200-MHz CMOS OPERATIONAL AMPLIFIER

FEATURES

- **Qualified For Automotive Applications**
- **Unity-Gain Bandwidth: 450 MHz**
- **Wide Bandwidth: 200 MHz GBW**
- **High Slew Rate: 360 V/s**
- **Low Noise: 5.8 nV/$\sqrt{Hz}$**
- **Excellent Video Performance**
  - **Differential Gain: 0.02%**
  - **Differential Phase: 0.05°**
  - **0.1-dB Gain Flatness: 75 MHz**
- **Input Range Includes Ground**
- **Rail-To-Rail Output (Within 100 mV)**
- **Low Input Bias Current: 3 pA**
- **Thermal Shutdown**
- **Single-Supply Operating Range: 2.5 V To 5.5 V**

APPLICATIONS

- **Video Processing**
- **Ultrasound**
- **Optical Networking, Tunable Lasers**
- **Photodiode Transimpedance Amplifiers**
- **Active Filters**
- **High-Speed Integrators**
- **Analog-To-Digital (A/D) Converter Input Buffers**
- **Digital-To-Analog (D/A) Converter Output Amplifiers**
- **Barcode Scanners**
- **Communications**

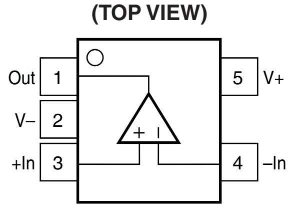
DESCRIPTION

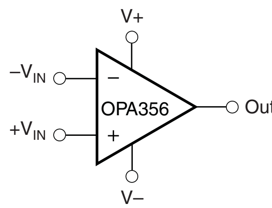
The OPA356 is a high-speed voltage-feedback CMOS operational amplifier designed for video and other applications requiring wide bandwidth. The OPA356 is unity gain stable and can drive large output currents. Differential gain is 0.02% and differential phase is 0.05°. Quiescent current is only 8.3 mA.

OPA356 is optimized for operation on single or dual supplies as low as 2.5 V (±1.25 V) and up to 5.5 V (±2.75 V). Common-mode input range for the OPA356 extends 100 mV below ground and up to 1.5 V from V+. The output swing is within 100 mV of the rails, supporting wide dynamic range.

The OPA356 is available in the SOT23-5 package and is specified over the –40°C to 125°C range.

DBV PACKAGE
(TOP VIEW)





ORDERING INFORMATION(1)

T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	SOT-23 – DBV	Reel of 3000	OPA356AQDBVRQ1	OOVQ

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

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.

ABSOLUTE MAXIMUM RATINGS(1)

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

V_S	Supply voltage, V+ to V–	7.5 V
V_{IN}	Signal input terminals voltage range(2)	–0.5 V to (V+ + 0.5 V)
	V– current(2)	10 mA
	Output short-circuit duration(3)	Continuous
θ_{JA}	Thermal impedance, junction to free air(4)	150°C/W
T_A	Operating free-air temperature range	–40°C to 125°C
T_{STG}	Storage temperature range	–65°C to 150°C
T_J	Junction temperature	160°C
T_{LEAD}	Lead temperature (soldering, 10 s)	300°C

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(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 one amplifier per package.
(4) The package thermal impedance is calculated in accordance with JESD 51-5.

RECOMMENDED OPERATING CONDITIONS

		MIN	MAX	UNIT
V_S	Supply voltage, V– to V+	2.7	5.5	V
T_A	Operating free-air temperature	–40	125	°C

ELECTRICAL CHARACTERISTICS

V_S = 2.7 V to 5.5 V, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	T_A (1)	MIN	TYP	MAX	UNIT
V_{OS}	Input offset voltage	V_S = 5 V, V_{CM} = V– + 0.8 V	25°C		±2	±9	mV
			Full range			±15	
$\Delta V_{OS}/\Delta T$	Offset voltage drift over temperature		Full range		±7		µV/°C
PSRR	Offset voltage drift vs power supply	V_S = 2.7 V to 5.5 V, V_{CM} = V_S/2 – 0.15 V	25°C		±80	±350	µV/V
I_B	Input bias current		25°C		3	±50	pA
I_{OS}	Input offset current		25°C		±1	±50	pA
V_n	Input voltage noise density	f = 1 MHz	25°C		5.8		nV/√Hz
I_n	Input current noise density	f = 1 MHz	25°C		50		fA/√Hz
V_{CM}	Input common-mode voltage range		25°C	V– – 0.1		V+ – 1.5	V
CMRR	Input common-mode rejection ratio	V_S = 5.5 V, –0.1 V < V_{CM} < 4 V	25°C	66	80		dB
			Full range	66			
Z_{ID}	Differential input impedance		25°C		10^{13} || 1.5		Ω || pF
Z_{ICM}	Common-mode input impedance		25°C		10^{13} || 1.5		Ω || pF
A_{OL}	Open-loop gain	V_S = 5 V, 0.3 V < V_O < 4.7 V	25°C	84	92		dB
			Full range	80			
f_{-3dB}	Small-signal bandwidth	G = +1, V_O = 100 mVp-p, R_F = 0 Ω	25°C		450		MHz
		G = +2, V_O = 100 mVp-p, R_L = 50 Ω			100		
		G = +2, V_O = 100 mVp-p, R_L = 150 Ω			170		
		G = +2, V_O = 100 mVp-p, R_L = 1 kΩ			200		
GBW	Gain-bandwidth product	G = +10, R_L = 1 kΩ	25°C		200		MHz
$f_{0.1dB}$	Bandwidth for 0.1-dB gain flatness	G = +2, V_O = 100 mVp-p, R_F = 560 Ω	25°C		75		MHz
SR	Slew rate	V_S = 5 V, G = +2, 4-V output step	25°C		+300 –360		V/µs
t_{rf}	Rise-and-fall time	G = +2, V_O = 200 mVp-p, 10% to 90%	25°C		2.4		ns
		G = +2, V_O = 2 Vp-p, 10% to 90%			8		
t_{settle}	Settling time 0.1%	V_S = 5 V, G = +2, 2-V output step	25°C		30		ns
	Settling time 0.01%		25°C		120		
	Overload recovery time	V_{IN} × Gain = V_S	25°C		8		ns
	Harmonic distortion, Second harmonic	G = +2, f = 1 MHz, VO = 2 Vp-p, R_L = 200 Ω	25°C		–81		dBc
	Harmonic distortion, Third harmonic		25°C		–93		
	Differential gain error	NTSC, R_L = 150 Ω	25°C		0.02		%
	Differential phase error	NTSC, R_L = 150 Ω	25°C		0.05		°
	Voltage output swing from rail	V_S = 5 V, R_L = 150 Ω, A_{OL} > 84 dB	25°C		0.2	0.3	V
		V_S = 5 V, R_L = 1 kΩ			0.1		
		V_S = 5 V, R_L = 50 Ω			0.4	0.6	
I_O	Output current (2), Continuous		25°C	±60			mA
	Output current (2), Peak	V_S = 5 V		±100			
		V_S = 3 V			±80		

