

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

SLOS039B – D3290, JULY 1989 – REVISED MARCH 1992

- **Single-Supply Operation:**  
Input Voltage Range Extends to Ground and Output Swings to Ground While Sinking Current
- **Input Offset Voltage . . . 300  $\mu\text{V}$  Max at 25°C for LT1014**
- **Offset Voltage Temperature Coefficient 2.5  $\mu\text{V}/^\circ\text{C}$  Max at LT1014**
- **Input Offset Current . . . 1.5 nA Max at 25°C for LT1014**
- **High Gain . . . 1.2  $\text{V}/\mu\text{V}$  Min ( $R_L = 2 \text{ k}\Omega$ ), 0.5  $\text{V}/\mu\text{V}$  Min ( $R_L = 600 \Omega$ ) for LT1014**
- **Low Supply Current . . . 2.2 mA Max at 25°C for LT 1014**
- **Low Peak-to-Peak Noise Voltage 0.55  $\mu\text{V}$  Typ**
- **Low Current Noise . . . 0.07  $\text{pA}/\sqrt{\text{Hz}}$  Typ**

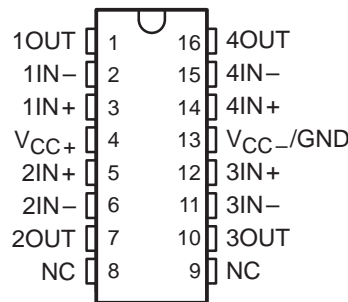
## description

The LT1014, LT1014A, and LT1014D are precision quad operational amplifiers with 14-pin industry-standard configuration. They feature low offset-voltage temperature coefficient, high gain, low supply current, and low noise.

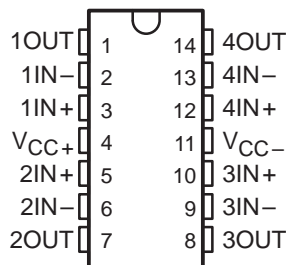
The LT1014, LT1014A, and LT1014D can be operated with both dual  $\pm 15 \text{ V}$  and single 5-V power supplies. The common-mode input voltage range includes ground, and the output voltage can also swing to within a few millivolts of ground. Crossover distortion is eliminated.

The LT1014C and LT1014 AC are characterized for operation from 0°C to 70°C. The LT1014I and LT1014DI are characterized for operation from -40°C to 105°C. The LT1014M, LT1014AM and LT1014DM are characterized for operation over the full military temperature range of -55°C to 125°C.

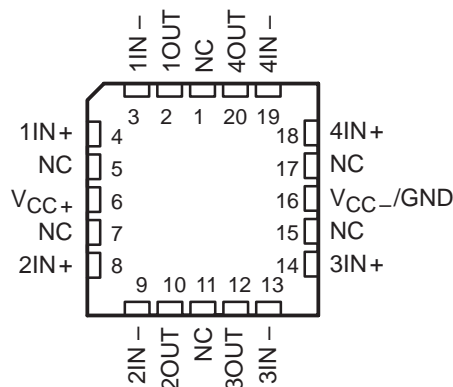
**DW PACKAGE  
(TOP VIEW)**



**J, OR N PACKAGE  
(TOP VIEW)**



**FK PACKAGE  
(TOP VIEW)**



NC – No internal connection

## AVAILABLE OPTIONS

T <sub>A</sub>	V <sub>IO</sub> max AT 25°C	PACKAGE			
		SMALL OUTLINE (W)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	300 $\mu\text{V}$	—	—	—	LT1014CN
	800 $\mu\text{V}$	LT1014DDW	—	—	LT1014DN
-40°C to 105°C	300 $\mu\text{V}$	—	—	—	LT1014IN
	800 $\mu\text{V}$	LT1014DIDW	—	—	LT1014DIN
-55°C to 125°C	180 $\mu\text{V}$	—	LT1014AMFK	LT1014AMJ	—
	300 $\mu\text{V}$	—	LT1014MFK	LT1014MJ	LT1014MN
	800 $\mu\text{V}$	LT1014DMDW	—	—	LT1014DMN

The DW package is available taped and reeled. Add the suffix R to the device type, (e.g., LT1014DDWR).

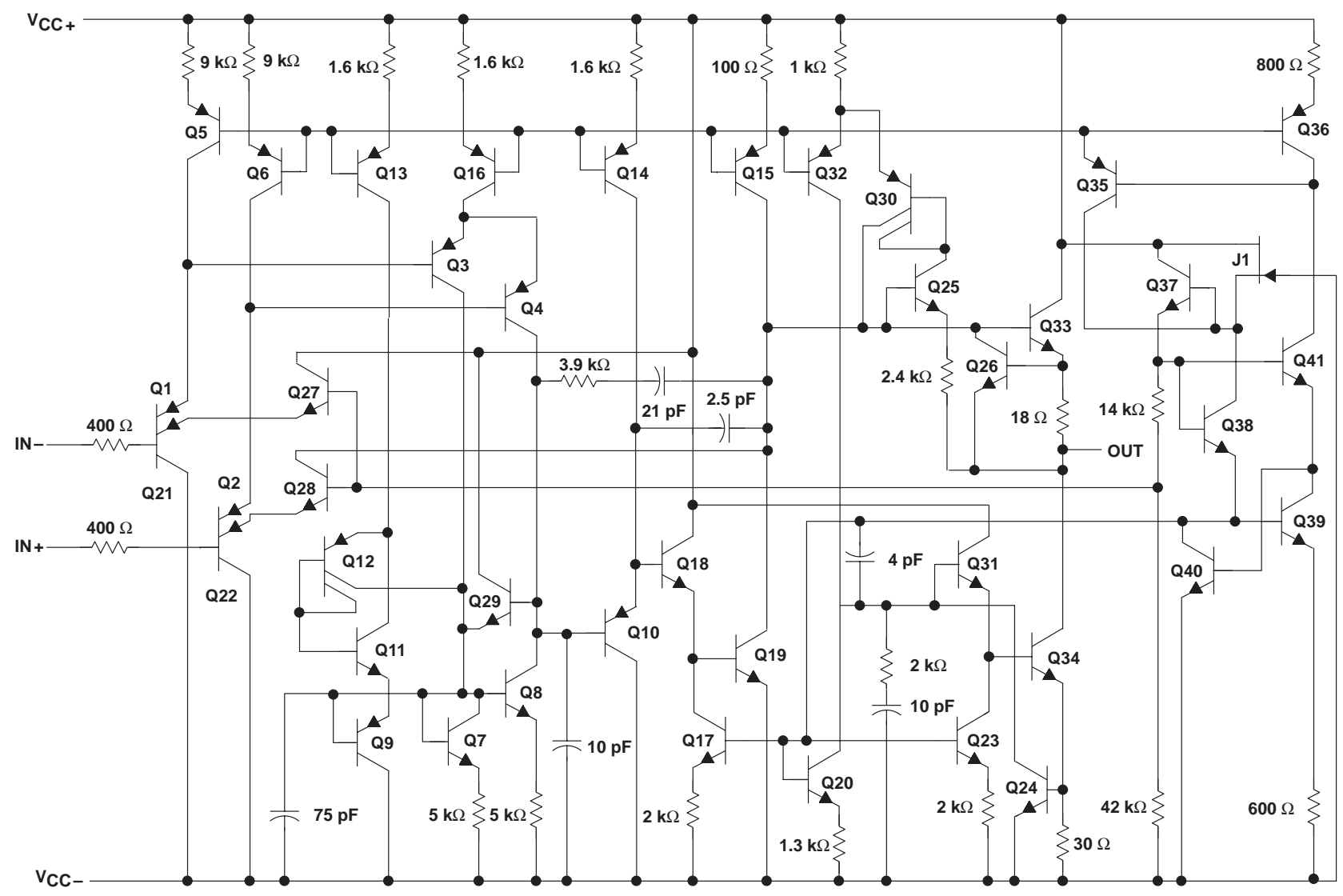
PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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schematic (each amplifier)



Component values are nominal.

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

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## absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC+}$ (see Note 1) .....	22 V
Supply voltage, $V_{CC-}$ (see Note 1) .....	–22 V
Differential input voltage (see Note 2) .....	$\pm 30$ V
Input voltage range, $V_I$ (any input, see Note 1) .....	$V_{CC-} - 5$ V to $V_{CC+}$
Duration of short-circuit current at (or below) $T_A = 25^\circ\text{C}$ (see Note 3) .....	unlimited
Continuous total power dissipation .....	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ : LT1014C, LT1014DC .....	–0°C to 70°C
LT1014I, LT10134DI .....	–40°C to 105°C
LT1014M, LT1014AM, LT1014DM .....	–55°C to 125°C
Storage temperature range .....	–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package .....	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: DW or N package .....	260°C
Case temperature for 60 seconds: FK package .....	260°C

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .  
 2. Differential voltages are at the noninverting input with respect to the inverting input.  
 3. The output may be shorted to either supply.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 105^\circ\text{C}$ POWER RATING	$T_A = 125^\circ\text{C}$ POWER RATING
DW	1025 mW	8.2 mW/°C	656 mW	369 mW	205 mW
FK	1375 mW	11.0 mW/°C	880 mW	495 mW	275 mW
J	1375 mW	11.0 mW/°C	880 mW	495 mW	275 mW
N	1150 mW	9.2 mW/°C	736 mW	414 mW	230 mW



