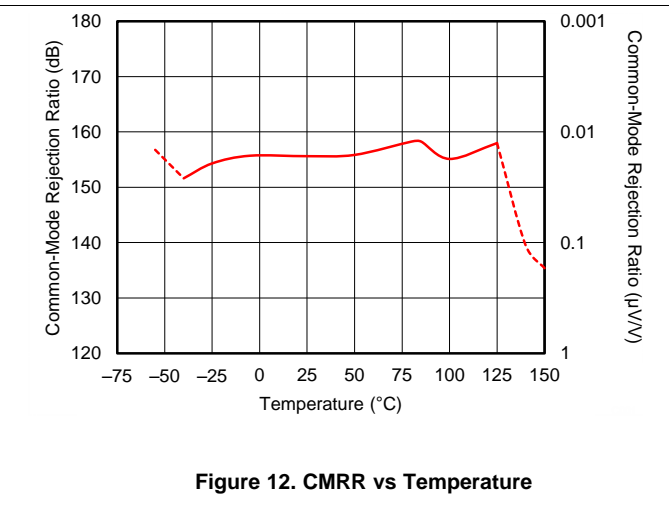
Figure 12. CMRR vs Temperature

at V_S = ±18 V, V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 100 pF (unless otherwise noted)

Figure 13. PSRR vs Temperature

Figure 14. 0.1-Hz to 10-Hz Noise

Figure 15. Input-Referred Voltage Noise Spectral Density vs Frequency (G = +101)

Figure 16. THD+N Ratio vs Frequency

Figure 17. THD+N vs Output Amplitude

Figure 18. Quiescent Current vs Supply Voltage

Product Folder Links: *OPA187 OPA2187 OPA4187*
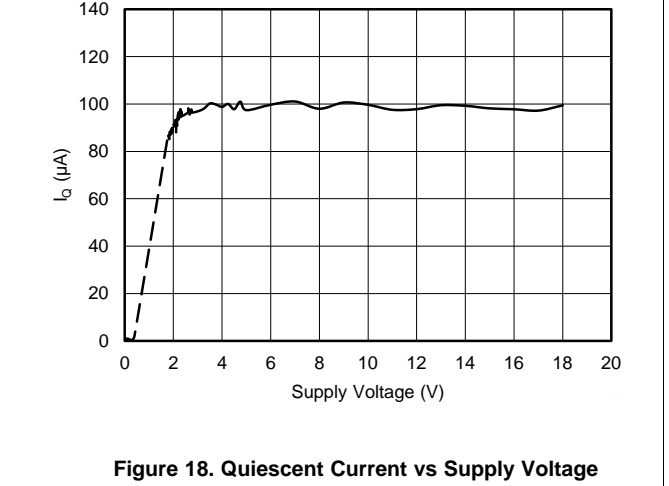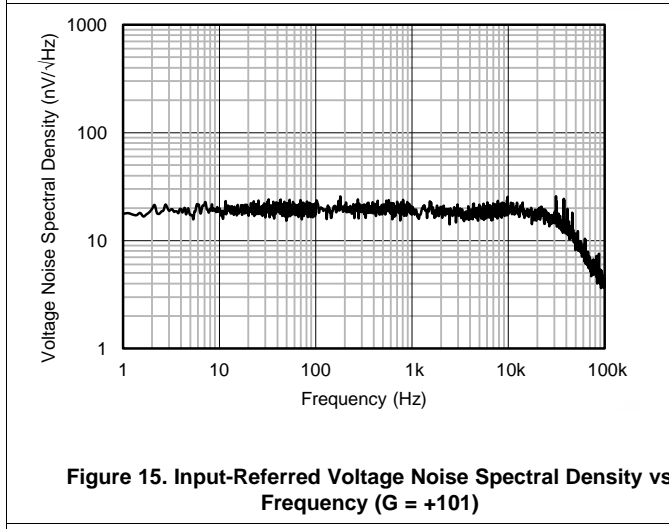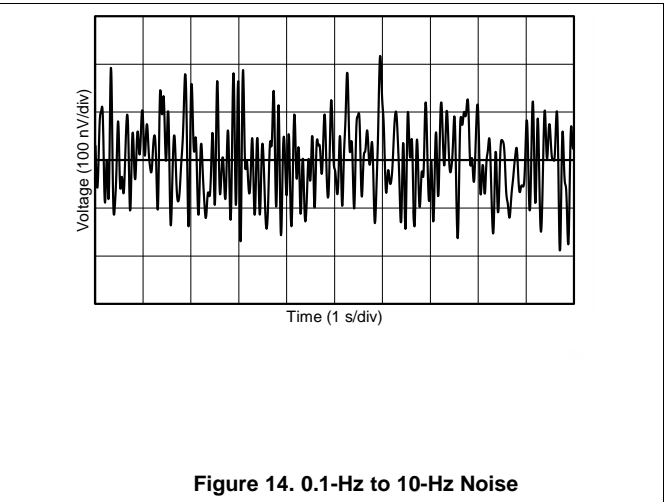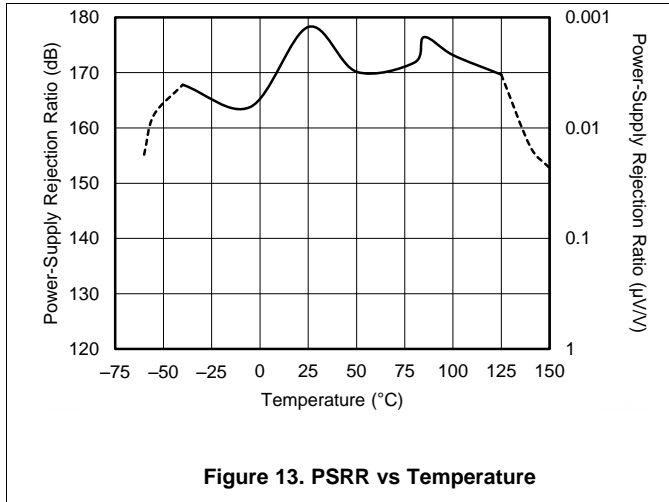
at V_S = ±18 V, V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 100 pF (unless otherwise noted)
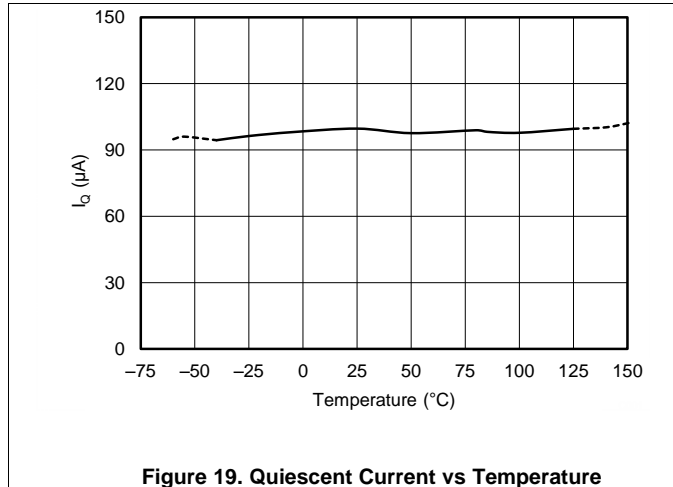

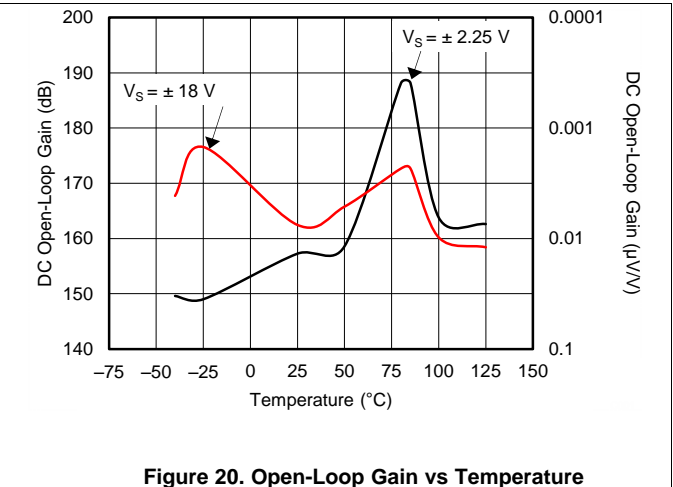**Figure 19. Quiescent Current vs Temperature**

