

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

SLOS018E – MAY 1988 REVISED SEPTEMBER 2001

- **Single-Supply Operation**
  - Input Voltage Range Extends to Ground
  - Output Swings to Ground While Sinking Current
- **Input Offset Voltage**
  - 150  $\mu\text{V}$  Max at 25°C for LT1013A
- **Offset Voltage Temperature Coefficient**
  - 2.5  $\mu\text{V}/^\circ\text{C}$  Max for LT1013A
- **Input Offset Current**
  - 0.8 nA Max at 25°C for LT1013A
- **High Gain . . . 1.5 V/ $\mu\text{V}$  Min ( $R_L = 2\text{ k}\Omega$ ),  
0.8 V/ $\mu\text{V}$  Min ( $R_L = 600\text{ k}\Omega$ ) for LT1013A**
- **Low Supply Current . . . 0.5 mA Max at  
 $T_A = 25^\circ\text{C}$  for LT1013A**
- **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 LT1013 devices are dual precision operational amplifiers, featuring high gain, low supply current, low noise, and low-offset-voltage temperature coefficient.

The LT1013 devices can be operated from a single 5-V power supply; the common-mode input voltage range includes ground, and the output can also swing to within a few millivolts of ground. Crossover distortion is eliminated. The LT1013 can be operated with both dual  $\pm 15\text{-V}$  and single 5-V supplies.

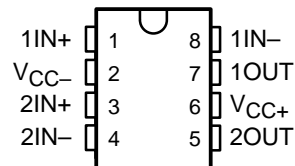
The LT1013C and LT1013AC, and LT1013D are characterized for operation from 0°C to 70°C. The LT1013I and LT1013AI, and LT1013DI are characterized for operation from –40°C to 105°C. The LT1013M and LT1013AM, and LT1013DM are characterized for operation over the full military temperature range of –55°C to 125°C.

## AVAILABLE OPTIONS

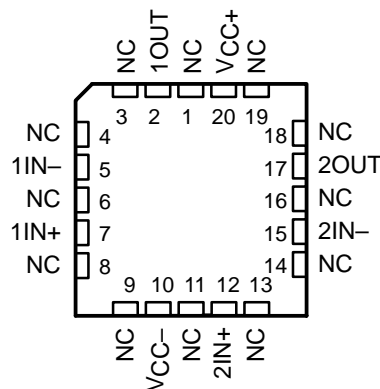
$T_A$	$V_{IO\text{max}}$ AT 25°C ( $\mu\text{V}$ )	PACKAGED DEVICES			
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	150	—	—	—	LT1013ACP
	300	—	—	—	LT1013CP
	800	LT1013DD	—	—	LT1013DP
–40°C to 105°C	150	—	—	—	LT1013AIP
	300	—	—	—	LT1013IP
	800	LT1013DID	—	—	LT1013DIP
–55°C to 125°C	150	—	LT1013AMFK	LT1013AMJG	—
	300	—	—	LT1013MJG	—
	800	LT1013DMD	—	LT1013DMJG	—

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LT1013DDR).

**D PACKAGE  
(TOP VIEW)**

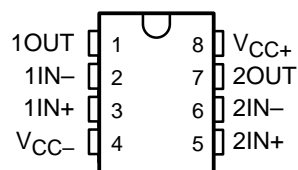


**FK PACKAGE  
(TOP VIEW)**



NC – No internal connection

**JG OR P PACKAGE  
(TOP VIEW)**



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.

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.

**TEXAS  
INSTRUMENTS**

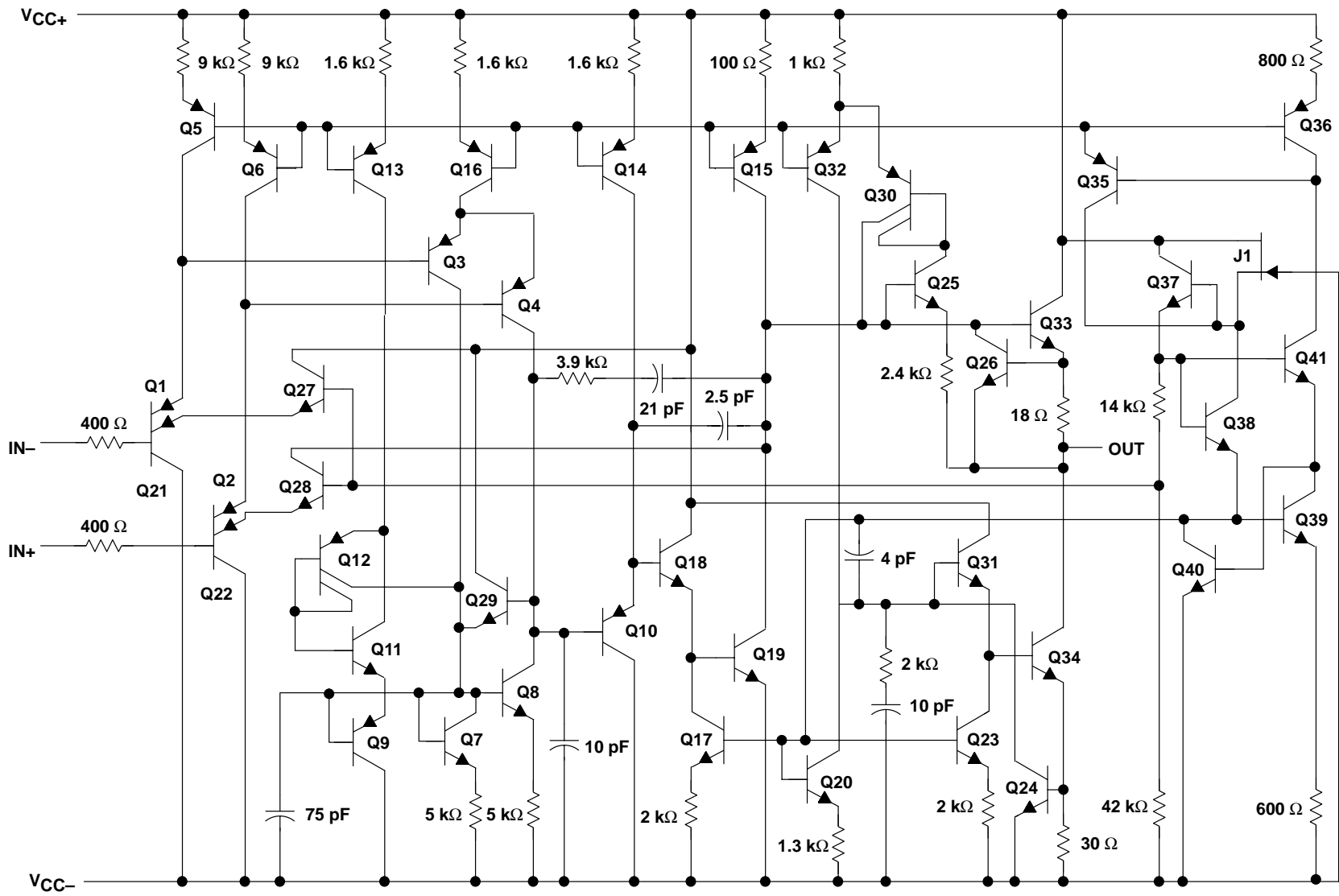
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On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

SLOS018E — MAY 1988 — REVISED SEPTEMBER 2001

## schematic (each amplifier)



Component values are nominal.

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

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

Supply voltage (see Note 1): $V_{CC+}$ .....	22 V
$V_{CC-}$ .....	-22 V
Input voltage range, $V_I$ (any input, see Note 1) .....	$V_{CC-} - 5\text{ V}$ to $V_{CC+}$
Differential input voltage (see Note 2) .....	$\pm 30\text{ V}$
Duration of short-circuit current at (or below) 25°C (see Note 3) .....	Unlimited
Package thermal impedance, $\theta_{JA}$ (see Note 4): D package .....	97°C/W
P package .....	85°C/W
Case temperature for 60 seconds: FK package .....	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package .....	260°C
JG package .....	300°C
Storage temperature range, $T_{stg}$ .....	-65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- 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  $IN+$  with respect to  $IN-$ .
  3. The output may be shorted to either supply.
  4. The package thermal impedance is calculated in accordance with JESD 51-7.