# LT1014C, LT1014DC QUAD PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1014C			LT1014DC			UNIT
			MIN	TYP ‡	MAX	MIN	TYP ‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C	60	300		200	800	$\mu\text{V}$	
		Full range			550		1000		
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range	0.4	2.5		0.7	5	$\mu\text{V}/^\circ\text{C}$	
Long-term drift of input offset voltage		25°C	0.5			0.5		$\mu\text{V}/\text{mo}$	
$I_{IO}$ Input offset current		25°C	0.15	1.5		0.15	1.5	nA	
		Full range			2.8		2.8		
$I_{IB}$ Input bias current		25°C	-12	-30		-12	-30	nA	
		Full range			-38		-38		
$V_{ICR}$ Common-mode input voltage range		25°C	-15 to 13.5	-15.3 to 13.8		-15 to 13.5	-15.3 to 13.8	V	
		Full range	-15 to 13			-15 to 13			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 2\ \text{k}\Omega$	25°C	$\pm 12.5$	$\pm 14$		$\pm 12.5$	$\pm 14$	V	
		Full range	$\pm 12$			$\pm 12$			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10\ \text{V}$ , $R_L = 600\ \Omega$	25°C	0.5	2		0.5	2	$\text{V}/\mu\text{V}$	
	$V_O = \pm 10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	25°C	1.2	8		1.2	8		
		Full range	0.7			0.7			
CMRR Common-mode rejection ratio	$V_{IC} = -15\ \text{V}$ to $13.5\ \text{V}$ , $V_{IC} = -15\ \text{V}$ to $13\ \text{V}$	25°C	97	117		97	117	dB	
		Full range	94			94			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 2\ \text{V}$ to $\pm 18\ \text{V}$	25°C	100	117		100	117	dB	
		Full range	97			97			
Channel separation	$V_O = \pm 10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	25°C	120	137		120	137	dB	
$r_{id}$ Differential input resistance		25°C	70	300		70	300	$\text{M}\Omega$	
$r_{ic}$ Common-mode input resistance		25°C	4			4		$\text{G}\Omega$	
$I_{CC}$ Supply current per amplifier		25°C	0.35	0.55		0.35	0.55	mA	
		Full range			0.6		0.6		

† Full range is 0°C to 70°C.

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .



# LT1014C, LT1014DC QUAD PRECISION OPERATIONAL AMPLIFIERS

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**electrical characteristics at specified free-air temperature,  $V_{CC\pm} = 5\text{ V}$ ,  $V_{CC-} = 0$ ,  $V_O = 1.4\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1014C			LT1014DC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C	90	450		250	950	$\mu\text{V}$	
		Full range			570		1200		
$I_{IO}$ Input offset current		25°C	0.2	2		0.2	2	nA	
		Full range			6		6		
$I_{IB}$ Input bias current		25°C	-15	-50		-15	-50	nA	
		Full range			-90		-90		
$V_{ICR}$ Common-mode input voltage range		25°C	0 to 3.5	-0.3 to 3.8		0 to 3.5	-0.3 to 3.8	V	
		Full range	0 to 3			0 to 3			
$V_{OM}$ Maximum peak output voltage swing	Output low, No load	25°C		15	25		15	25	mV
	Output low, $R_L = 600\ \Omega$ to GND	25°C		5	10		5	10	
	Full range				13			13	
	Output low, $I_{\text{sink}} = 1\text{ mA}$	25°C		220	350		220	350	V
	Output high, No load	25°C	4	4.4		4	4.4		
	Full range		3.2			3.2			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV}$ to $4\text{ V}$ , $R_L = 500\ \Omega$	25°C		1			1	$\text{V}/\mu\text{V}$	
		Full range							
$I_{CC}$ Supply current per amplifier		25°C	0.3	0.5		0.3	0.5	mA	
		Full range			0.55		0.55		

† Full range is 0°C to 70°C.

**operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{IC} = 0$ ,  $T_A = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		$\text{V}/\mu\text{s}$
$V_n$ Equivalent input noise voltage	$f = 10\text{ Hz}$		24		$\text{nV}/\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$		22		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		0.55		$\mu\text{V}$
$I_n$ Equivalent input noise current	$f = 10\text{ Hz}$		0.07		$\text{pA}/\sqrt{\text{Hz}}$

# LT1014I, LT1014DI QUAD PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1014I			LT1014DI			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$	Input offset voltage	$R_S = 50\ \Omega$	25°C	60	300	200	800	$\mu\text{V}$	
			Full range	550			1000		
$\alpha_{VIO}$	Temperature coefficient of input offset voltage		Full range	0.4	2.5	0.7	5	$\mu\text{V}/^\circ\text{C}$	
	Long-term drift of input offset voltage		25°C	0.5		0.5		$\mu\text{V}/\text{mo}$	
$I_{IO}$	Input offset current		25°C	0.15	1.5	0.15	1.5	nA	
			Full range	2.8			2.8		
$I_{IB}$	Input bias current		25°C	-12	-30	-12	-30	nA	
			Full range	-38			-38		
$V_{ICR}$	Common-mode input voltage range		25°C	-15 to 13.5	-15.3 to 13.8	-15 to 13.5	-15.3 to 13.8	V	
			Full range	-15 to 13		-15 to 13			
$V_{OM}$	Maximum peak output voltage swing	$R_L = 2\ \text{k}\Omega$	25°C	$\pm 12.5$	$\pm 14$	$\pm 12.5$	$\pm 14$	V	
			Full range	$\pm 12$			$\pm 12$		
$A_{VD}$	Large-signal differential voltage amplification	$V_O = \pm 10\ \text{V}$ , $R_L = 600\ \Omega$	25°C	0.5	2	0.5	2	$\text{V}/\mu\text{V}$	
			Full range	25°C	1.2	8	1.2		8
				$V_O = \pm 10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	0.7				0.7
CMRR	Common-mode rejection ratio	$V_{IC} = -15\ \text{V}$ to $13.5\ \text{V}$	25°C	97	117	97	117	dB	
			Full range	94			94		
$k_{SVR}$	Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 2\ \text{V}$ to $\pm 15\ \text{V}$	25°C	100	117	100	117	dB	
			Full range	97			97		
	Channel separation	$V_O = \pm 10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	25°C	120	137	120	137	dB	
$r_{id}$	Differential input resistance		25°C	70	300	70	300	$\text{M}\Omega$	
$r_{ic}$	Common-mode input resistance		25°C	4		4		$\text{G}\Omega$	
$I_{CC}$	Supply current per amplifier		25°C	0.35	0.55	0.35	0.55	mA	
			Full range	0.6			0.6		

† Full range is  $-40^\circ\text{C}$  to  $105^\circ\text{C}$ .

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .



# LT1014I, LT1014DI

## QUAD PRECISION OPERATIONAL AMPLIFIERS

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**electrical characteristics at specified free-air temperature,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0$ ,  $V_O = 1.4\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1014I			LT1014DI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C	90	450		250	950	$\mu\text{V}$	
		Full range			570		1200		
$I_{IO}$ Input offset current		25°C	0.2	2		0.2	2	nA	
		Full range			6		6		
$I_{IB}$ Input bias current		25°C	-15	-50		-15	-50	nA	
		Full range			-90		-90		
$V_{ICR}$ Common-mode input voltage range		25°C	0 to 3.5	-0.3 to 3.8		0 to 3.5	-0.3 to 3.8	V	
		Full range	0 to 3			0 to 3			
$V_{OM}$ Maximum peak output voltage swing	Output low, No load	25°C		15	25		15	25	mV
	Output low, $R_L = 600\ \Omega$ to GND	25°C		5	10		5	10	
	Full range				13			13	
	Output low, $I_{sink} = 1\text{ mA}$	25°C		220	350		220	350	V
	Output high, No load	25°C	4	4.4		4	4.4		
	Full range		3.2			3.2			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV}$ to $4\text{ V}$ , $R_L = 500\ \Omega$	25°C		1			1	$\text{V}/\mu\text{V}$	
$I_{CC}$ Supply current per amplifier		25°C		0.3	0.5		0.3	0.5	mA
		Full range			0.55			0.55	

† Full range is  $-40^\circ\text{C}$  to  $105^\circ\text{C}$ .

**operating characteristics,  $V_{CC+} = \pm 15\text{ V}$ ,  $V_{IC} = 0$ ,  $T_A = 25^\circ\text{C}$**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		$\text{V}/\mu\text{s}$
$V_n$ Equivalent input noise voltage	$f = 10\text{ Hz}$		24		$\text{nV}/\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$		22		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		0.55		$\mu\text{V}$
$I_n$ Equivalent input noise current	$f = 10\text{ Hz}$		0.07		$\text{pA}/\sqrt{\text{Hz}}$

electrical characteristics at specified free-air temperature,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1014M			LT1014AM			LT1014DM			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C		60	300		60	180		200	800	$\mu\text{V}$
		Full range			550			350			1000	
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range		0.5	2.5		0.5	2		0.5	2.5	$\mu\text{V}/^\circ\text{C}$
Long-term drift of input offset voltage		25°C		0.5			0.5			0.5		$\mu\text{V}/\text{mo}$
$I_{IO}$ Input offset current		25°C		0.15	1.5		0.15	0.8		0.15	1.5	nA
		Full range			5			2.8			5	
$I_{IB}$ Input bias current		25°C		-12	-30		-12	-20		-12	-30	nA
		Full range			-45			-30			-45	
$V_{ICR}$ Common-mode input voltage range		25°C	-15 to 13.5	-15.3 to 13.8		-15 to 13.5	-15.3 to 13.8		-15 to 13.5	-15.3 to 13.8		V
		Full range		-14.9 to 13			-14.9 to 13			-14.9 to 13		
$V_{OM}$ Maximum peak output voltage swing	$R_L = 2\ \text{k}\Omega$	25°C	$\pm 12.5$	$\pm 14$		$\pm 13$	$\pm 14$		$\pm 12.5$	$\pm 14$		V
		Full range		$\pm 11.5$			$\pm 12$			$\pm 11.5$		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10\ \text{V}$ , $R_L = 600\ \Omega$	25°C	0.5	2		0.8	2.2		0.5	2		$\text{V}/\mu\text{V}$
		25°C	1.2	8		1.5	8		1.2	8		
		Full range	0.25			0.4			0.25			
CMRR Common-mode rejection ratio	$V_{IC} = -15\ \text{V}$ to $13.5\ \text{V}$ $V_{IC} = -14.9\ \text{V}$ to $13\ \text{V}$	25°C	97	117		100	117		97	117		dB
		Full range	94			96			94			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 2\ \text{V}$ to $\pm 18\ \text{V}$	25°C	100	117		103	117		100	117		dB
		Full range	97			100			97			
Channel separation	$V_O = \pm 10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	25°C	120	137		123	137		120	137		dB
$r_{id}$ Differential input resistance		25°C	70	300		100	300		70	300		$\text{M}\Omega$
$r_{ic}$ Common-mode input resistance		25°C		4			4			4		$\text{G}\Omega$
$I_{CC}$ Supply current per amplifier		25°C		0.35	0.55		0.35	0.50		0.35	0.55	mA
		Full range			0.7			0.6			0.7	

† Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ .

‡ All typical values are at  $T_A = 25^\circ\text{C}$ .



electrical characteristics at specified free-air temperature,  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0$ ,  $V_O = 1.4\text{ V}$ ,  $V_{IC} = 0$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	LT1014M			LT1014AM			LT1014DM			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C		90	450		90	280		250	950	$\mu\text{V}$
		Full range		400	1500		400	960		800	2000	
	$R_S = 50\ \Omega$ , $V_{IC} = 0.1\text{ V}$	125°C		200	750		200	480		560	1200	
$I_{IO}$ Input offset current		25°C		0.2	2		0.2	1.3		0.2	2	nA
		Full Range			10			7			10	
$I_{IB}$ Input bias current		25°C		-15	-50		-15	-35		-15	-50	nA
		Full Range			-120			-90			-120	
$V_{ICR}$ Common-mode input voltage range		25°C	0 to 3.5	-0.3 to 3.8		0 to 3.5	-0.3 to 3.8		0 to 3.5	-0.3 to 3.8	V	
		Full range	0.1 to 3			0.1 to 3			0.1 to 3			
$V_{OM}$ Maximum peak output voltage swing	Output low, No load	25°C		15	25		15	25		15	25	mV
	Output low, $R_L = 600\ \Omega$ to GND	25°C		5	10		5	10		5	10	
		Full Range			18			15			18	
	Output low, $I_{sink} = 1\text{ mA}$	25°C		220	350		220	350		220	350	V
	Output high, No load	25°C		4	4.4		4	4.4		4	4.4	
		Full Range			3.1			3.2			3.1	
Output high, $R_L = 600\ \Omega$ to GND	25°C		3.4	4		3.4	4		3.4	4		
	Full Range			3.1			3.2			3.1		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV to }4\text{ V}$ , $R_L = 500\ \Omega$	25°C		1			1			1	$\text{V}/\mu\text{V}$	
$I_{CC}$ Supply current per amplifier		25°C		0.3	0.5		0.3	0.45		0.3	0.5	mA
		Full range			0.65			0.55			0.65	

$^\dagger$  Full range is -55°C to 125°C.

operating characteristics,  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{IC} = 0$ ,  $T_A = 25^\circ\text{C}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		$\text{V}/\mu\text{s}$
$V_n$ Equivalent input noise voltage	$f = 10\text{ Hz}$		24		$\text{nV}/\sqrt{\text{Hz}}$
	$f = 1\text{ kHz}$		22		
$V_{N(PP)}$ Peak-to-peak equivalent input noise voltage	$f = 0.1\text{ Hz to }10\text{ Hz}$		0.55		$\mu\text{V}$
$I_n$ Equivalent input noise current	$f = 10\text{ Hz}$		0.07		$\text{pA}/\sqrt{\text{Hz}}$

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
$V_{IO}$	Input offset voltage	vs Source resistance	1
		vs Temperature	2
$\Delta V_{IO}$	Change in input offset voltage	vs Time	3
$I_{IO}$	Input offset current	vs Temperature	4
$I_{IB}$	Input bias current	vs Temperature	5
$V_{IC}$	Common-mode input voltage	vs Input bias current	6
$A_{VD}$	Differential voltage amplification	vs Load resistance	7, 8
		vs Frequency	9, 10
	Channel separation	vs Frequency	11
	Output saturation voltage	vs Temperature	12
CMRR	Common-mode rejection ratio	vs Frequency	13
$k_{SVR}$	Supply voltage rejection ratio	vs Frequency	14
$I_{CC}$	Supply current	vs Temperature	15
$I_{OS}$	Short-circuit output current	vs Time	16
$V_n$	Equivalent input noise voltage	vs Frequency	17
$I_n$	Equivalent input noise current	vs Frequency	17
$V_{N(PP)}$	Peak-to-peak input noise voltage	vs Time	18
Pulse response	Small-signal	vs Time	19, 21
	Large-signal	vs Time	20, 22, 23
	Phase shift	vs Frequency	9

