36-V, SINGLE-SUPPLY, LOW-POWER OPERATIONAL AMPLIFIER

Check for Samples: OPA170-EP

FEATURES

- **Supply Range: +2.7V to +36V, ±1.35V to ±18V**
- **Low Noise: 19nV/√Hz**
- **RFI Filtered Inputs**
- **Input Range Includes the Negative Supply**
- **Input Range Operates to Positive Supply**
- **Rail-to-Rail Output**
- **Gain Bandwidth: 1.2MHz**
- **Low Quiescent Current: 110µA per Amplifier**
- **High Common-Mode Rejection: 120dB**
- **Low Bias Current: 15pA (max)**
- ***micro*Package:**
  - **Single in 5-Pin SOT553**

APPLICATIONS

- **Tracking Amplifier in Power Modules**
- **Merchant Power Supplies**
- **Transducer Amplifiers**
- **Bridge Amplifiers**
- **Temperature Measurements**
- **Strain Gauge Amplifiers**
- **Precision Integrators**
- **Battery-Powered Instruments**
- **Test Equipment**

SUPPORTS DEFENSE, AEROSPACE, AND MEDICAL APPLICATIONS

- **Controlled Baseline**
- **One Assembly or Test Site**
- **One Fabrication Site**
- **Available in Extended (–40°C to 150°C) Temperature Range** (1)
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**

(1) Additional temperature ranges available - contact factory

DESCRIPTION

The OPA170 is a 36-V, single-supply, low-noise operational amplifier that features a micro package with the ability to operate on supplies ranging from +2.7V (±1.35V) to +36V (±18V). It offers good offset, drift, and bandwidth with low quiescent current.

Unlike most op amps, which are specified at only one supply voltage, the OPA170 is specified from +2.7V to +36V. Input signals beyond the supply rails do not cause phase reversal. The OPA170 is stable with capacitive loads up to 300pF. The input can operate 100mV below the negative rail and within 2V of the positive rail for normal operation. Note that these devices can operate with full rail-to-rail input 100mV beyond the positive rail, but with reduced performance within 2V of the positive rail.

The OPA170 is available in the SOT553-5 package and is specified from –40°C to +150°C.

Package Footprint (to Scale)

Package Height (to Scale)

DRL (SOT553)

Smallest Packaging for 36V Op Amps

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.

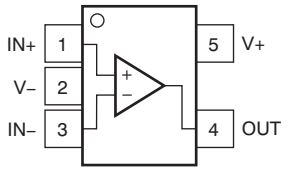
ORDERING INFORMATION(1)

T_A	PACKAGE	ORDERABLE PART NUMBER	TOP-SIDE MARKING	VID NUMBER
–40°C to 150°C	SOT553-5 - DRL	OPA170ASDRLTEP	SHN	V62/12627-01XE

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

PIN CONFIGURATIONS

DRL PACKAGE
SOT553-5
(TOP VIEW)



ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range, unless otherwise noted.

			UNIT
Supply voltage		±20, +40 (single supply)	V
Signal input terminals	Voltage	(V–) – 0.5 to (V+) + 0.5	V
	Current	±10	mA
Output short circuit(2)		Continuous	
Operating temperature		–40 to +150	°C
Storage temperature		–65 to +150	°C
Junction temperature		+150	°C
ESD ratings	Human body model (HBM)	4	kV
	Charged device model (CDM)	750	V

(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) Short-circuit to ground, one amplifier per package.

THERMAL INFORMATION

THERMAL METRIC(1)		OPA170 DRL (SOT553) 5 PINS	UNITS
θ_{JA}	Junction-to-ambient thermal resistance	226.8	°C/W
$\theta_{JC(top)}$	Junction-to-case(top) thermal resistance	80.3	
θ_{JB}	Junction-to-board thermal resistance	42.9	
ψ_{JT}	Junction-to-top characterization parameter	3.2	
ψ_{JB}	Junction-to-board characterization parameter	42.5	
$\theta_{JC(bottom)}$	Junction-to-case(bottom) thermal resistance	N/A	

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

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, **T_A = –40°C to +150°C.**
At T_A = +25°C, V_{CM} = V_{OUT} = V_S/2, and R_L = 10kΩ connected to V_S/2, unless otherwise noted.

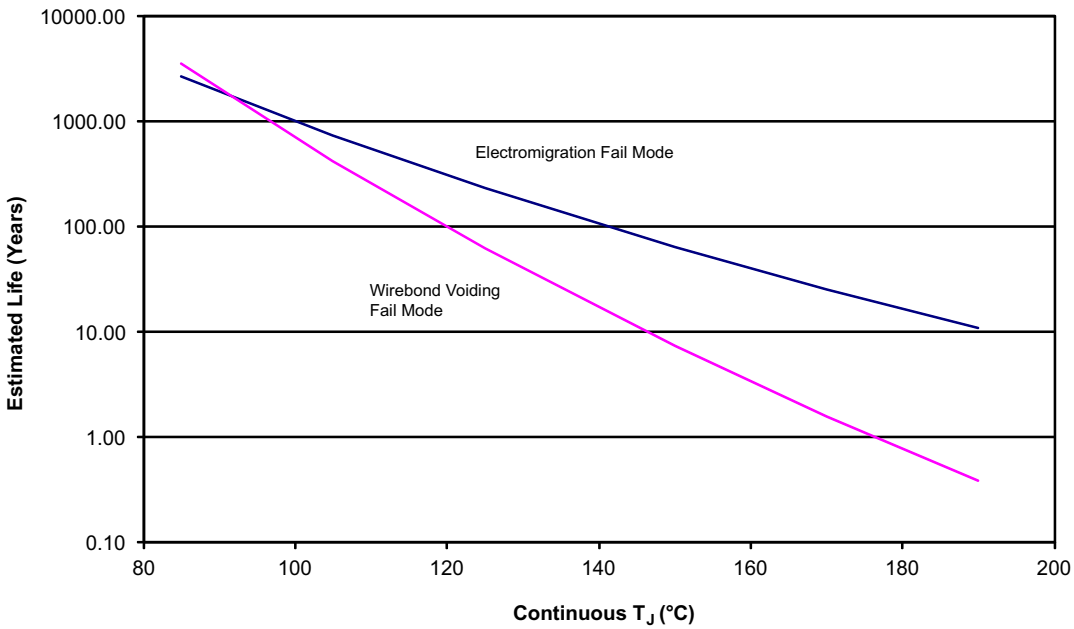
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
Input offset voltage	V_{OS}			0.25	±1.8	mV
Over temperature		**T_A = –40°C to +150°C**			**±2.5**	**mV**
Drift	**dV_{OS}/dT**			**±0.3**		**µV/°C**
vs power supply	**PSRR**	**V_S = +4V to +36V**		**1**	**±5**	**µV/V**
Channel separation, dc		dc		5		µV/V
INPUT BIAS CURRENT						
Input bias current	I_B			±8	±15	pA
Over temperature		**T_A = –40°C to +150°C**			**±8**	**nA**
Input offset current	I_{OS}			±4	±15	pA
Over temperature		**T_A = –40°C to +150°C**			**±8**	**nA**
NOISE						
Input voltage noise		f = 0.1Hz to 10Hz		2		μV_{PP}
Input voltage noise density	e_n	f = 100Hz		22		nV/√Hz
		f = 1kHz		19		nV/√Hz
INPUT VOLTAGE						
Common-mode voltage range[1]	V_{CM}		(V–) – 0.1V		(V+) – 2V	V
Common-mode rejection ratio	**CMRR**	**V_S = ±2V, (V–) – 0.1V < V_{CM} < (V+) – 2V**	**87**	**104**		**dB**
		V_S = ±18V, (V–) – 0.1V < V_{CM} < (V+) – 2V	**100**	**120**		**dB**
INPUT IMPEDANCE						
Differential				100 || 3		MΩ || pF
Common-mode				6 || 3		10^{12} Ω || pF
OPEN-LOOP GAIN						
Open-loop voltage gain	**A_{OL}**	**V_S = +4V to +36V, (V–) + 0.35V < V_O < (V+) – 0.35V**	**107**	**130**		**dB**
FREQUENCY RESPONSE						
Gain bandwidth product	GBP			1.2		MHz
Slew rate	SR	G = +1		0.4		V/µs
Settling time	t_S	To 0.1%, V_S = ±18V, G = +1, 10V step		20		µs
		To 0.01% (12 bit), V_S = ±18V, G = +1, 10V step		28		µs
Overload recovery time		V_{IN} × Gain > V_S		2		µs
Total harmonic distortion + noise	THD+N	G = +1, f = 1kHz, V_O = $3V_{RMS}$		0.0002		%

(1) The input range can be extended beyond (V+) – 2V up to V+. See the *Typical Characteristics* and *Application Information* sections for additional information.