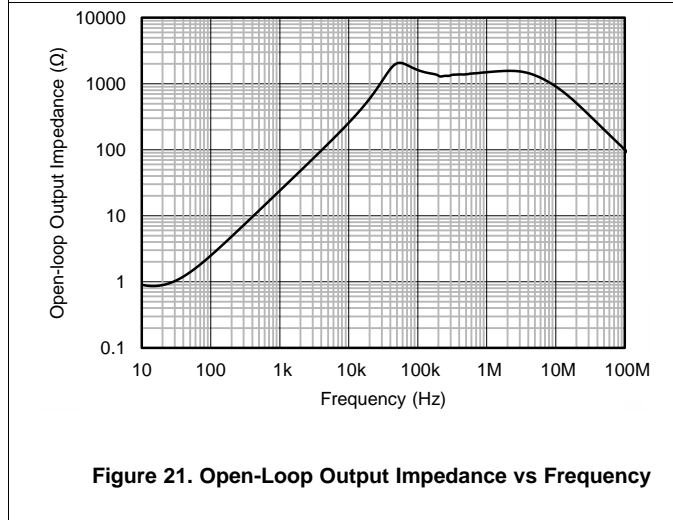**Figure 20. Open-Loop Gain vs Temperature**

Figure 21. Open-Loop Output Impedance vs Frequency
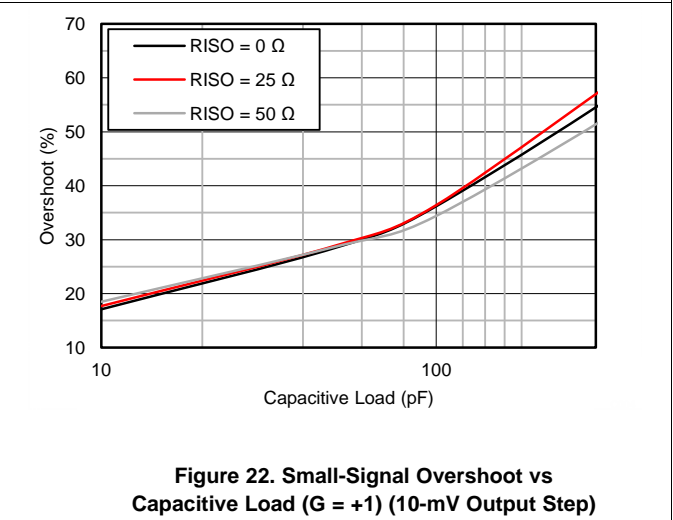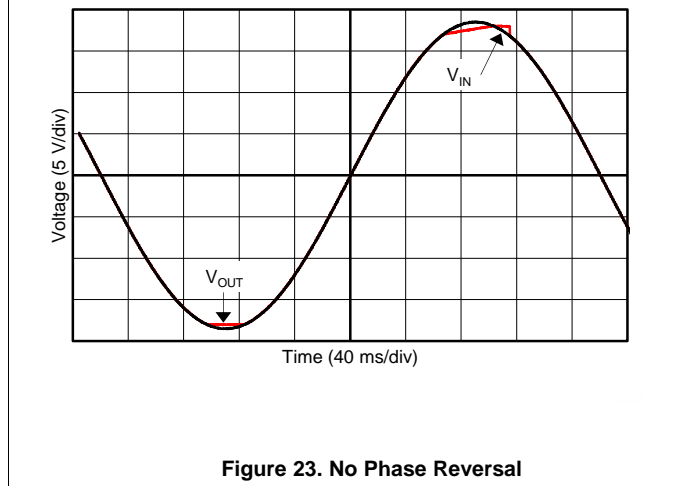

Figure 22. Small-Signal Overshoot vs Capacitive Load (G = +1) (10-mV Output Step)
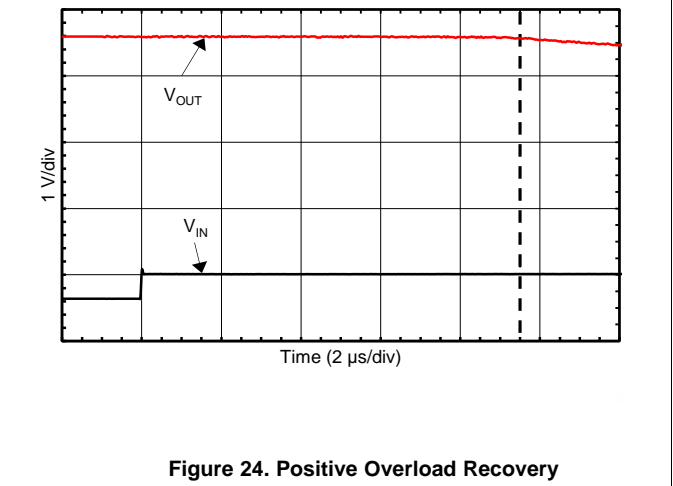

Figure 23. No Phase Reversal

Figure 24. Positive Overload Recovery

Product Folder Links: *OPA187 OPA2187 OPA4187*

at $V_S = \pm18$ V, $V_{CM} = V_S / 2$, $R_{LOAD} = 10$ kΩ connected to $V_S / 2$, and $C_L = 100$ pF (unless otherwise noted)

