Precision, Low-Noise, Rail-to-Rail Output, 36-V, Zero-Drift OPERATIONAL AMPLIFIERS

Check for Samples: OPA188

FEATURES

- **Low Offset Voltage: 25 μV (max)**
- **Zero-Drift: 0.03 μV/°C**
- **Low Noise: 8.8 nV/√Hz**
  0.1-Hz to 10-Hz Noise: 0.25 μV_{PP}
- **Excellent DC Precision:**
  PSRR: 142 dB
  CMRR: 146 dB
  Open-Loop Gain: 136 dB
- **Gain Bandwidth: 2 MHz**
- **Quiescent Current: 510 μA (max)**
- **Wide Supply Range: ±2 V to ±18 V**
- **Rail-to-Rail Output**
- **Input Includes Negative Rail**
- **RFI Filtered Inputs**
- ***Micro*SIZE Packages**

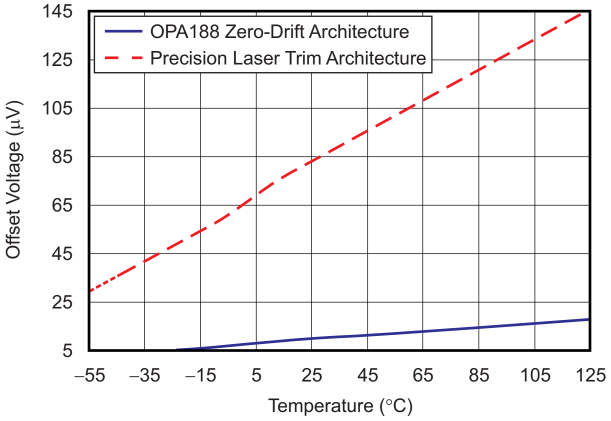
APPLICATIONS

- **Bridge Amplifiers**
- **Strain Gauges**
- **Test Equipment**
- **Transducer Applications**
- **Temperature Measurement**
- **Electronic Scales**
- **Medical Instrumentation**
- **Resistance Temperature Detectors**
- **Precision Active Filters**

DESCRIPTION

The OPA188 operational amplifier uses TI proprietary auto-zeroing techniques to provide low offset voltage (25 μV, max), and near zero-drift over time and temperature. This miniature, high-precision, low quiescent current amplifier offers high input impedance and rail-to-rail output swing within 15 mV of the rails. The input common-mode range includes the negative rail. Either single or dual supplies can be used in the range of +4 V to +36 V (±2 V to ±18 V).

The single version is available in the *Micro*SIZE SOT23-5, MSOP-8, and SO-8 packages. All versions are specified for operation from –40°C to +125°C.



Zero-Drift Amplifier Portfolio

VERSION	PRODUCT	OFFSET VOLTAGE (μV, max)	OFFSET VOLTAGE DRIFT (μV/°C, max)	BANDWIDTH (MHz)	INPUT VOLTAGE NOISE (μV_{PP}, f = 0.1 Hz to 10 Hz)
Single	OPA188 (4 V to 36 V)	±25	±0.085	2	0.25
	OPA333 (5 V)	±10	±0.05	0.35	1.1
	OPA378 (5 V)	±50	±0.25	0.9	0.4
	OPA735 (12 V)	±5	±0.05	1.6	2.5
Dual	OPA2188 (4 V to 36 V)	±25	±0.085	2	0.25
	OPA2333 (5 V)	±10	±0.05	0.35	1.1
	OPA2378 (5 V)	±50	±0.25	0.9	0.4
	OPA2735 (12 V)	±5	±0.05	1.6	2.5
Quad	OPA4188 (4 V to 36 V)	±25	±0.085	2	0.25
	OPA4330 (5 V)	±50	±0.25	0.35	1.1

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.