ELECTRICAL CHARACTERISTICS (continued)

Boldface limits apply over the specified temperature range, **T_A = –40°C to +150°C.**
At T_A = +25°C, V_{CM} = V_{OUT} = V_S/2, and R_L = 10kΩ connected to V_S/2, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
Voltage output swing from rail	**V_O**					
Positive rail		I_L = 0mA, V_S = +4V to +36V	10			mV
		I_L sourcing 1mA, V_S = +4V to +36V	130			mV
Negative Rail		I_L = 0mA, V_S = +4V to +36V			8	mV
		I_L sinking 1mA, V_S = +4V to +36V			72	mV
Over temperature		**V_S = 5V, R_L = 10kΩ**	**(V–) + 0.03**		**(V+) – 0.05**	**V**
		R_L = 10kΩ, A_{OL} ≥ 107dB	**(V–) + 0.35**		**(V+) – 0.35**	**V**
Short-circuit current	I_{SC}			+17/–20		mA
Capacitive load drive	C_{LOAD}			See Typical Characteristics		pF
Open-loop output resistance	R_O	f = 1MHz, I_O = 0A		900		Ω
POWER SUPPLY						
Specified voltage range	V_S		+2.7		+36	V
Quiescent current per amplifier	I_Q	I_O = 0A		110	145	µA
Over temperature		**I_O = 0A**			**160**	**µA**
TEMPERATURE						
Specified range			–40		+125	°C
Operating range			–40		+150	°C



(1) See datasheet for absolute maximum and minimum recommended operating conditions.

(2) Silicon operating life design goal is 10 years at 105°C junction temperature (does not include package interconnect life).

(3) Enhanced plastic product disclaimer applies.

Figure 1. OPA170-EP Operating Life Derating Chart

TYPICAL CHARACTERISTICS

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

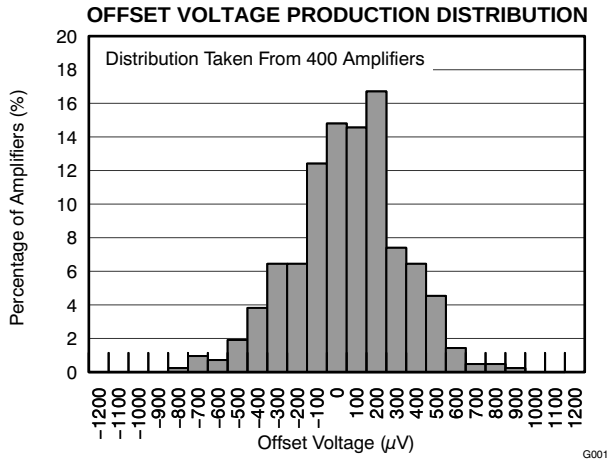


Figure 2.

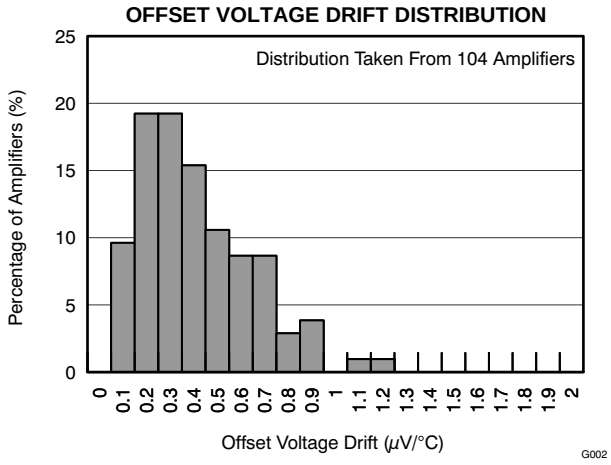
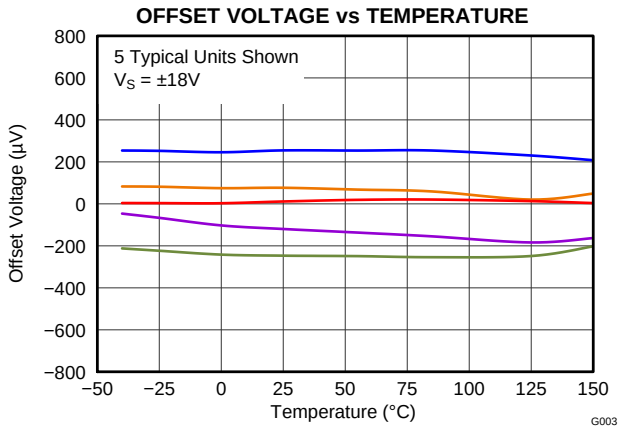


Figure 3.



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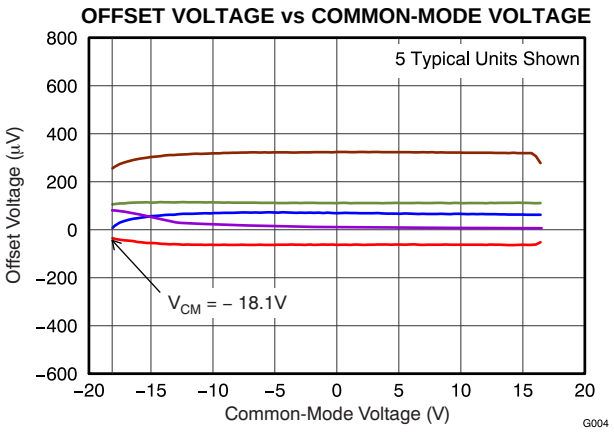
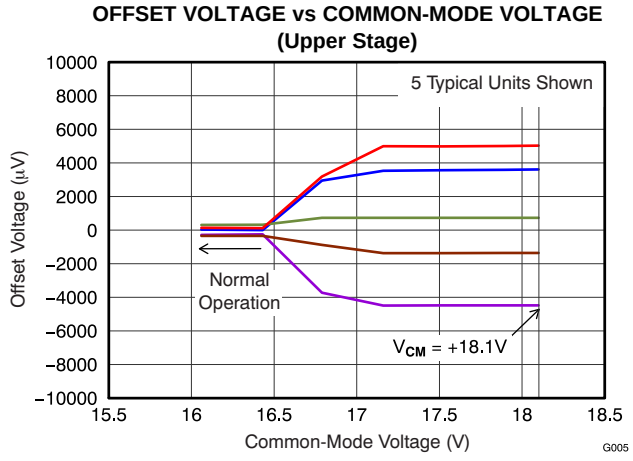


Figure 5.