LT1013, LT1013A, LT1013D  
DUAL 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 <sub>A</sub> <sup>†</sup>	LT1013C			LT1013AC			LT1013DC			UNIT
			MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
V <sub>IO</sub> Input offset voltage	R <sub>S</sub> = 50 Ω	25°C		60	300		40	150		200	800	μV
		Full range			400			240			1000	
α <sub>VIO</sub> Temperature coefficient of input offset voltage		Full range		0.4	2.5		0.3	2		0.7	5	μV/°C
		Long-term drift of input offset voltage	25°C		0.5			0.4			0.5	
I <sub>IO</sub> Input offset current		25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
		Full range			2.8			1.5			2.8	
I <sub>IB</sub> Input bias current		25°C		-15	-30		-12	-20		-15	-30	nA
		Full range			-38			-25			-38	
V <sub>ICR</sub> 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	-15 to 13			-15 to 13			-15 to 13			
V <sub>OM</sub> Maximum peak output voltage swing	R <sub>L</sub> = 2 kΩ	25°C	±12.5	±14		±13	±14		±12.5	±14	V	
		Full range	±12			±12.5			±12			
A <sub>VD</sub> Large-signal differential voltage amplification	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 600 Ω	25°C	0.5	0.2		0.8	2.5		0.5	2	V/μV	
	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 2 kΩ	25°C	1.2	7		1.5	8		1.2	7		
	Full range	0.7			1		0.7					
CMRR Common-mode rejection ratio	V <sub>IC</sub> = -15 V to 13.5 V	25°C	97	114		100	117		97	114	dB	
	V <sub>IC</sub> = -14.9 V to 13 V	Full range	94			98			94			
k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>IO</sub> )	V <sub>CC+</sub> = ±2 V to ±18 V	25°C	100	117		103	120		100	117	dB	
		Full range	97			101			97			
Channel separation	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 2 kΩ	25°C	120	137		123	140		120	137	dB	
r <sub>id</sub> Differential input resistance		25°C	70	300		100	400		70	300	MΩ	
r <sub>ic</sub> Common-mode input resistance		25°C		4			5			4	GΩ	
I <sub>CC</sub> Supply current per amplifier		25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
		Full range			0.7			0.55			0.6	

<sup>†</sup> Full range is 0°C to 70°C.  
<sup>‡</sup> All typical values are at T<sub>A</sub> = 25°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	$T_A$ †	LT1013C			LT1013AC			LT1013DC			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C		90	450		60	250		250	950	$\mu\text{V}$
		Full range			570			350			1200	
$I_{IO}$ Input offset current		25°C		0.3	2		0.2	1.3		0.3	2	nA
		Full range			6			3.5			6	
$I_{IB}$ Input bias current		25°C		-18	-50		-15	-35		-18	-50	nA
		Full range			-90			-55			-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		0 to 3.5	-0.3 to 3.8		V
		Full range	0 to 3			0 to 3			0 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				13			13			
	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			3.2			3.3			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			1		$\text{V}/\mu\text{V}$
		Full range			0.55			0.5			0.55	
$I_{CC}$ Supply current per amplifier		25°C		0.32	0.5		0.31	0.45		0.32	0.5	mA
		Full range						0.5				

† Full range is 0°C to 70°C.

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

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		$\text{pA}/\sqrt{\text{Hz}}$

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

PARAMETER	TEST CONDITIONS	T <sub>A</sub> <sup>†</sup>	LT1013I			LT1013AI			LT1013DI			UNIT
			MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
V <sub>IO</sub> Input offset voltage	R <sub>S</sub> = 50 Ω	25°C		60	300		40	150		200	800	μV
		Full range			550			300			1000	
α <sub>V<sub>IO</sub></sub> Temperature coefficient of input offset voltage		Full range		0.4	2.5		0.3	2		0.7	5	μV/°C
Long-term drift of input offset voltage		25°C		0.5			0.4			0.5		μV/mo
I <sub>IO</sub> Input offset current		25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
		Full range			2.8			1.5			2.8	
I <sub>IB</sub> Input bias current		25°C		-15	-30		-12	-20		-15	-30	nA
		Full range			-38			-25			-38	
V <sub>ICR</sub> 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		-15 to 13			-15 to 13			-15 to 13		
V <sub>OM</sub> Maximum peak output voltage swing	R <sub>L</sub> = 2 kΩ	25°C	±12.5	±14		±13	±14		±12.5	±14		V
		Full range		±12			±12.5			±12		
A <sub>VD</sub> Large-signal differential voltage amplification	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 600 Ω	25°C	0.5	0.2		0.8	2.5		0.5	2		V/μV
	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 2 kΩ	25°C	1.2	7		1.5	8		1.2	7		
	Full range		0.7			1			0.7			
CMRR Common-mode rejection ratio	V <sub>IC</sub> = -15 V to 13.5 V	25°C	97	114		100	117		97	114		dB
	V <sub>IC</sub> = -14.9 V to 13 V	Full range		94			97			94		
k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>IO</sub> )	V <sub>CC±</sub> = ±2 V to ±18 V	25°C	100	117		103	120		100	117		dB
		Full range		97			101			97		
Channel separation	V <sub>O</sub> = ±10 V, R <sub>L</sub> = 2 kΩ	25°C	120	137		123	140		120	137		dB
r <sub>id</sub> Differential input resistance		25°C	70	300		100	400		70	300		MΩ
r <sub>ic</sub> Common-mode input resistance		25°C		4			5			4		GΩ
I <sub>CC</sub> Supply current per amplifier		25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
		Full range			0.7			0.55			0.6	

<sup>†</sup> Full range is -40°C to 105°C.

<sup>‡</sup> All typical values are at T<sub>A</sub> = 25°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	$T_A$ †	LT1013I			LT1013AI			LT1013DI			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C		90	450		60	250		250	950	$\mu\text{V}$
		Full range			570			350			1200	
$I_{IO}$ Input offset current		25°C		0.3	2		0.2	1.3		0.3	2	nA
		Full range			6			3.5			6	
$I_{IB}$ Input bias current		25°C		-18	-50		-15	-35		-18	-50	nA
		Full range			-90			-55			-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		0 to 3.5	-0.3 to 3.8		V
		Full range	0 to 3			0 to 3			0 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				13			13			13	
	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	
	Output high, $R_L = 600\ \Omega$ to GND	25°C		3.4	4		3.4	4		3.4	4	
Full range			3.2			3.3			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			1	$\text{V}/\mu\text{V}$	
$I_{CC}$ Supply current per amplifier		25°C		0.32	0.5		0.31	0.45		0.32	0.5	mA
		Full range			0.55			0.5			0.55	

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

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

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		$\text{pA}/\sqrt{\text{Hz}}$

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

PARAMETER	TEST CONDITIONS	$T_A$ †	LT1013M			LT1013AM			LT1013DM			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C		60	300		40	150		200	800	$\mu\text{V}$
		Full range			550			300			1000	
$\alpha_{V_{IO}}$ Temperature coefficient of input offset voltage		Full range		0.5	2.5*		0.4	2*		0.5	2.5*	$\mu\text{V}/^\circ\text{C}$
		Long-term drift of input offset voltage	25°C		0.5			0.4			0.5	
$I_{IO}$ Input offset current		25°C		0.2	1.5		0.15	0.8		0.2	1.5	nA
		Full range			5			2.5			5	
$I_{IB}$ Input bias current		25°C		-15	-30		-12	-20		-15	-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	2.5		0.5	2	$\text{V}/\mu\text{V}$	
	$V_O = +10\ \text{V}$ , $R_L = 2\ \text{k}\Omega$	25°C	1.2	7		1.5	8		1.2	7		
	Full range	0.25			0.5			0.25				
CMRR Common-mode rejection ratio	$V_{IC} = -15\ \text{V}$ to $13.5\ \text{V}$	25°C	97	117		100	117		97	114	dB	
	$V_{IC} = -14.9\ \text{V}$ to $13\ \text{V}$	Full range	94			97			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	120		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	140		120	137	dB	
$r_{id}$ Differential input resistance		25°C	70	300		100	400		70	300	$\text{M}\Omega$	
$r_{ic}$ Common-mode input resistance		25°C		4			5			4	$\text{G}\Omega$	
$I_{CC}$ Supply current per amplifier		25°C		0.35	0.55		0.35	0.5		0.35	0.55	mA
		Full range			0.7			0.6			0.7	

\* On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.

† 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	$T_A$ †	LT1013M			LT1013AM			LT1013DM			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$	25°C	90	450		60	250		250	950	$\mu\text{V}$	
		Full range	400	1500		250	900		800	2000		
	$R_S = 50\ \Omega$ , $V_{IC} = 0.1\text{ V}$	125°C	200	750		120	450		560	1200		
$I_{IO}$ Input offset current		25°C	0.3	2		0.2	1.3		0.3	2	nA	
		Full range		10			6			10		
$I_{IB}$ Input bias current		25°C	-18	-50		-15	-35		-18	-50	nA	
		Full range		-120			-80			-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 to 3			0 to 3			0 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			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV to }4\text{ V}$ , $R_L = 500\ \Omega$	25°C	1			1			1		$\text{V}/\mu\text{V}$	
		Full range										
$I_{CC}$ Supply current per amplifier		25°C	0.32	0.5		0.31	0.45		0.32	0.5	mA	
		Full range		0.65			0.55			0.65		

† Full range is -55°C to 125°C.