TYPICAL CHARACTERISTICS†

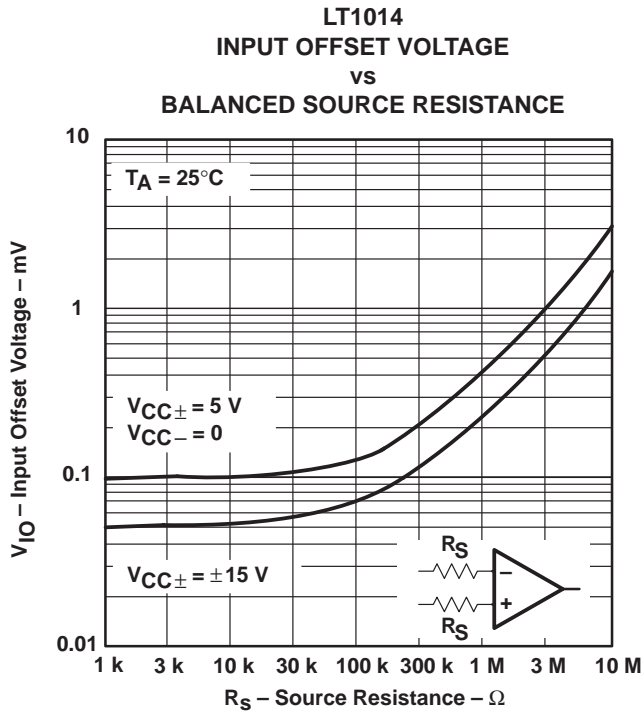


Figure 1

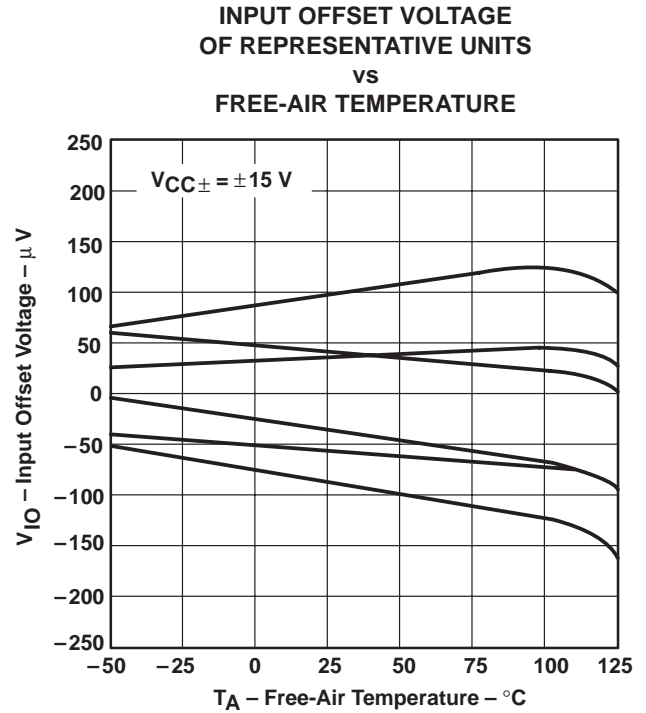


Figure 2

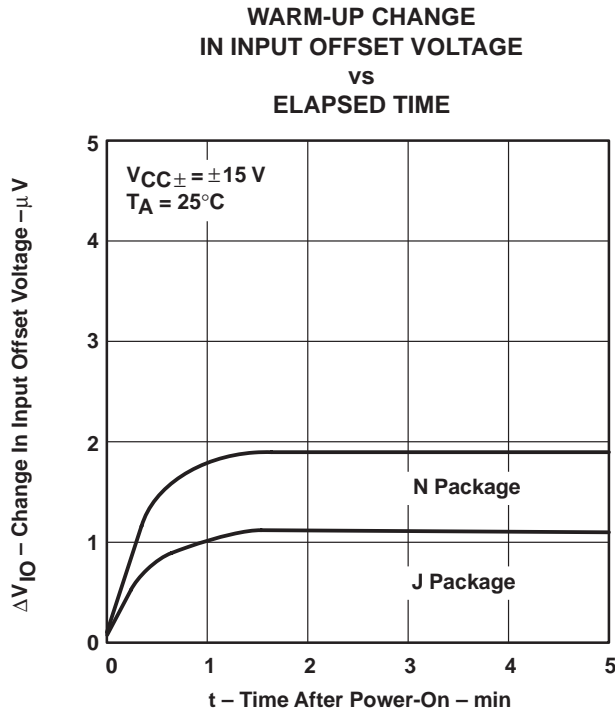


Figure 3

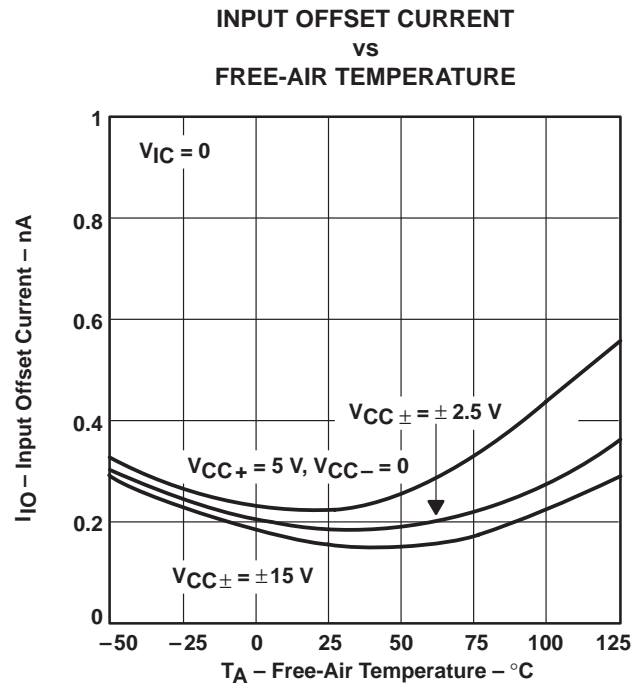


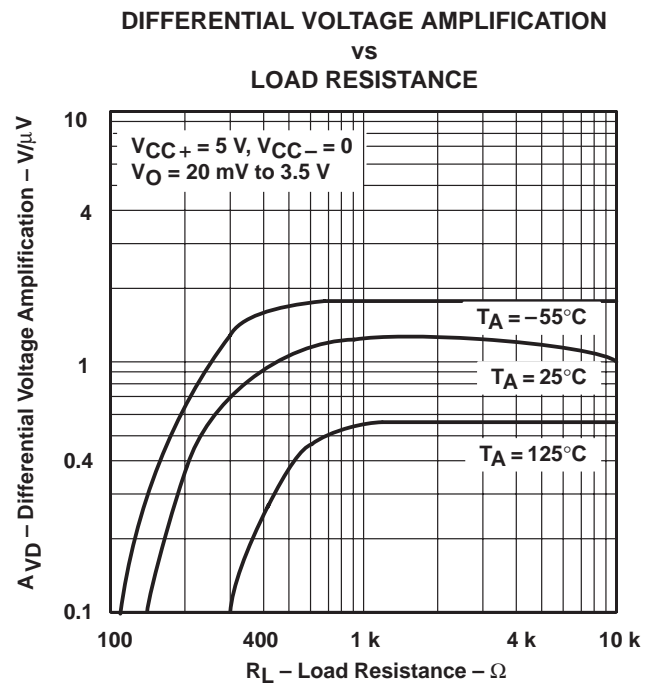
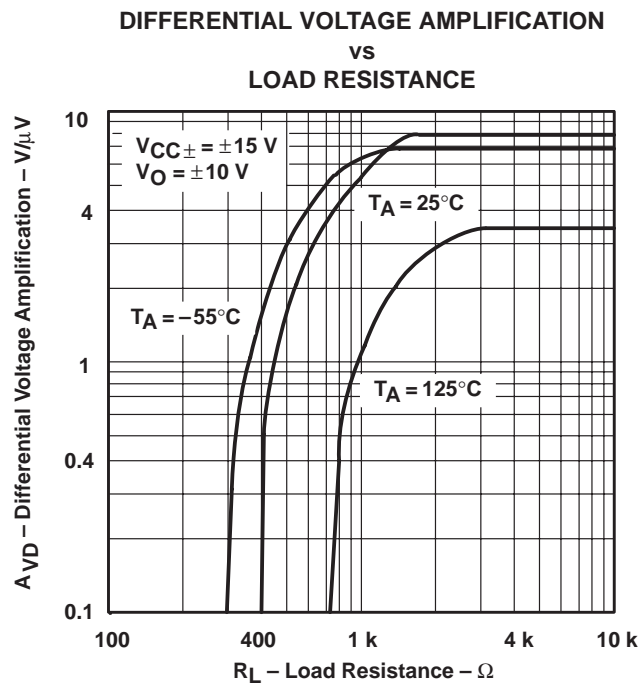
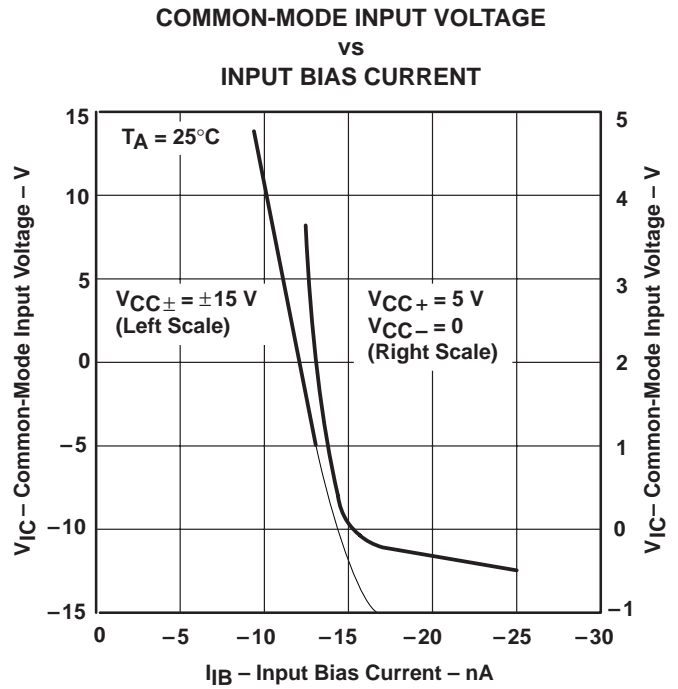
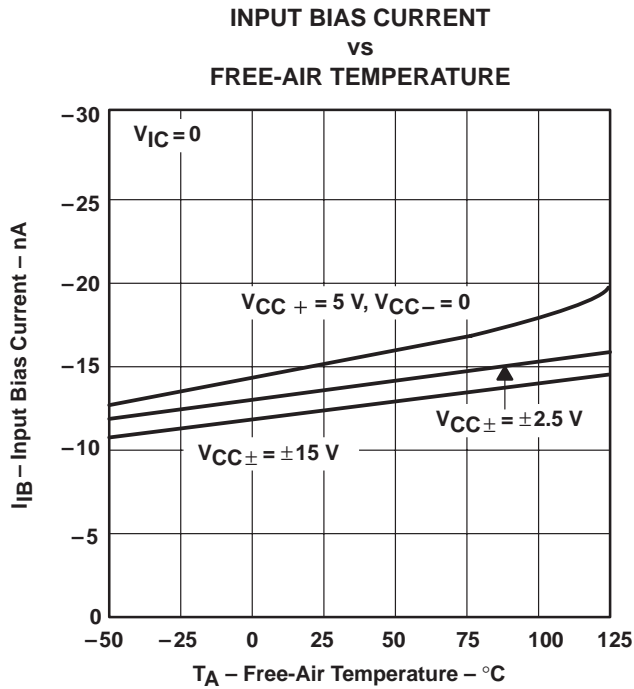
Figure 4

