National Semiconductor

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LMP7701/LMP7704 Precision, CMOS Input, RRIO, Wide Supply Range Amplifiers

General Description

The LMP7701 and LMP7704 are single, and quad low offset voltage, rail-to-rail input and output precision amplifiers with CMOS input stage and wide supply voltage range. The LMP7701 and LMP7704 are part of the LMP™ precision amplifier family and are ideal for sensor interface and other instrumentation applications.

The guaranteed low offset voltage of less than ±200 µV along with the guaranteed low input bias current of less than ±1 pA make the LMP7701 ideal for precision applications. The LMP7701 and LMP7704 are built utilizing VIP50 technology, which allows the combination of a CMOS input stage and a 12V common mode and supply voltage range. This makes the LMP7701 and LMP7704 great choices in many applications where conventional CMOS parts cannot operate under the desired voltage conditions.

The LMP7701 and LMP7704 have a rail-to-rail input stage that significantly reduces the CMRR glitch commonly associated with rail-to-rail input amplifiers. This is achieved by trimming both sides of the complimentary input stage, thereby reducing the difference between the NMOS and PMOS offsets. The output of the LMP7701 and LMP7704 swing within 40 mV of either rail to maximize the signal dynamic range in applications requiring low supply voltage.

The LMP7701 is offered in the space saving SOT23-5 package, and the quad LMP7704 is offered in the TSSOP-14 package. These small packages are ideal solutions for area constrained PC boards and portable electronics.

Features

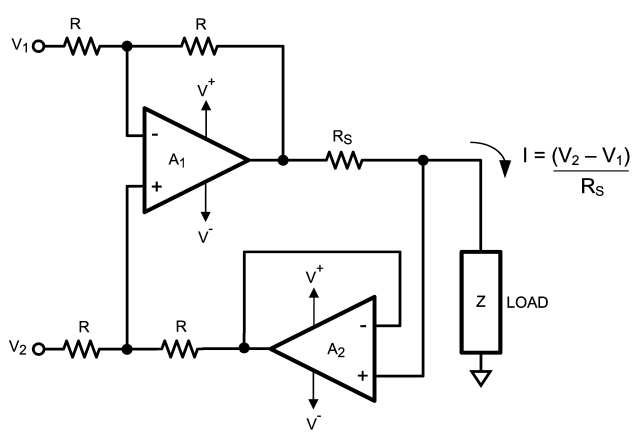
Unless otherwise noted, typical values at V_S = 5V

- Input offset voltage (LMP7701) ±200 µV (max)
- Input offset voltage (LMP7704) ±220 µV (max)
- Input bias current ±200 fA
- Input voltage noise 9 nV/$\sqrt{Hz}$
- CMRR 130 dB
- Open loop gain 130 dB
- Temperature range −40˚C to 125˚C
- Unity gain bandwidth 2.5 MHz
- Supply current (LMP7701) 715 µA
- Supply current (LMP7704) 2.9 mA
- Supply voltage range 2.7V to 12V
- Rail-to-rail input and output

Applications

- High impedance sensor interface
- Battery powered instrumentation
- High gain amplifiers
- DAC buffer
- Instrumentation amplifier
- Active filters

Typical Application



Precision Current Source

LMP™ is a trademark of National Semiconductor Corporation.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

ESD Tolerance (Note 2)	
Human Body Model	2000V
Machine Model	200V
V_{IN} Differential	±300 mV
Supply Voltage ($V_S = V^+ - V^-$)	13.2V
Voltage at Input/Output Pins	$V^+ + 0.3V$, $V^- - 0.3V$
Input Current	10 mA
Storage Temperature Range	−65˚C to +150˚C
Junction Temperature (Note 3)	+150˚C
Soldering Information	
Infrared or Convection (20 sec)	235˚C
Wave Soldering Lead Temp. (10 sec)	260˚C

Operating Ratings (Note 1)

Temperature Range (Note 3)	−40˚C to +125˚C
Supply Voltage ($V_S = V^+ - V^-$)	2.7V to 12V
Package Thermal Resistance (θ_{JA} (Note 3))	
5-Pin SOT23	234˚C/W
14-Pin TSSOP	122˚C/W

3V Electrical Characteristics (Note 4)

Unless otherwise specified, all limits are guaranteed for T_A = 25˚C, V^+ = 3V, V^- = 0V, $V_{CM} = V^+/2$, and R_L > 10 kΩ to $V^+/2$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage	LMP7701		±37	±200 **±500**	μV
		LMP7704		±56	±220 **±520**	
TCV_{OS}	Input Offset Voltage Drift	(Note 7)		±1	**±5**	μV/˚C
I_B	Input Bias Current	(Notes 7, 8) −40˚C ≤ T_A ≤ 85˚C		±0.2	±1 **±50**	pA
		(Notes 7, 8) −40˚C ≤ T_A ≤ 125˚C		±0.2	±1 **±400**	
I_{OS}	Input Offset Current			40		fA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 3V LMP7701	86 **80**	130		dB
		0V ≤ V_{CM} ≤ 3V LMP7704	84 **78**	130		
PSRR	Power Supply Rejection Ratio	2.7V ≤ V^+ ≤ 12V, Vo = $V^+/2$	86 **82**	98		dB
CMVR	Input Common-Mode Voltage Range	CMRR ≥ 80 dB CMRR ≥ 77 dB	−0.2 **−0.2**		3.2 **3.2**	V
A_{VOL}	Large Signal Voltage Gain	R_L = 2 kΩ (LMP7701) V_O = 0.3V to 2.7V	100 **96**	114		dB
		R_L = 2 kΩ (LMP7704) V_O = 0.3V to 2.7V	100 **94**	114		
		R_L = 10 kΩ V_O = 0.2V to 2.8V	100 **96**	124		

3V Electrical Characteristics (Note 4) (Continued)

Unless otherwise specified, all limits are guaranteed for T_A = 25˚C, V^+ = 3V, V^- = 0V, V_{CM} = $V^+/2$, and R_L > 10 kΩ to $V^+/2$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_O	Output Swing High	R_L = 2 kΩ to $V^+/2$ LMP7701		40	80 **120**	mV from V^+
		R_L = 2 kΩ to $V^+/2$ LMP7704		40	80 **150**	
		R_L = 10 kΩ to $V^+/2$ LMP7701		30	40 **60**	
		R_L = 10 kΩ to $V^+/2$ LMP7704		35	50 **100**	
	Output Swing Low	R_L = 2 kΩ to $V^+/2$ LMP7701		40	60 **80**	mV
		R_L = 2 kΩ to $V^+/2$ LMP7704		45	100 **170**	
		R_L = 10 kΩ to $V^+/2$ LMP7701		20	40 **50**	
		R_L = 10 kΩ to $V^+/2$ LMP7704		20	50 **90**	
I_O	Output Short Circuit Current (Notes 3, 9)	Sourcing V_O = $V^+/2$ V_{IN} = 100 mV	25 **15**	42		mA
		Sinking V_O = $V^+/2$ V_{IN} = −100 mV (LMP7701)	25 **20**	42		
		Sinking V_O = $V^+/2$ V_{IN} = −100 mV (LMP7704)	25 **15**	42		
I_S	Supply Current	LMP7701		0.670	1.0 **1.2**	mA
		LMP7704		2.9	3.5 **4.5**	
SR	Slew Rate (Note 10)	A_V = +1, V_O = 2 V_{PP} 10% to 90%		0.9		V/µs
GBW	Gain Bandwidth Product			2.5		MHz
THD+N	Total Harmonic Distortion + Noise	f = 1 kHz, Av = 1, R_L = 10 kΩ		0.02		%
e_n	Input-Referred Voltage Noise	f = 1 kHz		9		nV/$\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 100 kHz		1		fA/$\sqrt{Hz}$

5V Electrical Characteristics (Note 4)

