

# LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

SLOS018B – MAY 1988 – REVISED OCTOBER 1996

- **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**

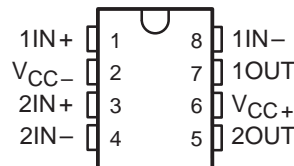
## description

The LT1013 is a dual precision operational amplifier featuring low offset voltage temperature coefficient, high gain, low supply current, and low noise.

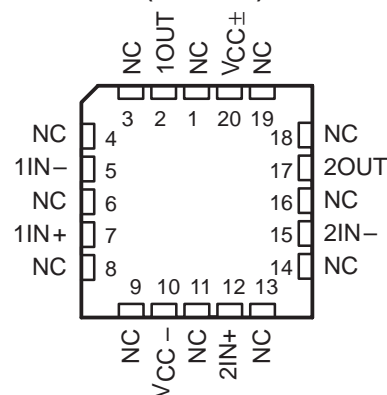
The LT1013 can be operated from a single 5-V power supply; the common-mode input voltage range includes ground, and the output can also swing to within a few millivolts of ground. Crossover distortion is eliminated. The LT1013 can be operated with both dual  $\pm 15\text{-V}$  and single 5-V supplies.

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.

**D PACKAGE  
(TOP VIEW)**

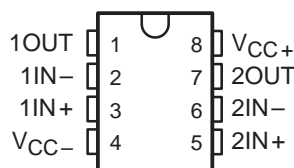


**FK PACKAGE  
(TOP VIEW)**



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, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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## AVAILABLE OPTIONS

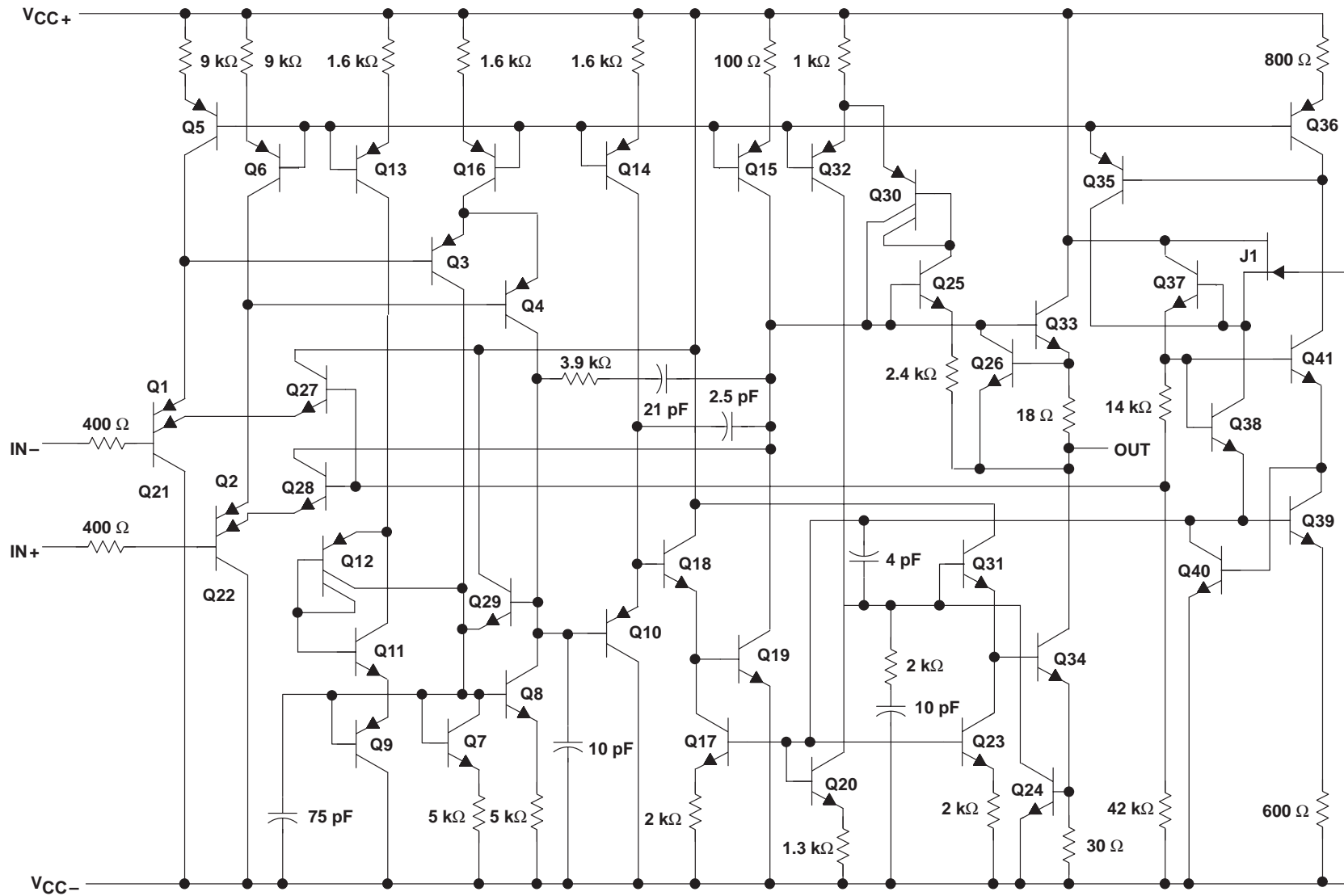
$T_A$	$V_{IOmax}$ AT 25°C	PACKAGED DEVICES				CHIP FORM (Y)
		SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	
0°C to 70°C	150 $\mu$ V	—	—	—	LT1013ACP	LT1013Y
	300 $\mu$ V	—	—	—	LT1013CP	
	800 $\mu$ V	LT1013DD	—	—	LT1013DP	
–40°C to 105°C	150 $\mu$ V	—	—	—	LT1013AIP	—
	300 $\mu$ V	—	—	—	LT1013IP	
	800 $\mu$ V	LT1013DID	—	—	LT1013DIP	
–55°C to 125°C	150 $\mu$ V	—	LT1013AMFK	—	LT1013AMP	—
	300 $\mu$ V	—	LT1013MFK	LT1013MJG	LT1013MP	
	800 $\mu$ V	LT1013DMD	—	LT1013DMJG	LT1013DMP	