Figure 25. Negative Overload Recovery

**Figure 26. Small-Signal Step Response
(100 mV)**

**Figure 27. Small-Signal Step Response
(100 mV)**

Figure 28. Large-Signal Step Response

Figure 29. Large-Signal Step Response

**Figure 30. Large-Signal Settling Time
(10-V Positive Step)**

Product Folder Links: *OPA187 OPA2187 OPA4187*
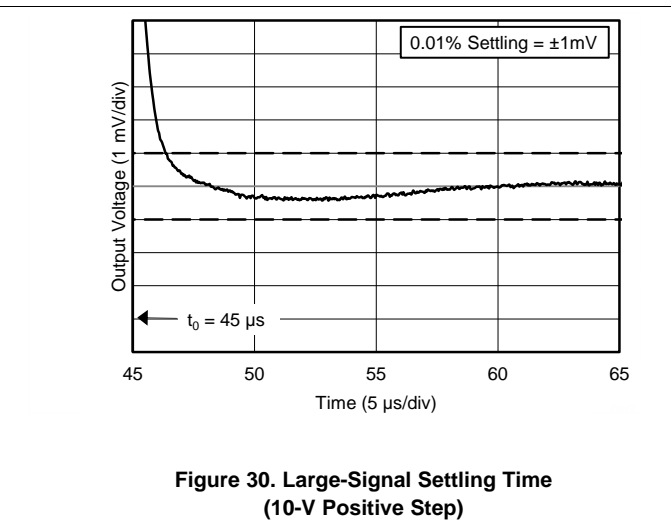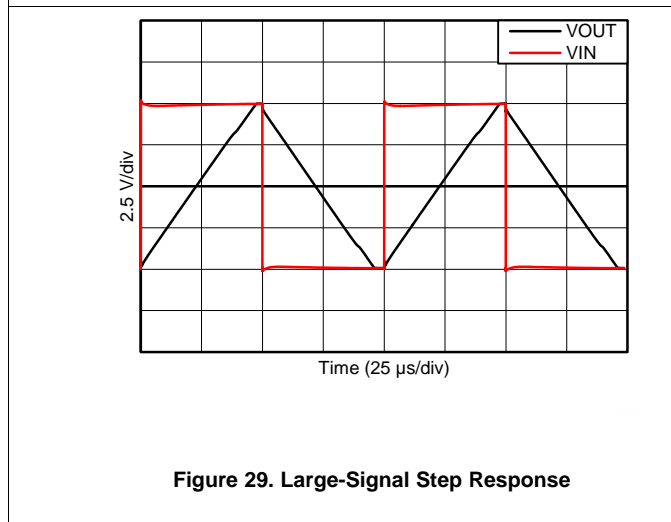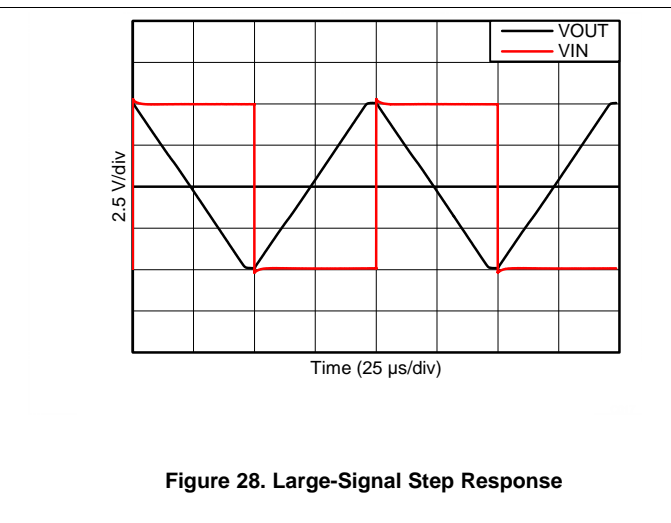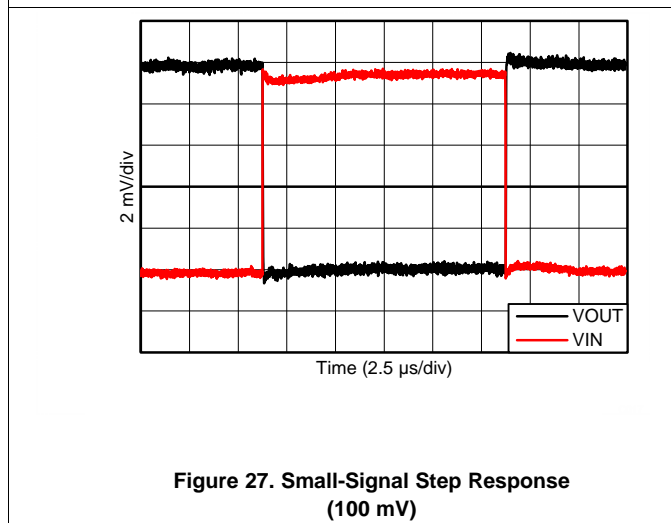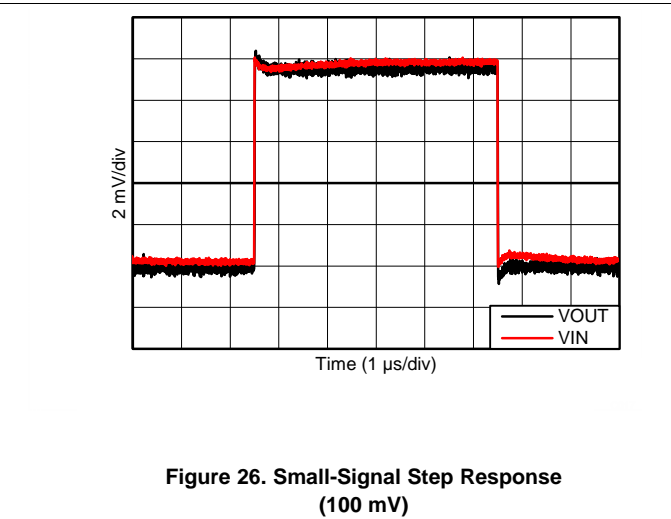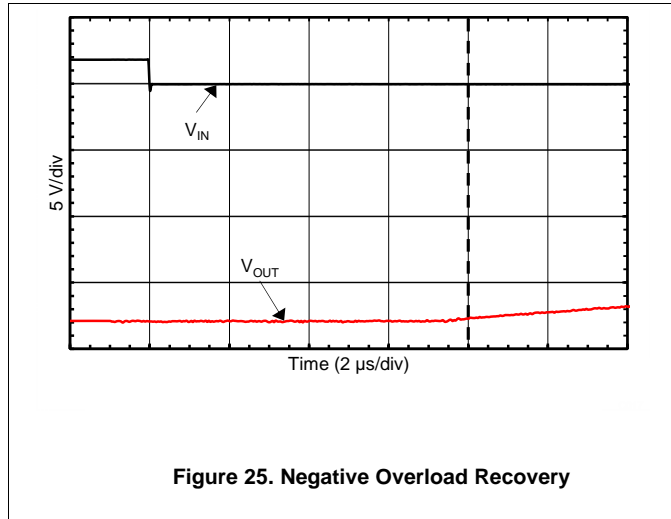
at V_S = ±18 V, V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 100 pF (unless otherwise noted)

**Figure 31. Large-Signal Settling Time
(10-V Negative Step)**

Figure 32. Short-Circuit Current vs Temperature

Figure 33. Maximum Output Voltage vs Frequency

Figure 34. Crosstalk vs Frequency

Figure 35. EMIRR IN+ vs Frequency

7 Detailed Description

7.1 Overview

The OPAx187 operational amplifier combines precision offset and drift with excellent overall performance, making the device ideal for many precision applicat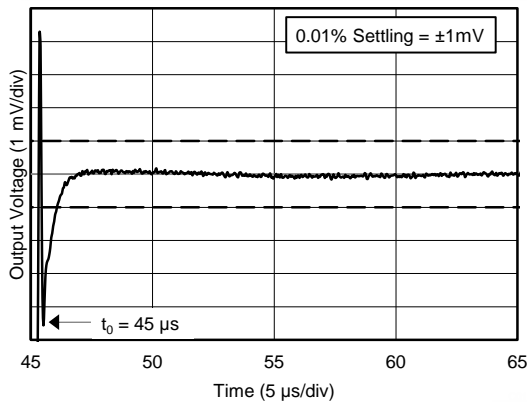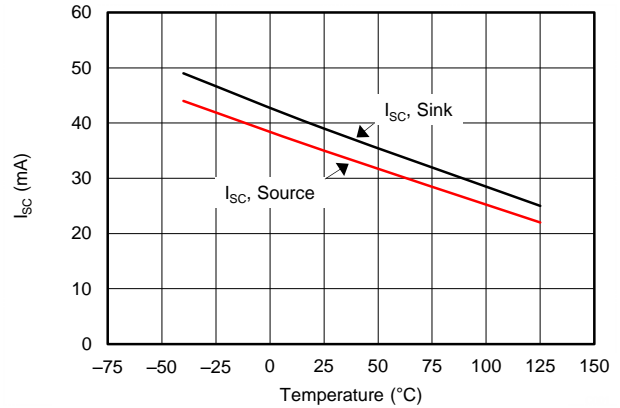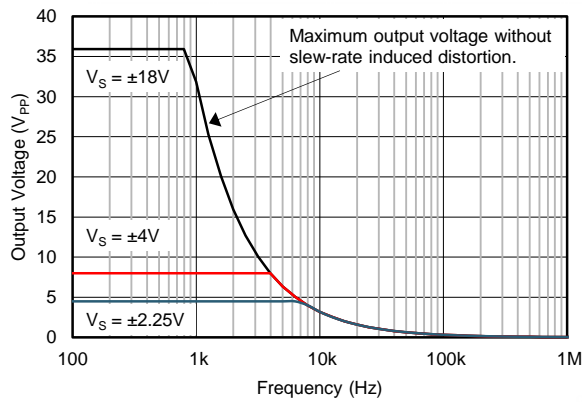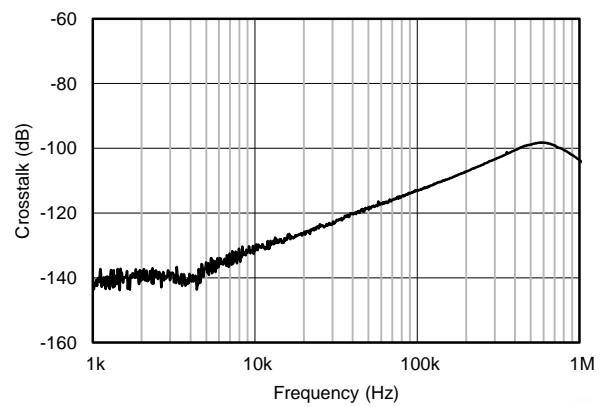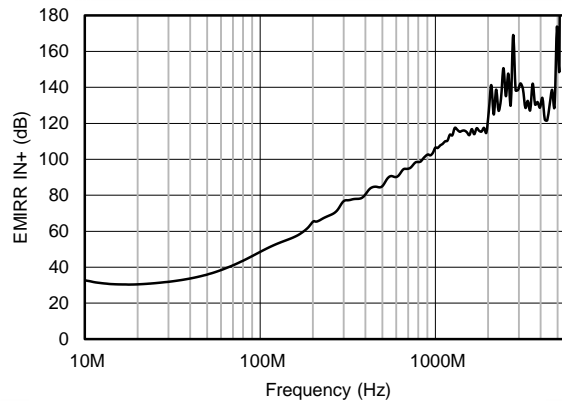ions. The precision offset drift of only 0.005 µV/°C provides stability over the entire temperature range. In addition, this device offers excellent overall performance with high CMRR, PSRR, and A_{OL}. As with all amplifiers, applications with noisy or high-impedance power supplies require decoupling capacitors close to the device pins. In most cases, 0.1-µF capacitors are adequate.