(1) Full range T_A = –40°C to 125°C
(2) See typical characteristic graph *Output Voltage Swing vs Output Current*.

ELECTRICAL CHARACTERISTICS (continued)

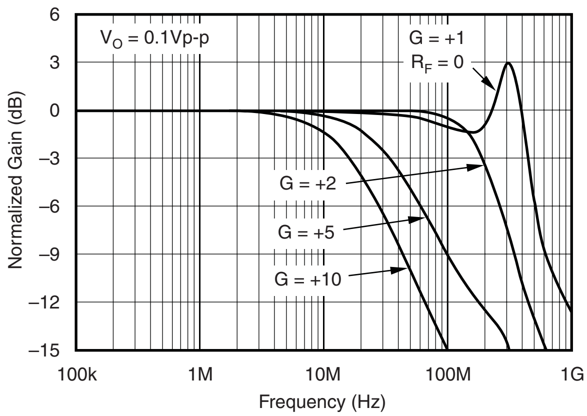
V_S = 2.7 V to 5.5 V, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A (1)	MIN	TYP	MAX	UNIT
	Short-circuit current		25°C		+250 –200		mA
	Closed-loop output impedance		25°C		0.02		Ω
I_Q	Quiescent current	V_S = 5 V, I_O = 0	25°C		8.3	11	mA
			Full range			14	
	Thermal shutdown junction temperature	Shutdown	25°C		160		°C
		Reset from shutdown			140		

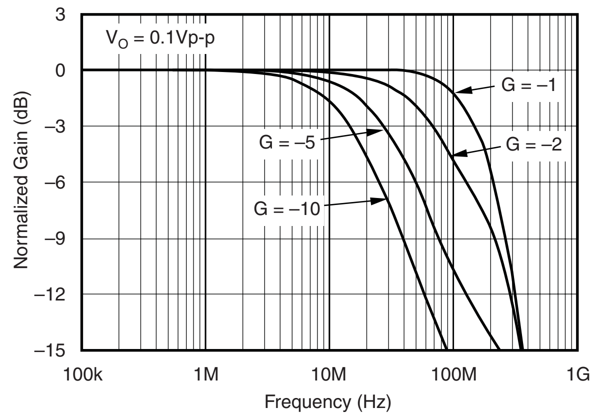
TYPICAL CHARACTERISTICS

T_A = 25°C, V_S = 5 V, G = +2, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

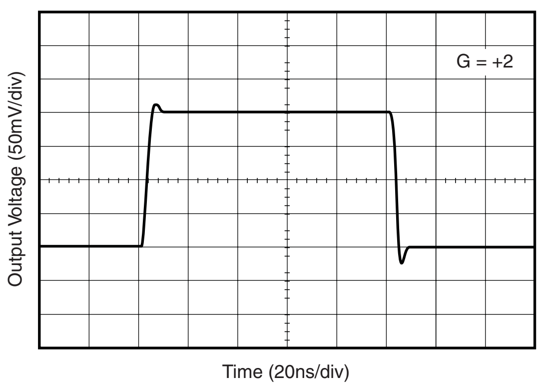
NON-INVERTING SMALL-SIGNAL FREQUENCY RESPONSE



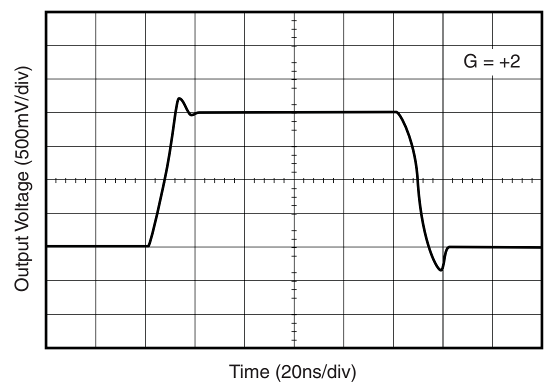
INVERTING SMALL-SIGNAL FREQUENCY RESPONSE



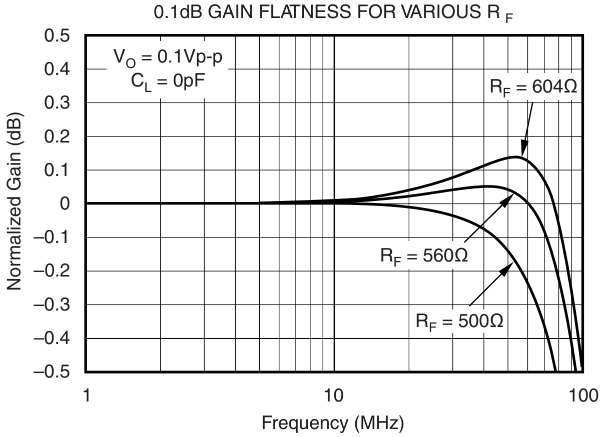
NON-INVERTING SMALL-SIGNAL STEP RESPONSE