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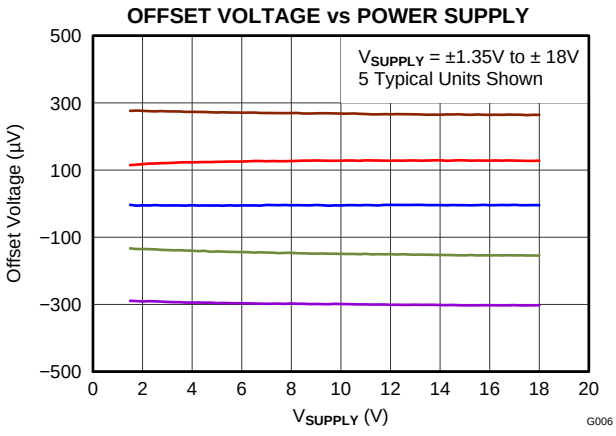


Figure 7.

TYPICAL CHARACTERISTICS (continued)

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

I_B AND I_{OS} vs COMMON-MODE VOLTAGE

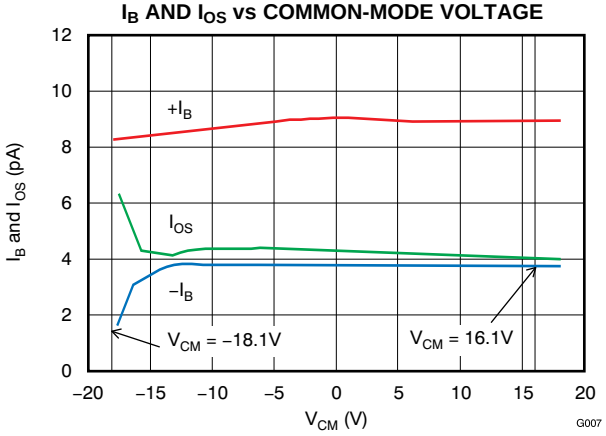


Figure 8.

INPUT BIAS CURRENT vs TEMPERATURE

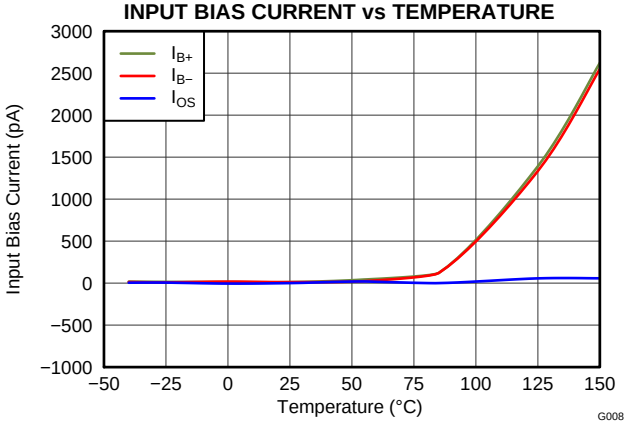


Figure 9.

OUTPUT VOLTAGE SWING vs OUTPUT CURRENT (Maximum Supply)

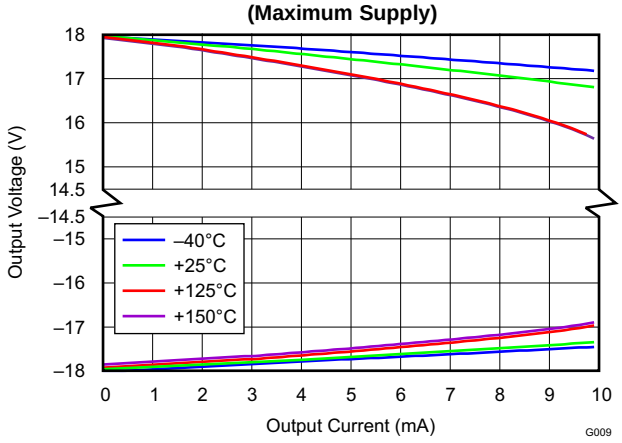


Figure 10.

CMRR AND PSRR vs FREQUENCY (Referred-to Input)

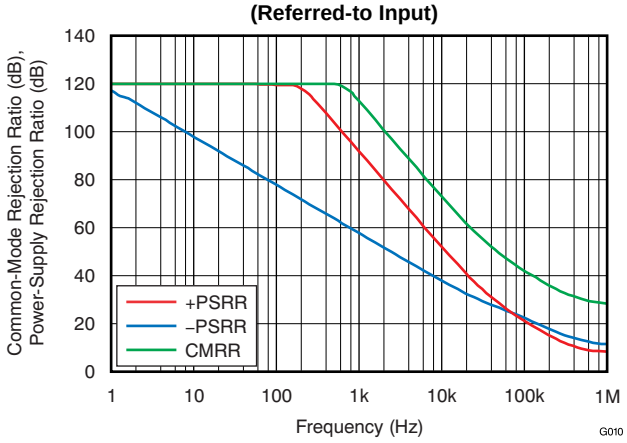


Figure 11.

CMRR vs TEMPERATURE

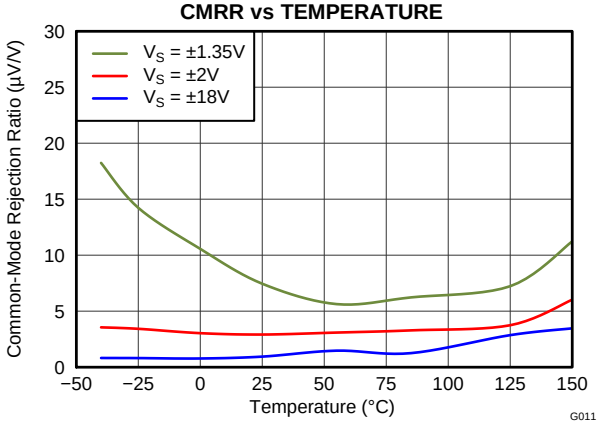


Figure 12.

PSRR vs TEMPERATURE

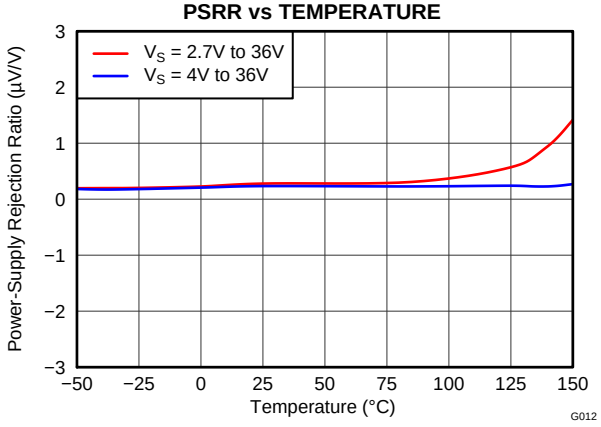


Figure 13.

TYPICAL CHARACTERISTICS (continued)

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

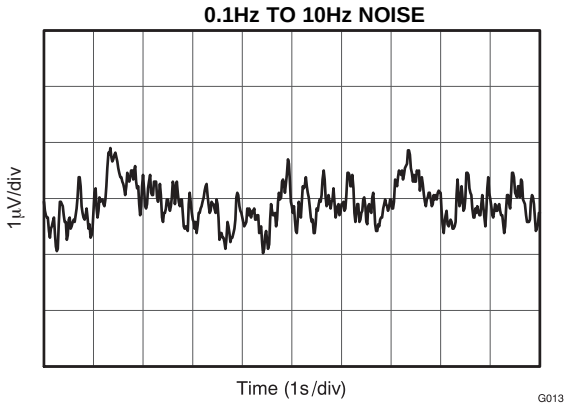


Figure 14.

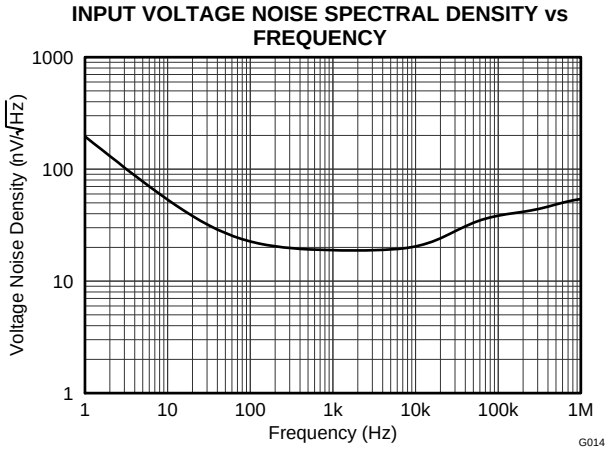


Figure 15.