The OPAx187 device is part of a family of zero-drift, low-power, rail-to-rail output operational amplifiers. These devices operate from 4.5 V to 36 V, are unity-gain stable, and are suitable for a wide range of general-purpose applications. The zero-drift architecture provides ultra-low input offset voltage and near-zero input offset voltage drift over temperature and time. This choice of architecture also offers outstanding ac performance, such as ultra-low broadband noise and zero flicker noise.

7.2 Functional Block Diagram

Figure 36 shows a representation of the proprietary OPAx187 architecture. Functional blocks CHOP1 and CHOP2 operate such that the non-idealities of GM1 are cancelled while the input signal is left in-phase. The integrated notch filter of the OPAx187 family suppresses most of the auto-zero amplifier carrier.
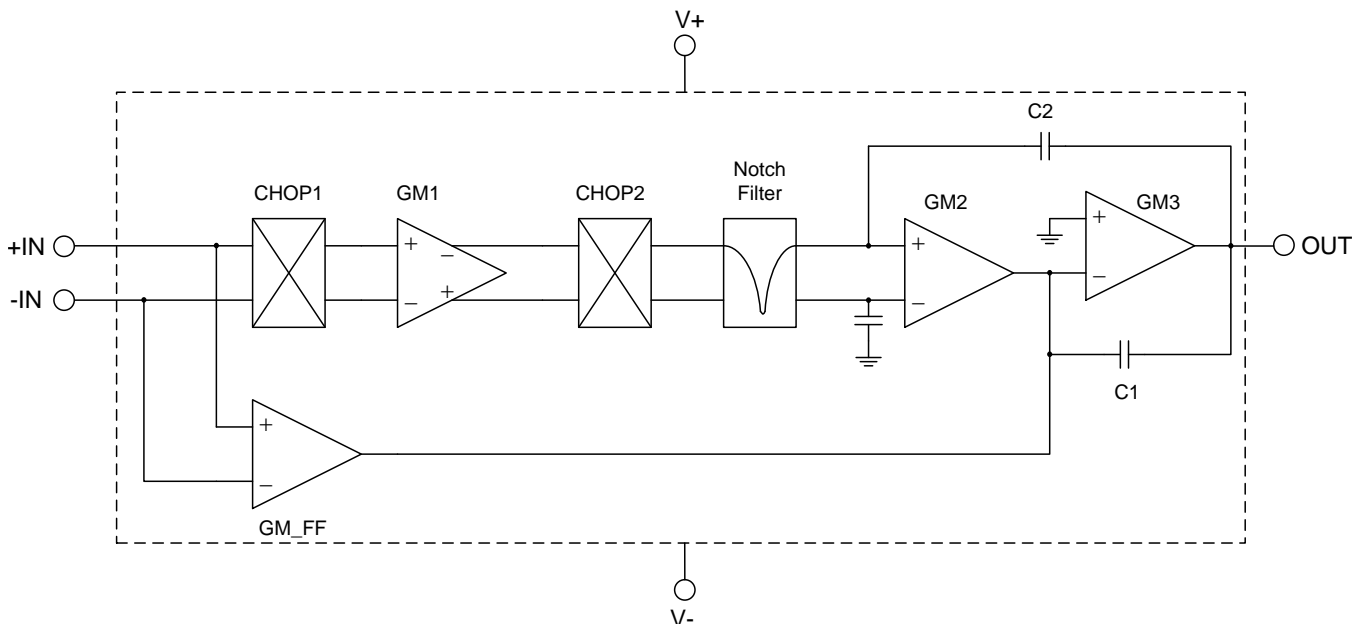
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Figure 36. Functional Block Diagram

7.3 Feature Description

The OPAx187 is unity-gain stable and free from unexpected output phase reversal. This device uses a proprietary, periodic autocalibration technique to provide ultra-low input offset voltage and near zero input offset voltage drift over temp and temperature. For lowest offset voltage and precision performance, optimize circuit layout and mechanical conditions. Avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. Cancel these thermally-generated potentials by making sure they are equal on both input pins. Other layout and design considerations include:

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.

Follow these guidelines to reduce the likelihood of junctions being at different temperatures, which may cause thermoelectric voltages of 0.1 µV/°C or higher, depending on the materials used.

7.3.1 Operating Characteristics

The OPAx187 device is specified for operation from 4.5 V to 36 V (±2.25 V to ±18 V). Many specifications apply from –40°C to +125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the *Typical Characteristics* section.

7.3.2 Phase-Reversal Protection

The OPAx187 device has an internal phase-reversal protection. Many op amps exhibit a phase reversal when the input is driven beyond its linear common-mode range. This condition is most often encountered in non-inverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The OPAx187 input prevents phase reversal with excessive common-mode voltage. Instead, the output limits into the appropriate rail. Figure 37 shows this performance.

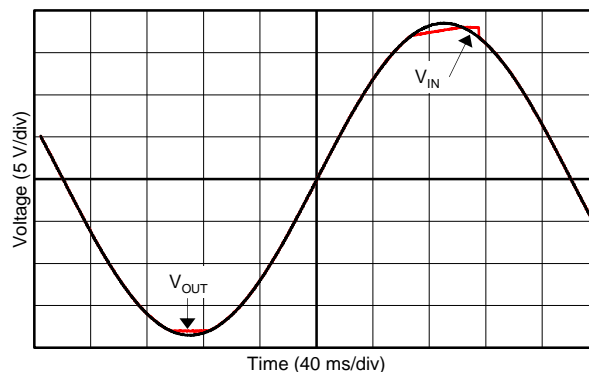**Figure 37. No Phase Reversal**

7.3.3 Input Bias Current Clock Feedthrough

Zero-drift amplifiers, such as the OPAx187, use switching on their inputs to correct for the intrinsic offset and drift of the amplifier. Charge injection from the integrated switches on the inputs can introduce very short transients in the input bias current of the amplifier. The extremely short duration of these pulses prevents them from being amplified, however they may be coupled to the output of the amplifier through the feedback network. The most effective method to prevent transients in the input bias current from producing additional noise at the amplifier output is to use a low-pass filter such as an RC network.

7.3.4 Internal Offset Correction

The OPAx187 op amp uses an auto-calibration technique with a time-continuous 125-kHz op amp in the signal path. This amplifier is zero-corrected every 22 µs using a proprietary technique. Upon power-up, the amplifier requires approximately 100 µs to achieve the specified V_{OS} accuracy. This design has no aliasing or flicker noise.

Product Folder Links: *OPA187 OPA2187 OPA4187*

Feature Description (continued)

7.3.5 EMI Rejection

The OPAx187 device uses integrated electromagnetic interference (EMI) filtering 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 OPAx187 benefits from these design improvements. Texas Instruments has developed the ability to accurately measure and quantify the immunity of an operational amplifier over a broad frequency spectrum extending from 10 MHz to 6 GHz. Figure 38 shows the results of this testing on the OPAx187. Table 2 lists the EMIRR IN+ values for the OPAx187 at particular frequencies commonly encountered in real-world applications. Applications listed in Table 2 may be centered on or operated near the particular frequency shown. Detailed information can also be found in *EMI Rejection Ratio of Operational Amplifiers*, available for download from www.ti.com.
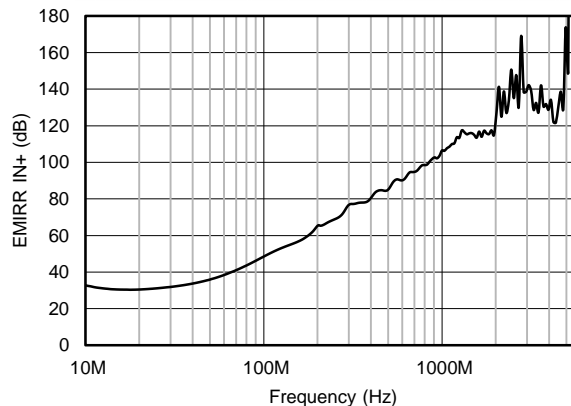

Figure 38. EMIRR Testing

Table 2. OPAx187 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION/ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	81.8 dB
900 MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications	102.7 dB
1.8 GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)	115.4 dB
2.4 GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz)	150.7 dB
3.6 GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	142.0 dB
5 GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)	173.8 dB