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

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		$\text{pA}/\sqrt{\text{Hz}}$

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

Table of Graphs

		FIGURE	
$V_{IO}$	Input offset voltage	vs Supply voltage	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
kSVR	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	19, 21
		Large signal	20, 22, 23
	Phase shift	vs Frequency	9



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TYPICAL CHARACTERISTICS†

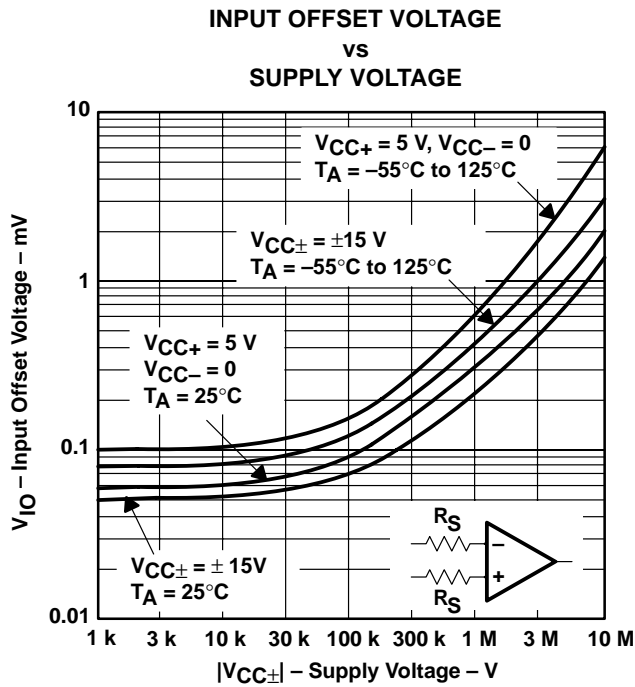


Figure 1

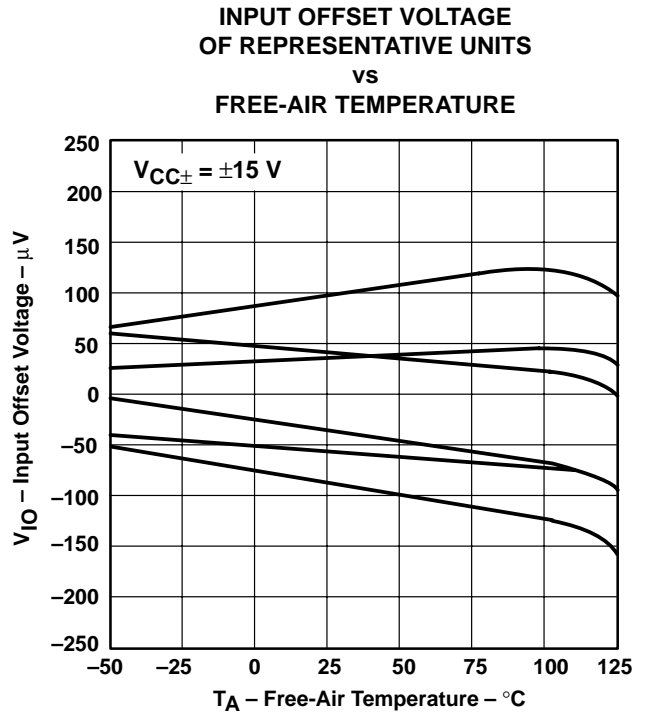


Figure 2