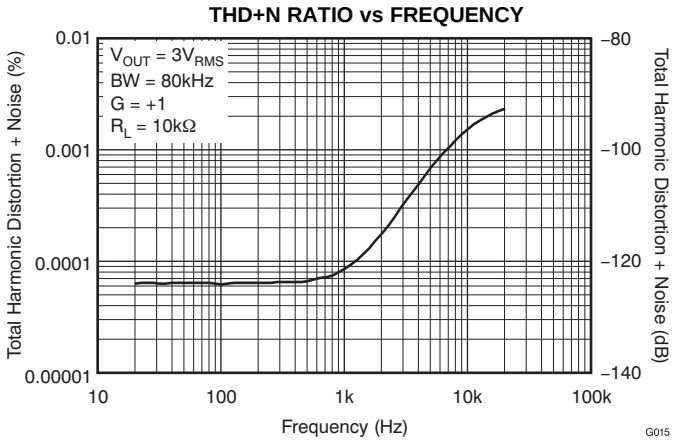


Figure 16.

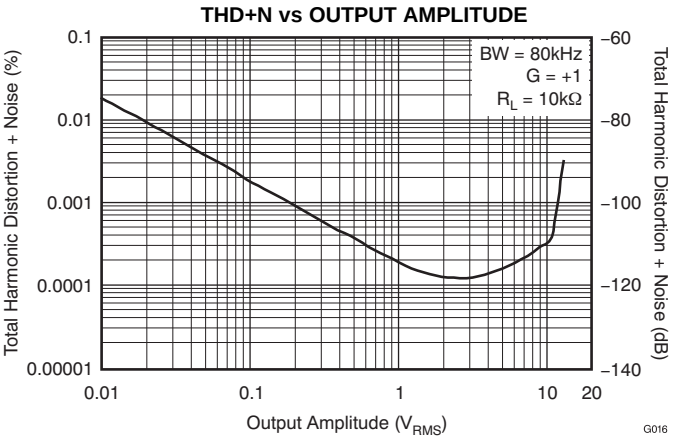


Figure 17.

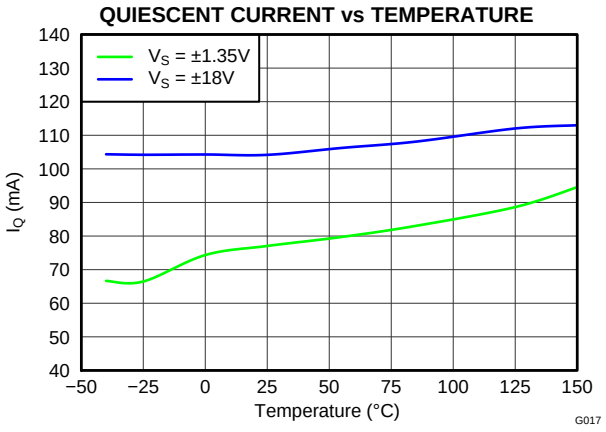


Figure 18.

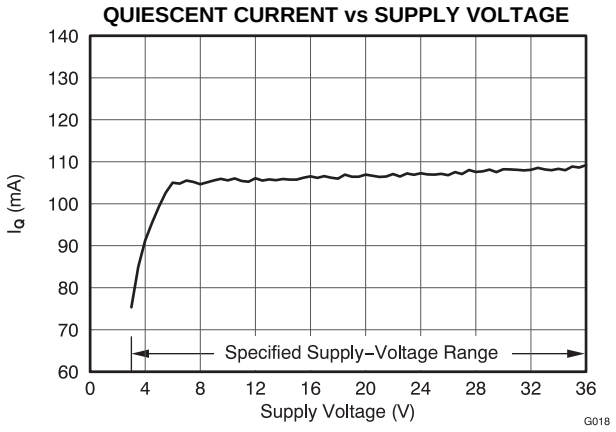


Figure 19.

TYPICAL CHARACTERISTICS (continued)

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

OPEN-LOOP GAIN AND PHASE vs FREQUENCY

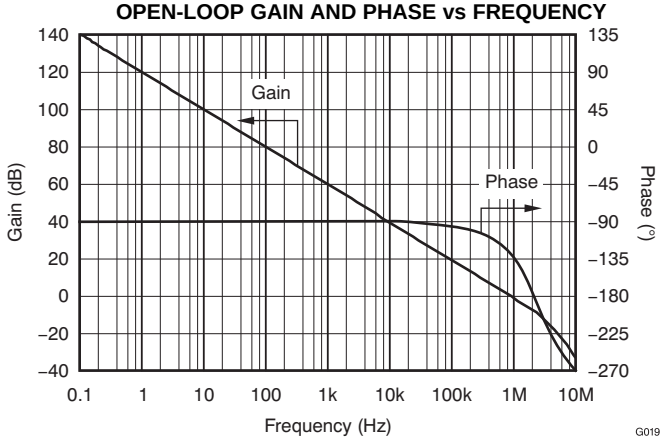


Figure 20.

CLOSED-LOOP GAIN vs FREQUENCY

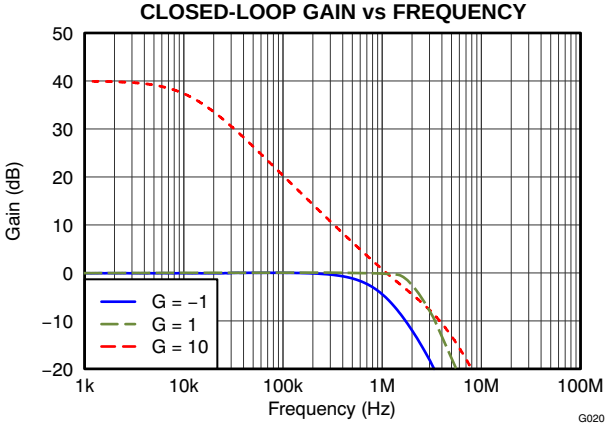


Figure 21.

OPEN-LOOP GAIN vs TEMPERATURE

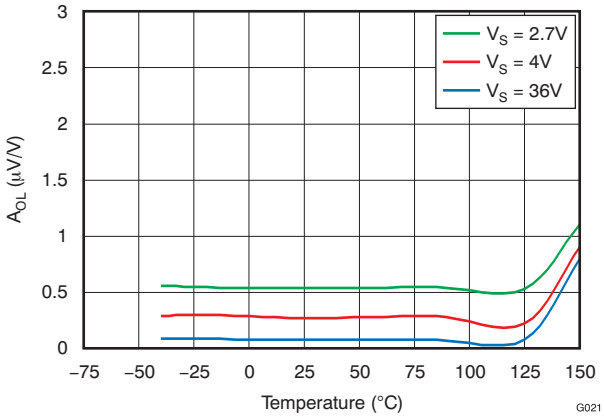


Figure 22.

OPEN-LOOP OUTPUT IMPEDANCE vs FREQUENCY

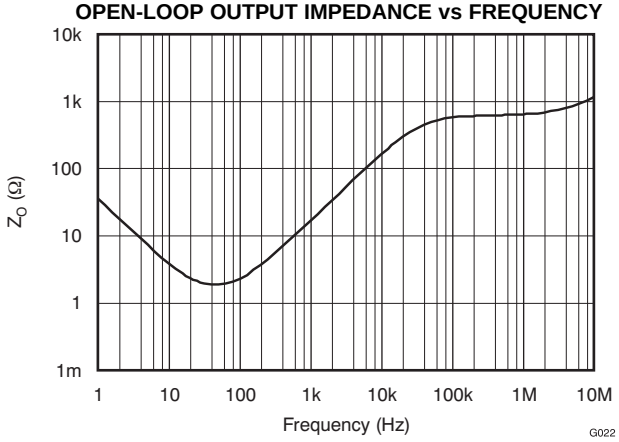


Figure 23.