7.3.6 Capacitive Load and Stability

The device dynamic characteristics are optimized for a range of common operating conditions. The combination of low closed-loop gain and high capacitive loads decreases the amplifier phase margin and can lead to gain peaking or oscillations. As a result, larger capacitive loads must be isolated from the output. The simplest way to achieve this isolation is to add a small resistor (for example, R_{OUT} equal to 50 Ω) in series with the output. Figure 39 illustrates small-signal overshoot versus capacitive load for several values of R_{OUT}. Also, for details of analysis techniques and application circuits, refer to *Feedback Plots Define Op Amp AC Performance*, available for download from www.ti.com.
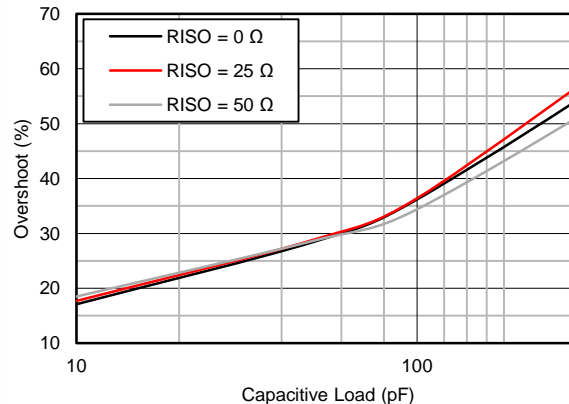
G = 1, R_L = 10 kΩ, 10-mV Output Step

Figure 39. Small-Signal Overshoot Versus Capacitive Load

7.3.7 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 may 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 them from accidental ESD events both before and during product assembly.

Having a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event is helpful. See Figure 40 for an illustration of the ESD circuits contained in the OPAx187 (indicated by 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 operational amplifier. 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 may activate. The absorption device has a trigger, or threshold voltage, that is above the normal operating voltage of the OPAx187 but below 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.

When the operational amplifier connects into a circuit (as shown in Figure 40), the ESD protection components are intended to remain inactive and do not become involved in the application circuit operation. However, circumstances may arise where an applied voltage exceeds the operating voltage range of a given pin. Should this condition occur, there is a risk that some internal ESD protection circuits may be biased on, and conduct current. Any such current flow occurs through steering-diode paths and rarely involves the absorption device.

Figure 40 shows a specific example where the input voltage, V_{IN}, exceeds the positive supply voltage (+V_S) by 500 mV or more. Much of what happens in the circuit depends on the supply characteristics. If +V_S 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 10 mA.

If the supply is not capable of sinking the current, V_{IN} may 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 $+V_S$ or $-V_S$ are at 0 V. Again, this question depends on the supply characteristic while at 0 V, or at a level below the input signal amplitude. If the supplies appear as high impedance, then the operational amplifier supply current may be supplied by the input source via the current-steering diodes. This state is not a normal bias condition; the amplifier most likely will not operate normally. 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, external TVS (Transient Voltage Suppressor) diodes may be added to the supply pins, as shown in Figure 40. The TVS voltage must be selected such that the diode does not turn on during normal operation. However, the TVS voltage should be low enough so that the TVS diode conducts if the supply pin begins to rise above the safe operating supply voltage level.
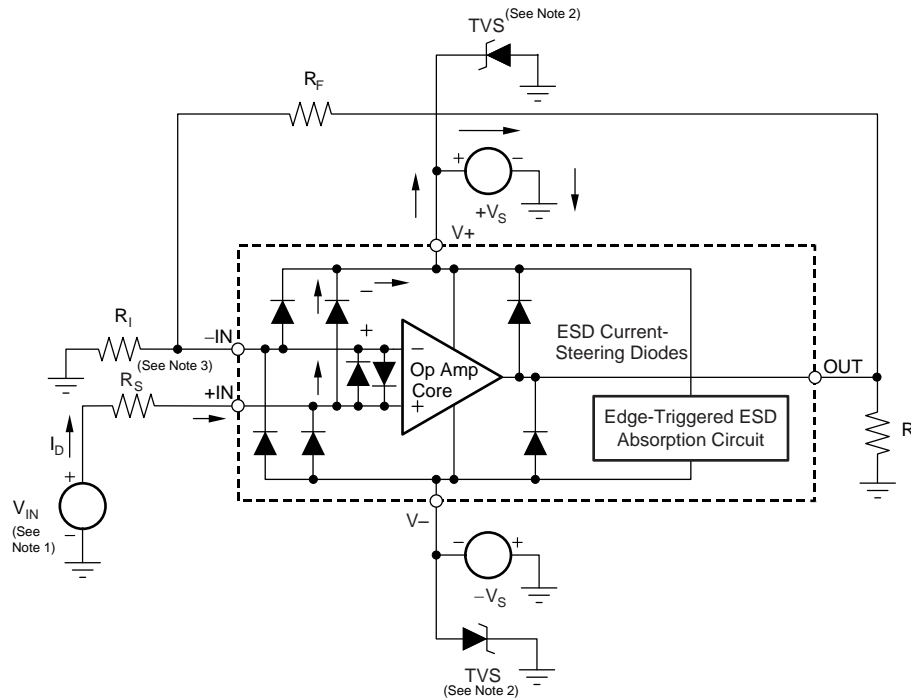
NOTE 1: $V_{IN} = +V_S + 500$ mV.

NOTE 2: TVS: $+V_{S(max)} > V_{TVSBR\ (min)} > +V_S$.

NOTE 3: Suggested value is approximately 1 kΩ.

Figure 40. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

The OPAx187 input terminals are protected from excessive differential voltage with back-to-back diodes, as shown in Figure 40. In most circuit applications, the input protection circuitry has no consequence. However, in low-gain or G = 1 circuits, fast-ramping input signals can forward-bias these diodes because the output of the amplifier cannot respond rapidly enough to the input ramp. If the input signal is fast enough to create this forward-bias condition, the input signal current must be limited to 10 mA or less. If the input signal current is not inherently limited, an input series resistor can be used to limit the signal input current. This input series resistor degrades the low-noise performance of the OPAx187. Figure 40 shows an example configuration that implements a current-limiting feedback resistor.

7.4 Device Functional Modes

The OPAx187 has a single functional mode and is operational when the power-supply voltage is greater than 4.5 V (±2.25 V). The maximum power supply voltage for the OPAx187 is 36 V (±18 V).

8 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. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The OPAx187 operational amplifier combines precision offset and drift with excellent overall performance, making it ideal for many precision applications. The precision offset drift of only 0.005 µV/°C provides stability over the entire temperature range. In addition, the device pairs excellent CMRR, PSRR, and A_{OL} dc performance with outstanding low-noise operation. As with all amplifiers, applications with noisy or high-impedance power supplies require decoupling capacitors close to the device pins. In most cases, 0.1-µF capacitors are adequate.

The following application examples highlight only a few of the circuits where the OPAx187 can be used.

8.2 Typical Applications

8.2.1 High-Side Voltage-to-Current (V-I) Converter

The circuit shown in Figure 41 is a high-side voltage-to-current (V-I) converter. The converter translates an input voltage of 0 V to 2 V into an output current of 0 mA to 100 mA. Figure 42 shows the measured transfer function for this circuit. The low offset voltage and offset drift of the OPA2187 facilitate excellent dc accuracy for the circuit.
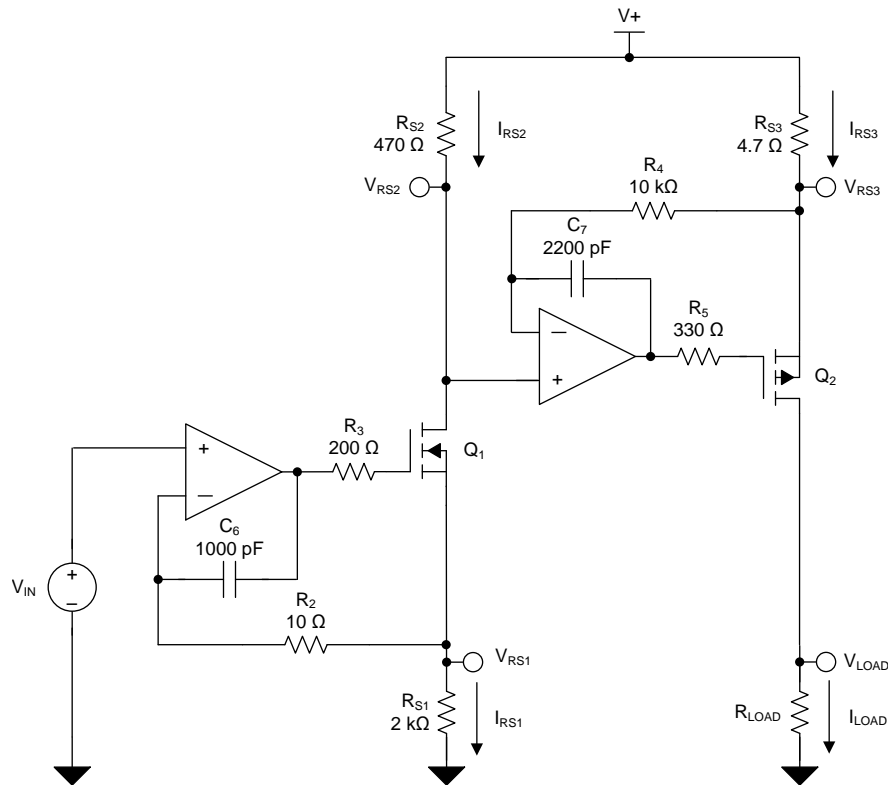
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Figure 41. High-Side Voltage-to-Current (V-I) Converter