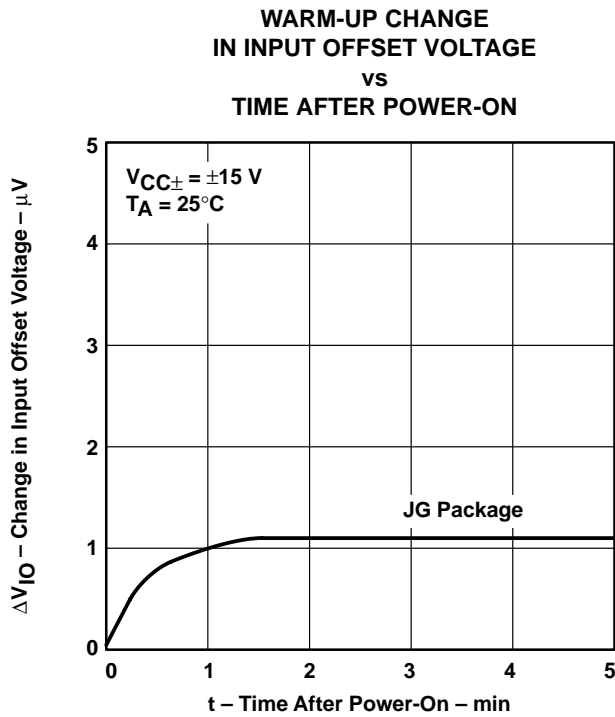


Figure 3

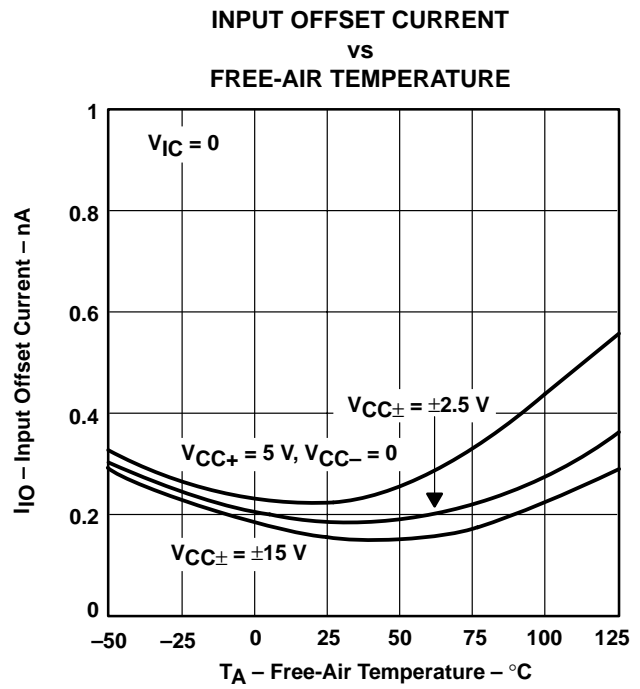


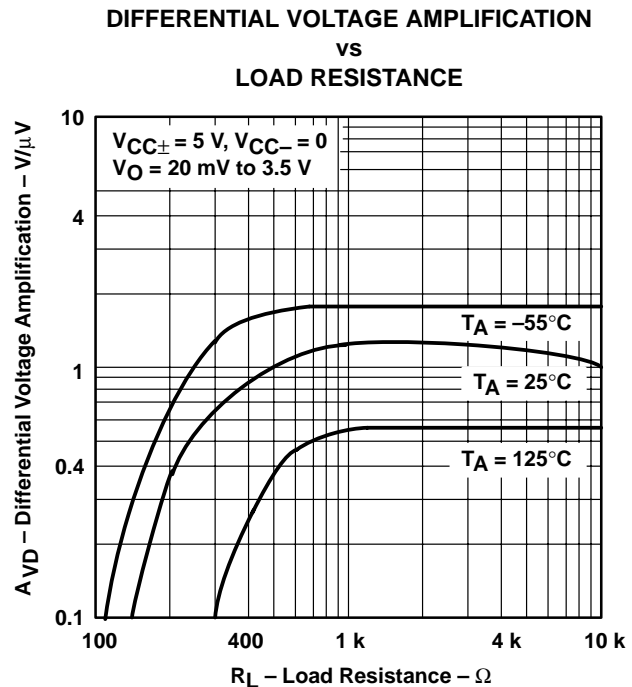
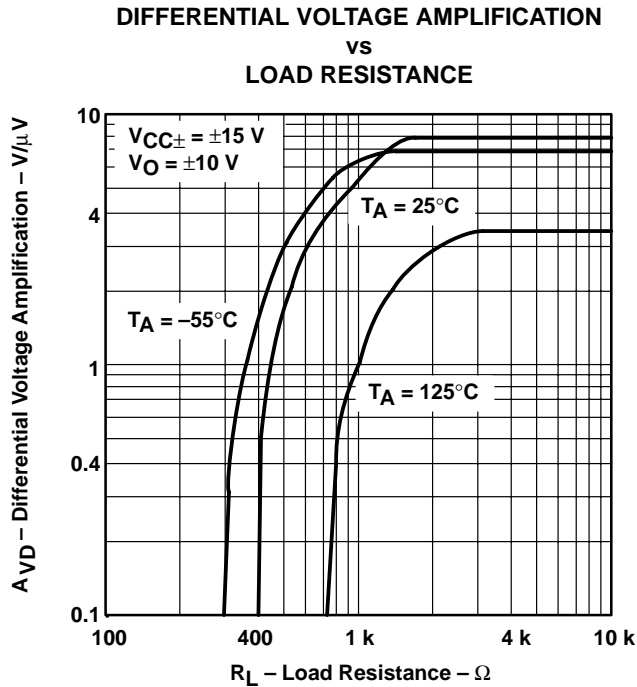
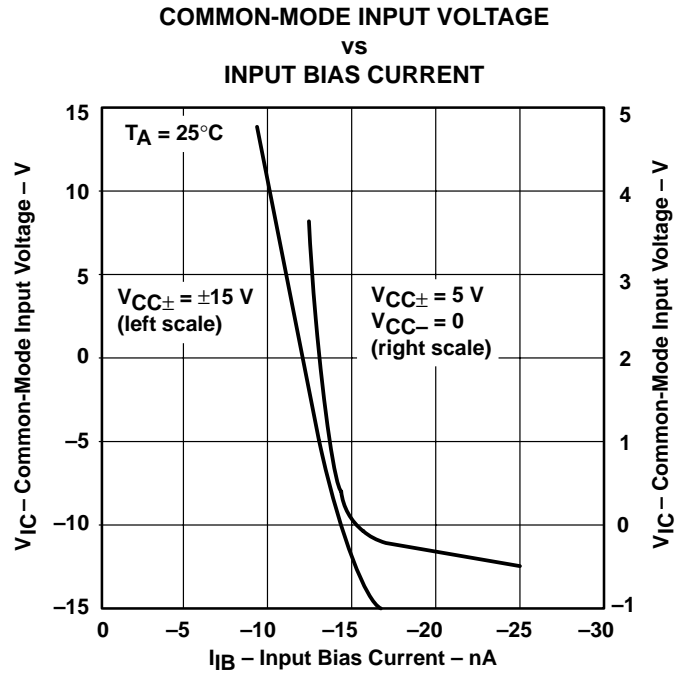
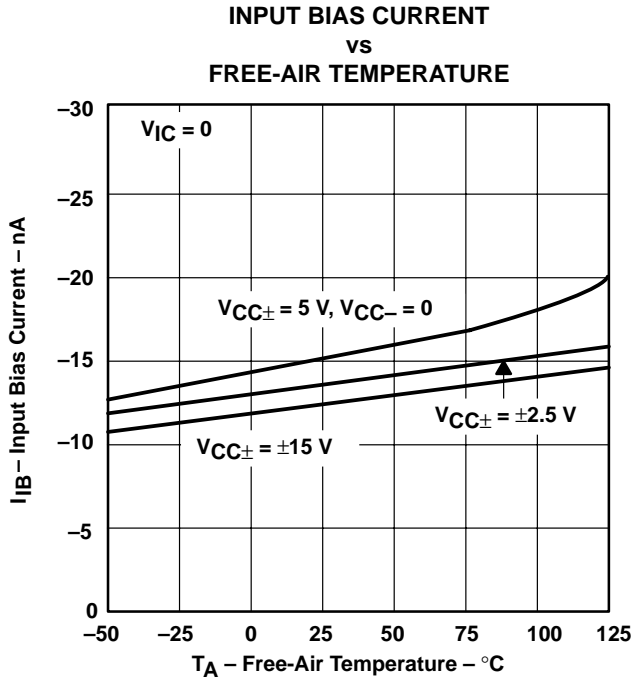
Figure 4

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

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

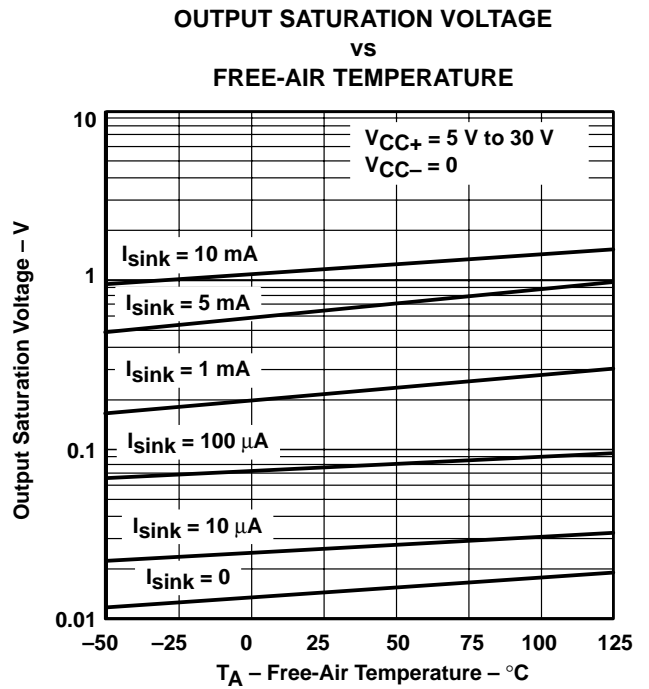
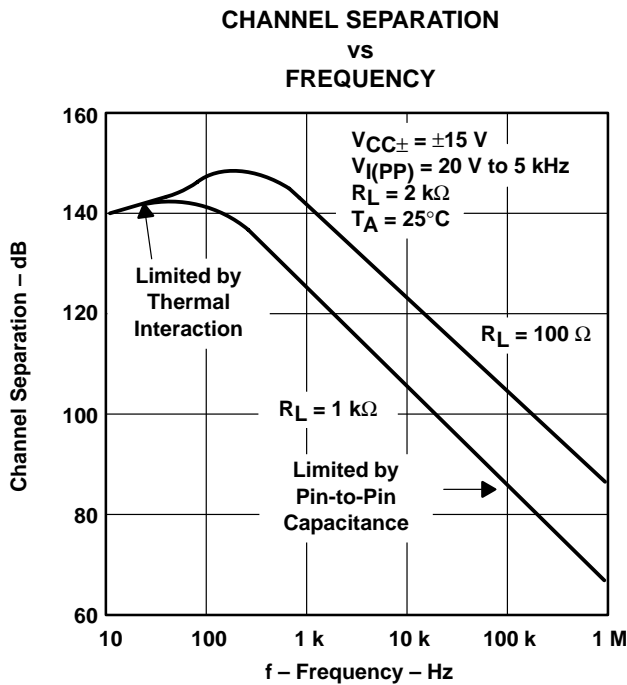
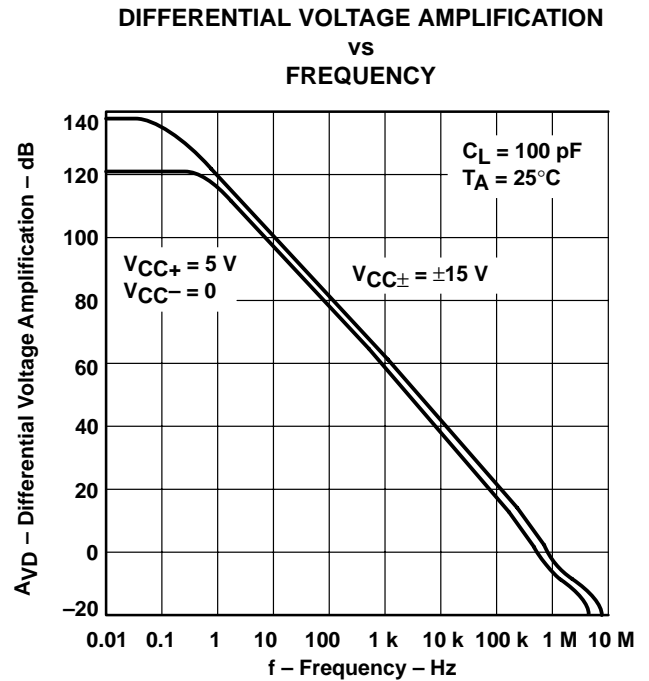
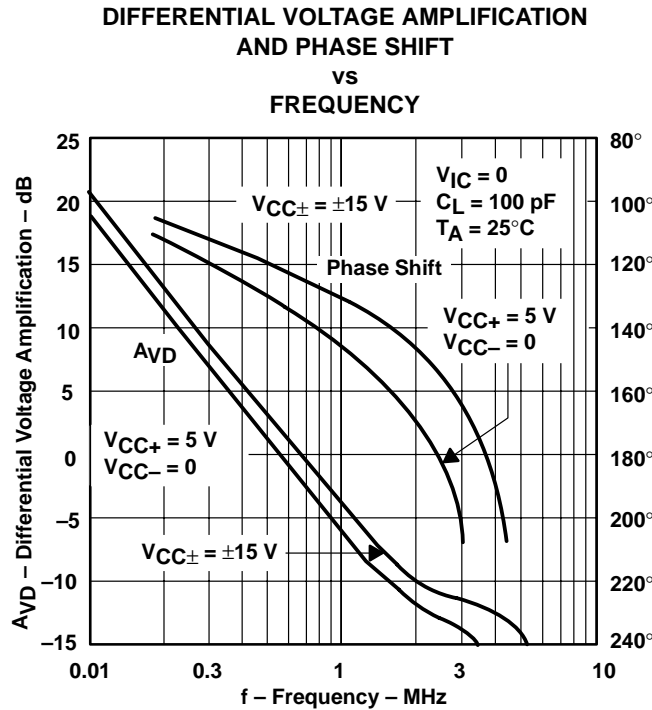
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## TYPICAL CHARACTERISTICS†