PACKAGE INFORMATION(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
OPA188	SOT23-5	DBV	–40°C to +125°C	QXZ	OPA188AIDBVT	Tape and Reel, 250
					OPA188AIDBVR	Tape and Reel, 3000
	SO-8	D	–40°C to +125°C	OPA188	OPA188AID	Rails, 75
					OPA188AIDR	Tape and Reel, 2500
	MSOP-8	DGK	–40°C to +125°C	QXX	OPA188AIDGKT	Tape and Reel, 250
					OPA188AIDGKR	Tape and Reel, 2500

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

		VALUE	UNIT
Supply voltage		±20, 40 (single supply)	V
Signal input terminals(2)	Voltage	(V–) – 0.5 to (V+) + 0.5	V
	Current	±10	mA
	Differential	±0.7	V
Output short-circuit(3)		Continuous	
Temperature range	Operating(4), T_A	–55 to +150	°C
	Storage, T_{stg}	–65 to +150	°C
	Junction, T_J	+150	°C
Electrostatic discharge (ESD) ratings	Human body model (HBM)	1.5	kV
	Charged device model (CDM)	1	kV

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and do not imply functional operation of the device at these or any other conditions beyond those indicated. 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) Short-circuit to ground.
(4) Provided device does not exceed maximum junction temperature (T_J) at any time.

ELECTRICAL CHARACTERISTICS:

High-Voltage Operation, V_S = ±4 V to ±18 V (V_S = +8 V to +36 V)

At T_A = +25°C, 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				±6	±25	μV
			T_A = –40°C to +125°C		±0.03	±0.085	μV/°C
PSRR	Power-supply rejection ratio		V_S = 4 V to 36 V, T_A = –40°C to +125°C		±0.075	±0.3	μV/V
	Long-term stability(2)				4		μV
INPUT BIAS CURRENT							
I_B	Input bias current		V_{CM} = V_S / 2		±160	±1400	pA
			T_A = –40°C to +125°C			±8	nA
I_{OS}	Input offset current				±320	±2800	pA
			T_A = –40°C to +125°C			±4	nA
NOISE							
e_n	Input voltage noise		f = 0.1 Hz to 10 Hz		250		nV_{PP}
	Input voltage noise		f = 0.1 Hz to 10 Hz		40		nV_{RMS}
	Input voltage noise density		f = 1 kHz		8.8		nV/√Hz
i_n	Input current noise density		f = 1 kHz		7		fA/√Hz
INPUT VOLTAGE RANGE							
V_{CM}	Common-mode voltage range		T_A = –40°C to +125°C	V–		(V+) – 1.5	V
CMRR	Common-mode rejection ratio		(V–) < V_{CM} < (V+) – 1.5 V	120	134		dB
			(V–) + 0.5 V < V_{CM} < (V+) – 1.5 V, V_S = ±18 V	130	146		dB
			(V–) + 0.5 V < V_{CM} < (V+) – 1.5 V, V_S = ±18 V, T_A = –40°C to +125°C	120	126		dB
INPUT IMPEDANCE							
	Differential				100 || 6		MΩ || pF
	Common-mode				6 || 9.5		10^{12} Ω || pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain		(V–) + 0.5 V < V_O < (V+) – 0.5 V	130	136		dB
			(V–) + 0.5 V < V_O < (V+) – 0.5 V, T_A = –40°C to +125°C	120	126		dB
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product				2		MHz
SR	Slew rate		G = +1		0.8		V/μs
	Settling time	0.1%	V_S = ±18 V, G = 1, 10-V step		20		μs
		0.01%	V_S = ±18 V, G = 1, 10-V step		27		μs
t_{OR}	Overload recovery time		V_{IN} × G = V_S		1		μs
THD+N	Total harmonic distortion + noise		1 kHz, G = 1, V_{OUT} = 1 Vrms		0.0001		%

---

(1) V_S / 2 = midsupply.

(2) 1000-hour life test at +125°C demonstrated randomly distributed variation in the range of measurement limits—approximately 4 μV.