Unless otherwise specified, all limits are guaranteed for T_A = 25˚C, V^+ = 5V, V^- = 0V, V_{CM} = $V^+/2$, and R_L > 10 kΩ to $V^+/2$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage	LMP7701		±37	±200 **±500**	µV
		LMP7704		±32	±220 **±520**	
TCV_{OS}	Input Offset Voltage Drift	(Note 7)		±1	**±5**	µV/˚C
I_B	Input Bias Current	(Notes 7, 8) −40˚C ≤ T_A ≤ 85˚C		±0.2	±1 **±50**	pA
		(Notes 7, 8) −40˚C ≤ T_A ≤ 125˚C		±0.2	±1 **±400**	
I_{OS}	Input Offset Current			40		fA

5V Electrical Characteristics (Note 4) (Continued)

Unless otherwise specified, all limits are guaranteed for T_A = 25˚C, V^+ = 5V, V^- = 0V, V_{CM} = V^+/2, and R_L > 10 kΩ to V^+/2. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 5V LMP7701	88 **83**	130		dB
		0V ≤ V_{CM} ≤ 5V LMP7704	86 **81**	130		
PSRR	Power Supply Rejection Ratio	2.7V ≤ V^+ ≤ 12V, V_O = V^+/2	86 **82**	100		dB
CMVR	Input Common-Mode Voltage Range	CMRR ≥ 80 dB CMRR ≥ 78 dB	−0.2 **−0.2**		5.2 **5.2**	V
A_{VOL}	Large Signal Voltage Gain	R_L = 2 kΩ (LMP7701) V_O = 0.3V to 4.7V	100 **96**	119		dB
		R_L = 2 kΩ (LMP7704) V_O = 0.3V to 4.7V	100 **94**	119		
		R_L = 10 kΩ V_O = 0.2V to 4.8V	100 **96**	130		
V_O	Output Swing High	R_L = 2 kΩ to V^+/2 LMP7701		60	110 **130**	mV from V^+
		R_L = 2 kΩ to V^+/2 LMP7704		60	120 **200**	
		R_L = 10 kΩ to V^+/2 LMP7701		40	50 **70**	
		R_L = 10 kΩ to V^+/2 LMP7704		40	60 **120**	
	Output Swing Low	R_L = 2 kΩ to V^+/2 LMP7701		50	80 **90**	mV
		R_L = 2 kΩ to V^+/2 LMP7704		50	120 **190**	
		R_L = 10 kΩ to V^+/2 LMP7701		30	40 **50**	
		R_L = 10 kΩ to V^+/2 LMP7704		30	50 **100**	
I_O	Output Short Circuit Current (Notes 3, 9)	Sourcing V_O = V^+/2 V_{IN} = 100 mV (LMP7701)	40 **28**	66		mA
		Sourcing V_O = V^+/2 V_{IN} = 100 mV (LMP7704)	38 **25**	66		
		Sinking V_O = V^+/2 V_{IN} = −100 mV (LMP7701)	40 **28**	76		
		Sinking V_O = V^+/2 V_{IN} = −100 mV (LMP7704)	40 **23**	76		
I_S	Supply Current	LMP7701		0.715	1.0 **1.2**	mA
		LMP7704		2.9	3.7 **4.6**	
SR	Slew Rate (Note 10)	A_V = +1, V_O = 4 V_{PP} 10% to 90%		1.0		V/µs
GBW	Gain Bandwidth Product			2.5		MHz
THD+N	Total Harmonic Distortion + Noise	f = 1 kHz, A_V = 1, R_L = 10 kΩ		0.02		%
e_n	Input-Referred Voltage Noise	f = 1 kHz		9		nV/$\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 100 kHz		1		fA/$\sqrt{Hz}$

±5V Electrical Characteristics (Note 4)

Unless otherwise specified, all limits are guaranteed for $T_A = 25^\circ C$, $V^+ = 5V$, $V^- = -5V$, $V_{CM} = 0V$, and $R_L > 10\ k\Omega$ to 0V. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage	LMP7701		±37	±200 **±500**	μV
		LMP7704		±37	±220 **±520**	
TCV_{OS}	Input Offset Voltage Drift	(Note 7)		±1	**±5**	μV/°C
I_B	Input Bias Current	(Notes 7, 8) $-40^\circ C \le T_A \le 85^\circ C$		±0.2	1 **±50**	pA
		(Notes 7, 8) $-40^\circ C \le T_A \le 125^\circ C$		±0.2	1 **±400**	
I_{OS}	Input Offset Current			40		fA
CMRR	Common Mode Rejection Ratio	$-5V \le V_{CM} \le 5V$ LMP7701	92 **88**	138		dB
		$-5V \le V_{CM} \le 5V$ LMP7704	90 **86**	138		
PSRR	Power Supply Rejection Ratio	$2.7V \le V^+ \le 12V$, $V_O = 0V$	86 **82**	98		dB
CMVR	Input Common-Mode Voltage Range	CMRR ≥ 80 dB CMRR ≥ 78 dB	−5.2 **−5.2**		5.2 **5.2**	V
A_{VOL}	Large Signal Voltage Gain	$R_L = 2\ k\Omega$ (LMP7701) $V_O = -4.7V$ to 4.7V	100 **98**	121		dB
		$R_L = 2\ k\Omega$ (LMP7704) $V_O = -4.7V$ to 4.7V	100 **94**	121		
		$R_L = 10\ k\Omega$ (LMP7701) $V_O = -4.8V$ to 4.8V	100 **98**	134		
		$R_L = 10\ k\Omega$ (LMP7704) $V_O = -4.8V$ to 4.8V	100 **97**	134		
V_O	Output Swing High	$R_L = 2\ k\Omega$ to 0V LMP7701		90	150 **170**	mV from V^+
		$R_L = 2\ k\Omega$ to 0V LMP7704		90	180 **290**	
		$R_L = 10\ k\Omega$ to 0V LMP7701		40	80 **100**	
		$R_L = 10\ k\Omega$ to 0V LMP7704		40	80 **150**	
	Output Swing Low	$R_L = 2\ k\Omega$ to 0V LMP7701		90	130 **150**	mV from V^-
		$R_L = 2\ k\Omega$ to 0V LMP7704		90	180 **290**	
		$R_L = 10\ k\Omega$ to 0V LMP7701		40	50 **60**	
		$R_L = 10\ k\Omega$ to 0V LMP7704		40	60 **110**	
I_O	Output Short Circuit Current (Notes 3, 9)	Sourcing $V_O = 0V$ $V_{IN} = 100$ mV (LMP7701)	50 **35**	86		mA
		Sourcing $V_O = 0V$ $V_{IN} = 100$ mV (LMP7704)	48 **33**	86		
		Sinking $V_O = 0V$ $V_{IN} = -100$ mV	50 **35**	84		

±5V Electrical Characteristics (Note 4) (Continued)

Unless otherwise specified, all limits are guaranteed for T_A = 25˚C, V^+ = 5V, V^- = –5V, V_{CM} = 0V, and R_L > 10 kΩ to 0V. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
I_S	Supply Current	LMP7701		0.790	1.1 **1.3**	mA
		LMP7704		3.2	4.2 **5.0**	mA
SR	Slew Rate (Note 10)	A_V = +1, V_O = 9 V_{PP} 10% to 90%		1.1		V/μs
GBW	Gain Bandwidth Product			2.5		MHz
THD+N	Total Harmonic Distortion + Noise	f = 1 kHz, A_V = 1, R_L = 10 kΩ		0.02		%
e_n	Input-Referred Voltage Noise	f = 1 kHz		9		nV/ $\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 100 kHz		1		fA/ $\sqrt{Hz}$

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics Tables.

Note 2: Human Body Model is 1.5 kΩ in series with 100 pF. Machine Model is 0Ω in series with 200 pF.

Note 3: The maximum power dissipation is a function of $T_{J(MAX)}$, θ_{JA}, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A)/ \theta_{JA}$. All numbers apply for packages soldered directly onto a PC board.

Note 4: Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.

Note 5: Typical values represent the parametric norm at the time of characterization.

Note 6: Limits are 100% production tested at 25˚C. Limits over the operating temperature range are guaranteed through correlations using the Statistical Quality Control (SQC) method.

Note 7: Guaranteed by design.