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

TYPICAL CHARACTERISTICS†

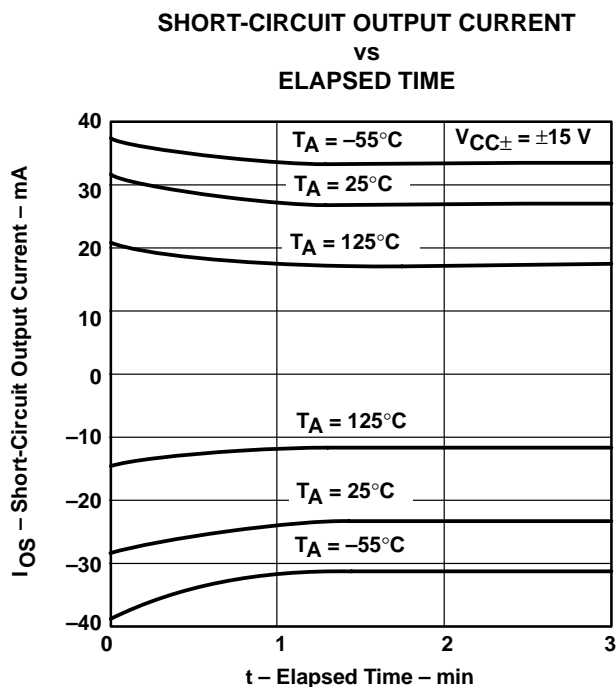
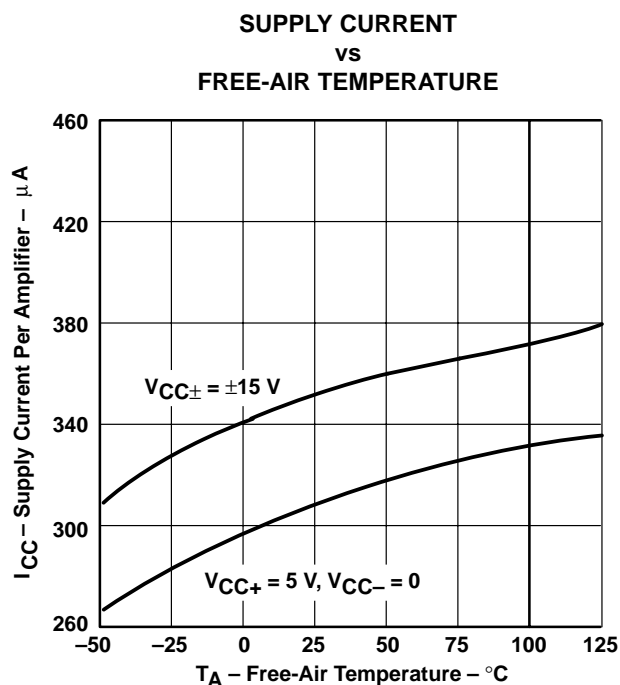
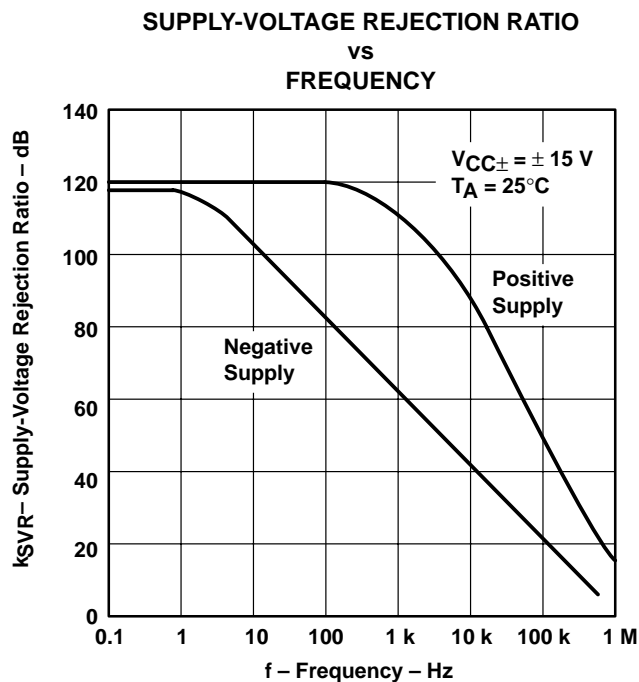
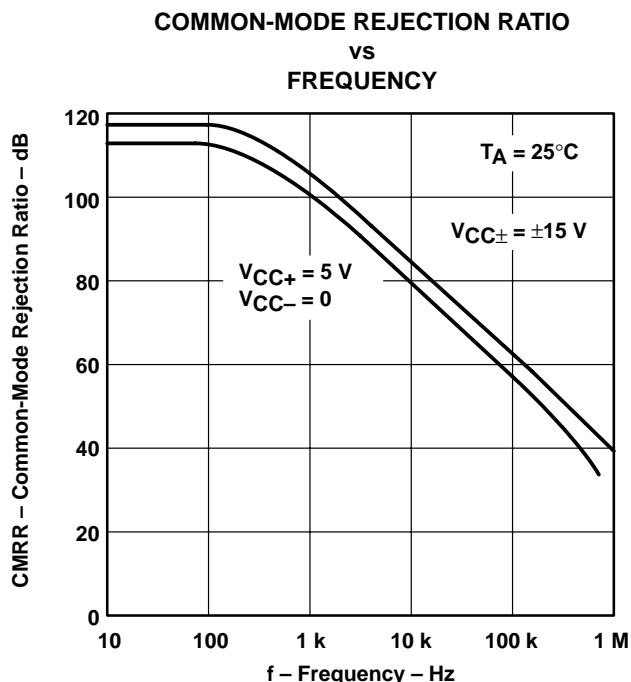


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# LT1013, LT1013A, LT1013D DUAL 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