SMALL-SIGNAL OVERSHOOT vs CAPACITIVE LOAD (100mV Output Step)

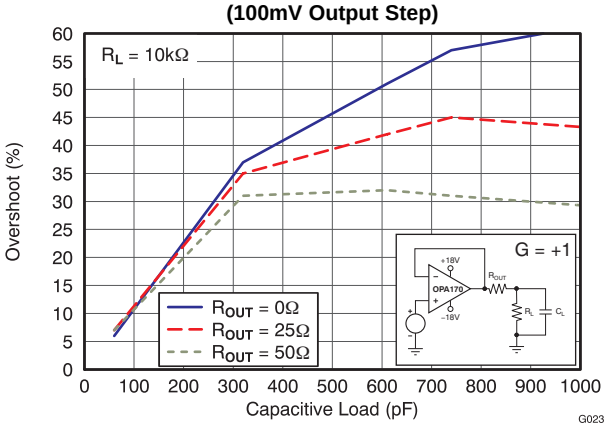


Figure 24.

SMALL-SIGNAL OVERSHOOT vs CAPACITIVE LOAD (100mV Output Step)

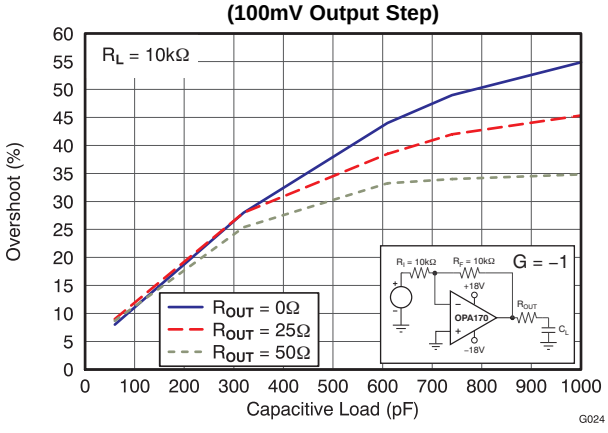


Figure 25.

TYPICAL CHARACTERISTICS (continued)

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

NO PHASE REVERSAL

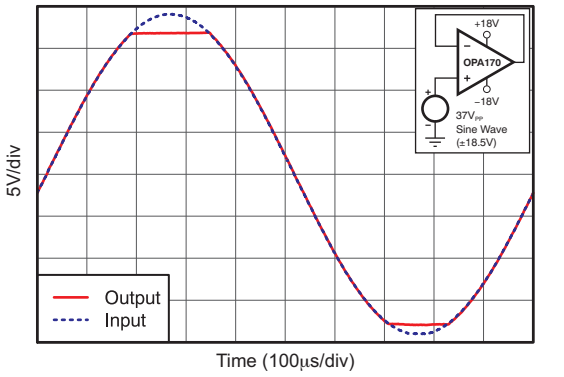


Figure 26.

POSITIVE OVERLOAD RECOVERY

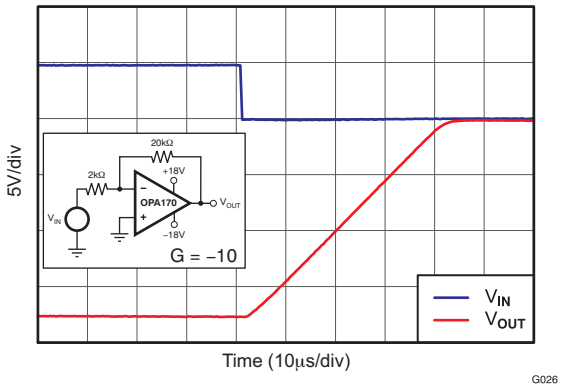


Figure 27.

NEGATIVE OVERLOAD RECOVERY

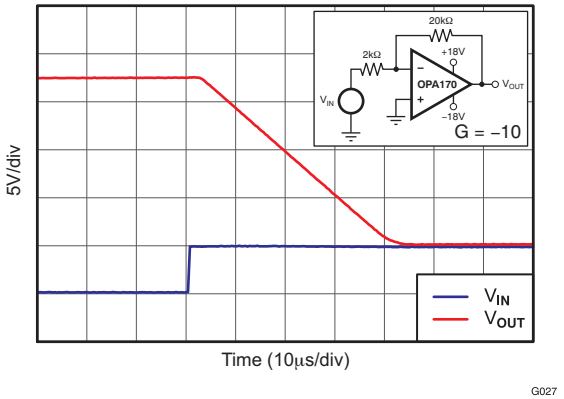


Figure 28.

SMALL-SIGNAL STEP RESPONSE (100mV)

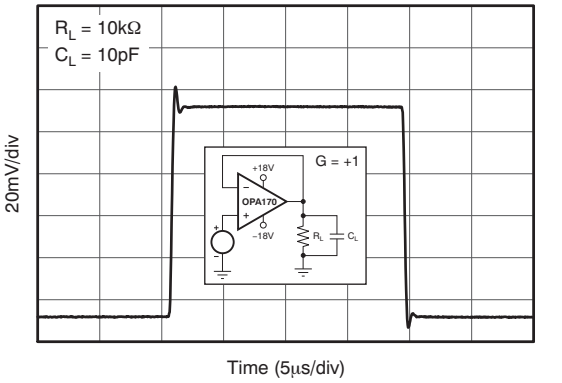


Figure 29.

SMALL-SIGNAL STEP RESPONSE (100mV)

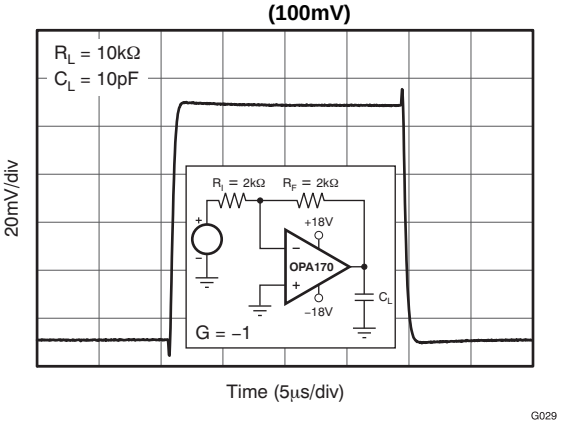


Figure 30.

LARGE-SIGNAL STEP RESPONSE

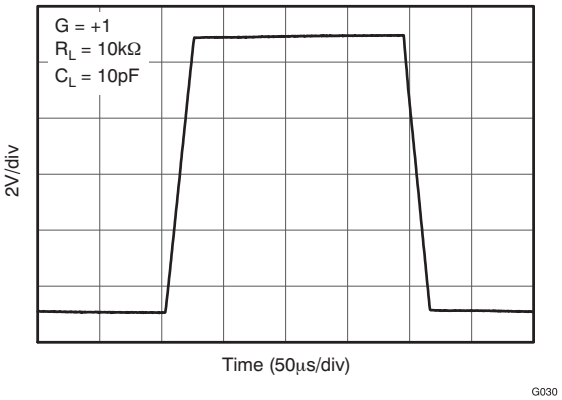


Figure 31.