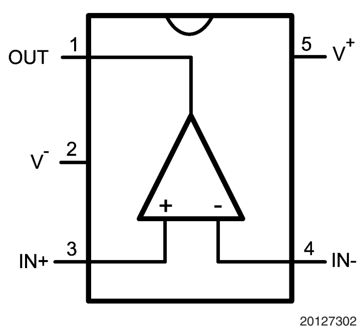
Note 8: Positive current corresponds to current flowing into the device.

Note 9: The short circuit test is a momentary test.

Note 10: The number specified is the slower of positive and negative slew rates.

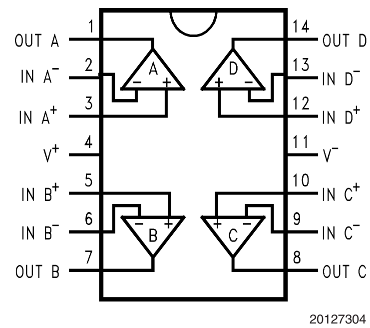
Connection Diagrams

5-Pin SOT23



Top View

14-Pin TSSOP



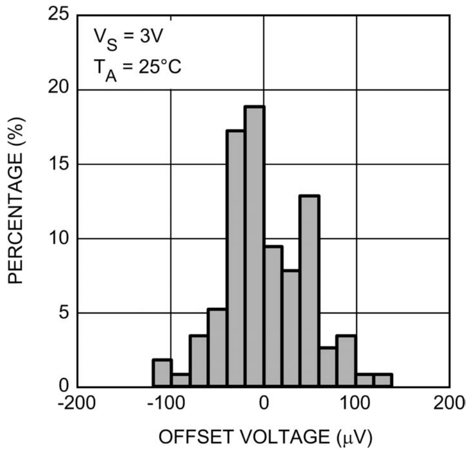
Top View

Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
5-Pin SOT23	LMP7701MF	AC2A	1k Units Tape and Reel	MF05A
	LMP7701MFX		3k Units Tape and Reel	
14-Pin TSSOP	LMP7704MT	LMP7704MT	94 Units/Rail	MTC14
	LMP7704MTX		2.5k Units Tape and Reel	

Typical Performance Characteristics
Unless otherwise noted: $T_A = 25^\circ C$, $V_{CM} = V_S/2$, $R_L > 10\ k\Omega$.

Offset Voltage Distribution



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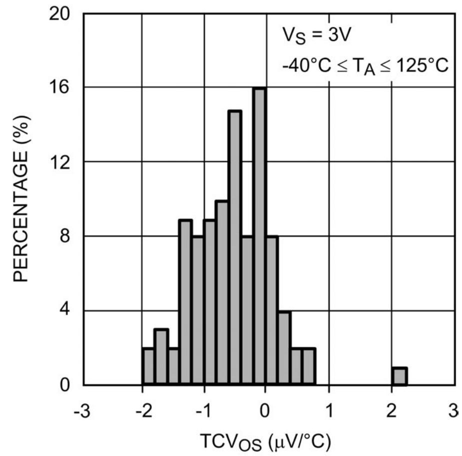
TCV_{OS} Distribution



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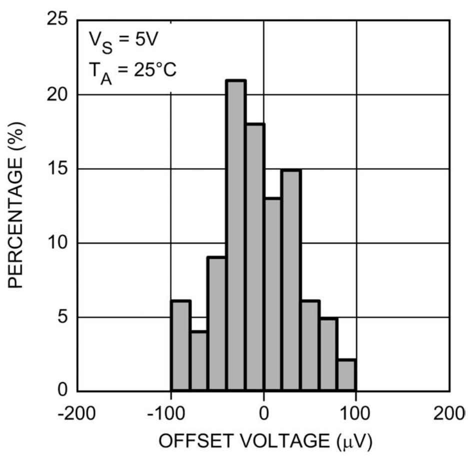
Offset Voltage Distribution



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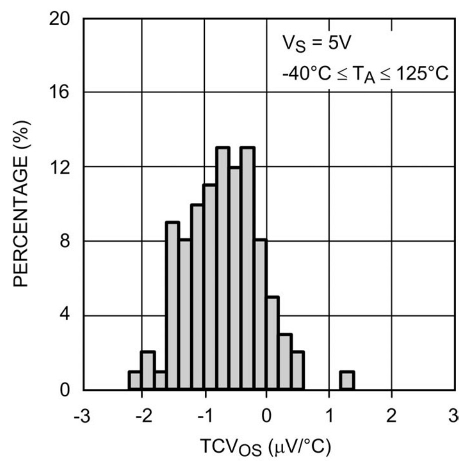
TCV_{OS} Distribution



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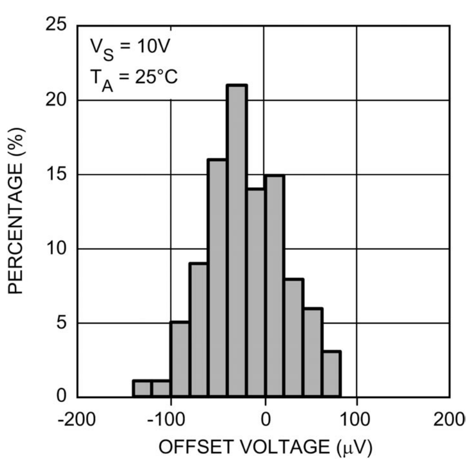
Offset Voltage Distribution



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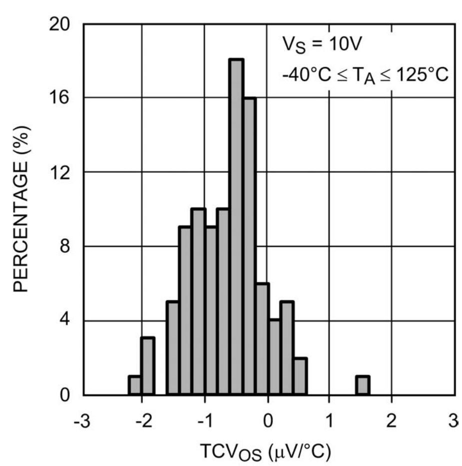

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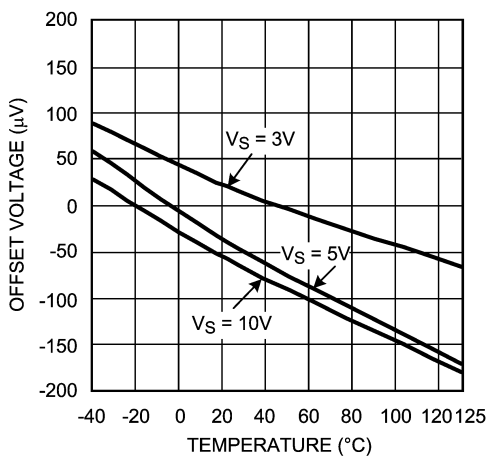
Typical Performance Characteristics Unless otherwise noted: T_A = 25˚C, V_{CM} = V_S/2, R_L > 10 kΩ. (Continued)

Offset Voltage vs. Temperature



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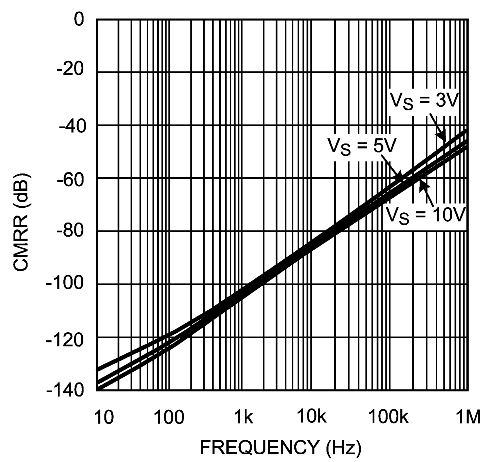
CMRR vs Frequency



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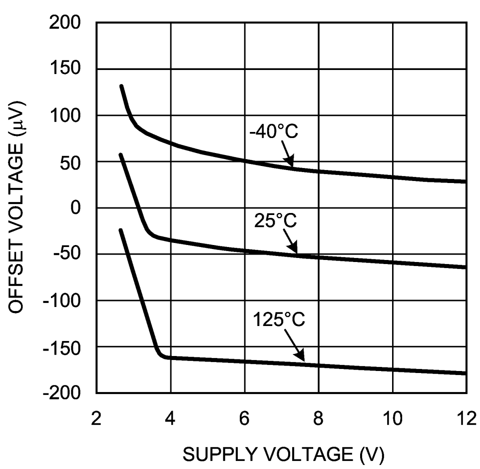
Offset Voltage vs. Supply Voltage