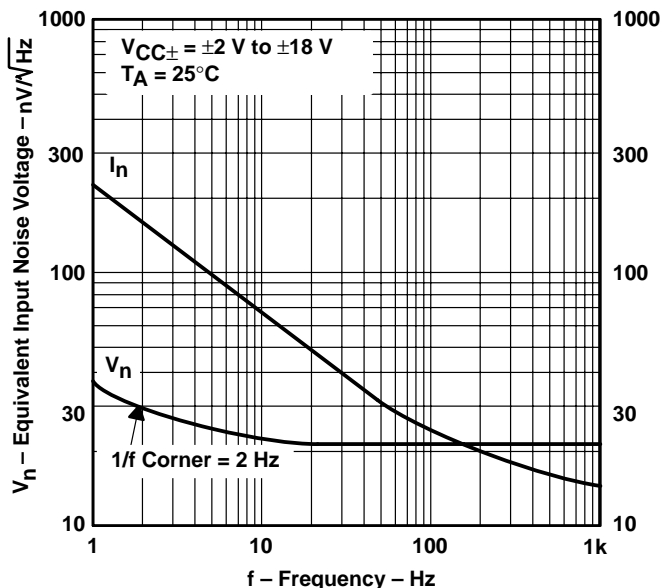


Figure 17

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

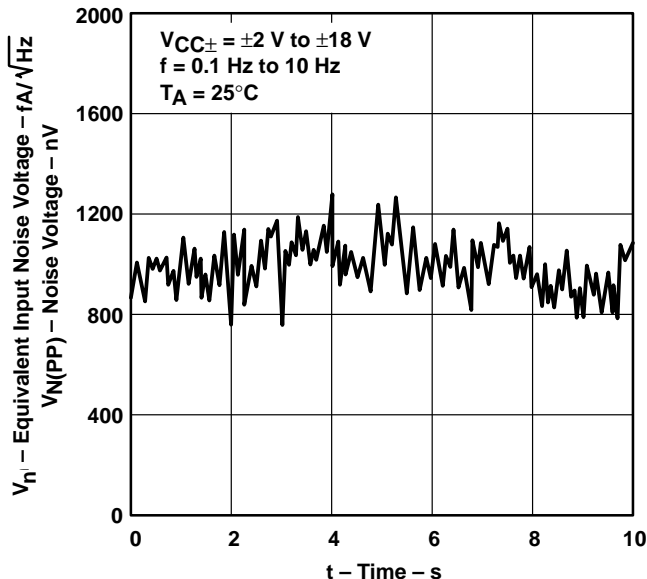


Figure 18

VOLTAGE-FOLLOWER  
 SMALL-SIGNAL  
 PULSE RESPONSE

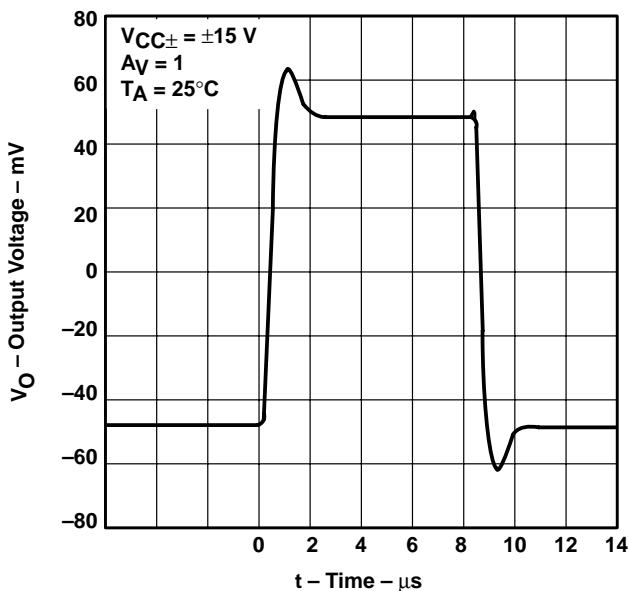


Figure 19

VOLTAGE-FOLLOWER  
 LARGE-SIGNAL  
 PULSE RESPONSE

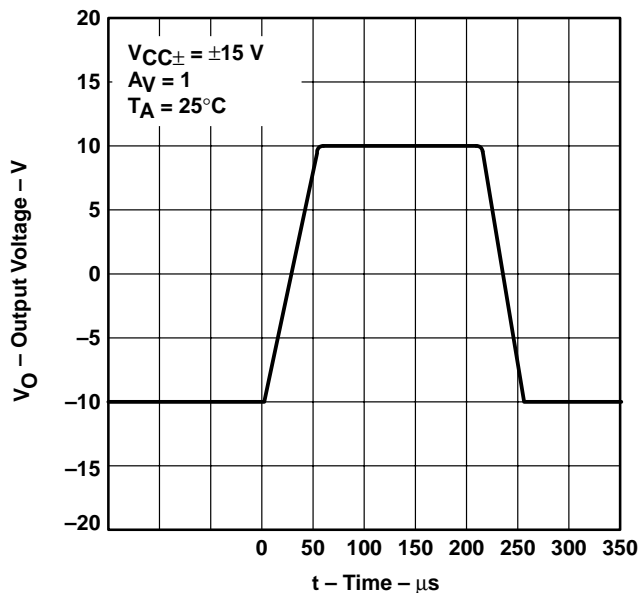


Figure 20

# LT1013, LT1013A, LT1013D DUAL PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER  
SMALL-SIGNAL  
PULSE RESPONSE

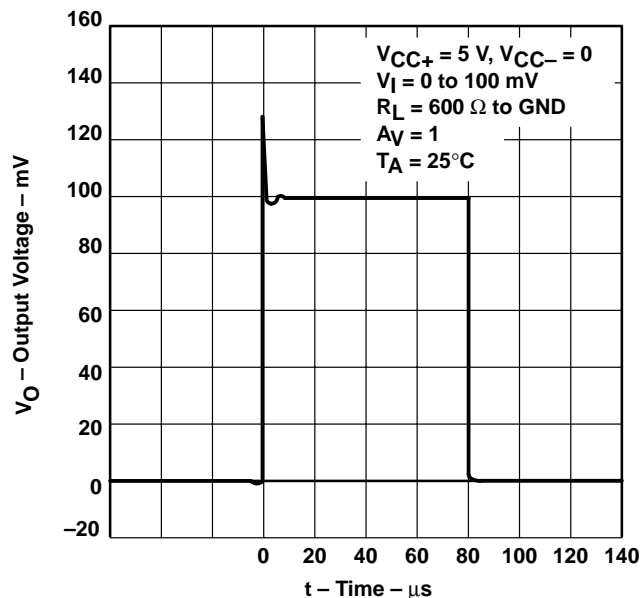


Figure 21

VOLTAGE-FOLLOWER  
LARGE-SIGNAL  
PULSE RESPONSE

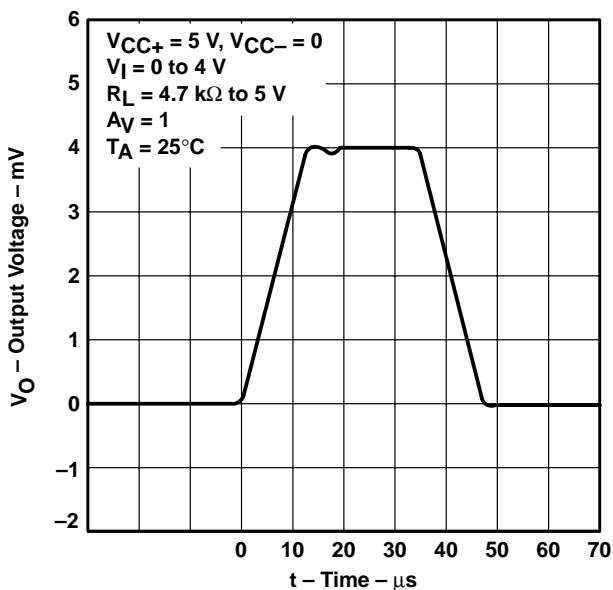


Figure 22

VOLTAGE-FOLLOWER  
LARGE-SIGNAL  
PULSE RESPONSE

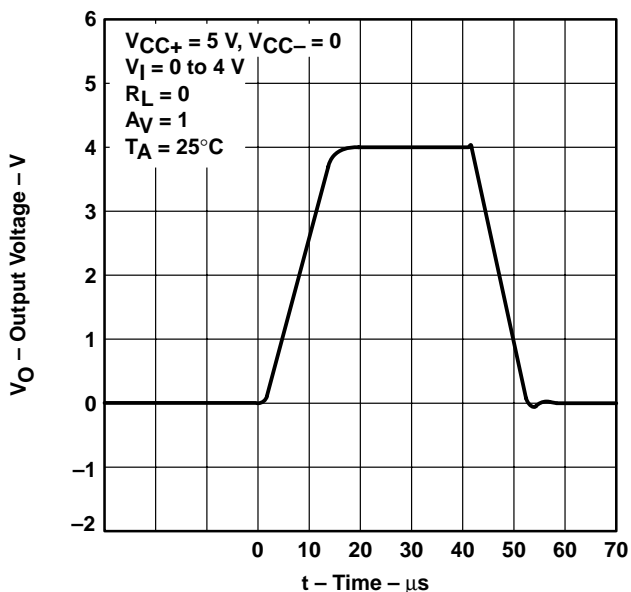


Figure 23



APPLICATION INFORMATION

single-supply operation

The LT1013 is fully specified for single-supply operation ( $V_{CC-} = 0$ ). The common-mode input voltage range includes ground, and the output swings to within a few millivolts of ground.

Furthermore, the LT1013 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 LT1013 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 flows from the substrate ( $V_{CC-}$  terminal) to the input, which can destroy the unit. On the LT1013, the 400- $\Omega$  resistors in series with the input [see *schematic (each amplifier)*] 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 lockup in servo systems. Because of a unique phase-reversal protection circuitry (Q21, Q22, Q27, and Q28), the LT1013 outputs do not reverse, even when the inputs are at  $-1.5$  V (see Figure 24).

This phase-reversal protection circuitry does not function when the other operational amplifier on the LT1013 is driven hard into negative saturation at the output. Phase-reversal protection does not work on amplifier 1 when amplifier 2 output is in negative saturation nor on amplifier 2 when amplifier 1 output is in negative saturation.

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 LT1013 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.