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

DIFFERENTIAL VOLTAGE AMPLIFICATION  
 and PHASE SHIFT  
 vs  
 FREQUENCY

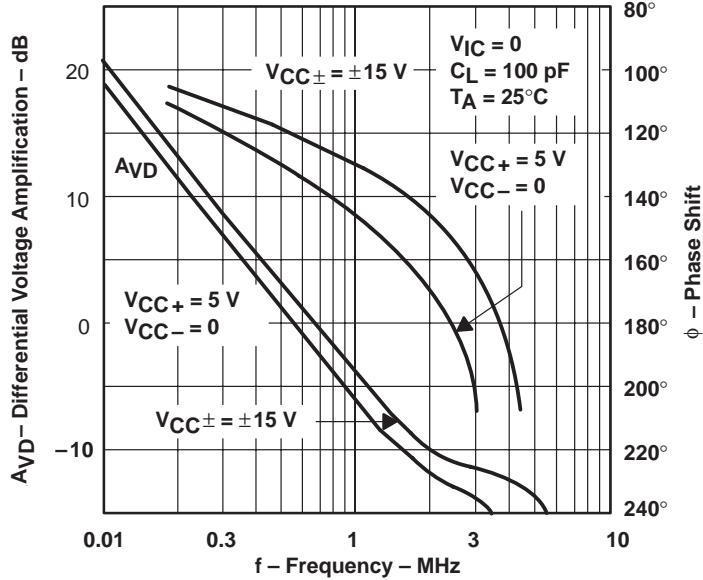


Figure 9

DIFFERENTIAL VOLTAGE AMPLIFICATION  
 vs  
 FREQUENCY

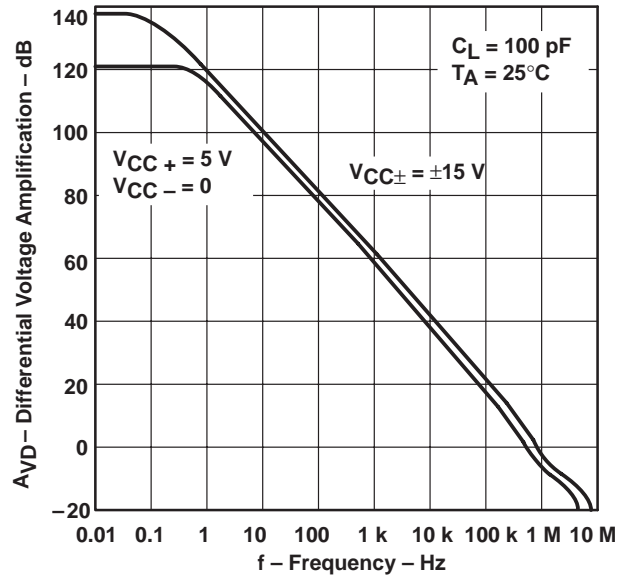


Figure 10

CHANNEL SEPARATION  
 vs  
 FREQUENCY

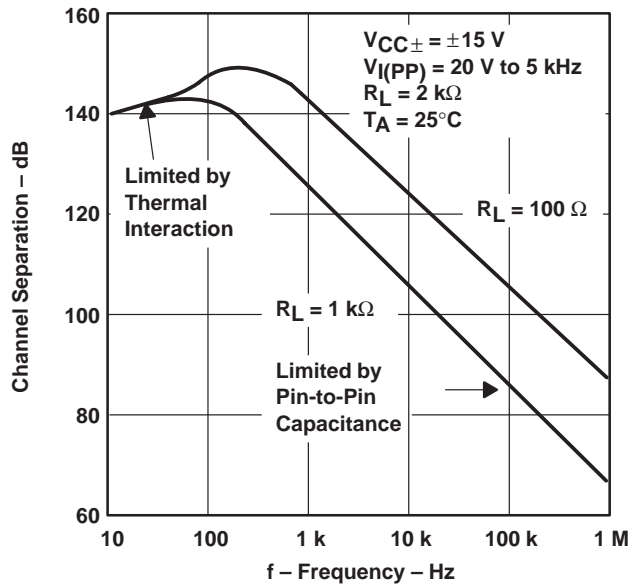


Figure 11

OUTPUT SATURATION VOLTAGE  
 vs  
 FREE-AIR TEMPERATURE

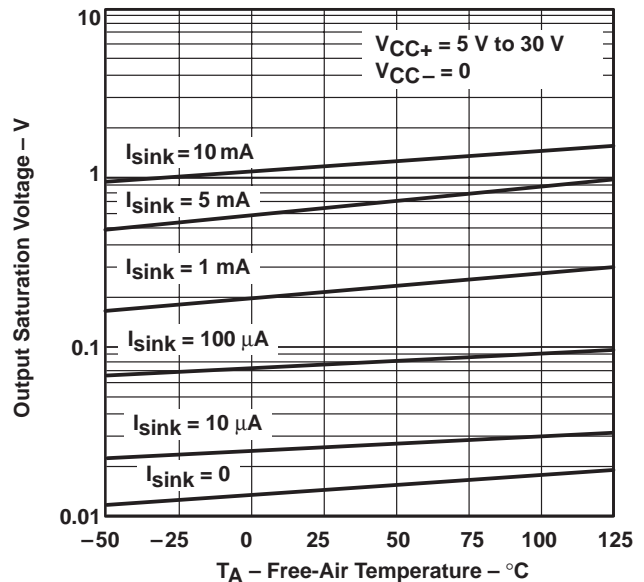


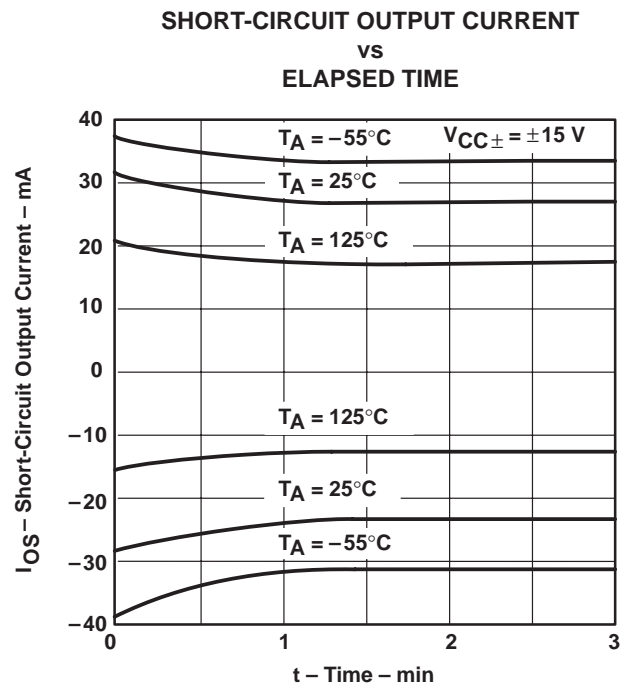
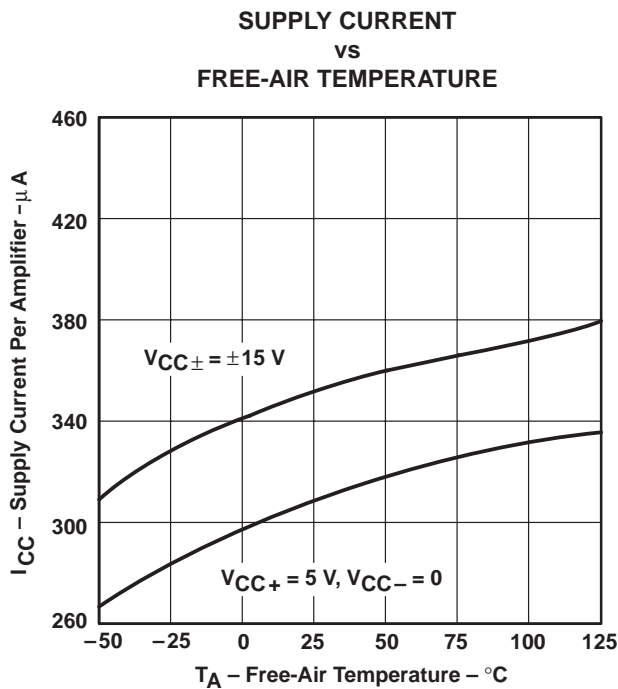
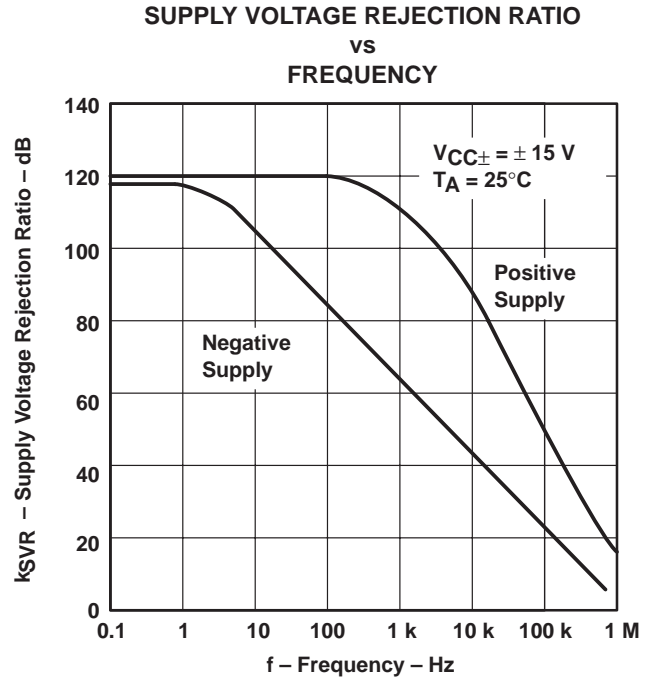
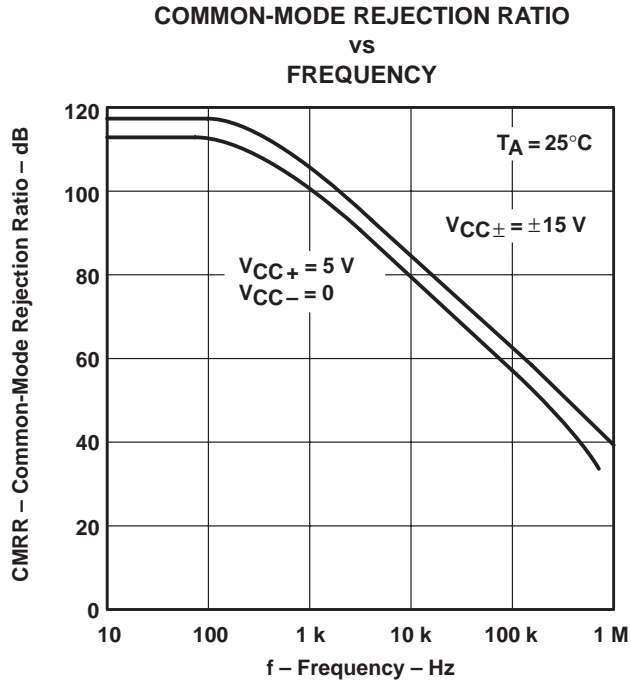
Figure 12

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE  
 AND EQUIVALENT INPUT NOISE CURRENT  
 vs  
 FREQUENCY