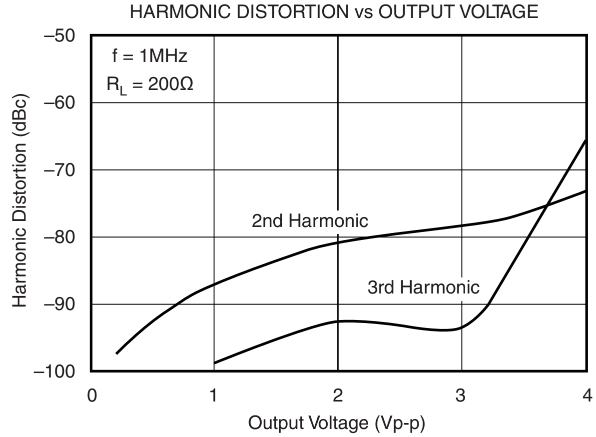
NON-INVERTING LARGE-SIGNAL STEP RESPONSE



0.1dB GAIN FLATNESS FOR VARIOUS R F



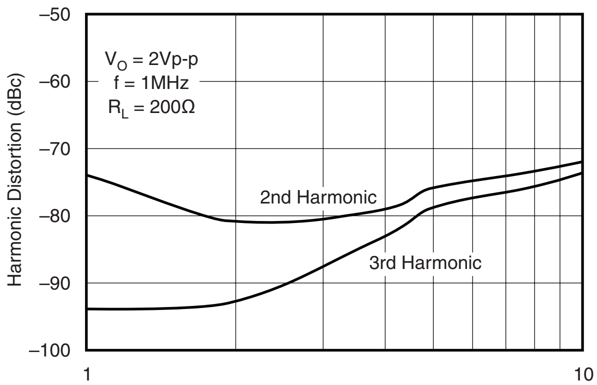
HARMONIC DISTORTION vs OUTPUT VOLTAGE



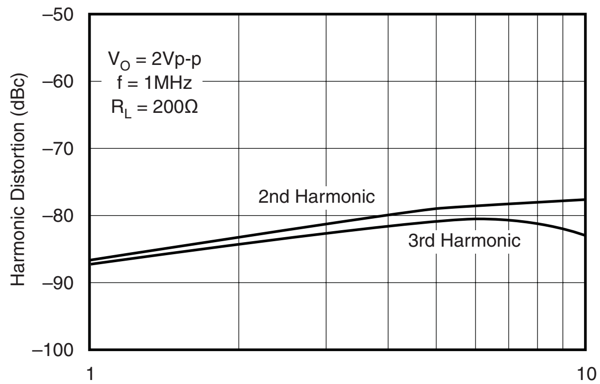
TYPICAL CHARACTERISTICS (continued)

T_A = 25°C, V_S = 5 V, G = +2, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

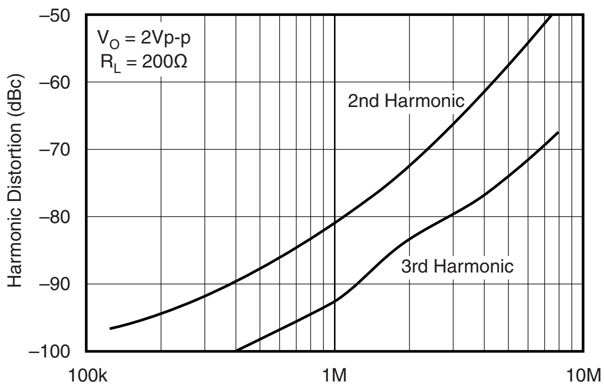
HARMONIC DISTORTION vs NON-INVERTING GAIN