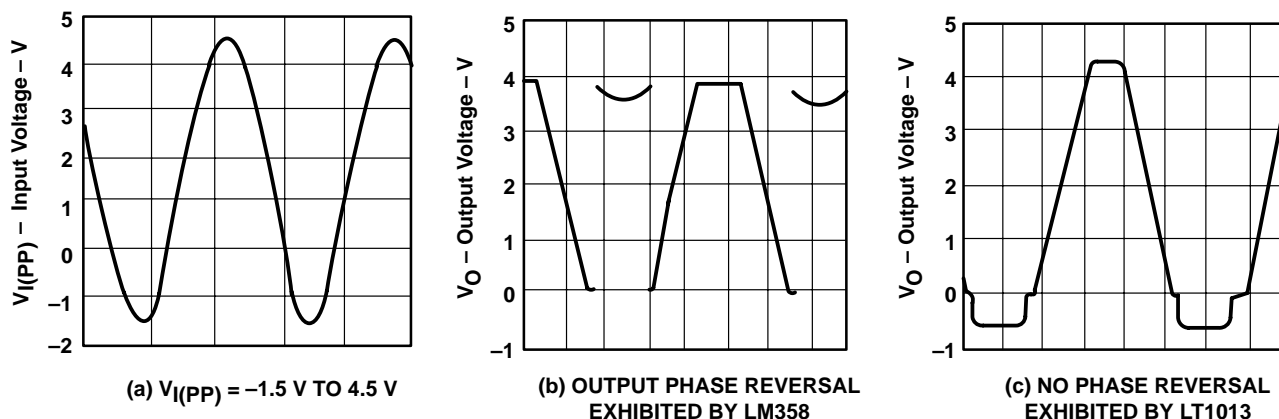


Figure 24. Voltage-Follower Response With Input Exceeding the Negative Common-Mode Input Voltage Range

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## APPLICATION INFORMATION

### comparator applications

The single-supply operation of the LT1013 lends itself for use as a precision comparator with TTL-compatible output. In systems using both operational amplifiers and comparators, the LT1013 can perform multiple duties (see Figures 25 and 26).

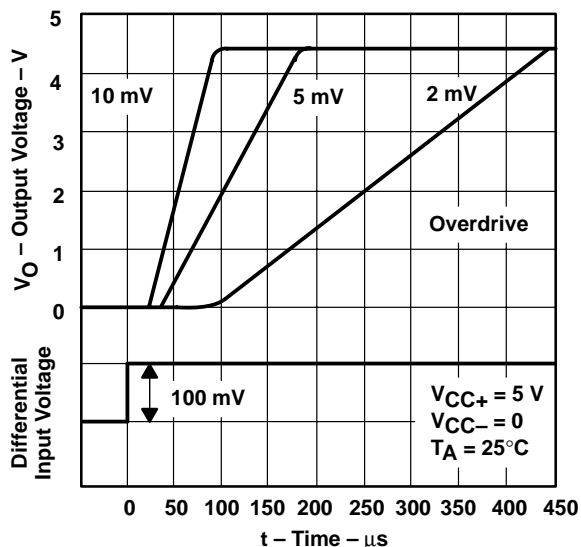


Figure 25. Low-to-High-Level Output Response for Various Input Overdrives

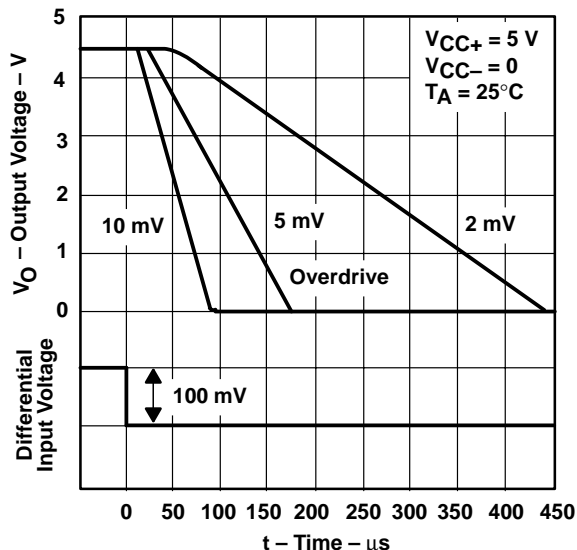


Figure 26. High-to-Low-Level Output Response for Various Input Overdrives

### low-supply operation

The minimum supply voltage for proper operation of the LT1013 is 3.4 V (three NiCad 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

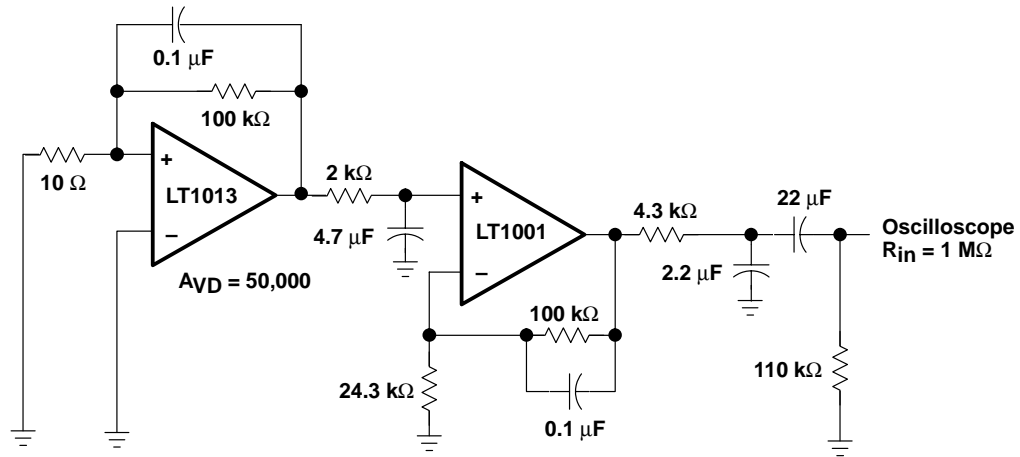
The test circuit for measuring input offset voltage and its temperature coefficient is shown in Figure 30. This circuit, with supply voltages increased to  $\pm 20$  V, also is used as the burn-in configuration.

The peak-to-peak equivalent input noise voltage of the LT1013 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.

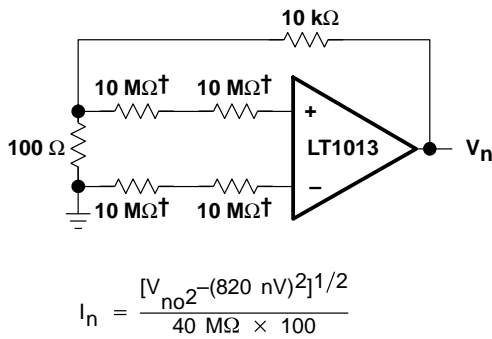
Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.

APPLICATION INFORMATION



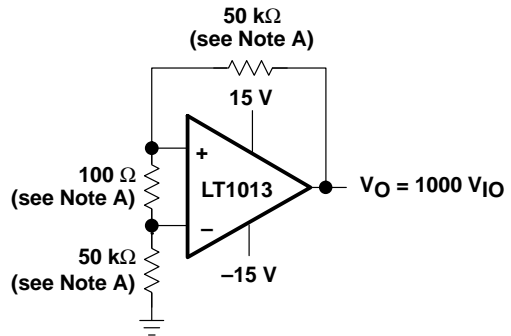
NOTE A: All capacitor values are for nonpolarized capacitors only.

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



† Metal-film resistor

Figure 28. Noise-Current Test Circuit and Formula



NOTE A: Resistors must have low thermoelectric potential.