ELECTRICAL CHARACTERISTICS: High-Voltage Operation, V_S = ±4 V to ±18 V (V_S = +8 V to +36 V) (continued)

At T_A = +25°C, 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
OUTPUT							
	Voltage output swing from rail		No load		6	15	mV
			R_L = 10 kΩ		220	250	mV
			T_A = –40°C to +125°C		310	350	mV
I_{SC}	Short-circuit current		Sinking		-18		mA
			Sourcing		+16		mA
R_O	Open-loop output resistance		f = 1 MHz, I_O = 0		120		Ω
C_{LOAD}	Capacitive load drive				1		nF
POWER SUPPLY							
V_S	Operating voltage range			4 to 36 (±2 to ±18)			V
I_Q	Quiescent current (per amplifier)		V_S = ±4 V to V_S = ±18 V		450	510	µA
			I_O = 0 mA, T_A = –40°C to +125°C			540	µA
TEMPERATURE RANGE							
	Temperature range	Specified		–40		+125	°C
		Operating		–55		+150	°C
		Storage		–65		+150	°C

ELECTRICAL CHARACTERISTICS:
Low-Voltage Operation, V_S = ±2 V to < ±4 V (V_S = +4 V to < +8 V)

At T_A = +25°C, 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			±6	±25	μV
		T_A = –40°C to +125°C		±0.03	±0.085	μV/°C
PSRR	Power-supply rejection ratio	V_S = 4 V to 36 V, T_A = –40°C to +125°C		0.075	0.3	μV/V
	Long-term stability[2]			4		μV
INPUT BIAS CURRENT						
I_B	Input bias current			±160	±1400	pA
		T_A = –40°C to +125°C			±8	nA
I_{OS}	Input offset current			±320	±2800	pA
		T_A = –40°C to +125°C			±4	nA
NOISE						
e_n	Input voltage noise	f = 0.1 Hz to 10 Hz		250		nV_{PP}
	Input voltage noise	f = 0.1 Hz to 10 Hz		40		nV_{RMS}
	Input voltage noise density	f = 1 kHz		8.8		$nV/\sqrt{Hz}$
i_n	Input current noise density	f = 1 kHz		7		$fA/\sqrt{Hz}$
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	T_A = –40°C to +125°C	V–		(V+) – 1.5	V
CMRR	Common-mode rejection ratio	(V–) < V_{CM} < (V+) – 1.5 V	106	114		dB
		(V–) + 0.5 V < V_{CM} < (V+) – 1.5 V, V_S = ±2 V	114	120		dB
		(V–) + 0.5 V < V_{CM} < (V+) – 1.5 V, V_S = ±2 V, T_A = –40°C to +125°C	110	120		dB
INPUT IMPEDANCE						
	Differential			100 || 6		MΩ || pF
	Common-mode			6 || 95		10^{12} Ω || pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	(V–) + 0.5 V < V_O < (V+) – 0.5 V, R_L = 5 kΩ	110	120		dB
		(V–) + 0.5 V < V_O < (V+) – 0.5 V	120	130		dB
		(V–) + 0.5 V < V_O < (V+) – 0.5 V, T_A = –40°C to +125°C	110	120		dB
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product			2		MHz
SR	Slew rate	G = +1		0.8		V/μs
t_{OR}	Overload recovery time	V_{IN} × G = V_S		1		μs
THD+N	Total harmonic distortion + noise	1 kHz, G = 1, V_{OUT} = 1 Vrms		0.0001		%

(1) V_S / 2 = midsupply.
(2) 1000-hour life test at +125°C demonstrated randomly distributed variation in the range of measurement limits—approximately 4 μV.

ELECTRICAL CHARACTERISTICS: Low-Voltage Operation, V_S = ±2 V to < ±4 V (V_S = +4 V to < +8 V) (continued)

At T_A = +25°C, 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
OUTPUT							
	Voltage output swing from rail		No load		6	15	mV
			R_L = 10 kΩ		220	250	mV
			T_A = –40°C to +125°C		310	350	mV
I_{SC}	Short-circuit current		Sinking		-18		mA
			Sourcing		+16		mA
R_O	Open-loop output resistance		f = 1 MHz, I_O = 0		120		Ω
C_{LOAD}	Capacitive load drive				1		nF
POWER SUPPLY							
V_S	Operating voltage range				4 to 36 (±2 to ±18)		V
I_Q	Quiescent current (per amplifier)		V_S = ±2 V to V_S = ±4 V		425	480	μA
			I_O = 0 mA, T_A = –40°C to +125°C			525	μA
TEMPERATURE RANGE							
	Temperature range	Specified		–40		+125	°C
		Operating		–55		+150	°C
		Storage		–65		+150	°C