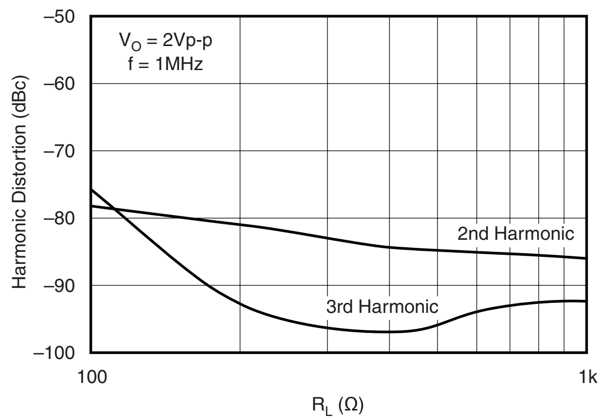
HARMONIC DISTORTION vs INVERTING GAIN



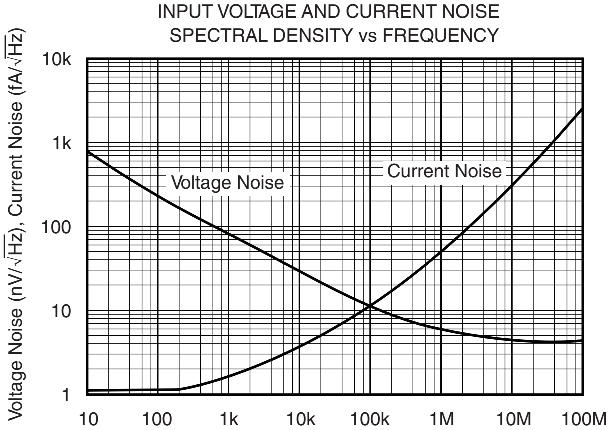
HARMONIC DISTORTION vs FREQUENCY



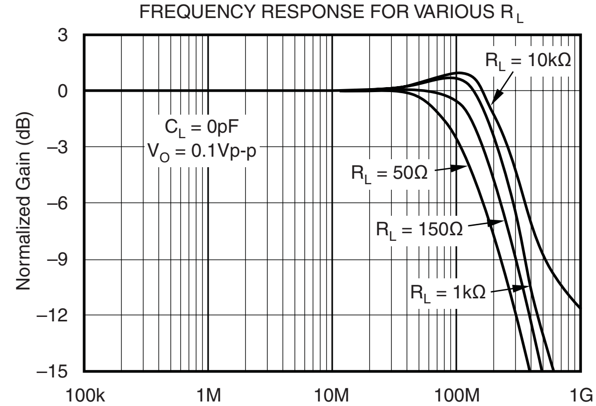
HARMONIC DISTORTION vs LOAD RESISTANCE



INPUT VOLTAGE AND CURRENT NOISE SPECTRAL DENSITY vs FREQUENCY

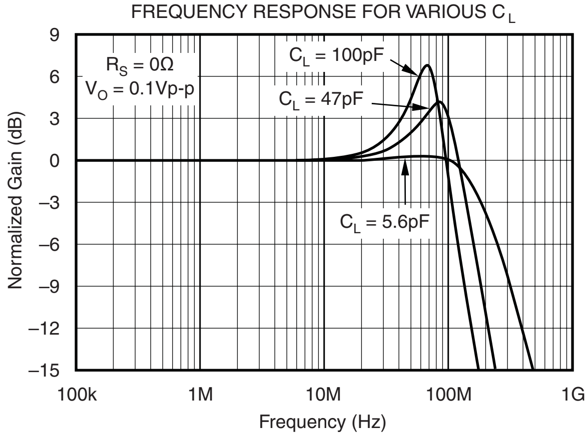


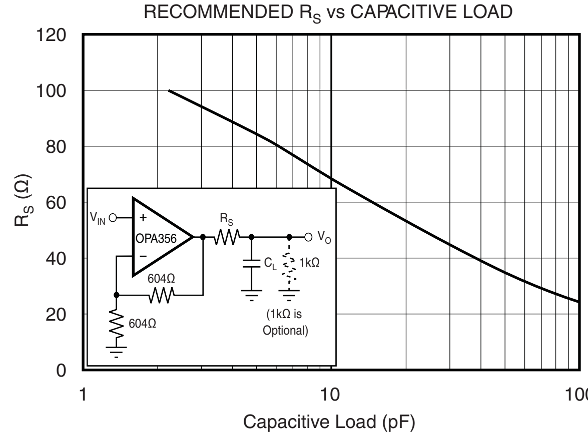
FREQUENCY RESPONSE FOR VARIOUS R_L

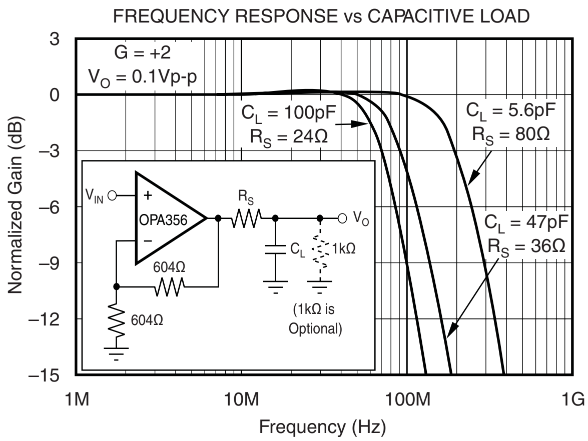


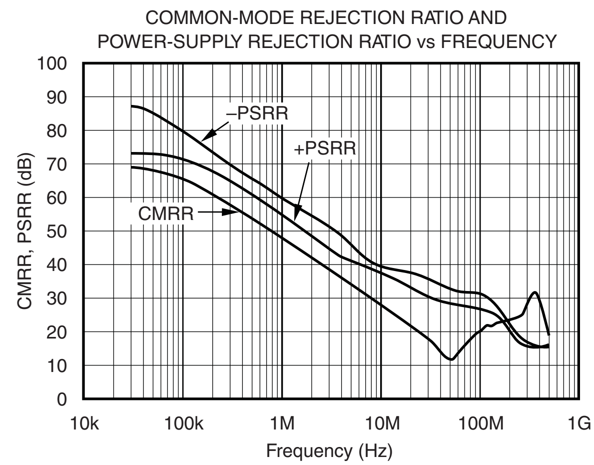
TYPICAL CHARACTERISTICS (continued)

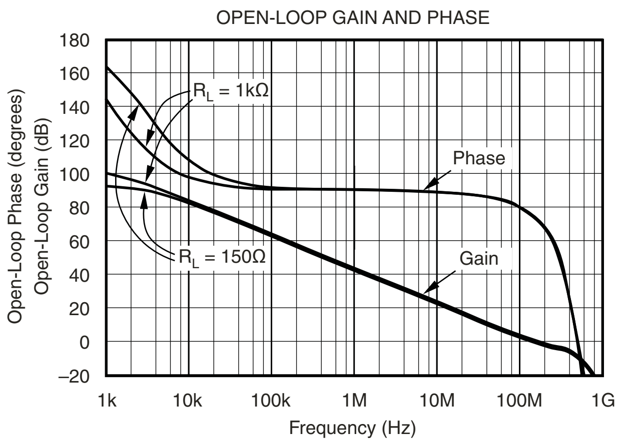
T_A = 25°C, V_S = 5 V, G = +2, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