Typical Applications (continued)

8.2.1.1 Design Requirements

The design requirements are:
- Supply voltage: 5 V DC
- Input: 0 V to 2 V DC
- Output: 0 mA to 100 mA DC

8.2.1.2 Detailed Design Procedure

The V-I transfer function of the circuit is based on the relationship between the input voltage, V_{IN}, and the three current sensing resistors, R_{S1}, R_{S2}, and R_{S3}. The relationship between V_{IN} and R_{S1} determines the current that flows through the first stage of the design. The current gain from the first stage to the second stage is based on the relationship between R_{S2} and R_{S3}.

This application benefits from an operational amplifier with low offset voltage, low temperature drift, and rail-to-rail output. The OPAx187 CMOS operational amplifier is a high-precision, ultra-low offset, ultra-low drift amplifier, optimized for wide-voltage, single-supply operation, with an output swing to within 5 mV of the positive rail. The OPAx187 family uses chopping techniques to provide low initial offset voltage and near-zero drift over time and temperature. Low offset voltage and low drift reduce the offset error in the system, making this device appropriate for precise dc control. The rail-to-rail output stage of the OPAx187 makes sure that the output swing of the operational amplifier is able to fully control the gate of the MOSFET devices within the supply rails.

A detailed error analysis, design procedure, and additional measured results are given in reference design TIPD102, a step-by-step process to design a *High-Side Voltage-to-Current (V-I) Converter*.

TI Precision Designs	For step-by-step design procedure, circuit schematics, bill of materials, PCB files, simulation results, and test results, refer to TI Precision Design TIPD102, *High-Side Voltage-to-Current (V-I) Converter* (SLAU502).

8.2.1.3 Application Curve

Figure 42 shows the measured transfer function for the high-side voltage-to-current converter shown in Figure 41.
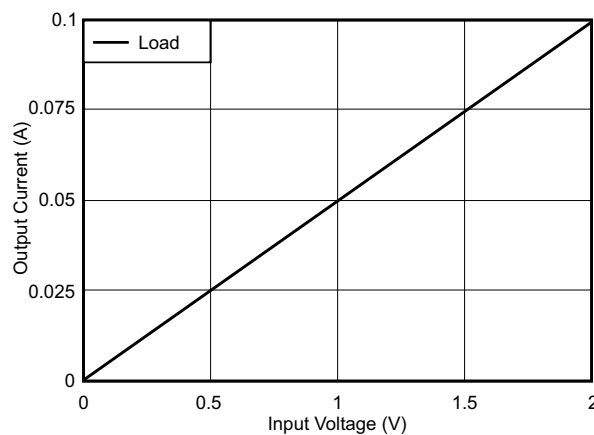

Figure 42. Measured Transfer Function for High-Side V-I Converter

Product Folder Links: *OPA187 OPA2187 OPA4187*

8.2.2 Discrete INA + Attenuation for ADC With 3.3-V Supply

NOTE

The TINA-TI files shown in the following sections require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.

Figure 43 shows an example of how the OPAx187 is used as a high-voltage, high-impedance front-end for a precision, discreet instrumentation amplifier with attenuation. The INA159 provides the attenuation that allows this circuit to easily interface with 3.3-V or 5-V analog-to-digital converters (ADCs). Click the following link download the TINA-TI file: Discrete INA.
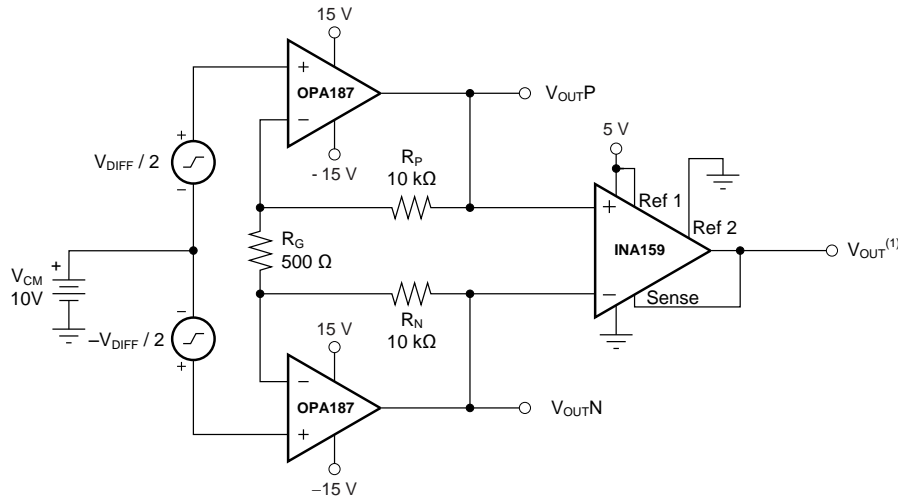
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(1) $V_{OUT} = V_{DIFF} \times (41 / 5) + (Ref\ 1) / 2$.

Figure 43. Discrete INA + Attenuation for ADC With 3.3-V Supply

8.2.3 Bridge Amplifier

Figure 44 shows the basic configuration for a bridge amplifier. Click the following link to download the TINA-TI file: Bridge Amplifier Circuit.
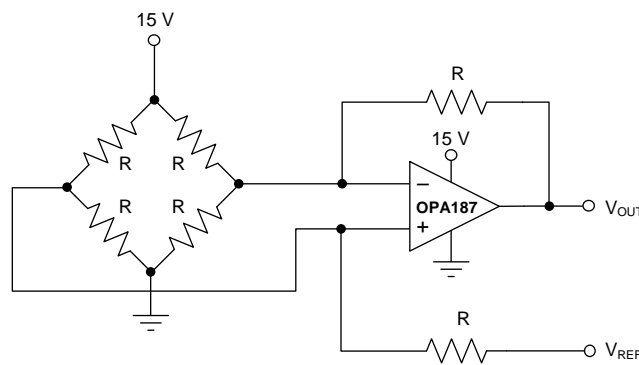
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Figure 44. Bridge Amplifier

8.2.4 Low-Side Current Monitor

Figure 45 shows the OPAx187 configured in a low-side current-sensing application. The load current (I_{LOAD}) creates a voltage drop across the shunt resistor (R_{SHUNT}). This voltage is amplified by the OPAx187, with a gain of 201. The load current is set from 0 A to 500 mA, which corresponds to an output voltage range from 0 V to 10 V. The output range can be adjusted by changing the shunt resistor or gain of the configuration. Click the following link to download the TINA-TI file: Current-Sensing Circuit.
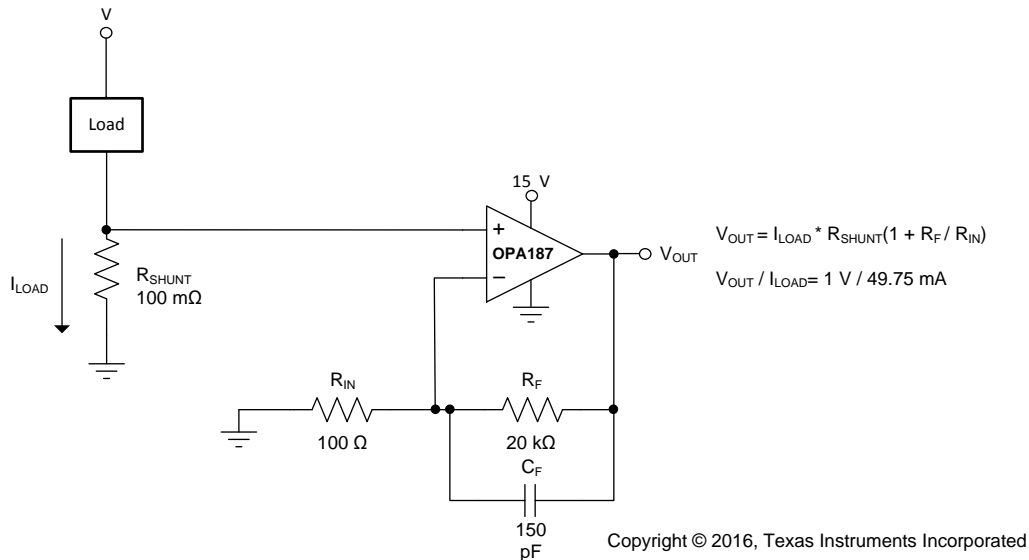
Figure 45. Low-Side Current Monitor