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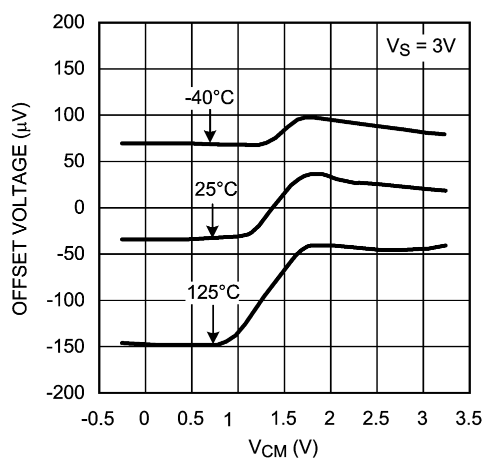
Offset Voltage vs. V_{CM}



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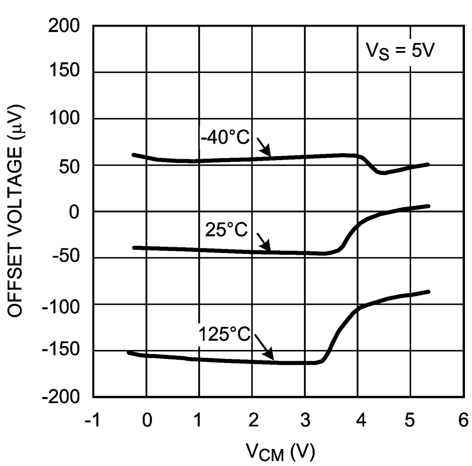
Offset Voltage vs. V_{CM}



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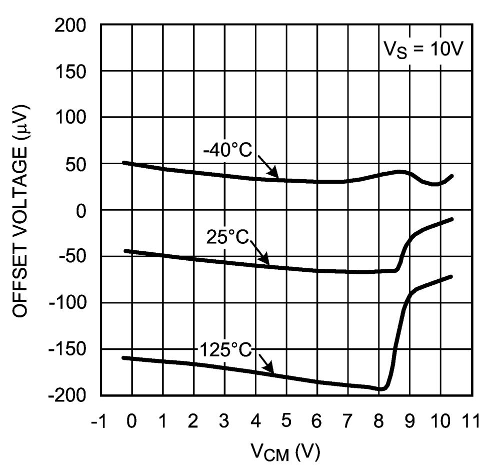
Offset Voltage vs. V_{CM}



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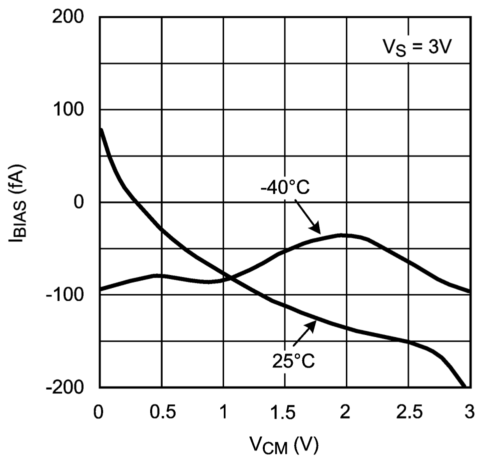
Typical Performance Characteristics Unless otherwise noted: T_A = 25˚C, V_{CM} = V_S/2, R_L > 10 kΩ. (Continued)

Input Bias Current vs. V_{CM}



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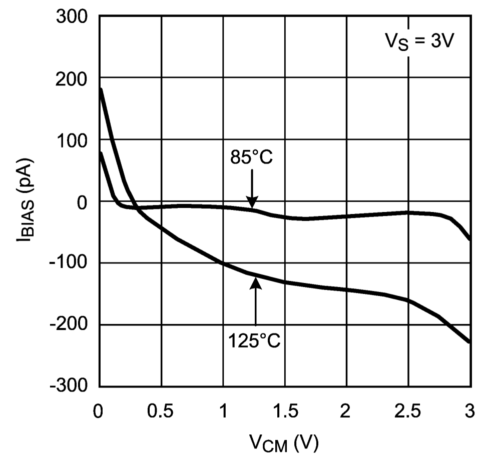
Input Bias Current vs. V_{CM}



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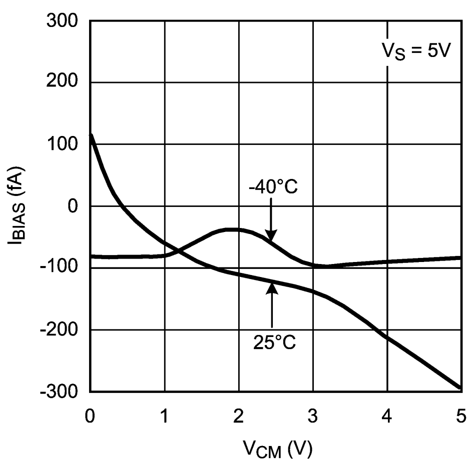
Input Bias Current vs. V_{CM}



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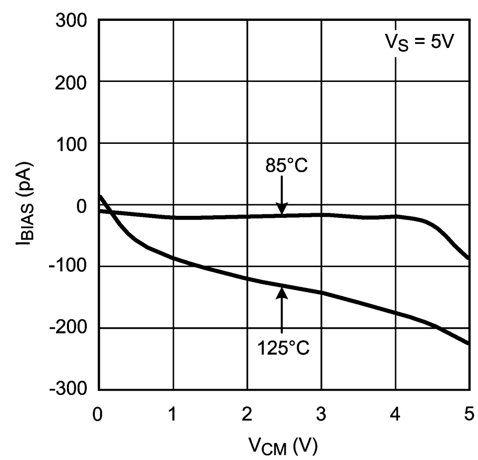
Input Bias Current vs. V_{CM}



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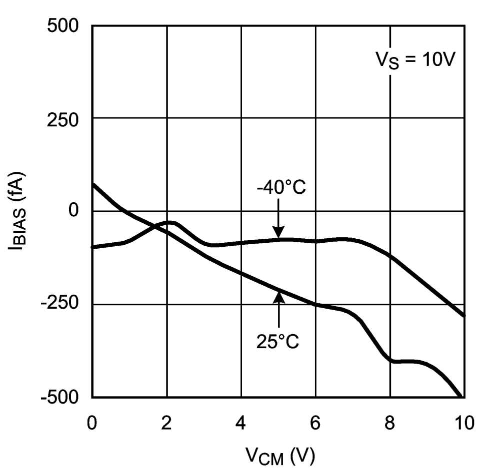
Input Bias Current vs. V_{CM}



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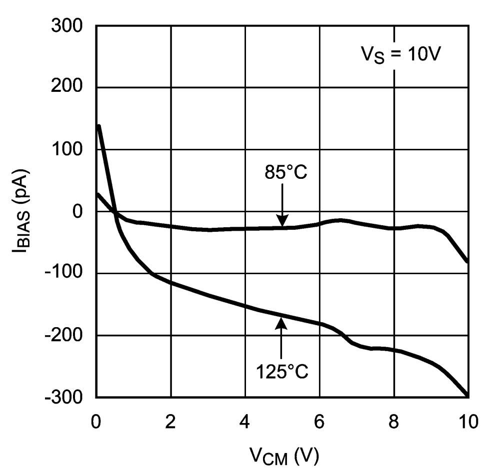
Input Bias Current vs. V_{CM}