TYPICAL CHARACTERISTICS (continued)

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

LARGE-SIGNAL STEP RESPONSE

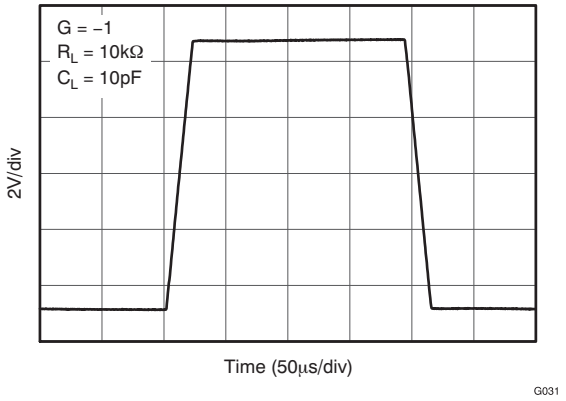


Figure 32.

LARGE-SIGNAL SETTLING TIME (10V Positive Step)

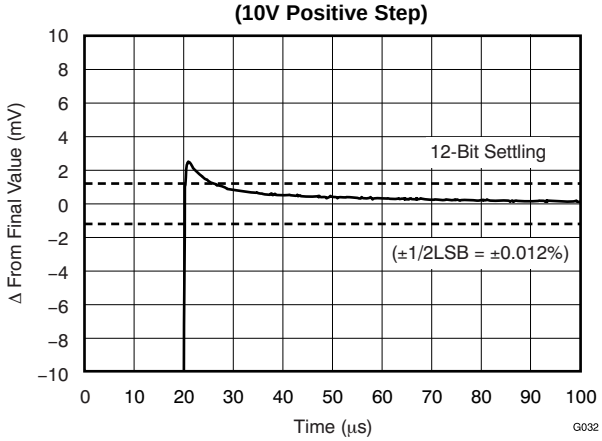


Figure 33.

LARGE-SIGNAL SETTLING TIME (10V Negative Step)

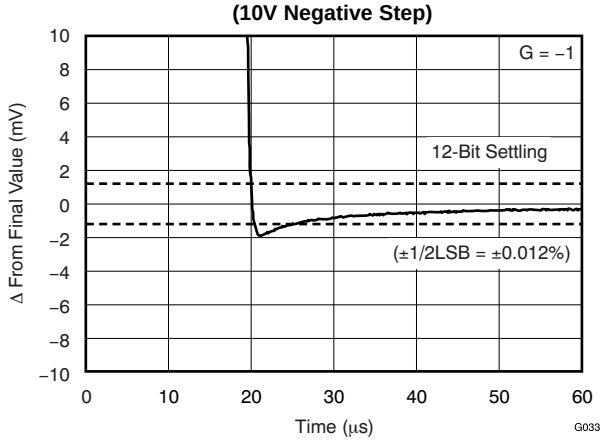


Figure 34.

SHORT-CIRCUIT CURRENT vs TEMPERATURE

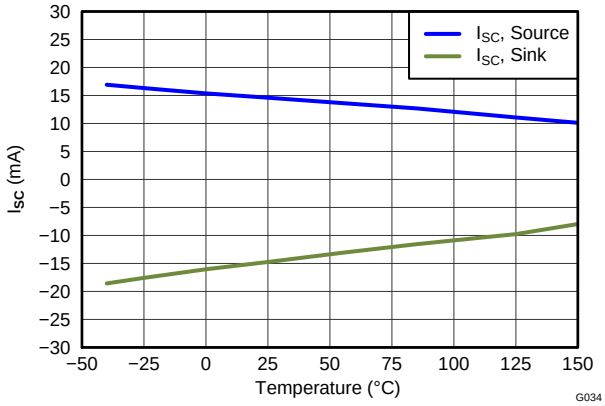


Figure 35.

MAXIMUM OUTPUT VOLTAGE vs FREQUENCY

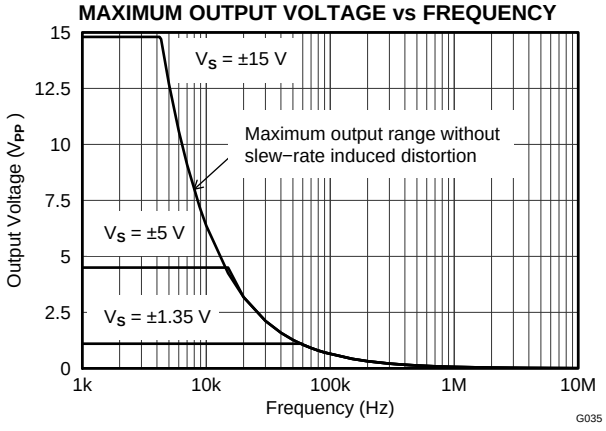


Figure 36.

EMIRR IN+ vs FREQUENCY

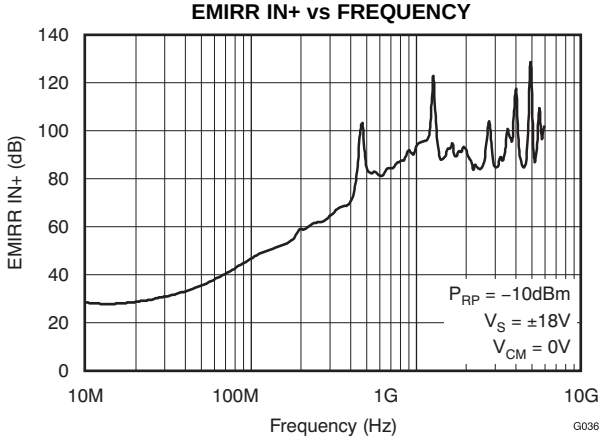


Figure 37.

APPLICATION INFORMATION

The OPA170 operational amplifier provides high overall performance. This device is ideal for many general-purpose applications. The excellent offset drift of only 2µV/°C provides excellent stability over the entire temperature range. In addition, the device offers very good overall performance with high CMRR, PSRR, and A_{OL}. As with all amplifiers, applications with noisy or high-impedance power supplies require decoupling capacitors placed close to the device pins. In most cases, 0.1µF capacitors are adequate.

OPERATING CHARACTERISTICS

The OPA170 is specified for operation from 2.7V to 36V (±1.35V to ±18V). Many of the specifications apply from –40°C to +150°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the Typical Characteristics.

GENERAL LAYOUT GUIDELINES

For best operational performance of the device, good printed circuit board (PCB) layout practices are recommended. Low-loss, 0.1µF bypass capacitors should be connected between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable to single-supply applications.

COMMON-MODE VOLTAGE RANGE

The input common-mode voltage range of the OPA170 extends 100mV below the negative rail and within 2V of the positive rail for normal operation.

This device can operate with full rail-to-rail input 100mV beyond the positive rail, but with reduced performance within 2V of the positive rail. The typical performance in this range is summarized in Table 1.

PHASE-REVERSAL PROTECTION

The OPA170 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 noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input of the OPA170 prevents phase reversal with excessive common-mode voltage. Instead, the output limits into the appropriate rail. This performance is shown in Figure 38.

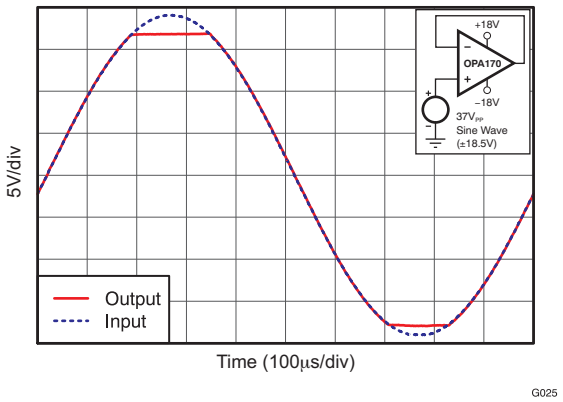


Figure 38. No Phase Reversal

Table 1. Typical Performance Range

PARAMETER	MIN	TYP	MAX	UNIT
Input Common-Mode Voltage	**(V+) – 2**		**(V+) + 0.1**	**V**
Offset voltage		7		mV
vs Temperature		**12**		**µV/°C**
Common-mode rejection		65		dB
Open-loop gain		60		dB
Gain-bandwidth product		0.3		MHz
Slew rate		0.3		V/µs

CAPACITIVE LOAD AND STABILITY

The dynamic characteristics of the OPA170 have been optimized for common operating conditions. The combination of low closed-loop gain and high capacitive loads decreases the phase margin of the amplifier and can lead to gain peaking or oscillations. As a result, heavier 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 50Ω) in series with the output. Figure 39 and Figure 40 illustrate graphs of small-signal overshoot versus capacitive load for several values of R_{OUT}. Also, refer to Applications Bulletin AB-028, *Feedback Plots Define Op Amp AC Performance* (literature number SBOA015, available for download from the TI website), for details of analysis techniques and application circuits.