8.2.5 Programmable Power Supply

Figure 46 shows the OPAx187 configured as a precision programmable power supply using the 16-bit, voltage output DAC8581 and the OPA548 high-current amplifier. This application amplifies the digital-to-analog converter (DAC) voltage by a value of five, and handles a large variety of capacitive and current loads. The OPAx187 in the front-end provides precision and low drift across a wide range of inputs and conditions. Click the following link to download the TINA-TI file: Programmable Power-Supply Circuit.
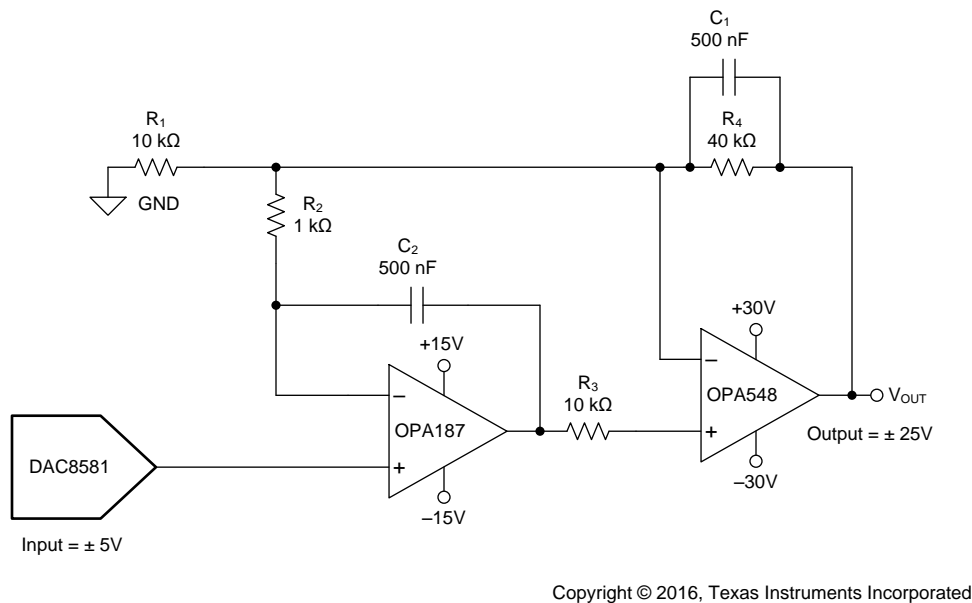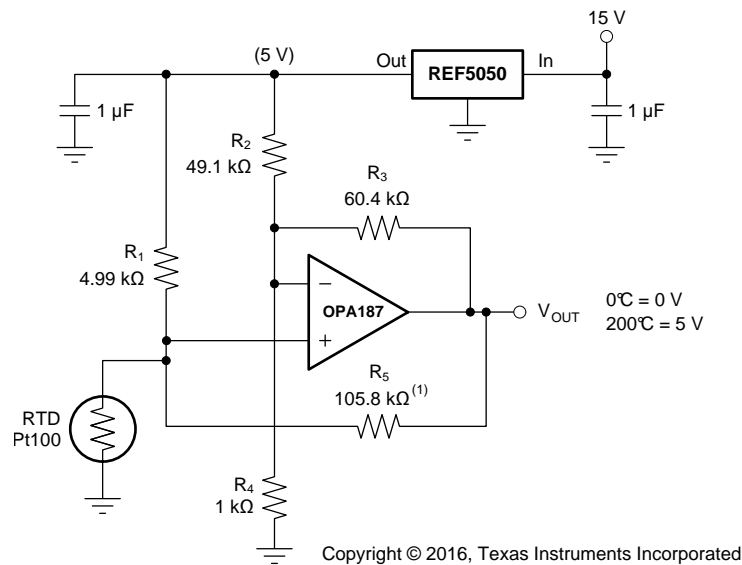

Figure 46. Programmable Power Supply

8.2.6 RTD Amplifier With Linearization

See *Analog Linearization Of Resistance Temperature Detectors*, for an in-depth analysis of Figure 47. Click the following link to download the TINA-TI file: RTD Amplifier With Linearization.

(1)   R$_5$ provides positive-varying excitation to linearize output.

Figure 47. RTD Amplifier With Linearization

9 Power Supply Recommendations

The OPAx187 is specified for operation from 4.5 V to 36 V (±2.25 V to ±18 V); many specifications apply from –40°C to +125°C. The *Typical Characteristics* presents parameters that can exhibit significant variance with regard to operating voltage or temperature.

> **CAUTION**
>
> Supply voltages larger than 40 V can permanently damage the device (see the *Absolute Maximum Ratings*).

Place 0.1-μF 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 the *Layout* section.

10 Layout

10.1 Layout Guidelines

For best operational performance of the device, use good printed circuit board (PCB) layout practices, including:

- Low-ESR, 0.1-µF ceramic bypass capacitors must be connected between each supply pin and ground; place the capacitors as close to the device as possible. A single bypass capacitor from V+ to ground is applicable to single-supply applications.
- To reduce parasitic coupling, run the input traces as far away from the supply lines as possible.
- A ground plane helps distribute heat and reduces EMI noise pickup.
- Place the external components as close to the device as possible. This configuration prevents parasitic errors (such as the Seebeck effect) from occurring.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
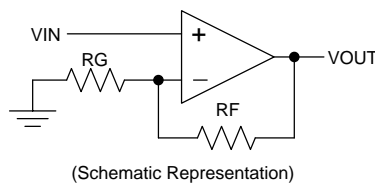
10.2 Layout Example
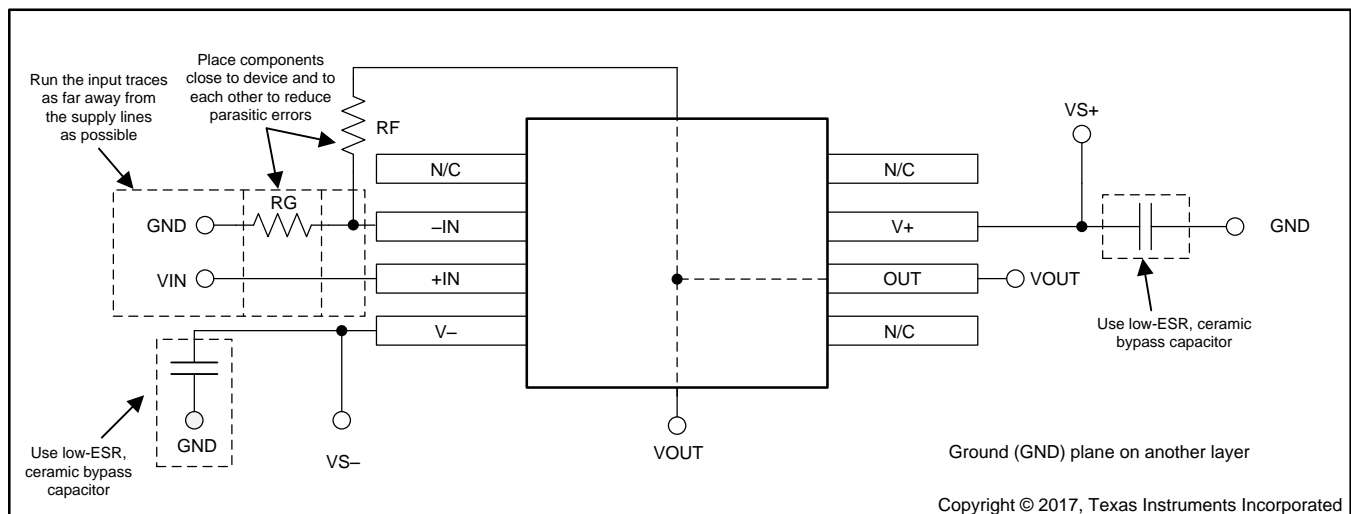
Figure 48. Layout Example

11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

11.1.1.1 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI™ is a free, fully-functional version of the TINA software, preloaded with a library of macro models, in addition to a range of both passive and active models. TINA-TI 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 Analog eLab Design Center, TINA-TI offers extensive post-processing capability that lets users format results various ways. Virtual instruments offer users 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 (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.