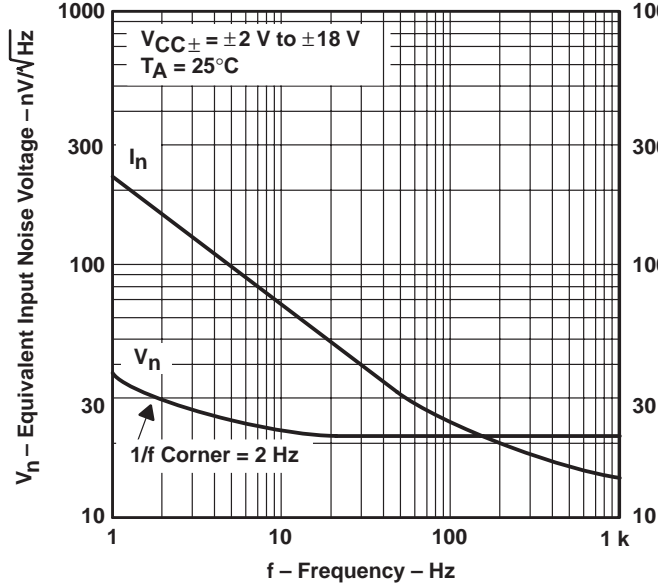


Figure 17

PEAK-TO-PEAK INPUT NOISE VOLTAGE  
 OVER A  
 10-SECOND PERIOD

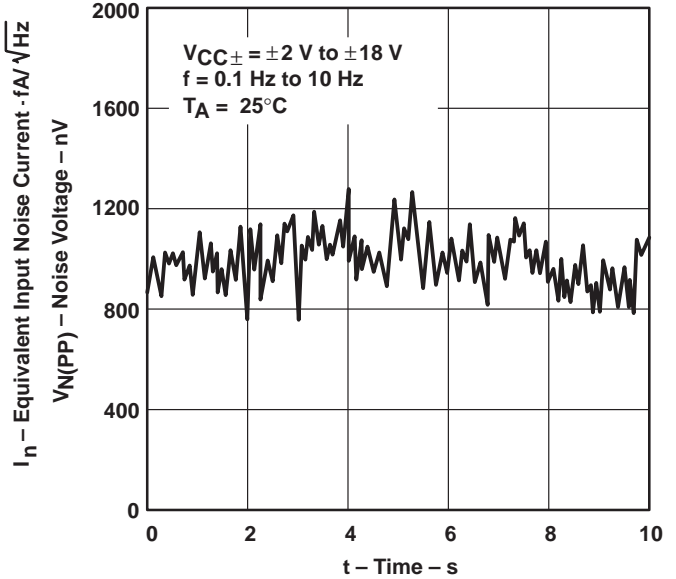


Figure 18

VOLTAGE-FOLLOWER  
 SMALL-SIGNAL  
 PULSE RESPONSE

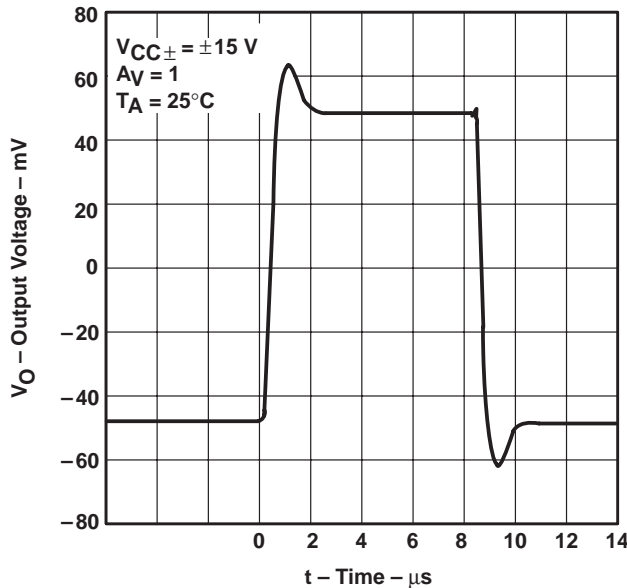


Figure 19

VOLTAGE-FOLLOWER  
 LARGE-SIGNAL  
 PULSE RESPONSE

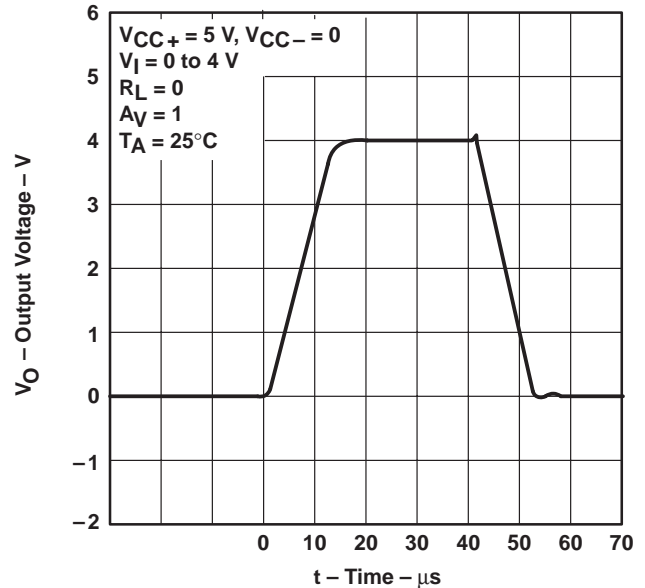
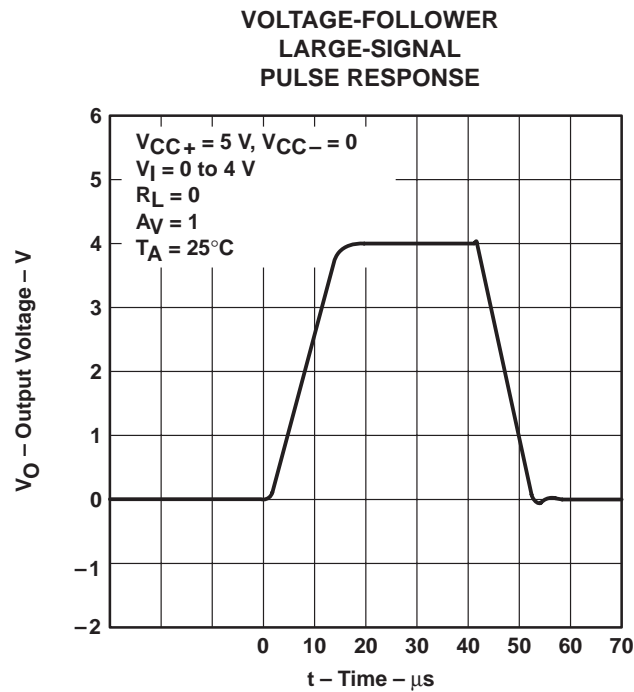
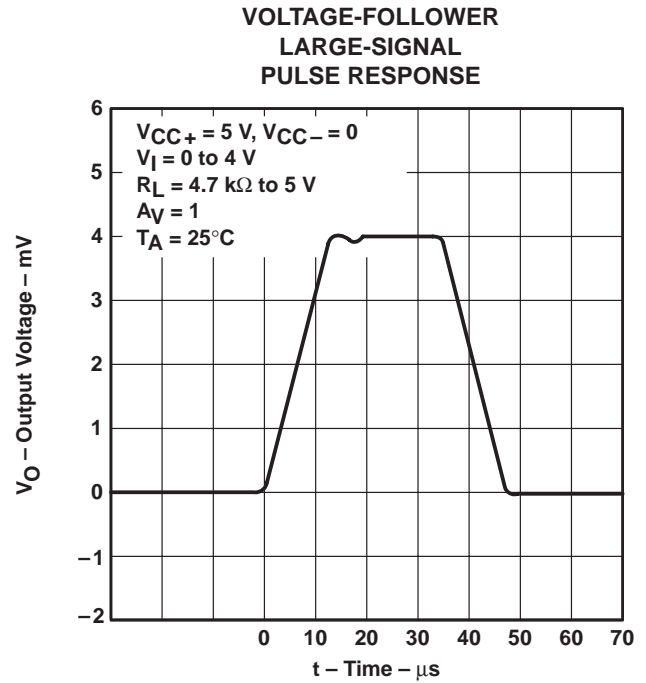
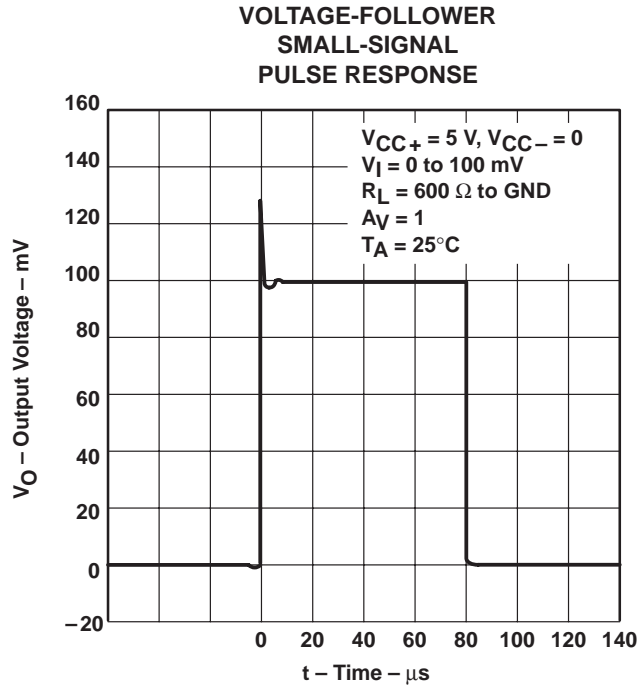


Figure 20

# LT1014, LT1014A, LT1014D QUAD PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS





APPLICATION INFORMATION

single-supply operation

The LT1014 is fully specified for single-supply operation ( $V_{CC-} = 0$ ). The common-mode input voltage range includes ground, and the output swings within a few millivolts of ground.

Furthermore, the LT1014 has specific circuitry that addresses the difficulties of single-supply operation, both at the input and at the output. At the input, the driving signal can fall below 0 V, either inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, the LT1014 is designed to deal with the following two problems that can occur:

1. On many other operational amplifiers, when the input is more than a diode drop below ground, unlimited current will flow from the substrate ( $V_{CC-}$  terminal) to the input, which can destroy the unit. On the LT1014, the 400- $\Omega$  resistors in series with the input (see schematic) protect the device even when the input is 5 V below ground.
2. When the input is more than 400 mV below ground (at  $T_A = 25^\circ\text{C}$ ), the input stage of similar type operational amplifiers saturates and phase reversal occurs at the output. This can cause lock-up in servo systems. Because of a unique phase-reversal protection circuitry (Q21, Q22, Q27, and Q28), the LT1014 outputs do not reverse, even when the inputs are at  $-1.5$  V (see Figure 24).