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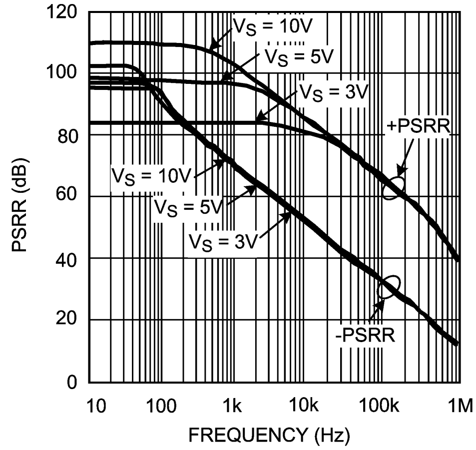
Typical Performance Characteristics Unless otherwise noted: $T_A = 25^\circ C$, $V_{CM} = V_S/2$, $R_L > 10\ k\Omega$. (Continued)

PSRR vs. Frequency



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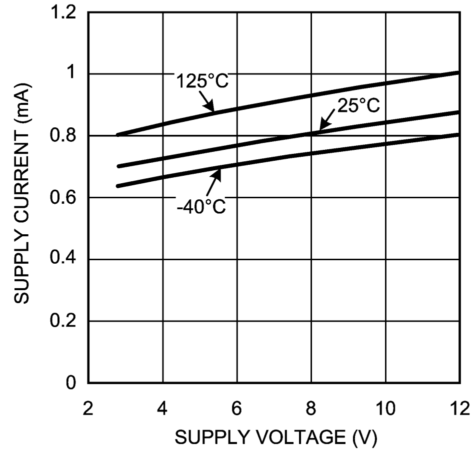
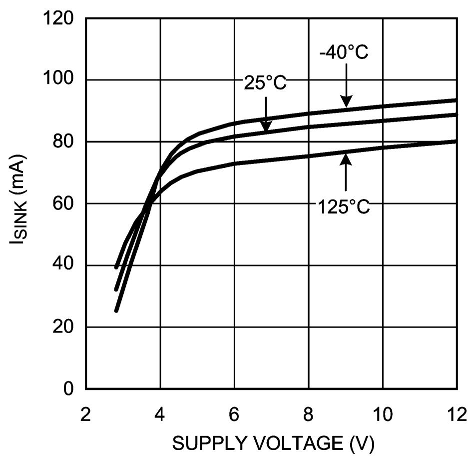
Supply Current vs. Supply Voltage



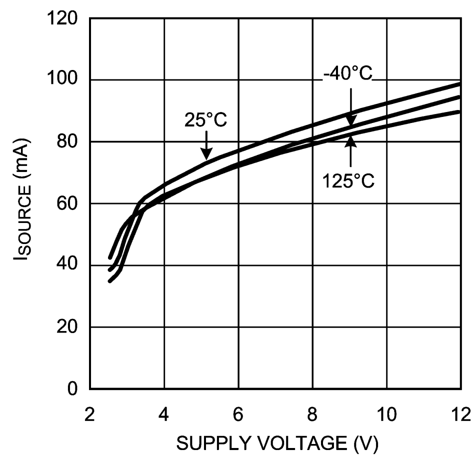
20127311

Sinking Current vs. Supply Voltage



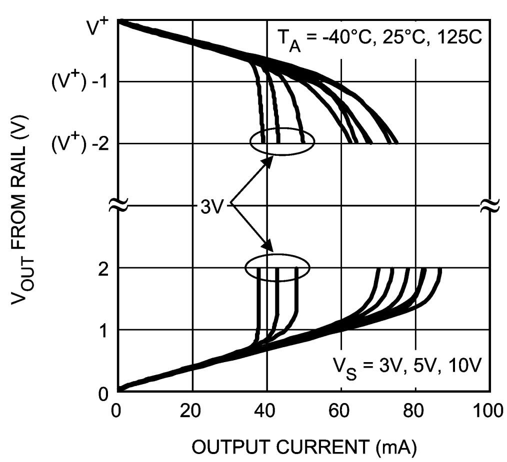
20127313

Sourcing Current vs. Supply Voltage



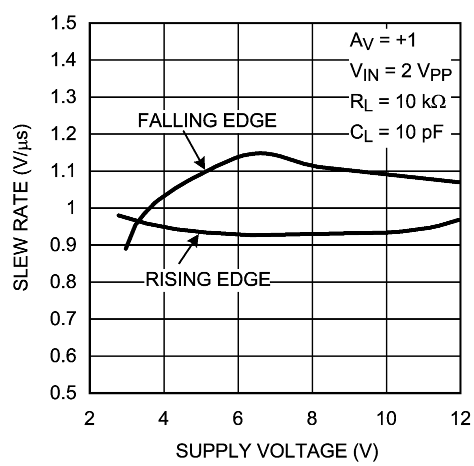
20127312

Output Voltage vs. Output Current



20127316

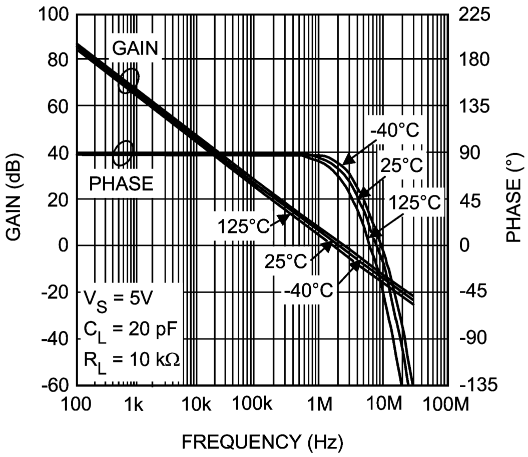
Slew Rate vs. Supply Voltage



20127317

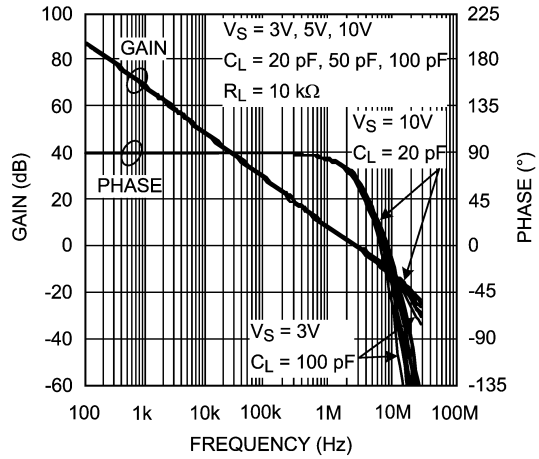
Typical Performance Characteristics Unless otherwise noted: T_A = 25˚C, V_{CM} = V_S/2, R_L > 10 kΩ. (Continued)

Open Loop Frequency Response



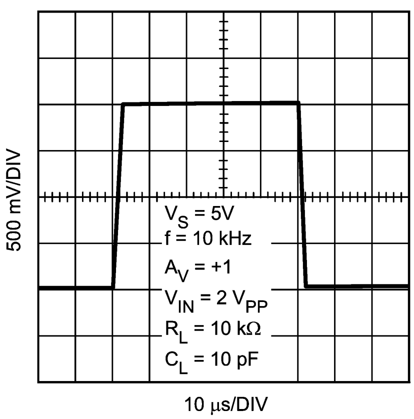
20127315

Open Loop Frequency Response



20127314

Large Signal Step Response



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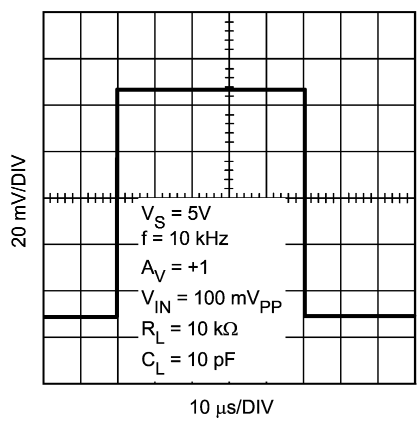
Small Signal Step Response



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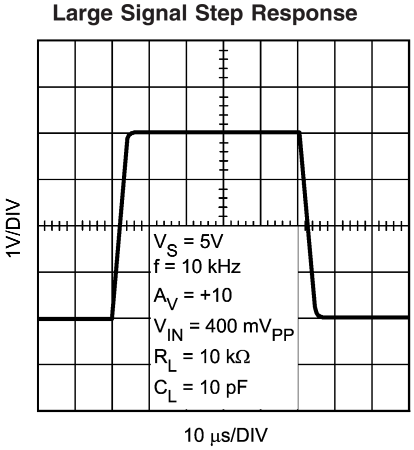
Large Signal Step Response