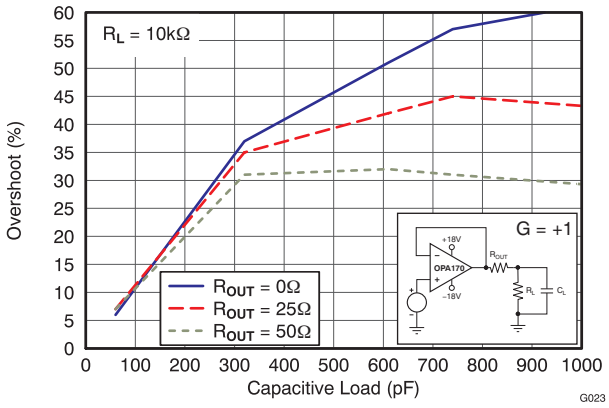


Figure 39. Small-Signal Overshoot versus Capacitive Load (100mV Output Step, G = +1)

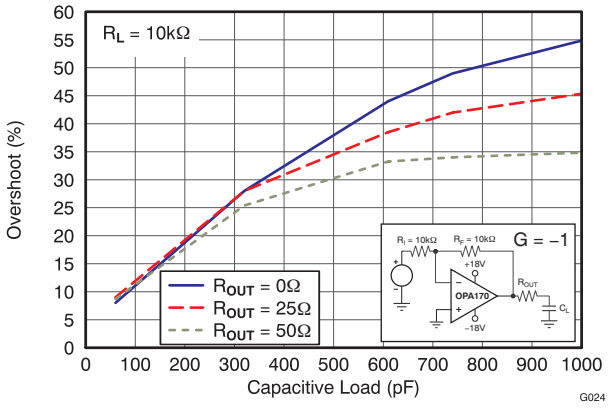


Figure 40. Small-Signal Overshoot versus Capacitive Load (100mV Output Step, G = –1)

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.

These ESD protection diodes also provide in-circuit, input overdrive protection, as long as the current is limited to 10mA as stated in the Absolute Maximum Ratings. Figure 41 shows how a series input resistor may be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input and its value should be kept to a minimum in noise-sensitive applications.

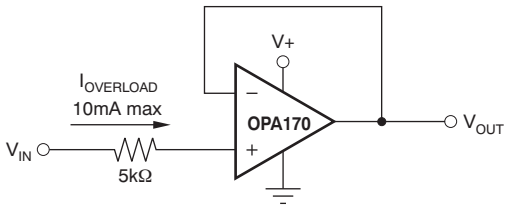


Figure 41. Input Current Protection

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

When the operational amplifier connects into a circuit, the ESD protection components are intended to remain inactive and 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 of the internal ESD protection circuits may be biased on, and conduct current. Any such current flow occurs through ESD cells and rarely involves the absorption device.

If there is an uncertainty about the ability of the supply to absorb this current, external zener diodes may be added to the supply pins. The zener voltage must be selected such that the diode does not turn on during normal operation. However, its zener voltage should be low enough so that the zener diode conducts if the supply pin begins to rise above the safe operating supply voltage level.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA170ASDRLTEP	ACTIVE	SOT-5X3	DRL	5	250	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	DAQ	Samples
V62/12627-01XE	ACTIVE	SOT-5X3	DRL	5	250	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-40 to 150	DAQ	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 finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

OTHER QUALIFIED VERSIONS OF OPA170-EP :

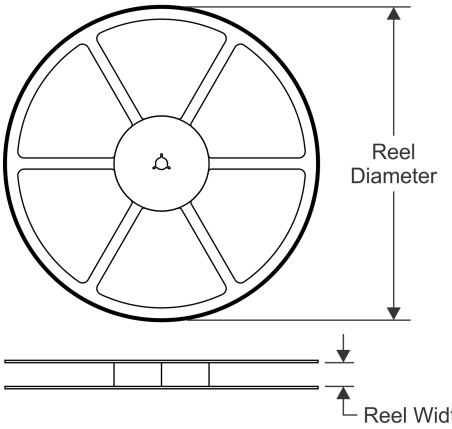
- Catalog: OPA170
- Automotive: OPA170-Q1

NOTE: Qualified Version Definitions:

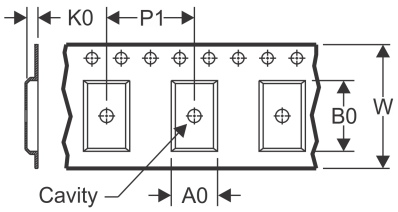
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

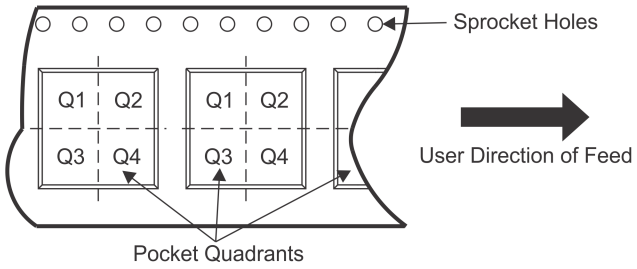


TAPE DIMENSIONS



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

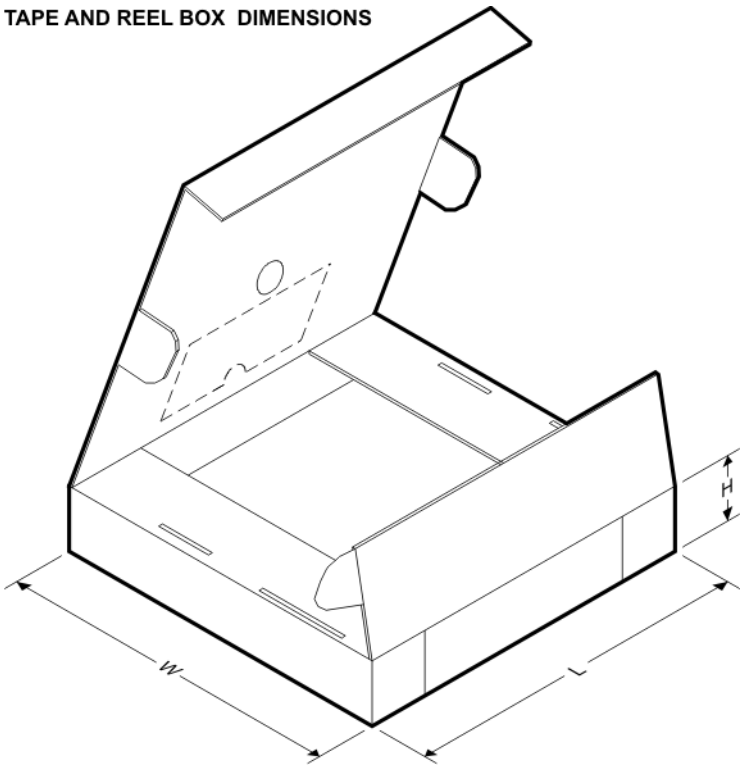
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
OPA170ASDRLTEP	SOT-5X3	DRL	5	250	180.0	8.4	1.98	1.78	0.69	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