This phase-reversal protection circuitry, however, does not function when the other operational amplifier on the LT1014 is driven hard into negative saturation at the output. Phase-reversal protection does not work on amplifier:

- 1 when 4's output is in negative saturation (the outputs of 2 and 3 have no effect).
- 2 when 3's output is in negative saturation (the outputs of 1 and 4 have no effect).
- 3 when 2's output is in negative saturation (the outputs of 1 and 4 have no effect).
- 4 when 1's output is in negative saturation (the outputs of 2 and 3 have no effect).

At the output, other single-supply designs either cannot swing to within 600 mV of ground or cannot sink more than a few microamperes while swinging to ground. The all-NPN output stage of the LT1014 maintains its low output resistance and high gain characteristics until the output is saturated. In dual-supply operations, the output stage is free of crossover distortion.

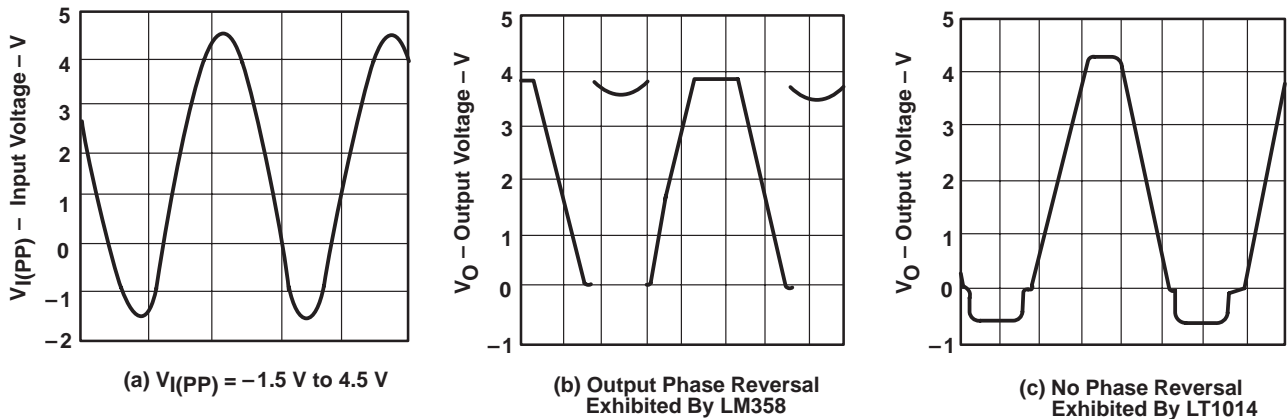


Figure 24. Voltage-Follower Response With Input Exceeding the Negative Common-Mode Input Voltage Range

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## APPLICATION INFORMATION

### comparator applications

The single-supply operation of the LT1014 lends itself for use as a precision comparator with TTL-compatible output. In systems using both operational amplifiers and comparators, the LT1014 can perform multiple duties. Refer to Figures 25 and 26.

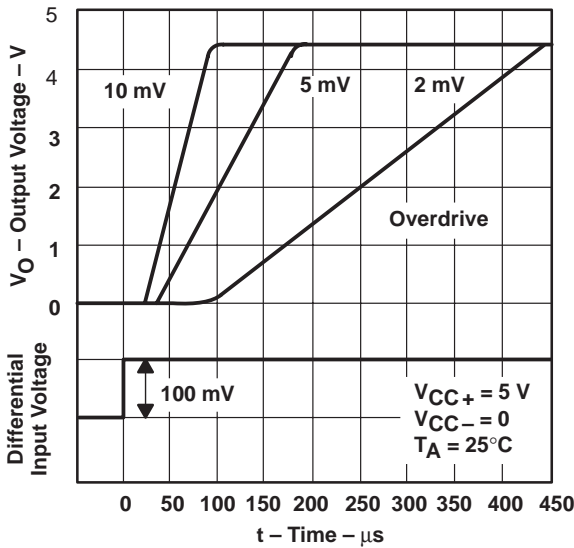


Figure 25. Low-to-High-Level Output Response for Various Input Overdrives

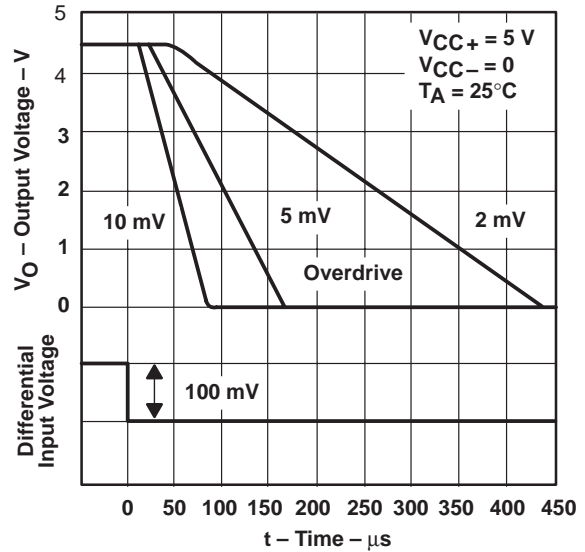


Figure 26. High-to-Low-Level Output Response for Various Input Overdrives

### low-supply operation

The minimum supply voltage for proper operation of the LT1014 is 3.4 V (three Ni-Cad batteries). Typical supply current at this voltage is 290  $\mu$ A; therefore, power dissipation is only 1 mW per amplifier.

### offset voltage and noise testing

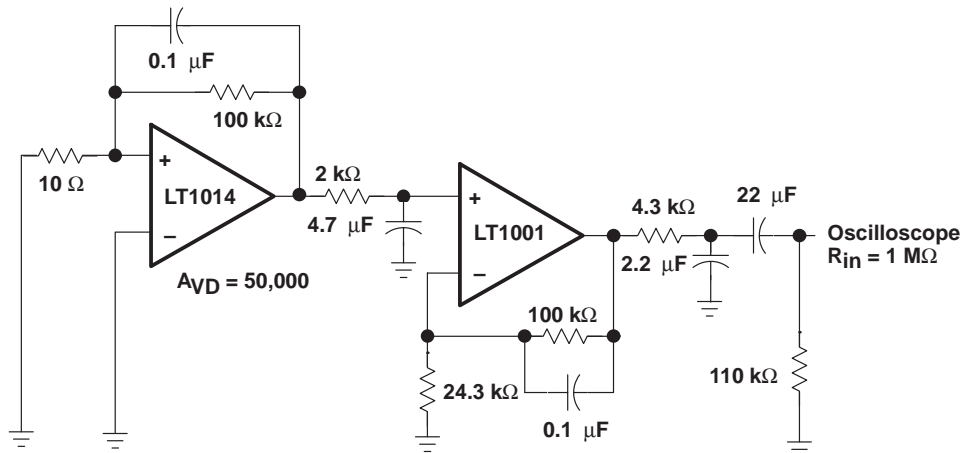
The test circuit for measuring input offset voltage and its temperature coefficient is shown in Figure 30. This circuit with supply voltages increased to  $\pm 20$  V is also used as the burn-in configuration.

The peak-to-peak equivalent input noise voltage of the LT1014 is measured using the test circuit shown in Figure 27. The frequency response of the noise tester indicates that the 0.1-Hz corner is defined by only one zero. The test time to measure 0.1-Hz to 10-Hz noise should not exceed 10 seconds, as this time limit acts as an additional zero to eliminate noise contribution from the frequency band below 0.1 Hz.

An input noise voltage test is recommended when measuring the noise of a large number of units. A 10-Hz input noise voltage measurement correlates well with a 0.1-Hz peak-to-peak noise reading because both results are determined by the white noise and the location of the  $1/f$  corner frequency.

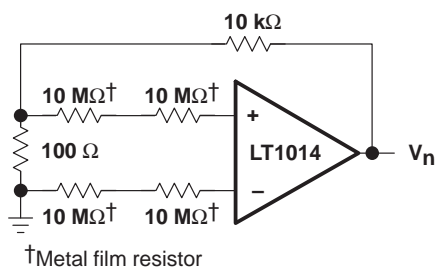
Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.

APPLICATION INFORMATION



NOTE: All capacitor values are for nonpolarized capacitors only.

Figure 27. 0.1-Hz to 10-Hz Peak-to-Peak Noise Test Circuit



†Metal film resistor

$$I_n = \frac{[V_{no^2} - (820 \text{ nV})^2]^{1/2}}{40 \text{ M}\Omega \times 100}$$