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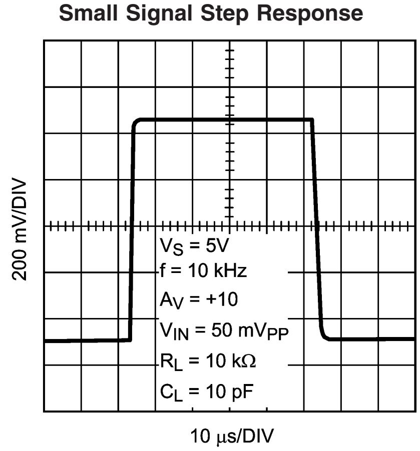
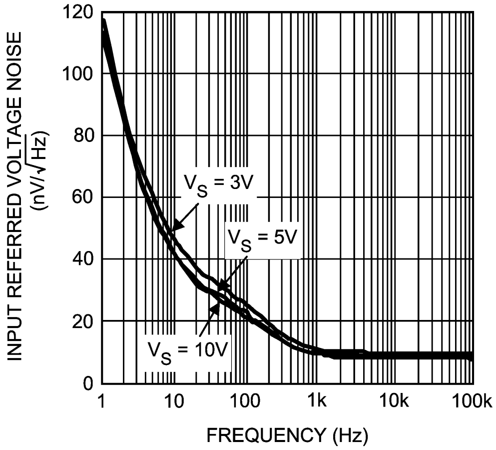
Small Signal Step Response



20127326

Typical Performance Characteristics Unless otherwise noted: $T_A = 25^\circ C$, $V_{CM} = V_S/2$, $R_L > 10\ k\Omega$. (Continued)

Input Voltage Noise vs. Frequency



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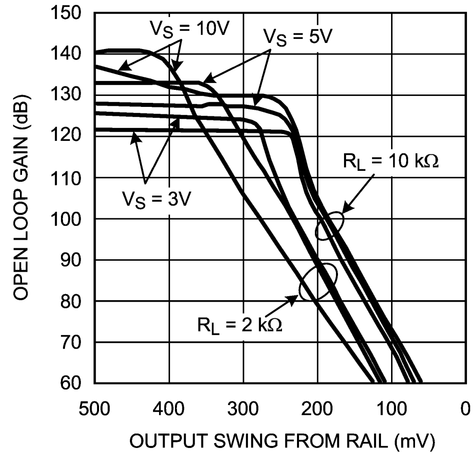
Open Loop Gain vs. Output Voltage Swing



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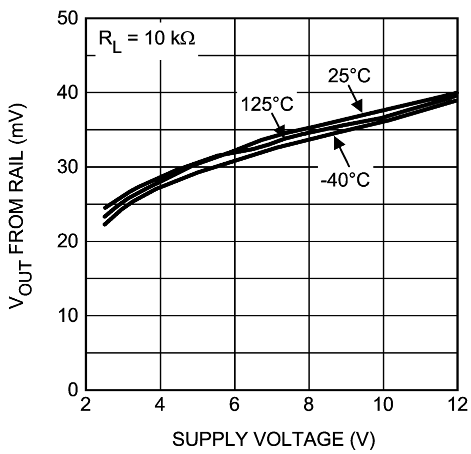
Output Swing High vs. Supply Voltage



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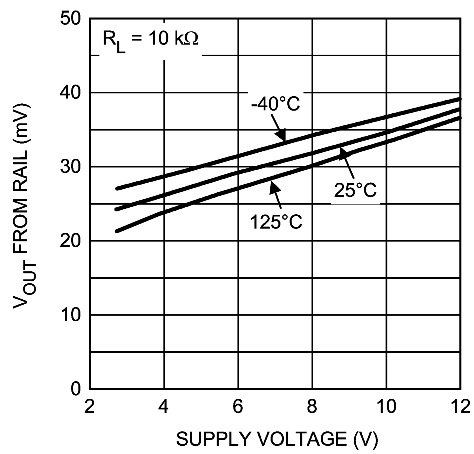
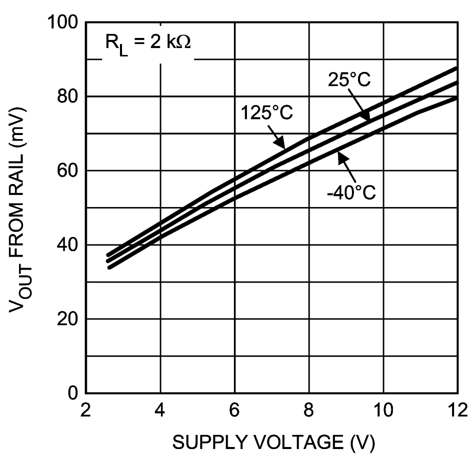
Output Swing Low vs. Supply Voltage



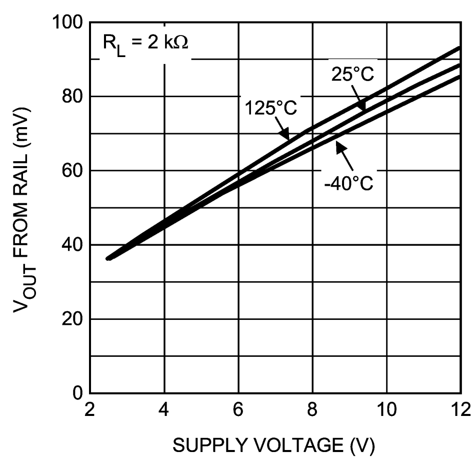
20127335

Output Swing High vs. Supply Voltage



20127332

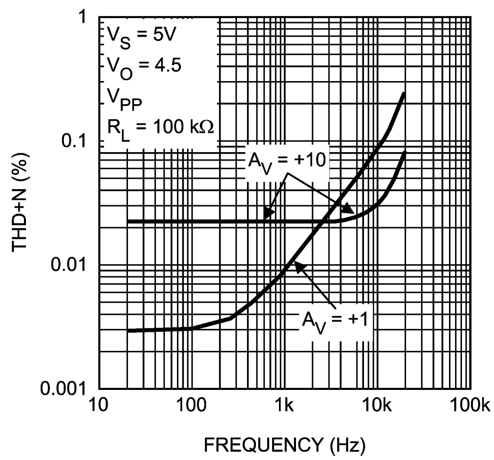
Output Swing Low vs. Supply Voltage



20127334

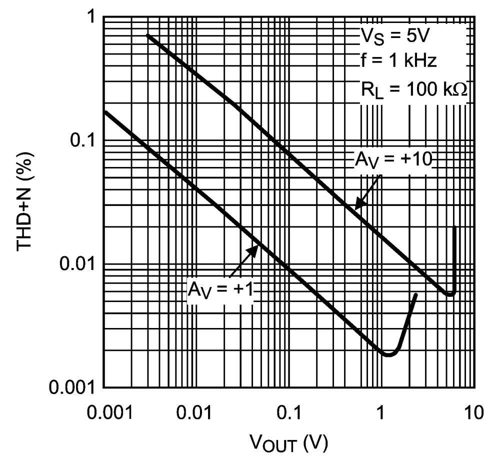
Typical Performance Characteristics Unless otherwise noted: T_A = 25˚C, V_{CM} = V_S/2, R_L > 10 kΩ. (Continued)

THD+N vs. Frequency



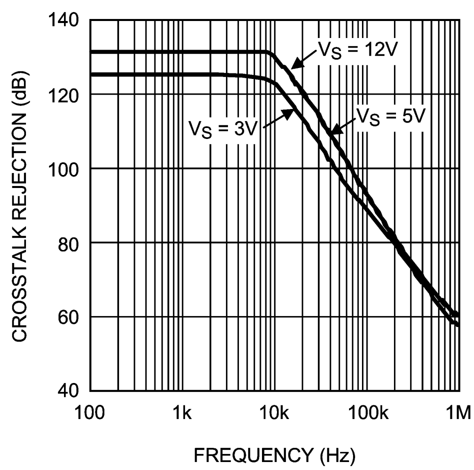
20127328

THD+N vs. Output Voltage



20127329

Crosstalk Rejection Ratio vs. Frequency (LMP7704)



20127353

Application Notes

LMP7701/LMP7704

The LMP7701 and LMP7704 are single and quad low offset voltage, rail-to-rail input and output precision amplifiers with CMOS input stage and wide supply voltage range of 2.7V to 12V. The LMP7701 and LMP7704 have a very low input bias current of only ±200 fA at room temperature.