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

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## APPLICATION INFORMATION

### typical applications

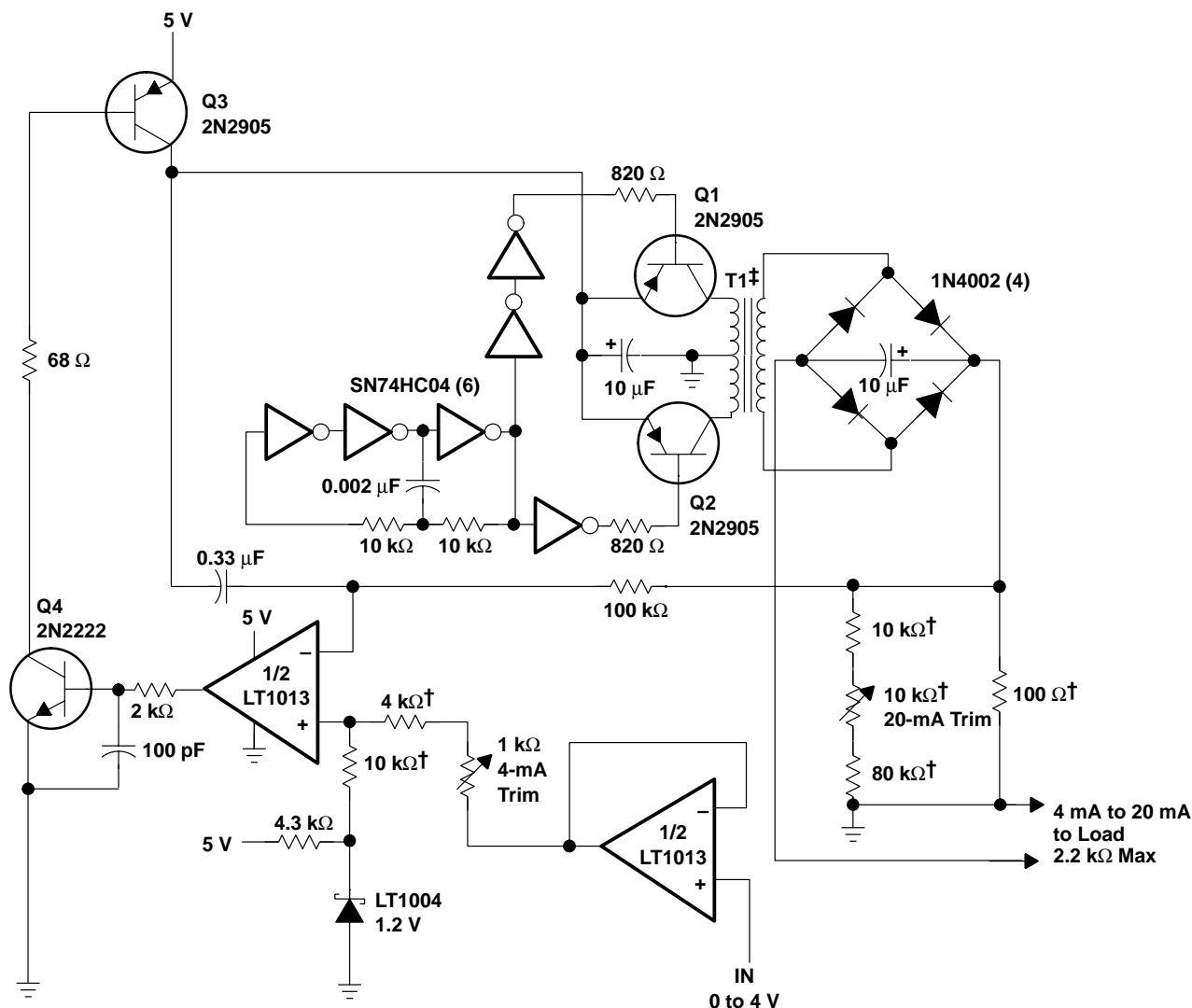
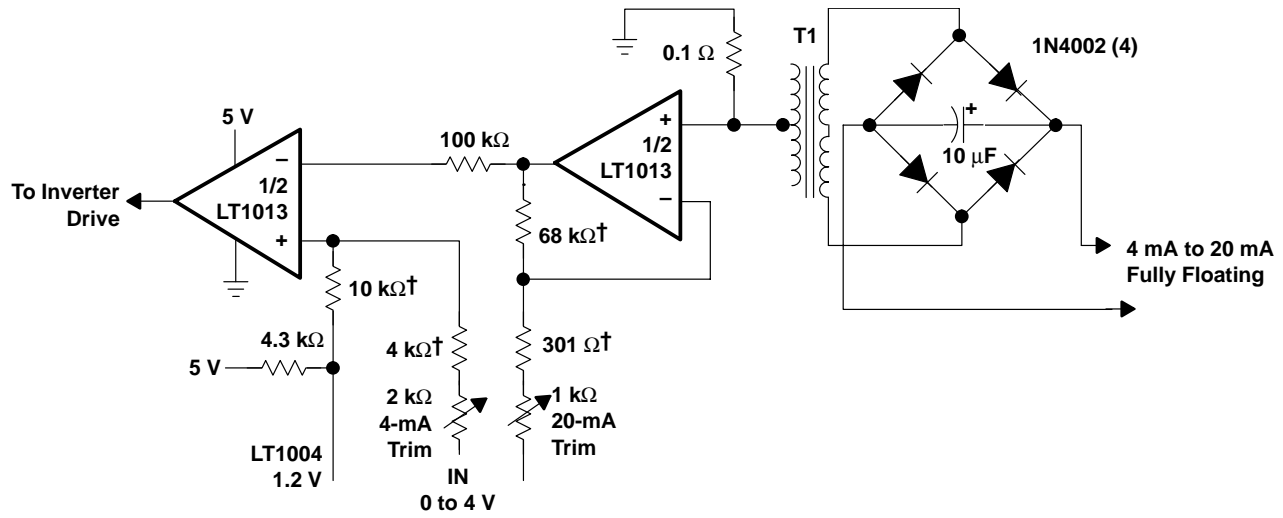


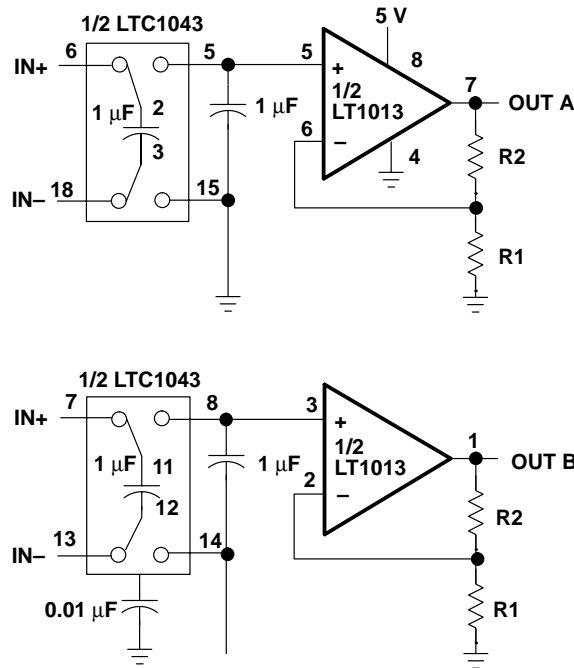
Figure 30. 5-V 4-mA to 20-mA Current Loop Transmitter With 12-Bit Accuracy

APPLICATION INFORMATION



† 1% film resistor

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



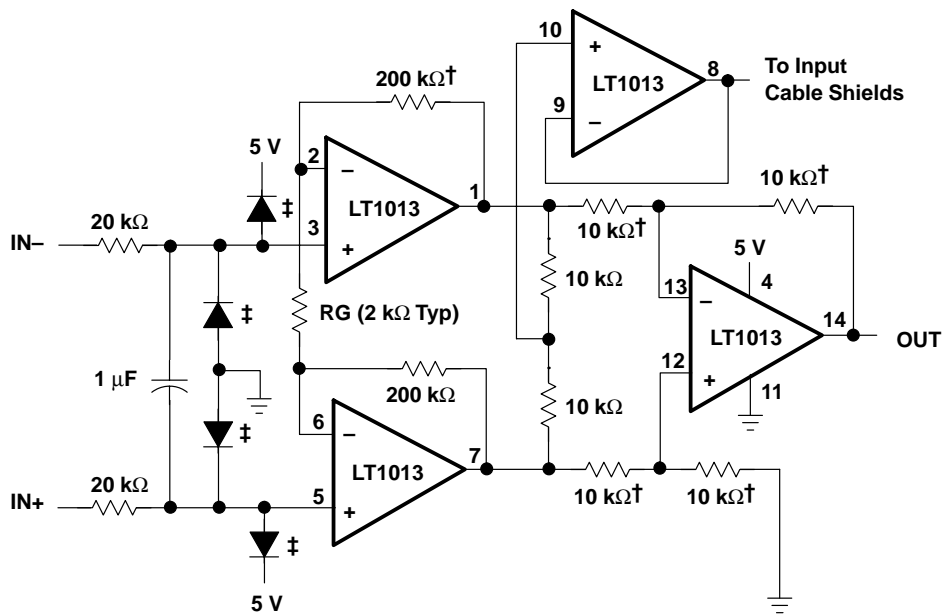
NOTE A:  $V_{IO} = 150 \mu\text{V}$ ,  $A_{VD} = (R1/R2) + 1$ ,  $\text{CMRR} = 120 \text{ dB}$ ,  $V_{ICR} = 0 \text{ to } 5 \text{ V}$

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

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## APPLICATION INFORMATION



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

‡ For high source impedances, use 2N2222 diodes.

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

Figure 33. 5-V Precision Instrumentation Amplifier

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