†Metal film resistor

Figure 28. Noise Current Test Circuit and Formula

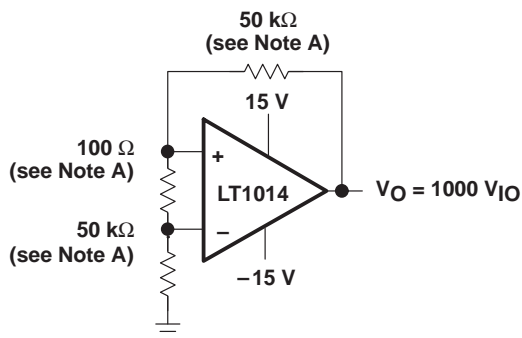
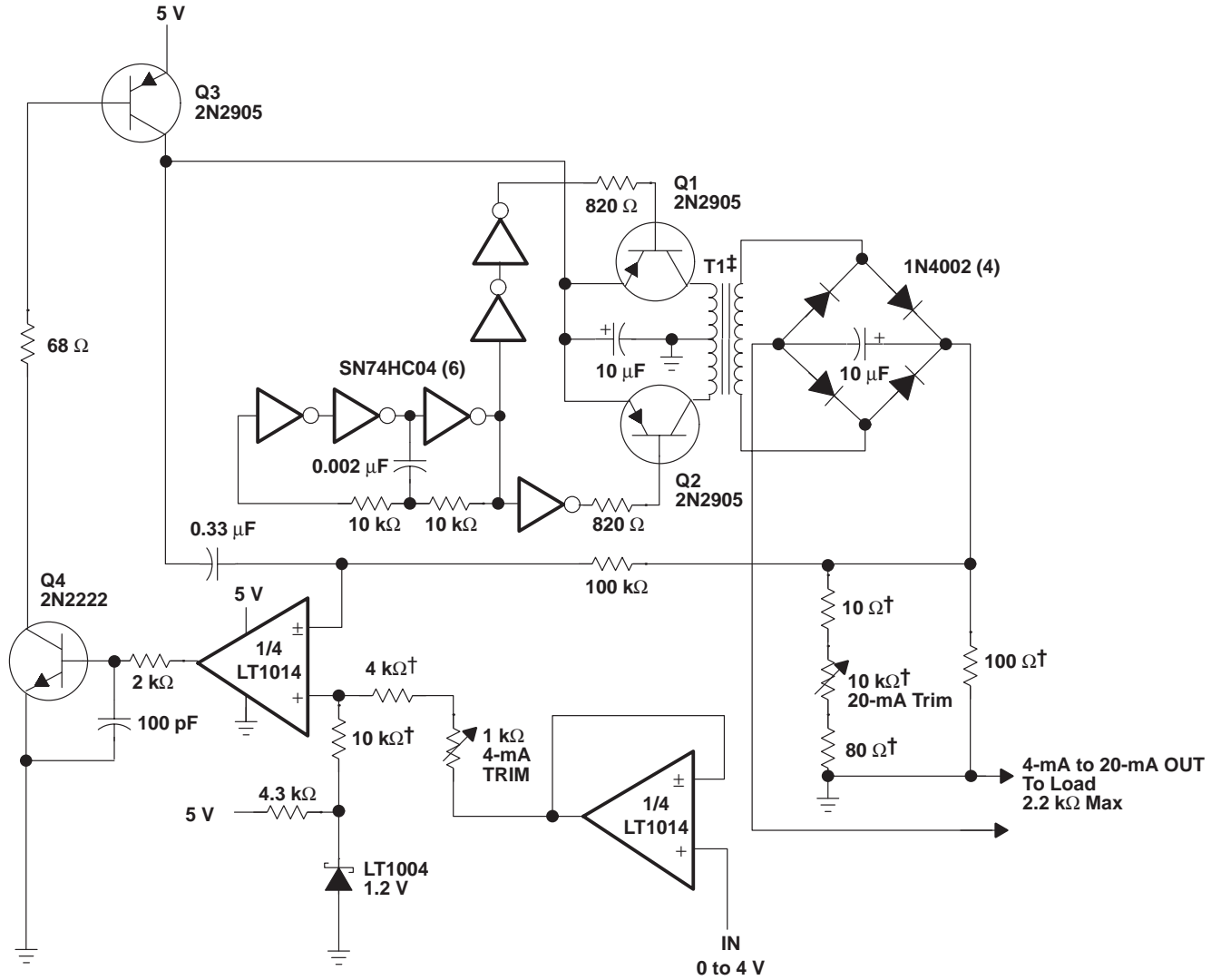


Figure 29. Test Circuit for  $V_{IO}$  and  $\alpha V_{IO}$

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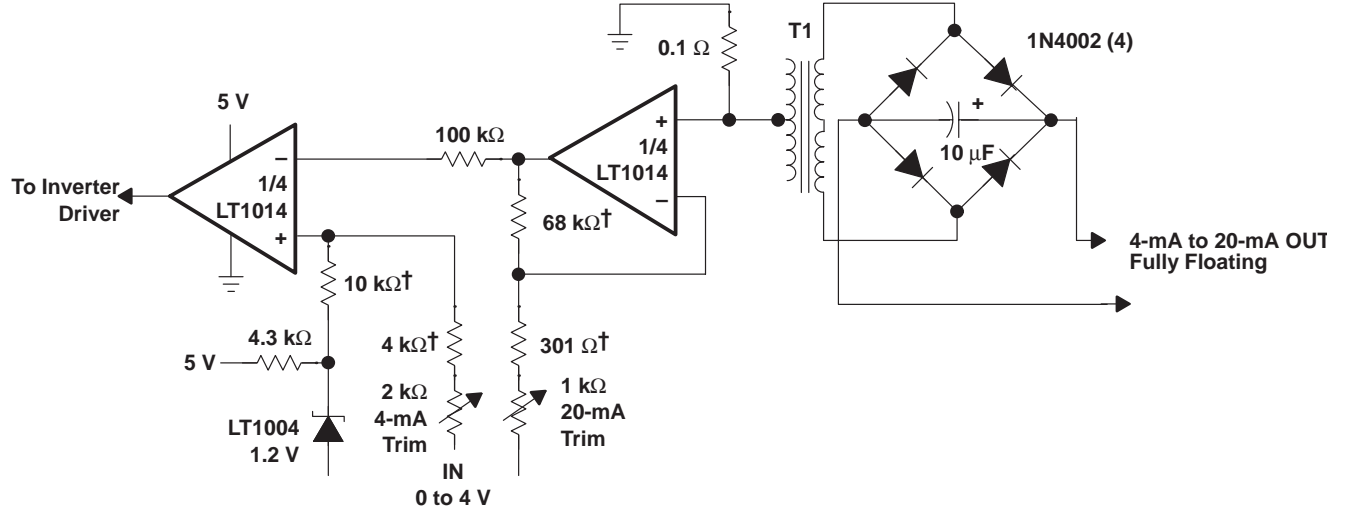
## APPLICATION INFORMATION



† 1% film resistor. Match 10-kΩ resistors 0.05%.  
‡ T1 = PICO-31080

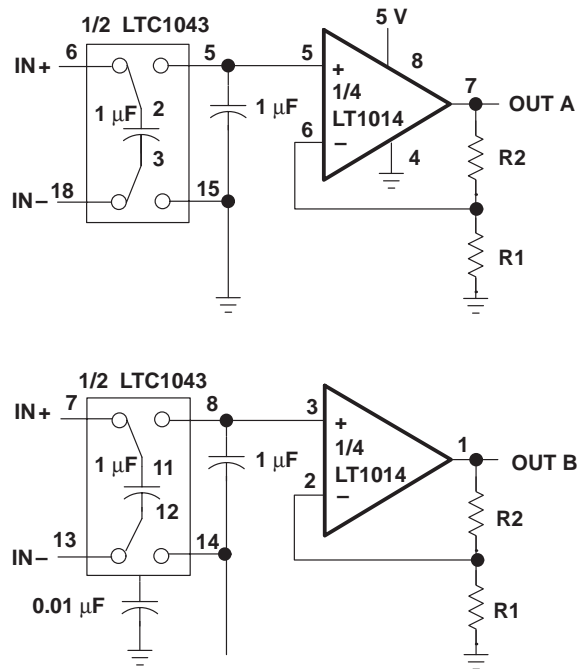
Figure 30. 5-V Powered 4-mA – 20-mA Current Loop Transmitter With 12-Bit Accuracy

APPLICATION INFORMATION



† 1% film resistor.

Figure 31. Fully Floating Modification to 4-mA – 20-mA Current Loop Transmitter With 8-Bit Accuracy



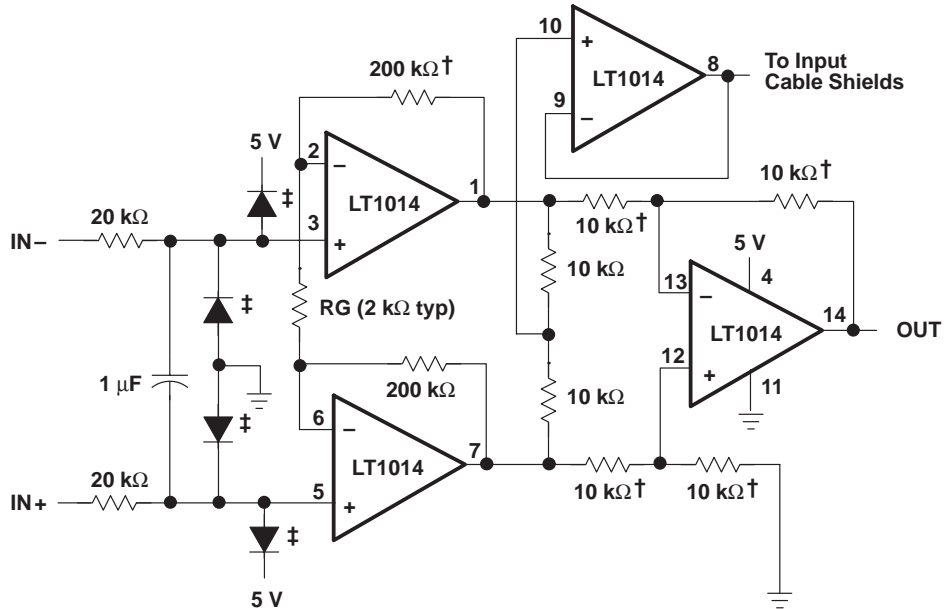
NOTE A:  $V_{IO} = 150 \mu\text{V}$ ,  $A_{VD} = (R1/R2) + 1$ ,  $\text{CMRR} = 120 \text{ dB}$ ,  $V_{ICR} = 0 \text{ to } 5 \text{ V}$ .

Figure 32. 5-V Single-Supply Dual Instrumentation Amplifier

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## APPLICATION INFORMATION



† 1% film resistor. Match 10-kΩ resistors 0.05%.

‡ For high source impedances, use 2N2222 as diodes (with collector connected to base).

NOTE A:  $A_{VD} = (400,000/R_G) + 1$

**Figure 33. 5-V Powered Precision Instrumentation Amplifier**

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