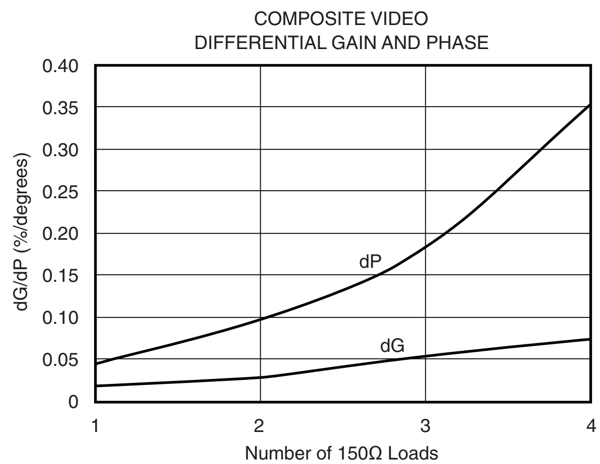








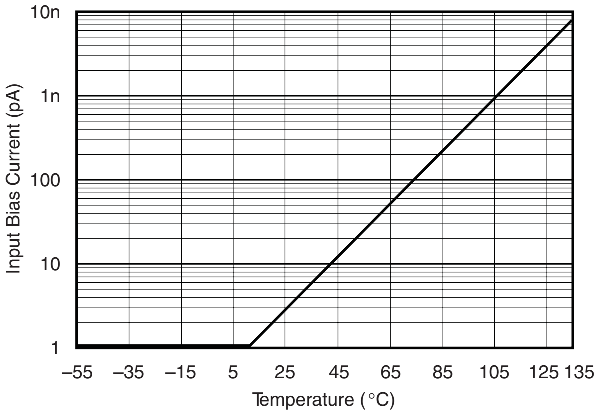




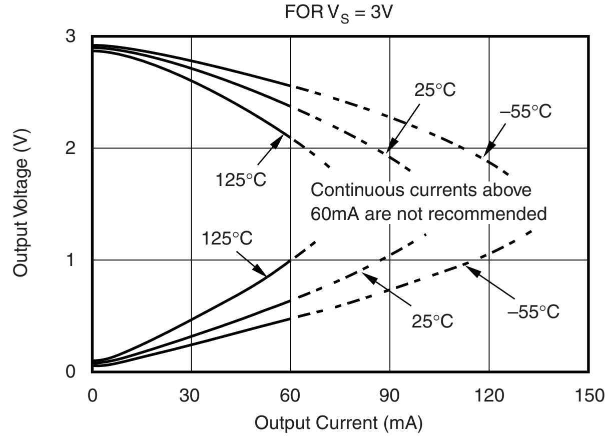
TYPICAL CHARACTERISTICS (continued)

T_A = 25°C, V_S = 5 V, G = +2, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)

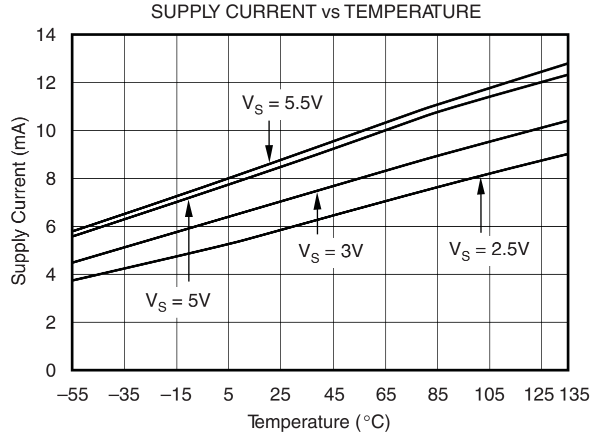
INPUT BIAS CURRENT vs TEMPERATURE



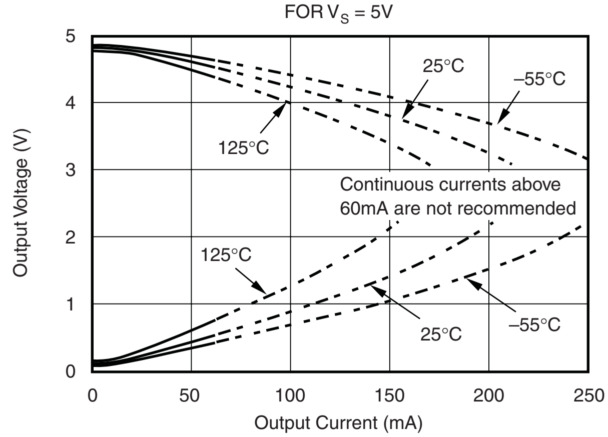
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT FOR V_S = 3V



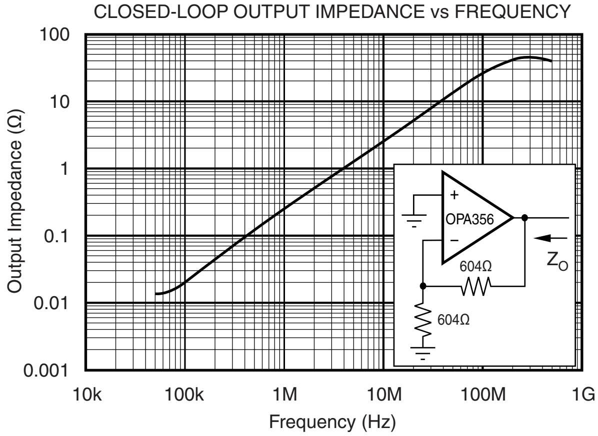
SUPPLY CURRENT vs TEMPERATURE



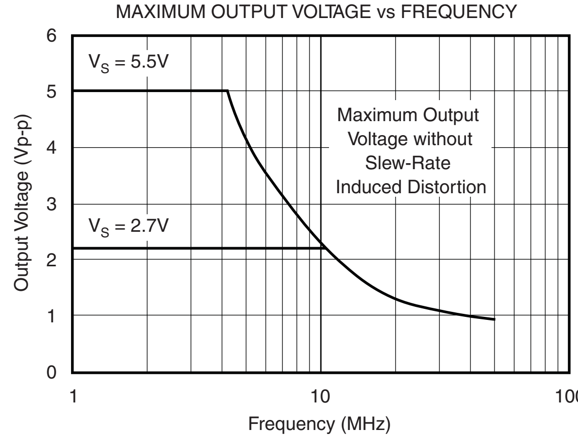
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT FOR V_S = 5V