THERMAL INFORMATION

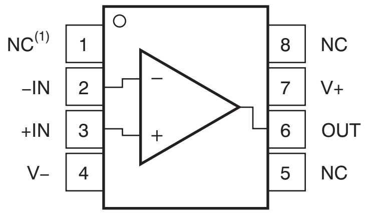
THERMAL METRIC(1)		OPA188			UNITS
		D (SO)	DGK (MSOP)	DBV (SOT23)	
		8 PINS	8 PINS	5 PINS	
θ_{JA}	Junction-to-ambient thermal resistance	TBD	TBD	TBD	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	TBD	TBD	TBD	
θ_{JB}	Junction-to-board thermal resistance	TBD	TBD	TBD	
ψ_{JT}	Junction-to-top characterization parameter	TBD	TBD	TBD	
ψ_{JB}	Junction-to-board characterization parameter	TBD	TBD	TBD	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	TBD	TBD	TBD	

---

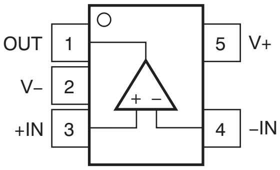
(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

PIN CONFIGURATIONS

OPA188
D, DGK PACKAGES (SO-8, MSOP-8)
(TOP VIEW)



OPA188
DBV PACKAGE (SOT23-5)
(TOP VIEW)



(1) NC = no connection.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
OPA188AID	PREVIEW	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA188	
OPA188AIDBVR	PREVIEW	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 125	QXZ	
OPA188AIDBVT	PREVIEW	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	Call TI	Level-2-260C-1 YEAR	-40 to 125	QXZ	
OPA188AIDGKR	PREVIEW	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	QXX	
OPA188AIDGKT	PREVIEW	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	QXX	
OPA188AIDR	PREVIEW	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA188	

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

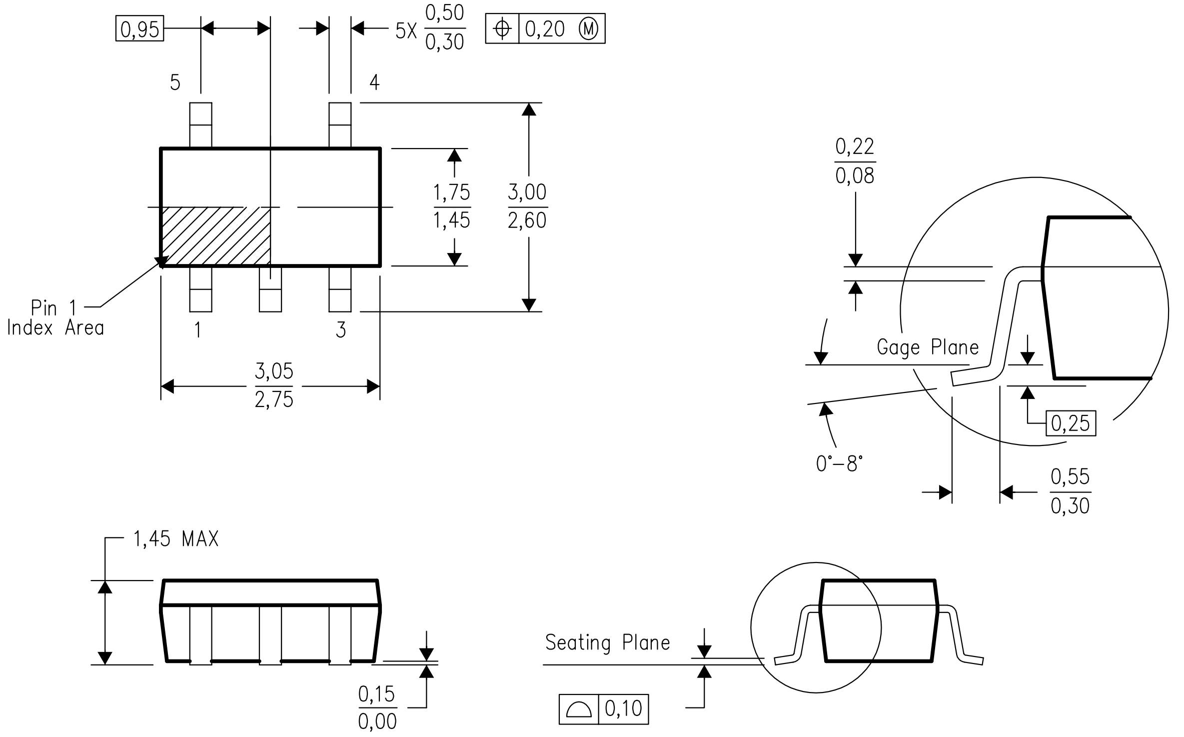
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Only one of markings shown within the brackets will appear on the physical device.