11.1.1.2 TI Precision Designs

TI Precision Designs are analog solutions created by TI's precision analog applications experts which offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits. TI Precision Designs are available online at http://www.ti.com/ww/en/analog/precision-designs/.

11.1.1.3 WEBENCH® Filter Designer

WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The WEBENCH Filter Designer lets users create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

Available as a web-based tool from the WEBENCH Design Center, WEBENCH® Filter Designer lets users design, optimize, and simulate complete multistage active filter solutions within minutes.

11.2 Documentation Support

11.2.1 Related Documentation

For related documentation, see the following:

- *Operational Amplifier Gain Stability, Part 3: AC Gain-Error Analysis*
- *Operational Amplifier Gain Stability, Part 2: DC Gain-Error Analysis*
- *Using Infinite-Gain, MFB Filter Topology In Fully Differential Active Filters*
- *Op Amp Performance Analysis*
- *Single-Supply Operation of Operational Amplifiers*
- *Tuning in Amplifiers*
- *Shelf-Life Evaluation of Lead-Free Component Finishes*

Submit Documentation Feedback

Product Folder Links: *OPA187 OPA2187 OPA4187*

11.3 Related Links

Table 3 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 3. Related Links

PARTS	PRODUCT FOLDER	SAMPLE AND BUY	TECHNICAL DOCUMENTS	TOOLS AND SOFTWARE	SUPPORT AND COMMUNITY
OPA187	Click here	Click here	Click here	Click here	Click here
OPA2187	Click here	Click here	Click here	Click here	Click here
OPA4187	Click here	Click here	Click here	Click here	Click here

11.4 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on the *Alert me* button 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

11.5 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community.* Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.6 Trademarks

TINA-TI, E2E are trademarks of Texas Instruments.
WEBENCH is a registered trademark of Texas Instruments.
Bluetooth is a registered trademark of Bluetooth SIG, Inc.
DesignSoft, TINA are trademarks of DesignSoft, Inc.
All other trademarks are the property of their respective owners.

11.7 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.

11.8 Glossary

SLYZ022 — *TI Glossary*.
    This glossary lists and explains terms, acronyms, and definitions.

12 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 Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA187IDBVR	PREVIEW	SOT-23	DBV	5	3000	TBD	Call TI	Call TI	-40 to 125		
OPA187IDGKR	PREVIEW	VSSOP	DGK	8	2500	TBD	Call TI	Call TI	-40 to 125		
OPA2187ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OP2187	Samples
OPA2187IDGKR	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	16TV	Samples
OPA2187IDGKT	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	16TV	Samples
OPA2187IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OP2187	Samples
POPA187IDBVR	ACTIVE	SOT-23	DBV	5	3000	TBD	Call TI	Call TI	-40 to 125		Samples
POPA187IDGKR	ACTIVE	VSSOP	DGK	8	2500	TBD	Call TI	Call TI	-40 to 125		Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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.

PACKAGE MATERIALS INFORMATION

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS

A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
OPA2187IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2187IDGKT	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2187IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA2187IDGKR	VSSOP	DGK	8	2500	367.0	367.0	35.0
OPA2187IDGKT	VSSOP	DGK	8	250	210.0	185.0	35.0
OPA2187IDR	SOIC	D	8	2500	367.0	367.0	35.0

Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4073253/P

4214839/C   04/2017

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.

PKG

5X (1.1)

1

5X (0.6)

5

SYMM

2

(1.9)

2X (0.95)

3

4

(R0.05) TYP

(2.6)

LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

SOLDER MASK
OPENING

METAL

EXPOSED METAL

0.07 MAX
ARROUND

NON SOLDER MASK
DEFINED
(PREFERRED)

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

EXPOSED METAL

0.07 MIN
ARROUND

SOLDER MASK
DEFINED
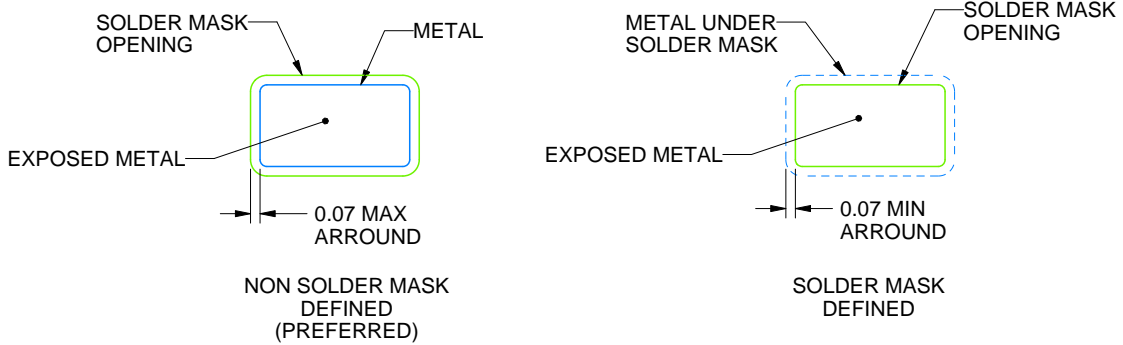
SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. 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/C   04/2017

NOTES: (continued)

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

D (R−PDSO−G8)   PLASTIC SMALL OUTLINE

0.197 (5,00)
0.189 (4,80)
C

8   5

0.244 (6,20)
0.228 (5,80)

0.157 (4,00)
0.150 (3,80)
D

Pin 1
Index Area

1   4

0.050 (1,27)

0.020 (0,51)
0.012 (0,31)

⊕ 0.010 (0,25) Ⓜ

0.069 (1,75) Max

0.010 (0,25)
0.004 (0,10)

0.010 (0,25)
0.005 (0,13)

Gauge Plane

0.004 (0,10)

Seating Plane

0.010 (0,25)

0°−8°

0.050 (1,27)
0.016 (0,40)

4040047−3/M   06/11

NOTES: A.   All linear dimensions are in inches (millimeters).
         B.   This drawing is subject to change without notice.
         C.   Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall
              not exceed 0.006 (0,15) each side.
         D.   Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
         E.   Reference JEDEC MS−012 variation AA.

TEXAS INSTRUMENTS
www.ti.com

D (R−PDSO−G8)   PLASTIC SMALL OUTLINE

Example Board Layout
(Note C)

Stencil Openings
(Note D)

6x1,27

8x0,55

8x1,50   6x1,27

5,40   5,40

Example
Non Soldermask Defined Pad

Example
Pad Geometry
(See Note C)

0,60

1,55

Example
Solder Mask Opening
(See Note E)

0,07

All Around

4211283−2/E 08/12

NOTES: A.   All linear dimensions are in millimeters.
         B.   This drawing is subject to change without notice.
         C.   Publication IPC−7351 is recommended for alternate designs.
         D.   Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should
              contact their board assembly site for stencil design recommendations. Refer to IPC−7525 for other stencil recommendations.
         E.   Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

TEXAS
INSTRUMENTS
www.ti.com

DGK (S−PDSO−G8)   PLASTIC SMALL−OUTLINE PACKAGE

4073329/E 05/06

NOTES: A. All linear dimensions are in millimeters.
        B. This drawing is subject to change without notice.
        C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
        D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
        E. Falls within JEDEC MO−187 variation AA, except interlead flash.

DGK (S−PDSO−G8)   PLASTIC SMALL OUTLINE PACKAGE

Example Board Layout

Example Stencil Openings
Based on a stencil thickness
of .127mm (.005inch).
(See Note D)

(0,65)TYP.

8X(0,45)

(0,65)TYP.

8

5

8X(1,45)

PKG
C

(4,4)

PKG
C

(4,4)

1

4

PKG
C

PKG
C

Example
Non Soldermask Defined Pad

Example
Solder Mask Opening
(See Note E)

(0,45)

(1,45)

Pad Geometry
(See Note C)

(0,05)
All Around

4221236/A 11/13

NOTES: A. All linear dimensions are in millimeters.
         B. This drawing is subject to change without notice.
         C. Publication IPC−7351 is recommended for alternate designs.
         D.   Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should
             contact their board assembly site for stencil design recommendations. Refer to IPC−7525 for other stencil recommendations.
         E.   Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE