

## Low-Cost, CMOS, Rail-to-Rail, I/O OPERATIONAL AMPLIFIERS

### FEATURES

- RAIL-TO-RAIL INPUT AND OUTPUT
- WIDE SUPPLY RANGE:  
Single Supply: 4V to 12V  
Dual Supplies:  $\pm 2$  to  $\pm 6$
- LOW QUIESCENT CURRENT: 160 $\mu$ A
- FULL-SCALE CMRR: 90dB
- LOW OFFSET: 160 $\mu$ V
- HIGH SPEED: 1MHz, 0.6V/ $\mu$ s
- *Micro*SIZE PACKAGES:  
SOT23-5, MSOP-8, TSSOP-14
- LOW INPUT BIAS CURRENT: 1pA

### APPLICATIONS

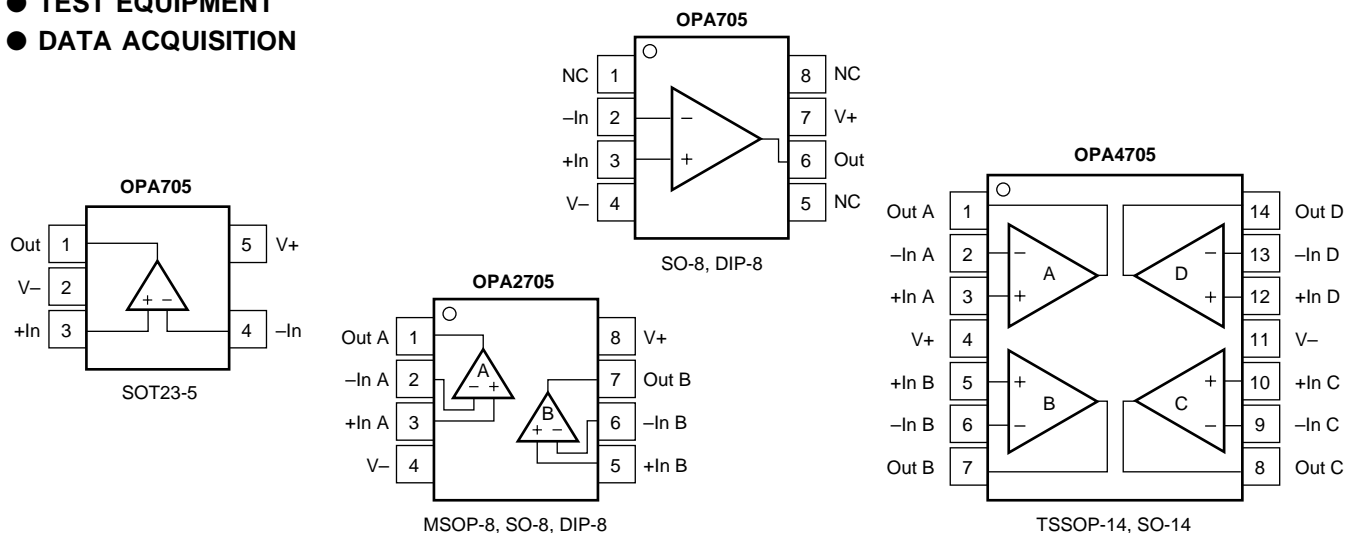
- AUTOMOTIVE APPLICATIONS:  
Audio, Sensor Applications, Security Systems
- PORTABLE EQUIPMENT
- ACTIVE FILTERS
- TRANSDUCER AMPLIFIER
- TEST EQUIPMENT
- DATA ACQUISITION

### DESCRIPTION

The OPA705 series low-cost op amps are optimized for applications requiring rail-to-rail input and output swing. Single, dual, and quad versions are offered in a variety of packages. While the quiescent current is less than 200 $\mu$ A per amplifier, the OPA705 still offers excellent dynamic performance (1MHz GBW and 0.6V/ $\mu$ s SR) and unity-gain stability.

The OPA705 series is fully specified and guaranteed over the supply range of  $\pm 2$ V to  $\pm 6$ V. Input swing extends 300mV beyond the rail and the output swings to within 40mV of the rail.

The single version (OPA705) is available in the *Micro*SIZE SOT23-5 and in the standard SO-8 surface-mount packages. Dual version (OPA2705) is available in the MSOP-8, SO-8, and DIP-8 packages. The quad OPA4705 is available in the TSSOP-14 and SO-14 packages. All are specified for operation from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Supply Voltage, V+ to V-.....	13.2V
Signal Input Terminals, Voltage <sup>(2)</sup> ..... (V-) -0.3V to (V+) +0.3V	
Current <sup>(2)</sup> .....	10mA
Output Short-Circuit <sup>(3)</sup> .....	Continuous
Operating Temperature .....	-55°C to +125°C
Storage Temperature .....	-65°C to +150°C
Junction Temperature.....	+150°C
Lead Temperature (soldering, 10s).....	+300°C

NOTES: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. (2) Input terminals are diode-clamped to the power supply rails. Input signals that can swing more than 0.3V beyond the supply rails should be current-limited to 10mA or less. (3) Short-circuit to ground, one amplifier per package.



## ELECTROSTATIC DISCHARGE SENSITIVITY

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/ORDERING INFORMATION

PRODUCT	DESCRIPTION	MINIMUM RECOMMENDED GAIN	PACKAGE	PACKAGE DRAWING NUMBER	PACKAGE MARKING	ORDERING NUMBER <sup>(1)</sup>	TRANSPORT MEDIA
OPA705NA	Single, GBW = 1MHz	1	SOT23-5	331	A05	OPA705NA/250	Tape and Reel
OPA705UA	Single, GBW = 1MHz	1	SO-8	182	OPA705UA	OPA705NA/3K OPA705UA	Tape and Reel Rails
OPA705PA	Single, GBW = 1MHz	1	DIP-8	006	OPA705PA	OPA705UA/2K5 OPA705PA	Tape and Reel Rails
OPA2705EA	Dual, GBW = 1MHz	1	MSOP-8	337	B05	OPA2705EA/250	Tape and Reel
OPA2705UA	Dual, GBW = 1MHz	1	SO-8	182	OPA2705UA	OPA2705EA/2K5 OPA2705UA	Tape and Reel Rails
OPA2705PA	Dual, GBW = 1MHz	1	DIP-8	006	OPA2705PA	OPA2705UA/2K5 OPA2705PA	Tape and Reel Rails
OPA4705EA	Quad, GBW = 1MHz	1	TSSOP-14	357	OPA4705EA	OPA4705EA/250	Tape and Reel
OPA4705UA	Quad, GBW = 1MHz	1	SO-14	235	OPA4705UA	OPA4705EA/2K5 OPA4705UA	Tape and Reel Rails
						OPA4705UA/2K5	Tape and Reel

NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /3K indicates 3000 devices per reel). Ordering 3000 pieces of "OPA705NA/3K" will get a single 3000-piece Tape and Reel.

# ELECTRICAL CHARACTERISTICS: $V_S = 4V$ to $12V$

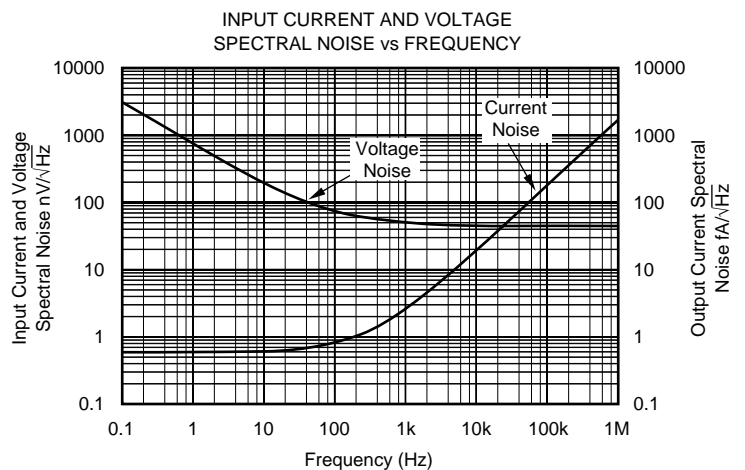
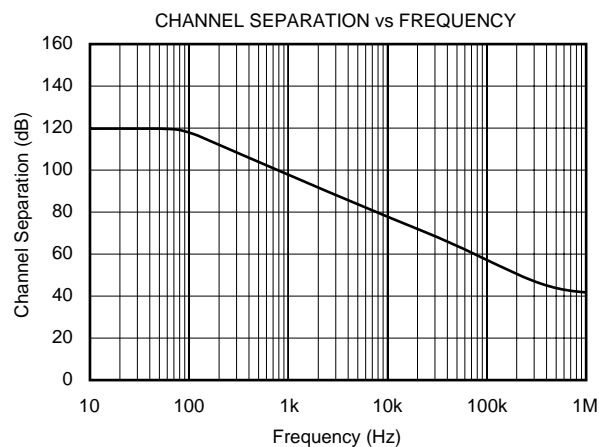
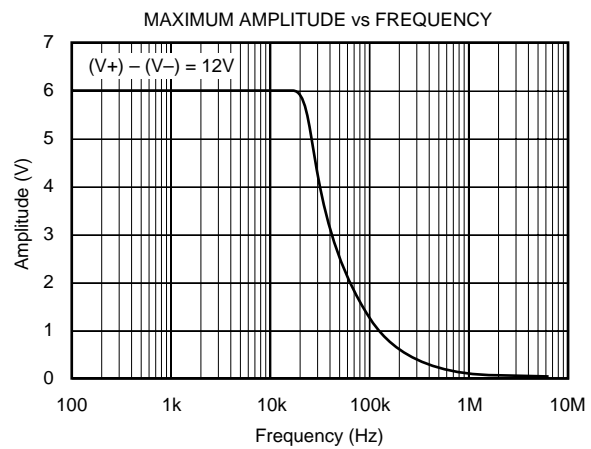
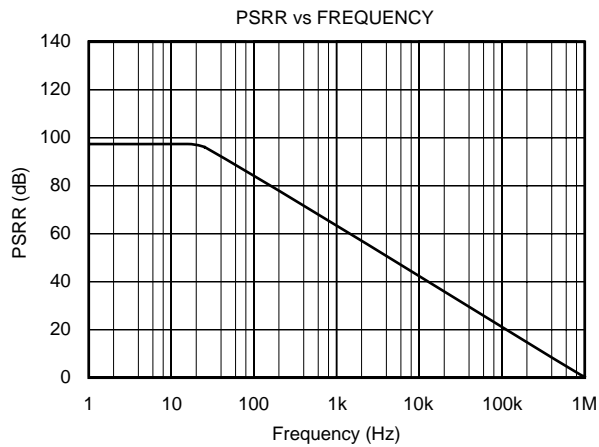
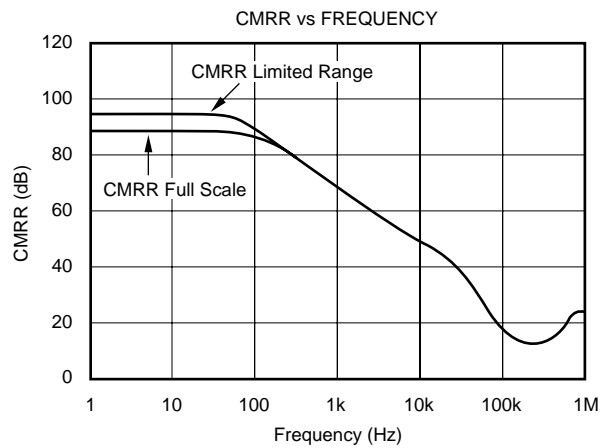
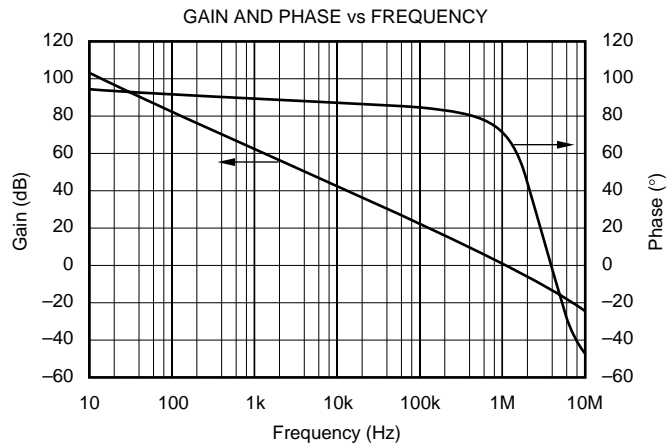
**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$

At  $T_A = +25^{\circ}C$ ,  $R_L = 20k\Omega$  connected to  $V_S/2$  and  $V_{OUT} = V_S/2$ , unless otherwise noted.

PARAMETER	CONDITION	OPA705NA, UA, PA OPA2705EA, UA, PA OPA4705EA, UA			UNITS
		MIN	TYP	MAX	
<b>OFFSET VOLTAGE</b> Input Offset Voltage $V_{OS}$ <b>Drift</b> $dV_{OS}/dT$ vs Power Supply PSRR <b>Over Temperature</b> Channel Separation, dc $f = 1kHz$	$V_S = \pm 5V, V_{CM} = 0V$ $T_A = -40^{\circ}C$ to $+85^{\circ}C$ $V_S = \pm 2V$ to $\pm 6V, V_{CM} = 0V$ <b><math>V_S = \pm 2V</math> to <math>\pm 6V, V_{CM} = 0V</math></b> $R_L = 20k\Omega$		$\pm 0.5$ <b><math>\pm 4</math></b> 20 <b>100</b> 1 98	$\pm 5$  100	mV $\mu V/^{\circ}C$ $\mu V/V$ <b><math>\mu V/V</math></b> $\mu V/V$ dB
<b>INPUT VOLTAGE RANGE</b> Common-Mode Voltage Range $V_{CM}$ Common-Mode Rejection Ratio CMRR <b>over Temperature</b> <b>over Temperature</b>	$V_S = \pm 5V, (V-) - 0.3V < V_{CM} < (V+) + 0.3V$ <b><math>V_S = \pm 5V, (V-) &lt; V_{CM} &lt; (V+)</math></b> $V_S = \pm 5V, (V-) - 0.3V < V_{CM} < (V+) - 2V$ <b><math>V_S = \pm 5V, (V-) &lt; V_{CM} &lt; (V+) - 2V</math></b>	$(V-) - 0.3$ 66  66	 77 <b>74</b> 96 <b>93</b>	$(V+) + 0.3$    	V dB <b>dB</b> dB <b>dB</b>
<b>INPUT BIAS CURRENT</b> Input Bias Current $I_B$ Input Offset Current $I_{OS}$	$V_S = \pm 5V, V_{CM} = 0V$ $V_S = \pm 5V, V_{CM} = 0V$		$\pm 1$ $\pm 0.5$	$\pm 10$ $\pm 10$	pA pA
<b>INPUT IMPEDANCE</b> Differential Common-Mode			$4 \cdot 10^9 \parallel 4$ $5 \cdot 10^{12} \parallel 4$		$\Omega \parallel pF$ $\Omega \parallel pF$
<b>NOISE</b> Input Voltage Noise, $f = 0.1Hz$ to $10Hz$ Input Voltage Noise Density, $f = 1kHz$ $e_n$ Current Noise Density, $f = 1kHz$ $i_n$	$V_S = \pm 5V, V_{CM} = 0V$ $V_S = \pm 5V, V_{CM} = 0V$ $V_S = \pm 5V, V_{CM} = 0V$		6 45 2.5		$\mu Vp-p$ $nV/\sqrt{Hz}$ $fA/\sqrt{Hz}$
<b>OPEN-LOOP GAIN</b> Open-Loop Voltage Gain $A_{OL}$ <b>over Temperature</b> <b>over Temperature</b>	$R_L = 100k\Omega, (V-)+0.1V < V_O < (V+)-0.1V$ $R_L = 20k\Omega, (V-)+0.075V < V_O < (V+)-0.075V$ <b><math>R_L = 20k\Omega, (V-)+0.075V &lt; V_O &lt; (V+)-0.075V</math></b> $R_L = 5k\Omega, (V-)+0.15V < V_O < (V+)-0.15V$ <b><math>R_L = 5k\Omega, (V-)+0.15V &lt; V_O &lt; (V+)-0.15V</math></b>	100  100	120 110 <b>106</b> 110 <b>106</b>		dB dB <b>dB</b> dB <b>dB</b>
<b>OUTPUT</b> Voltage Output Swing from Rail  Output Current $I_{OUT}$ Short-Circuit Current $I_{SC}$ Capacitive Load Drive $C_{LOAD}$	$R_L = 100k\Omega, A_{OL} > 80dB$ $R_L = 20k\Omega, A_{OL} > 100dB$ $R_L = 5k\Omega, A_{OL} > 100dB$ $ V_S - V_{OUT}  < 1V$		40  $\pm 10$ $\pm 40$	75 150	mV mV mV mA mA
See Typical Performance Curves					
<b>FREQUENCY RESPONSE</b> Gain-Bandwidth Product GBW Slew Rate SR Settling Time, 0.1% $t_S$ 0.01% Overload Recovery Time Total Harmonic Distortion + Noise THD+N	$C_L = 100pF$ $G = +1$ $V_S = \pm 5V, G = +1$ $V_S = \pm 5V, 5V$ Step, $G = +1$ $V_S = \pm 5V, 5V$ Step, $G = +1$ $V_{IN} \cdot \text{Gain} = V_S$ $V_S = \pm 5V, V_O = 3Vp-p, G = +1, f = 1kHz$		1 0.6 15 20 3 0.02		MHz V/ $\mu s$ $\mu s$ $\mu s$ $\mu s$ %
<b>POWER SUPPLY</b> Specified Voltage Range, Single Supply $V_S$ Specified Voltage Range, Dual Supplies $V_S$ Operating Voltage Range Quiescent Current (per amplifier) $I_Q$ <b>over Temperature</b>	$I_O = 0$	4 $\pm 2$	3.6 to 12 160 <b>200</b>	12 $\pm 6$ 200	V V V $\mu A$ $\mu A$
<b>TEMPERATURE RANGE</b> Specified Range Operating Range Storage Range Thermal Resistance $\theta_{JA}$ SOT23-5 Surface-Mount MSOP-8 Surface-Mount TSSOP-14 Surface-Mount SO-8 Surface Mount SO-14 Surface Mount DIP-8		-40 -55 -65	   200 150 100 150 100 100	85 125 150	$^{\circ}C$ $^{\circ}C$ $^{\circ}C$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$

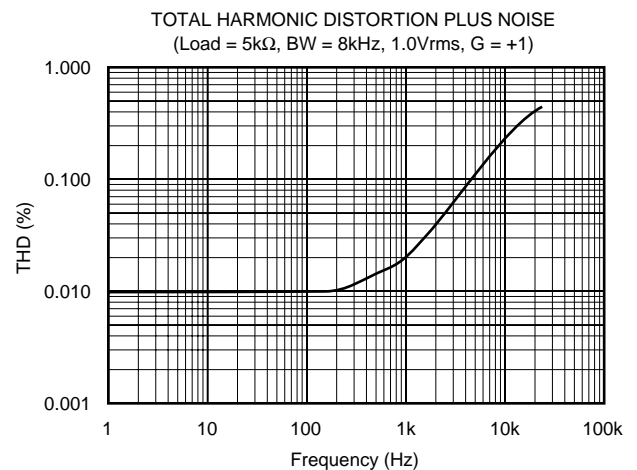
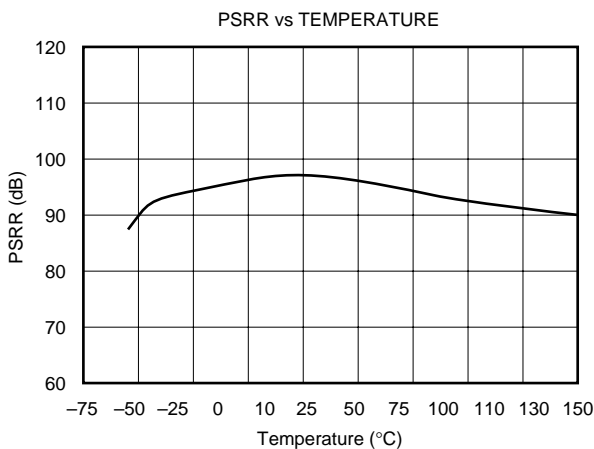
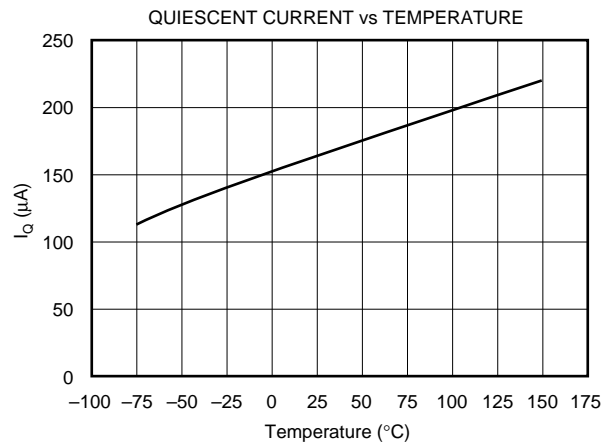
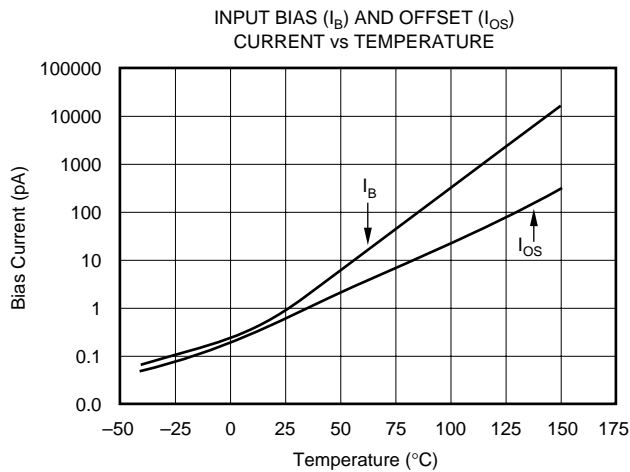
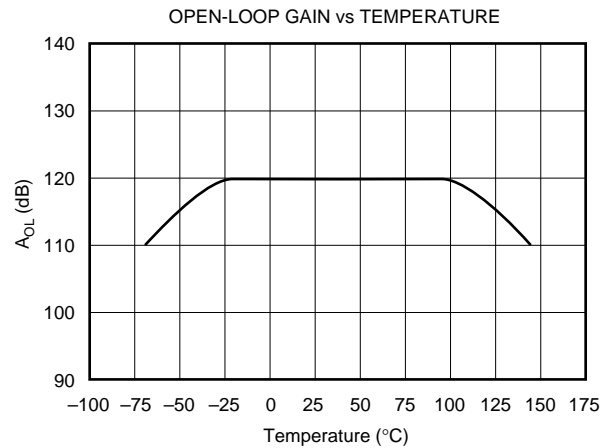
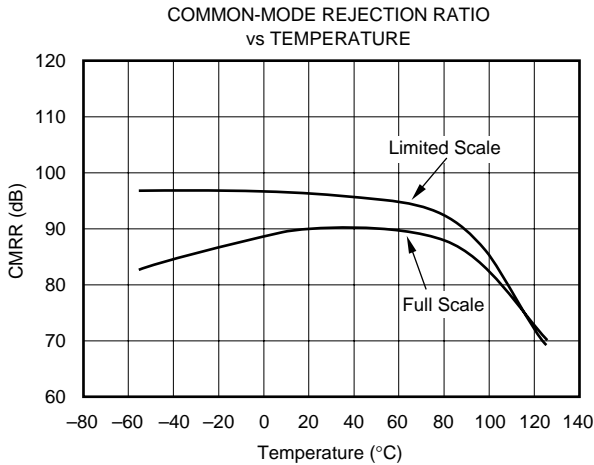
# TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$ , and  $R_L = 20\text{k}\Omega$ , unless otherwise noted.



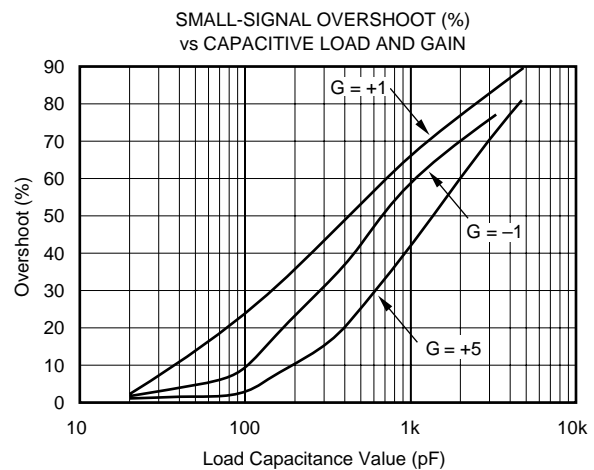
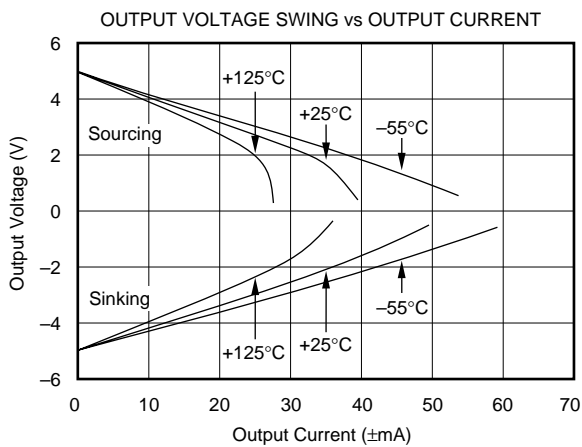
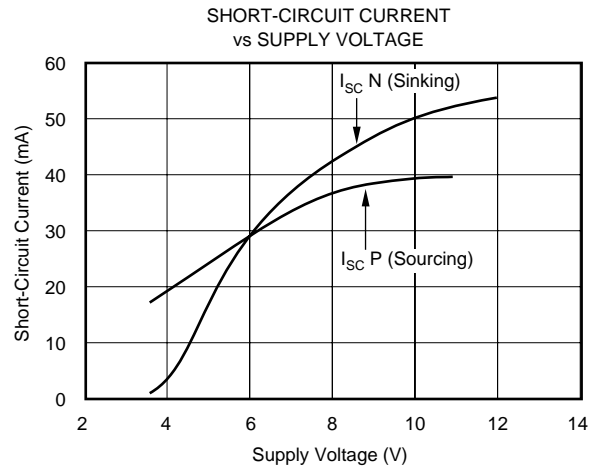
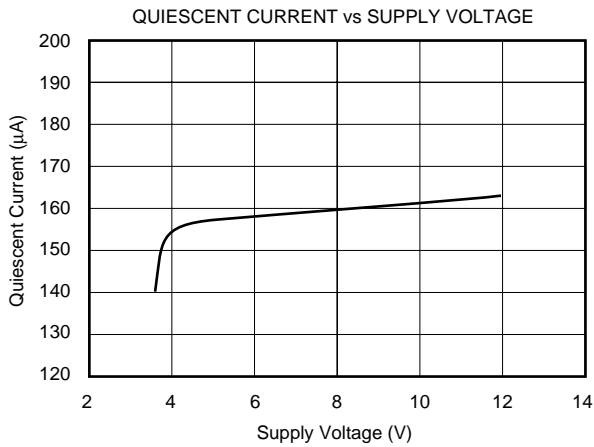
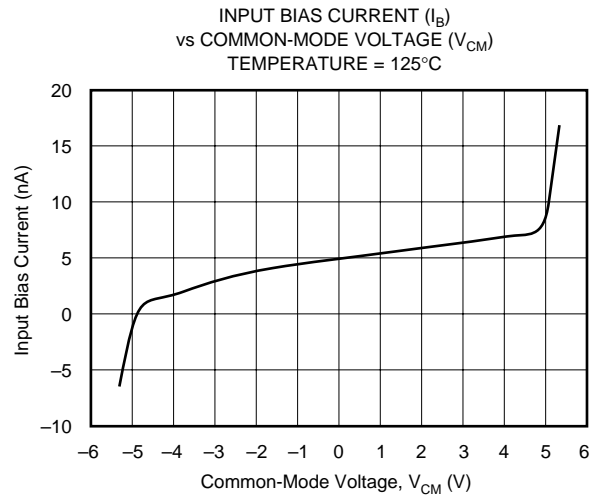
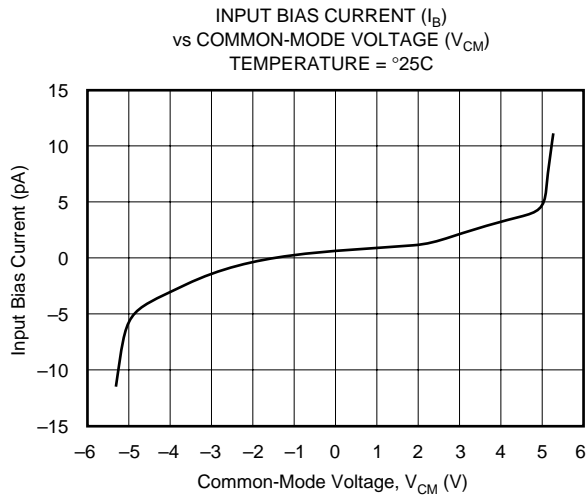
# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$ , and  $R_L = 20\text{k}\Omega$ , unless otherwise noted.



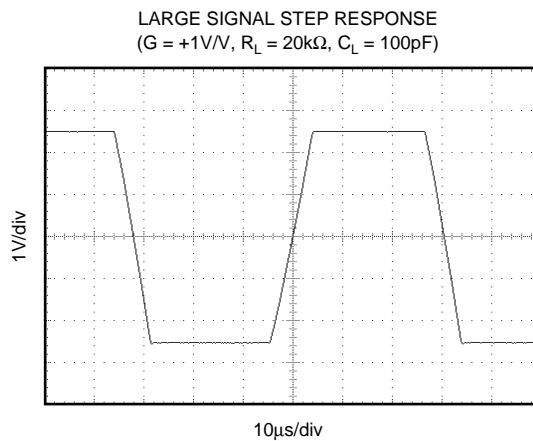
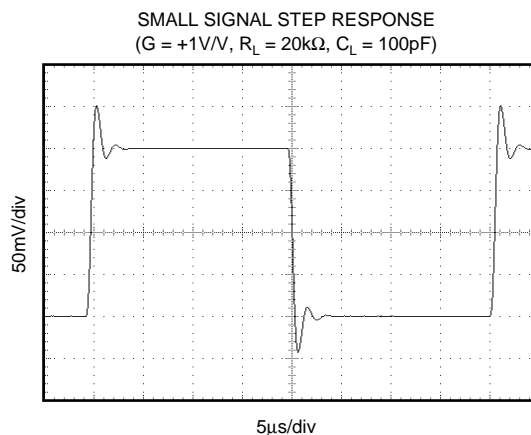
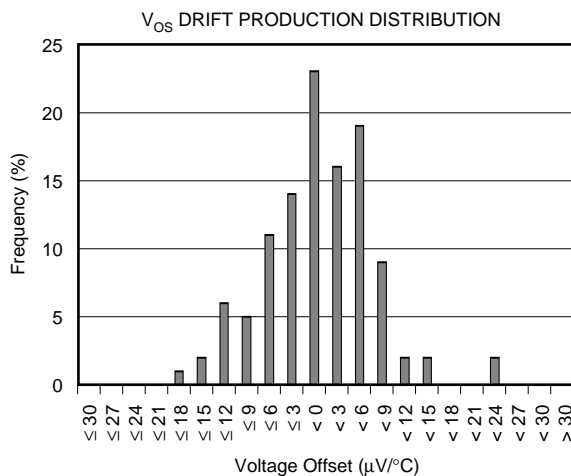
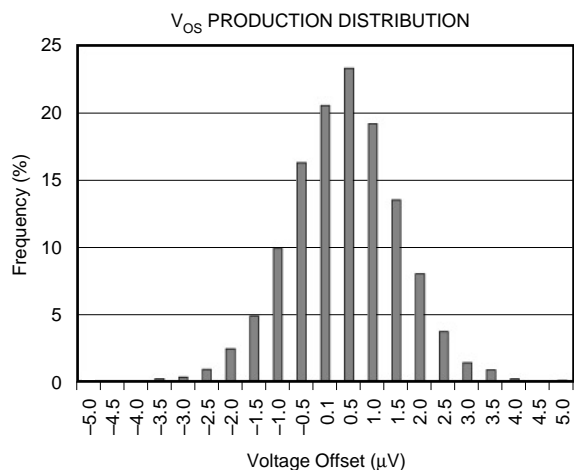
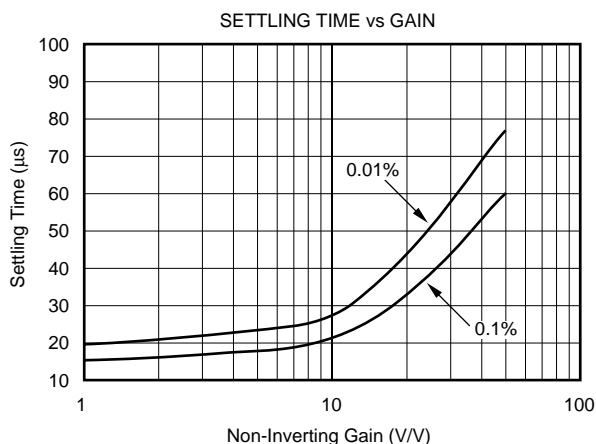
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At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$ , and  $R_L = 20\text{k}\Omega$ , unless otherwise noted.



# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = \pm 5\text{V}$ , and  $R_L = 20\text{k}\Omega$ , unless otherwise noted.



# APPLICATIONS INFORMATION

OPA705 series op amps can operate on 160 $\mu$ A quiescent current from a single (or split) supply in the range of 4V to 12V ( $\pm 2$ V to  $\pm 6$ V), making them highly versatile and easy to use. The OPA705 is unity-gain stable and offers 1MHz bandwidth and 0.6V/ $\mu$ s slew rate.

Rail-to-rail input and output swing helps maintain dynamic range, especially in low supply applications. Figure 1 shows the input and output waveforms for the OPA705 in unity-gain configuration. Operation is from a  $\pm 5$ V supply with a 100k $\Omega$  load connected to  $V_S/2$ . The input is a 10Vp-p sinusoid. Output voltage is approximately 10Vp-p.

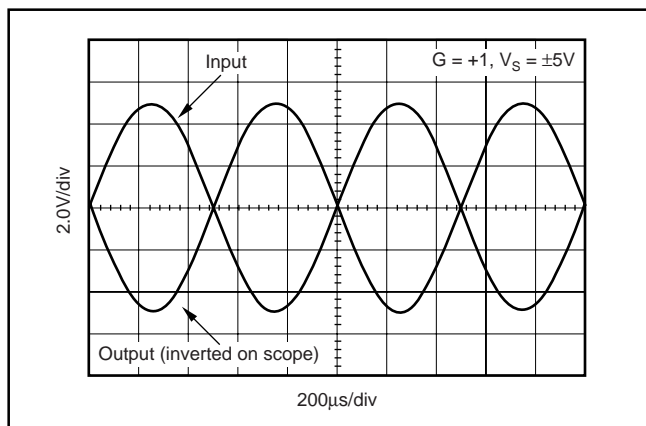


FIGURE 1. Rail-to-Rail Input and Output.

Power-supply pins should be bypassed with 1000pF ceramic capacitors in parallel with 1 $\mu$ F tantalum capacitors.

## OPERATING VOLTAGE

OPA705 series op amps are fully specified and guaranteed from +4V to +12V over a temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ . Parameters that vary significantly with operating voltages or temperature are shown in the Typical Characteristics.

## RAIL-TO-RAIL INPUT

The input common-mode voltage range of the OPA705 series extends 300mV beyond the supply rails at room temperature. This is achieved with a complementary input stage—an N-channel input differential pair in parallel with a P-channel differential pair, as shown in Figure 2. The N-channel pair is active for input voltages close to the positive rail, typically  $(V_+) - 2.0$ V to 300mV above the positive supply, while the P-channel pair is on for inputs from 300mV below the negative supply to approximately  $(V_+) - 1.5$ V. There is a small transition region, typically  $(V_+) - 2.0$ V to  $(V_+) - 1.5$ V, in which both pairs are on. This 500mV transition region can vary  $\pm 100$ mV with process variation. Thus, the transition region (both stages on) can range from  $(V_+) - 2.1$ V to  $(V_+) - 1.4$ V on the low end, up to  $(V_+) - 1.9$ V to  $(V_+) - 1.6$ V on the high end. Within the 500mV transition region PSRR, CMRR, offset voltage, and offset drift, and THD may vary compared to operation outside this region.

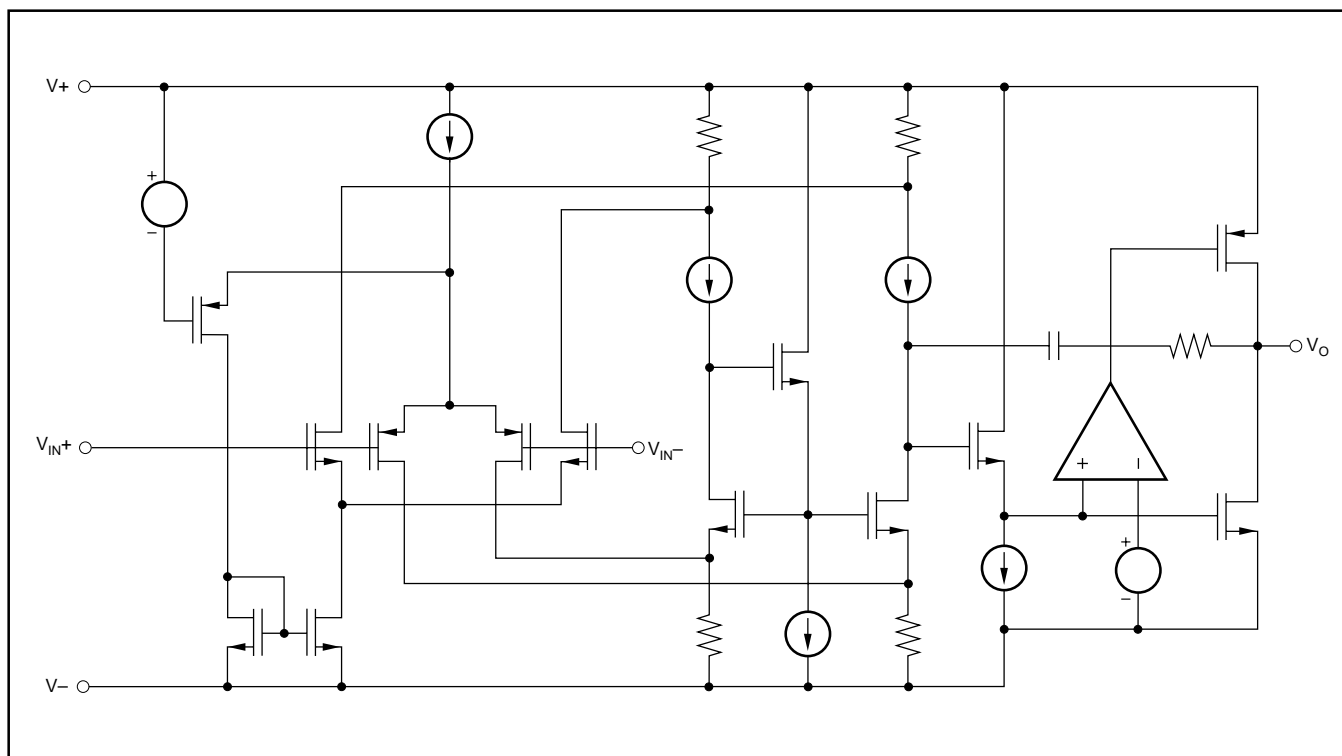


FIGURE 2. Simplified Schematic.



## INPUT VOLTAGE

Device inputs are protected by ESD diodes that will conduct if the input voltages exceed the power supplies by more than approximately 300mV. Momentary voltages greater than 300mV beyond the power supply can be tolerated if the current is limited to 10mA. This is easily accomplished with an input resistor, as shown in Figure 3. Many input signals are inherently current-limited to less than 10mA; therefore, a limiting resistor is not always required. The OPA705 features no phase inversion when the inputs extend beyond supplies if the input current is limited, as seen in Figure 4.

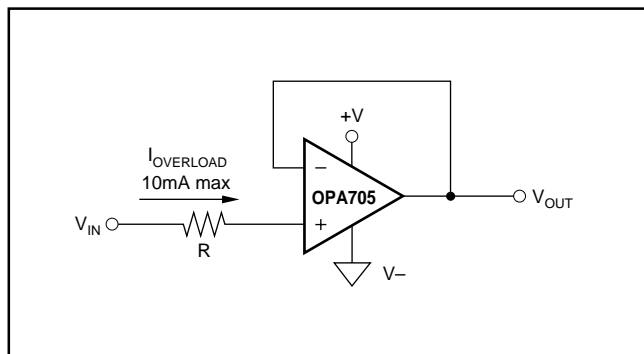


FIGURE 3. Input Current Protection for Voltages Exceeding the Supply Voltage.

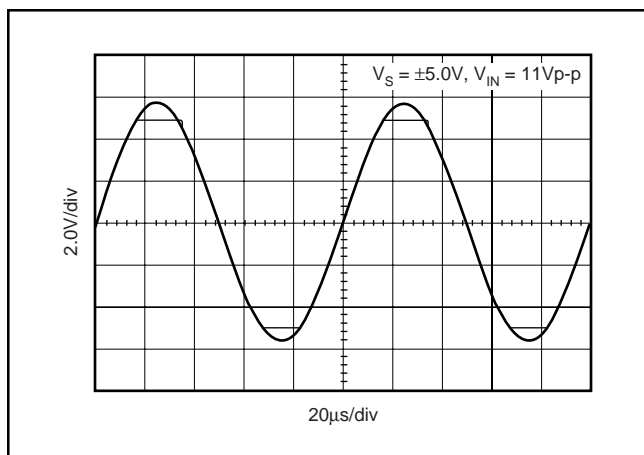


FIGURE 4. OPA705—No Phase Inversion with Inputs Greater than the Power-Supply Voltage.

## RAIL-TO-RAIL OUTPUT

A class AB output stage with common-source transistors is used to achieve rail-to-rail output. This output stage is capable of driving 1k $\Omega$  loads connected to any point between V+ and ground. For light resistive loads (> 100k $\Omega$ ), the output voltage can swing to 40mV from the supply rail. With moderate resistive loads (20k $\Omega$ ), the output can swing to within 75mV from the supply rails while maintaining high open-loop gain (see the typical performance curve “Output Voltage Swing vs Output Current”).

## CAPACITIVE LOAD AND STABILITY

The OPA705 series op amps can drive up to 1000pF pure capacitive load. Increasing the gain enhances the amplifier’s ability to drive greater capacitive loads (see the typical performance curve “Small Signal Overshoot vs Capacitive Load”).

One method of improving capacitive load drive in the unity-gain configuration is to insert a 10 $\Omega$  to 20 $\Omega$  resistor inside the feedback loop, as shown in Figure 5. This reduces ringing with large capacitive loads while maintaining DC accuracy.

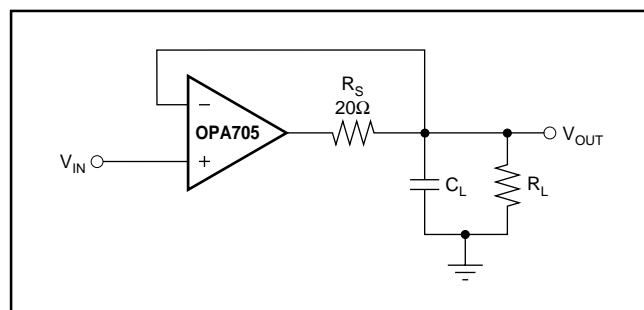


FIGURE 5. Series Resistor in Unity-Gain Buffer Configuration Improves Capacitive Load Drive.

## APPLICATION CIRCUITS

The OPA705 series op amps are optimized for driving medium-speed sampling data converters. Figure 6 shows the OPA2705 in a dual-supply buffered reference configuration for the DAC7644. The DAC7644 is a 16-bit, low-power, quad-voltage output converter. Small size makes the combination ideal for automatic test equipment, data acquisition systems, and other low-power space-limited applications.

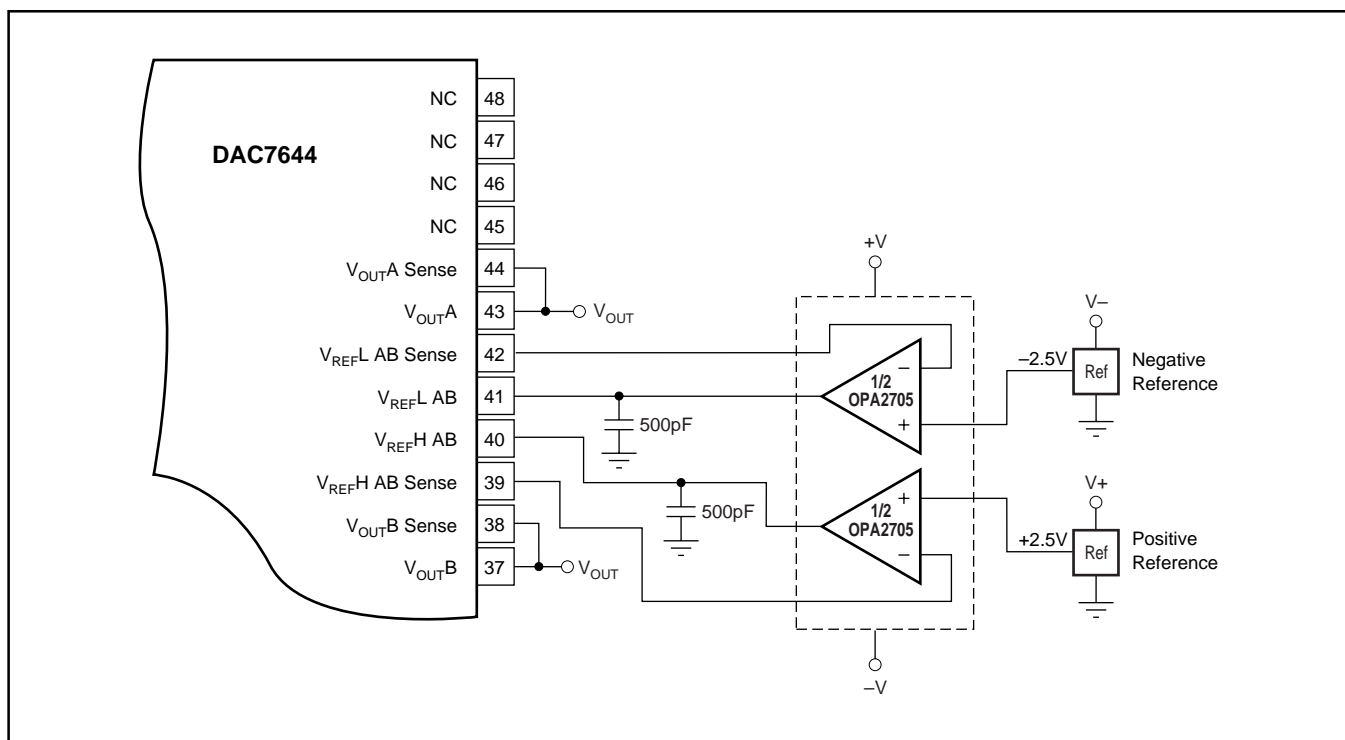


FIGURE 6. OPA705 as Dual Supply Configuration-Buffered References for the DAC7644.

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