The wide supply voltage range of 2.7V to 12V over the extensive temperature range of −40˚C to 125˚C makes the LMP7701 and LMP7704 excellent choices for low voltage precision applications with extensive temperature requirements.

The LMP7701 and LMP7704 have only ±37 μV of typical input referred offset voltage and this offset is guaranteed to be less than ±500 μV and ±520 μV, respectively, over temperature. This minimal offset voltage allows more accurate signal detection and amplification in precision applications.

The low input bias current of only ±200 fA along with the low input referred voltage noise of 9 nV/ $\sqrt{Hz}$ give the LMP7701 and LMP7704 superiority for use in sensor applications. Lower levels of noise introduced by the amplifier mean better signal fidelity and a higher signal-to-noise ratio.

National Semiconductor is heavily committed to precision amplifiers and the market segment they serve. Technical support and extensive characterization data is available for sensitive applications or applications with a constrained error budget.

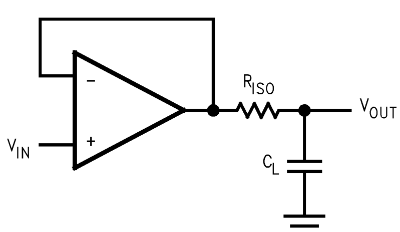
The LMP7701 is offered in the space saving SOT23-5 package, and the LMP7704 is offered in the TSSOP-14 package. These small packages are ideal solutions for area constrained PC boards and portable electronics.

CAPACITIVE LOAD

The LMP7701 and LMP7704 can be connected as a non-inverting unity gain follower. This configuration is the most sensitive to capacitive loading.

The combination of a capacitive load placed on the output of an amplifier along with the amplifier's output impedance creates a phase lag which in turn reduces the phase margin of the amplifier. If the phase margin is significantly reduced, the response will be either underdamped or it will oscillate.

In order to drive heavier capacitive loads, an isolation resistor, R_{ISO} in *Figure 1* should be used. By using this isolation resistor, the capacitive load is isolated from the amplifier's output, and hence, the pole caused by C_L is no longer in the feedback loop. The larger the value of R_{ISO}, the more stable the output voltage will be. If values of R_{ISO} are sufficiently large, the feedback loop will be stable independent of the value of C_L. However, larger values of R_{ISO} result in reduced output swing and reduced output current drive.



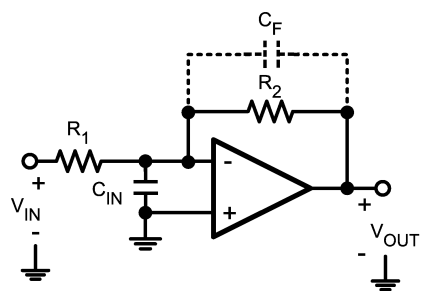
20127321

FIGURE 1. Isolating Capacitive Load

INPUT CAPACITANCE

CMOS input stages inherently have low input bias current and higher input referred voltage noise. The LMP7701 and LMP7704 enhance this performance by having the low input bias current of only ±200 fA, as well as, a very low input referred voltage noise of 9 nV/ $\sqrt{Hz}$. In order to achieve this a larger input stage has been used. This larger input stage increases the input capacitance of the LMP7701, LMP7704. The typical value of this input capacitance, C_{IN}, for the LMP7701 and LMP7704 is 25 pF. The input capacitance will interact with other impedances such as gain and feedback resistors, which are seen on the inputs of the amplifier, to form a pole. This pole will have little or no effect on the output of the amplifier at low frequencies and DC conditions, but will play a bigger role as the frequency increases. At higher frequencies, the presence of this pole will decrease phase margin and will also cause gain peaking. In order to compensate for the input capacitance, care must be taken in choosing feedback resistors. In addition to being selective in picking values for the feedback resistor, a capacitor can be added to the feedback path to increase stability.

The DC gain of the circuit shown in *Figure 2* is simply $-R_2/R_1$.



$$A_V = -\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1}$$

20127344

FIGURE 2. Compensating for Input Capacitance

For the time being, ignore C_F. The AC gain of the circuit in *Figure 2* can be calculated as follows:

$$\frac{V_{OUT}}{V_{IN}}(s) = \frac{-R_2/R_1}{\left[1 + \frac{s}{\left(\frac{A_0 R_1}{R_1 + R_2}\right)} + \frac{s^2}{\left(\frac{A_0}{C_{IN} R_2}\right)}\right]}$$

This equation is rearranged to find the location of the two poles:

$$P_{1,2} = \frac{-1}{2C_{IN}}\left[\frac{1}{R_1} + \frac{1}{R_2} \pm \sqrt{\left(\frac{1}{R_1} + \frac{1}{R_2}\right)^2 - \frac{4\,A_0 C_{IN}}{R_2}}\,\right] \tag{1}$$

As shown in *Equation (1)*, as values of R_1 and R_2 are increased, the magnitude of the poles is reduced, which in turn decreases the bandwidth of the amplifier. Whenever

Application Notes (Continued)

possible, it is best to chose smaller feedback resistors. *Figure 3* shows the effect of feedback resistor on the LMP7701 and LMP7704 bandwidth.

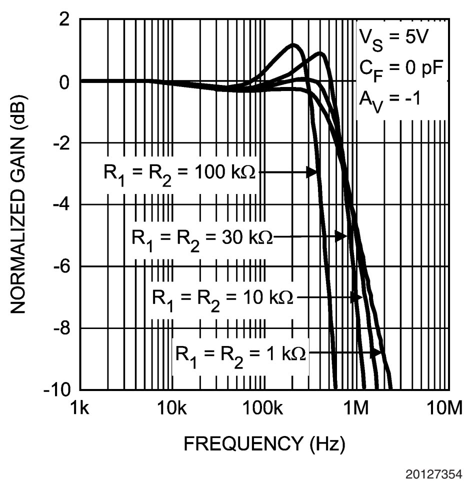


FIGURE 3. Closed Loop Gain vs. Frequency

Furthermore, R_1 and R_2 are related by the gain of the amplifier. As shown in *Figure 2*

$A_V = -R_2 / R_1$, or alternatively

$R_2 = -A_V R_1$

Equation (1) has two poles. In most cases, it is the presence of pairs of poles that causes gain peaking. In order to eliminate this effect, the poles should be placed in Butterworth position, since poles in Butterworth position do not cause gain peaking. To achieve a Butterworth pair, the quantity under the square root in *Equation (1)* should be set to equal −1. Using this fact and the relation between R_1 and R_2, one can find the optimum value for R_1 as shown in *Equation (2)*. If R_1 is chosen to be larger than this optimum value, gain peaking will occur.

$$R_1 < \frac{(1 - A_V)^2}{2A_0 A_V C_{IN}} \tag{2}$$

In *Figure 2*, C_F is added to compensate for input capacitance and to increase stability. Additionally, C_F reduces or eliminates the gain peaking that can be caused by having a larger feedback resistor. *Figure 4* shows how C_F reduces gain peaking.