CLOSED-LOOP OUTPUT IMPEDANCE vs FREQUENCY

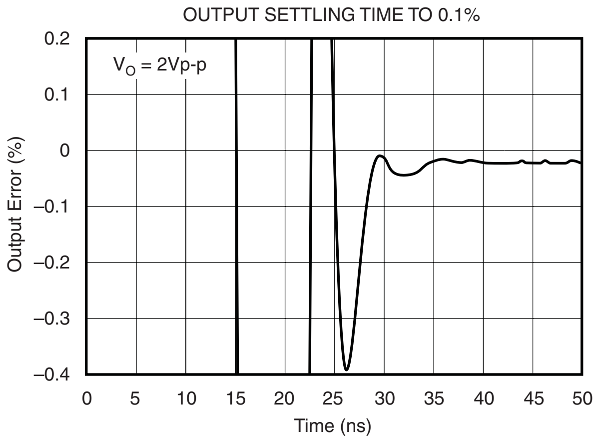


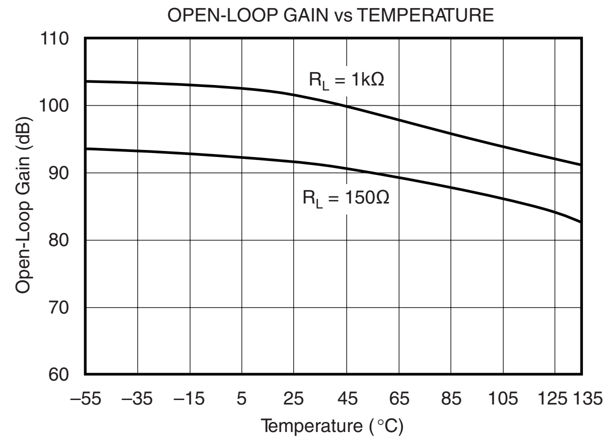
MAXIMUM OUTPUT VOLTAGE vs FREQUENCY

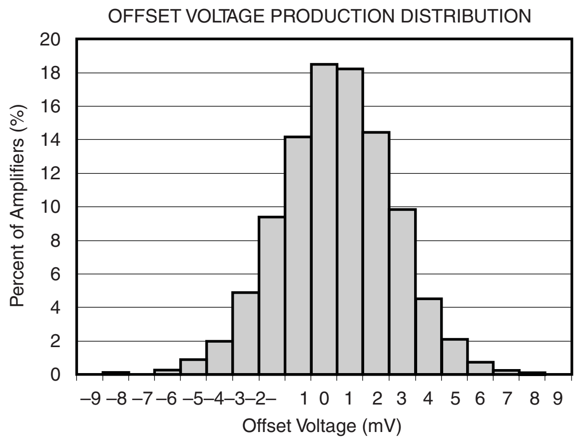


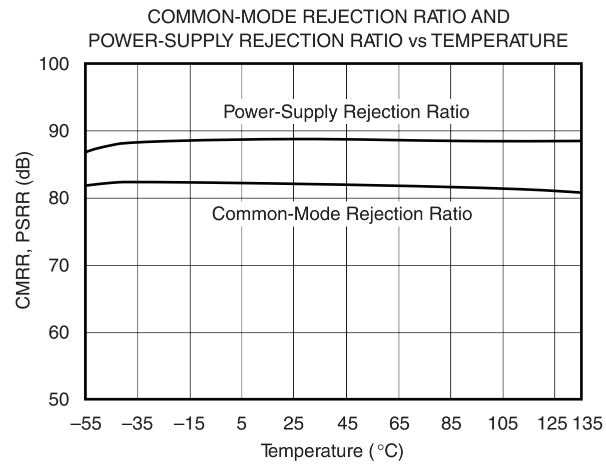
TYPICAL CHARACTERISTICS (continued)

T_A = 25°C, V_S = 5 V, G = +2, R_F = 604 Ω, R_L = 150 Ω connected to V_S/2 (unless otherwise noted)









APPLICATION INFORMATION

The OPA356 is a CMOS high-speed voltage-feedback operational amplifier designed for video and other general-purpose applications.

The amplifier features a 200-MHz gain bandwidth and 360-V/μs slew rate, but it is unity-gain stable and can be operated as a 1-V/V voltage follower.

Its input common-mode voltage range includes ground, allowing the OPA356 to be used in virtually any single-supply application up to a supply voltage of 5.5 V.

PCB Layout

Good high-frequency PC board layout techniques should be employed for the OPA356. Generous use of ground planes, short direct signal traces, and a suitable bypass capacitor located at the V+ pin assure clean, stable operation. Large areas of copper also provide a means of dissipating heat that is generated within the amplifier in normal operation.

Sockets are definitely not recommended for use with any high-speed amplifier.

A 10-μF ceramic bypass capacitor is the minimum recommended value; adding a 1-μF or larger tantalum capacitor in parallel can be beneficial when driving a low-resistance load. Providing adequate bypass capacitance is essential to achieving very low harmonic and intermodulation distortion.

Operating Voltage

The OPA356 is specified over a power-supply range of 2.7 V to 5.5 V (±1.35 V to ±2.75 V). However, the supply voltage may range from 2.5 V to 5.5 V (±1.25 V to ±2.75 V). Supply voltages higher than 7.5 V (absolute maximum) can permanently damage the amplifier.

Parameters that vary significantly over supply voltage or temperature are shown in the *Typical Characteristics* section of this data sheet.

Output Drive

The OPA356 output stage is capable of driving a standard back-terminated 75-Ω video cable. By back-terminating a transmission line, it does not exhibit a capacitive load to its driver. A properly back-terminated 75-Ω cable does not appear as capacitance; it presents only a 150-Ω resistive load to the OPA356 output.

The output stage can supply high short-circuit current (typically over 200 mA). Therefore, an on-chip thermal shutdown circuit is provided to protect the OPA356 from dangerously high junction temperatures. At 160°C, the protection circuit will shut down the amplifier. Normal operation will resume when the junction temperature cools to below 140°C.

NOTE:

It is not recommended to run a continuous dc current in excess of ±60 mA. See the "Output Voltage Swing vs Output Current" graph in the *Typical Characteristics* section of this data sheet.

Input and ESD Protection

All OPA356 pins are static protected with internal ESD protection diodes tied to the supplies, as shown in Figure 1. These diodes provide overdrive protection if the current is externally limited to 10 mA by the source or by a resistor.

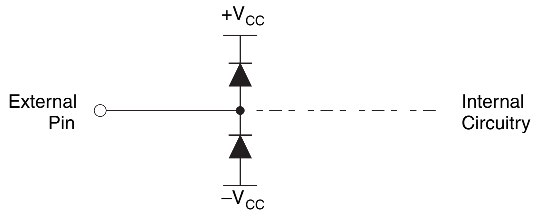


Figure 1. Internal ESD Protection

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
OPA356AQDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	

(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.