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

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

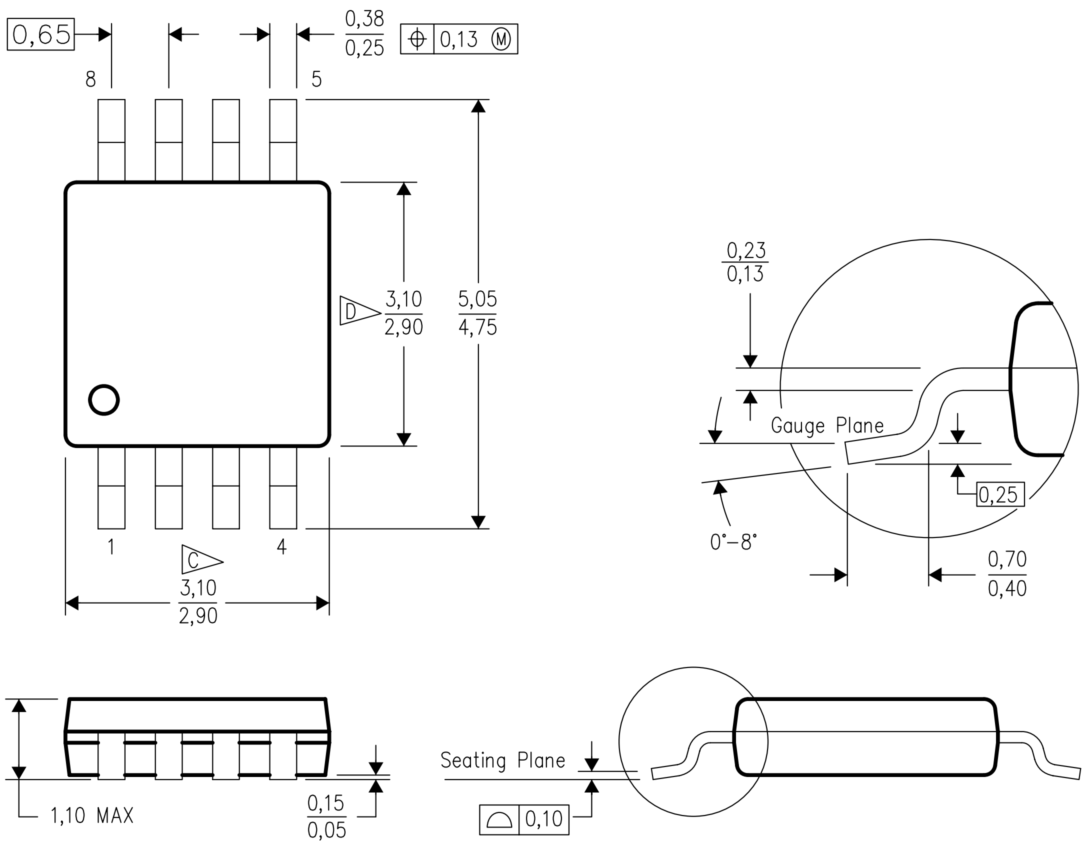
DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4073253–4/K 03/2006

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–178 Variation AA.