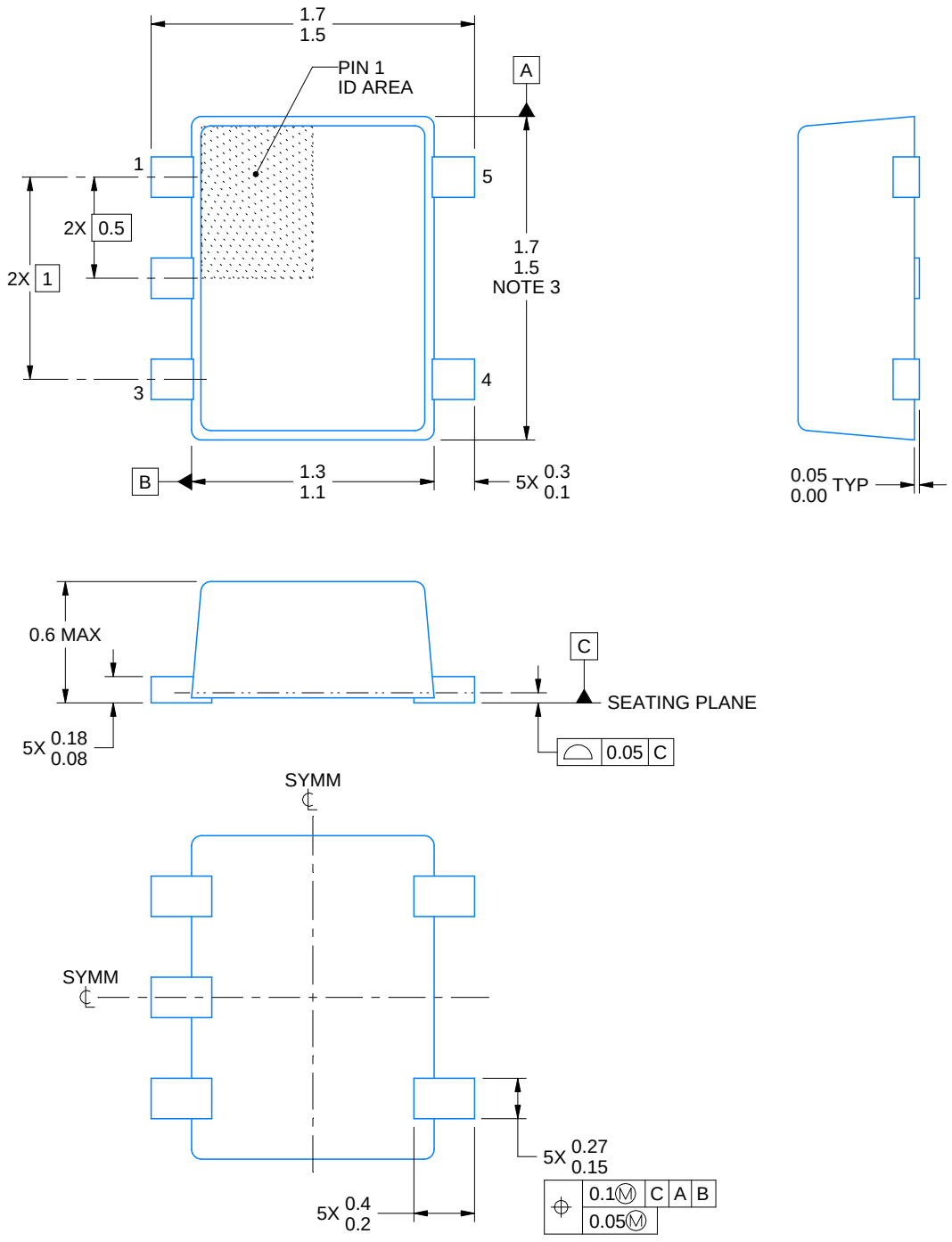
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA170ASDRLTEP	SOT-5X3	DRL	5	250	202.0	201.0	28.0

PACKAGE OUTLINE

DRL0005A

SOT - 0.6 mm max height

PLASTIC SMALL OUTLINE



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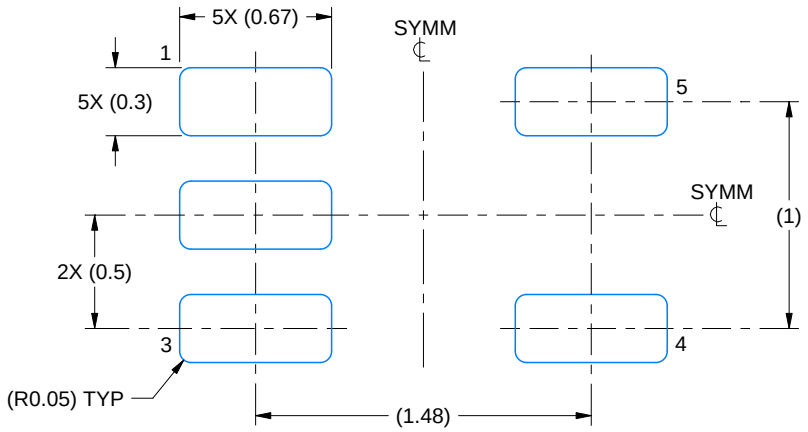
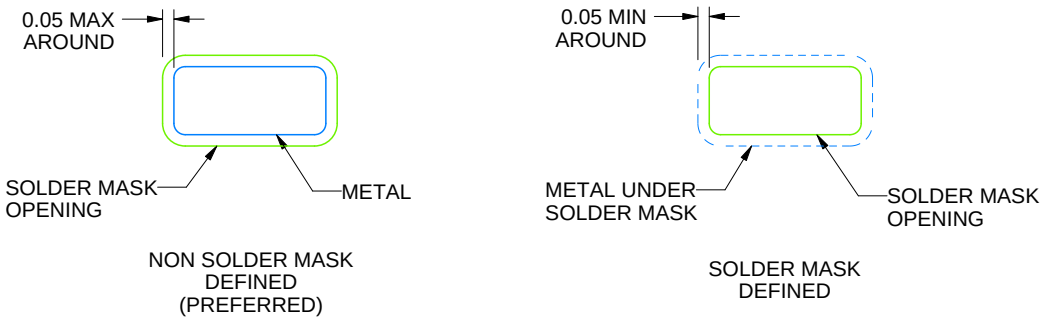
NOTES:

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-293 Variation UAAD-1



LAND PATTERN EXAMPLE
SCALE:30X

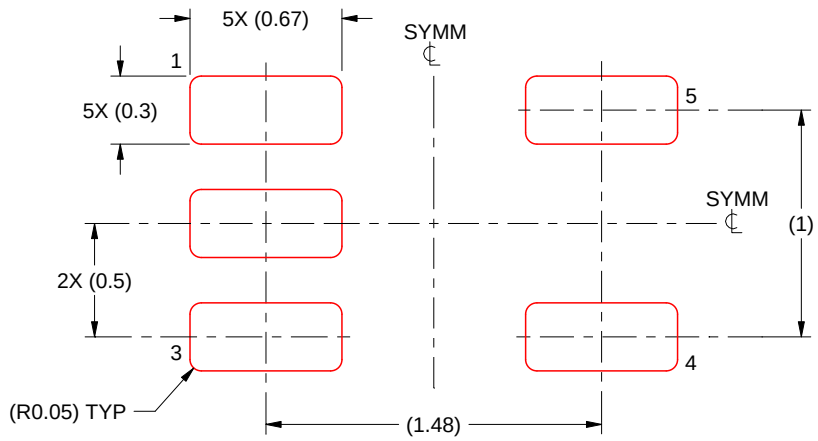


SOLDERMASK DETAILS

4220753/B 12/2020

NOTES: (continued)

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



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:30X

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NOTES: (continued)

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

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