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.

OTHER QUALIFIED VERSIONS OF OPA356-Q1 :

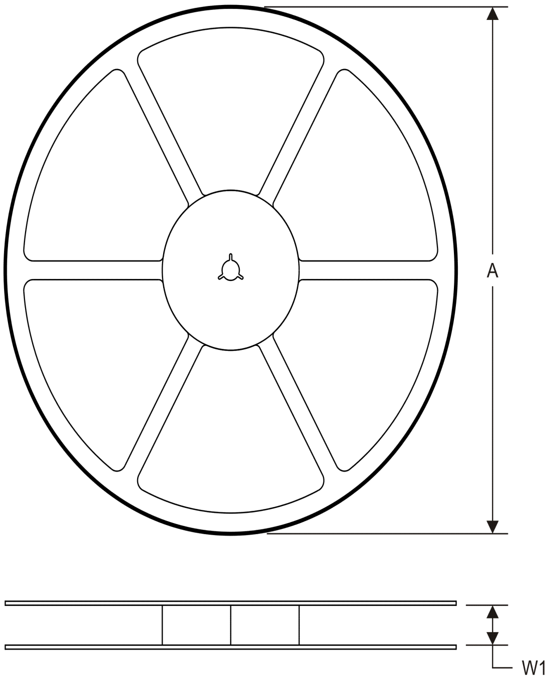
- Catalog: OPA356

NOTE: Qualified Version Definitions:

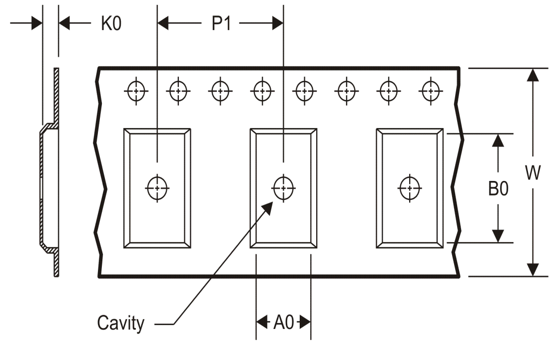
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



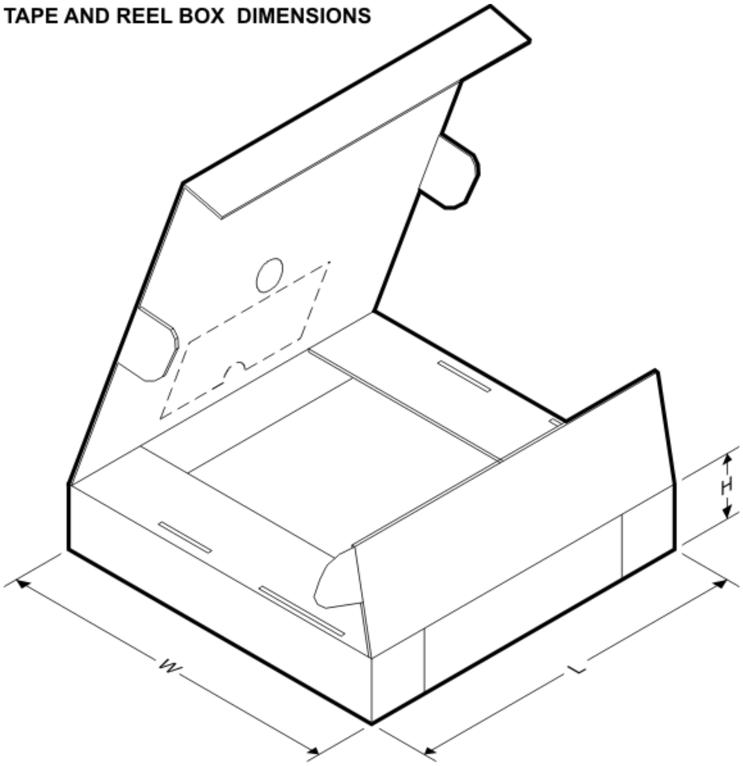
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

TAPE AND REEL INFORMATION

*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
OPA356AQDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.1	1.39	4.0	8.0	Q3