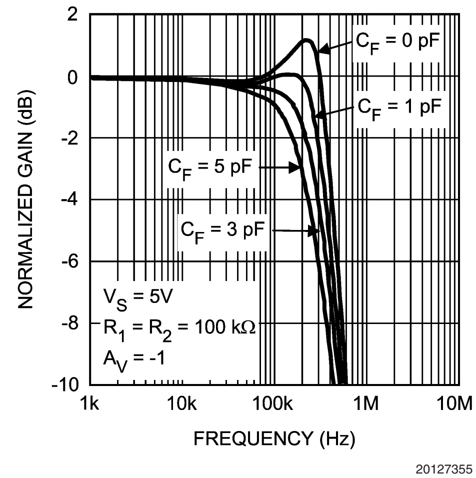


FIGURE 4. Closed Loop Gain vs. Frequency with Compensation

DIODES BETWEEN THE INPUTS

The LMP7701 and LMP7704 have a set of anti-parallel diodes between its input pins, as shown in *Figure 5*. These diodes are present to protect the input stage of the amplifier. At the same time, they limit the amount of differential input voltage that is allowed on the input pins. A differential signal larger than one diode voltage drop might damage the diodes. The differential signal between the inputs needs to be limited to ±300 mV or the input current needs to be limited to ±10 mA.

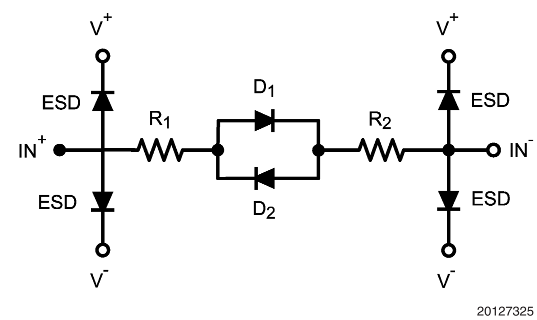


FIGURE 5. Input of LMP7701

PRECISION CURRENT SOURCE

The LMP7701 and LMP7704 can be used as a precision current source in many different applications. *Figure 6* shows a typical precision current source. This circuit implements a precision voltage controlled current source. Amplifier A1 is a differential amplifier that uses the voltage drop across R_S as the feedback signal. Amplifier A2 is a buffer that eliminates the error current from the load side of the R_S resistor that would flow in the feedback resistor if it were connected to the load side of the R_S resistor. In general, the circuit is stable as long as the closed loop bandwidth of amplifier A2 is greater then the closed loop bandwidth of amplifier A1. Note that if A1 and A2 are the same type of amplifiers, then the feedback around A1 will reduce its bandwidth compared to A2.

Application Notes (Continued)

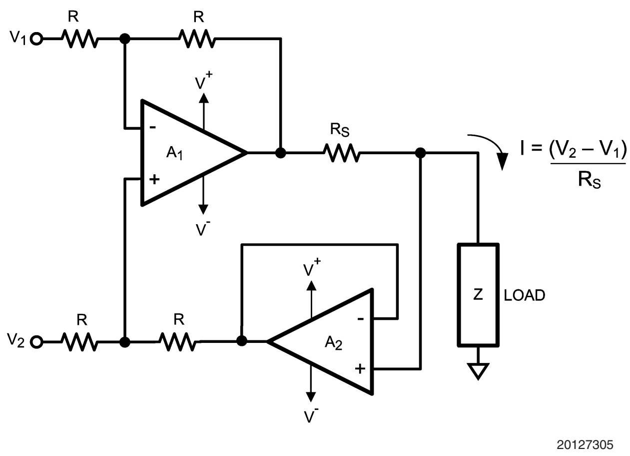


FIGURE 6. Precision Current Source

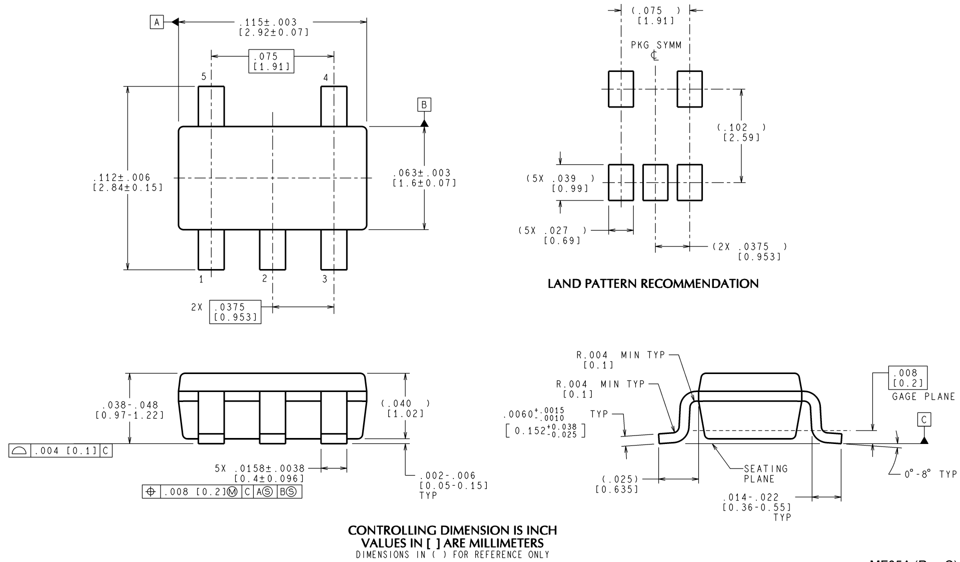
The equation for output current can be derived as follows:

$$\frac{V_2R}{R+R} + \frac{(V_0 - IR_S)R}{R+R} = \frac{V_1R}{R+R} + \frac{V_0R}{R+R}$$

Solving for the current I results in the following equation:

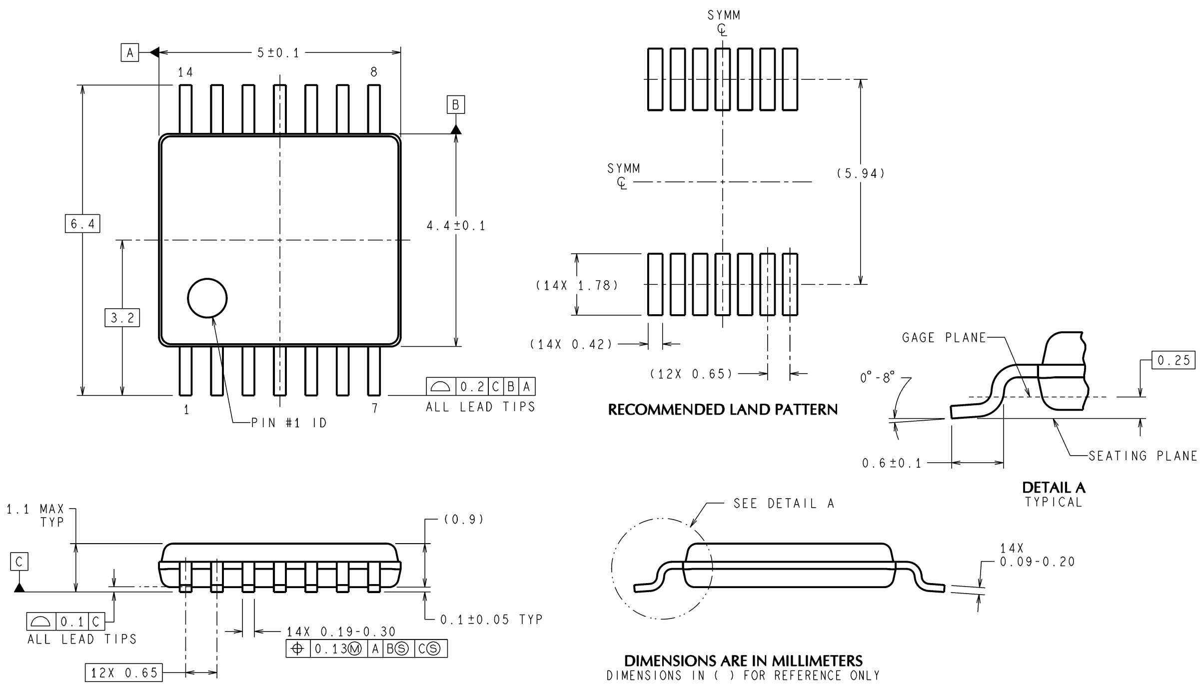
$$I = \frac{V_2 - V_1}{R_S}$$

Physical Dimensions inches (millimeters) unless otherwise noted



MF05A (Rev C)

5-Pin SOT23
NS Package Number MF05A



MTC14 (Rev D)

14-Pin TSSOP
NS Package Number MTC14

Notes

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