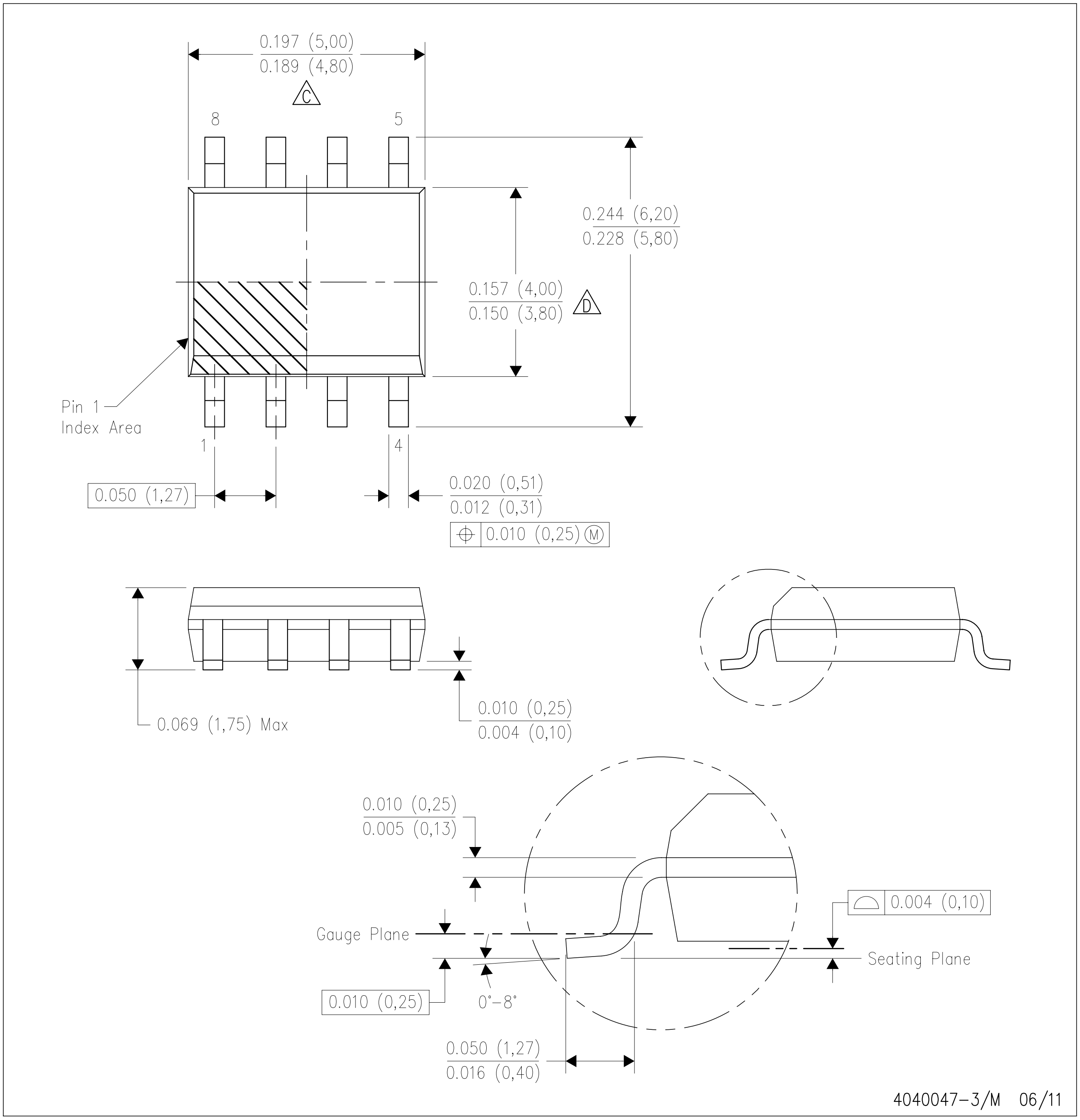
DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE



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.

D (R-PDSO-G8) PLASTIC SMALL OUTLINE



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.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265