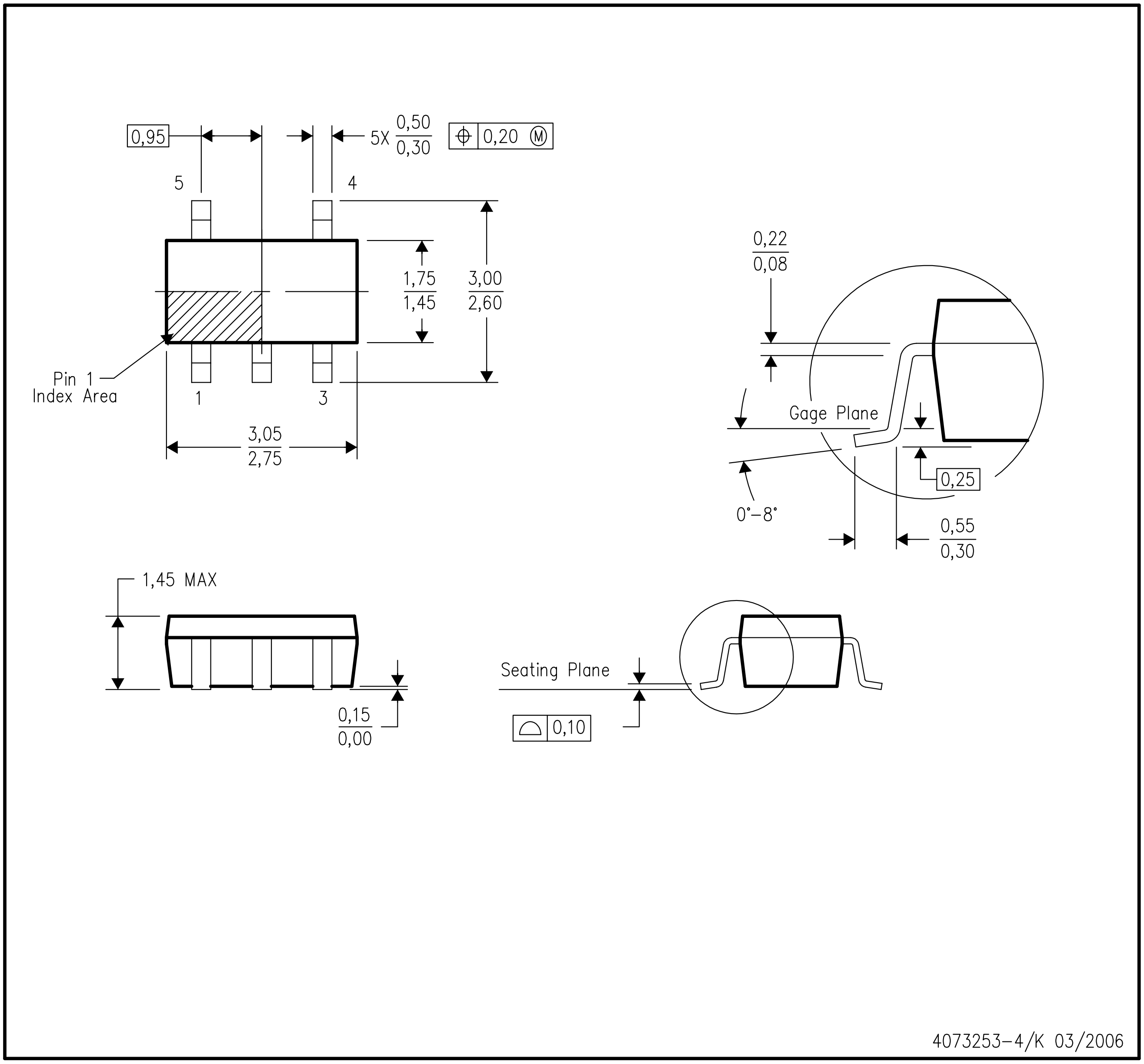
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

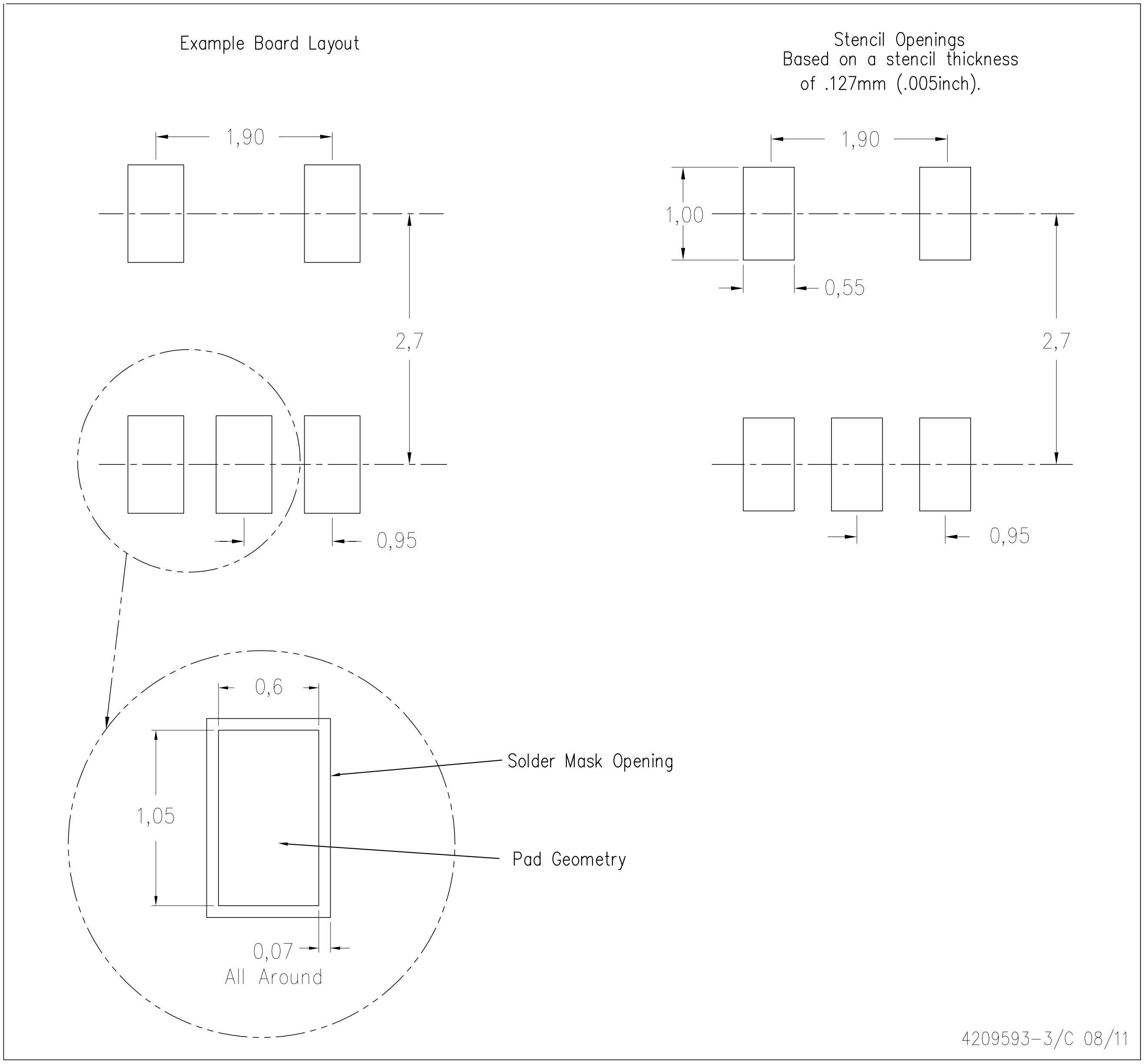
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA356AQDBVRQ1	SOT-23	DBV	5	3000	210.0	185.0	35.0

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



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.

DBV (R-PDSO-G5) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC-7351 is recommended for alternate designs.
E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

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

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