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



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schematic (each amplifier)



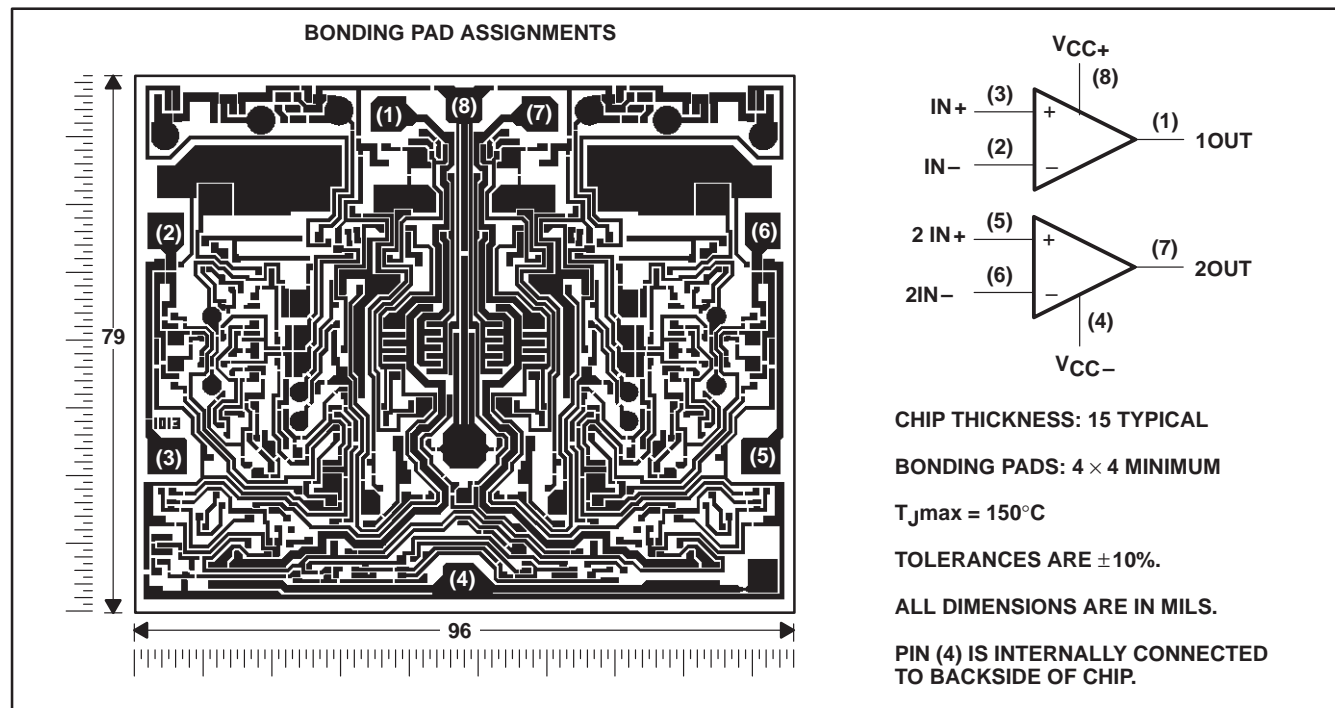
Component values are nominal.

# LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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## LT1013Y chip information

This chip, when properly assembled, displays characteristics similar to the LT1013. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



## 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) $25^{\circ}\text{C}$ (see Note 3)	unlimited
Operating free-air temperature range, $T_A$ : LT1013C, LT1013AC, LT1013D	$-0^{\circ}\text{C}$ to $70^{\circ}\text{C}$
LT1013I, LT1013AI, LT1013DI	$-40^{\circ}\text{C}$ to $105^{\circ}\text{C}$
LT1013M, LT1013AM, LT1013DM	$-55^{\circ}\text{C}$ to $125^{\circ}\text{C}$
Storage temperature range	$-65^{\circ}\text{C}$ to $150^{\circ}\text{C}$
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds: D or P package	$260^{\circ}\text{C}$
Case temperature for 60 seconds: FK package	$260^{\circ}\text{C}$
Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds: JG package	$300^{\circ}\text{C}$

- 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  $IN+$  with respect to  $IN-$ .
3. The output may be shorted to either supply.

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	LT1013C			LT1013AC			LT1013DC			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		$\mu V$
		Full range		400		240		1000				
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range	0.4	2.5		0.3	2		0.7	5		$\mu V/^\circ C$
Long-term drift of input offset voltage		25°C	0.5			0.4			0.5			$\mu V/mo$
$I_{IO}$ 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				
$I_{IB}$ Input bias current		25°C	–15	–30		–12	–20		–15	–30		nA
		Full range		–38		–25		–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		–15 to 13.5	–15.3 to 13.8		V
		Full range	–15 to 13			–15 to 13			–15 to 13			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 2 k\Omega$	25°C	$\pm 12.5$	$\pm 14$		$\pm 13$	$\pm 14$		$\pm 12.5$	$\pm 14$		V
		Full range	$\pm 12$			$\pm 12.5$			$\pm 12$			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L = 600 \Omega$	25°C	0.5	0.2		0.8	2.5		0.5	2		V/ $\mu V$
	$V_O = \pm 10$ V, $R_L = 2 k\Omega$	25°C	1.2	7		1.5	8		1.2	7		
		Full range	0.7			1			0.7			
CMRR Common-mode rejection ratio	$V_{IC} = -15$ V to 13.5 V	25°C	97	114		100	117		97	114		dB
	$V_{IC} = -14.9$ V to 13 V	Full range	94			98			94			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC+} = \pm 2$ V to $\pm 18$ V	25°C	100	117		103	120		100	117		dB
		Full range	97			101			97			
Channel separation	$V_O = \pm 10$ V, $R_L = 2 k\Omega$	25°C	120	137		123	140		120	137		dB
$r_{id}$ Differential input resistance		25°C	70	300		100	400		70	300		M $\Omega$
$r_{ic}$ Common-mode input resistance		25°C	4			5			4			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		0.55		0.6				

† Full range is 0°C to 70°C.

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

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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 <sub>A</sub> <sup>†</sup>	LT1013C			LT1013AC			LT1013DC			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>IO</sub>	Input offset voltage	R <sub>S</sub> = 50 Ω	25°C		90	450		60	250		250	950	μV
			Full range			570			350			1200	
I <sub>IO</sub>	Input offset current		25°C		0.3	2		0.2	1.3		0.3	2	nA
			Full range			6			3.5			6	
I <sub>IB</sub>	Input bias current		25°C		−18	−50		−15	−35		−18	−50	nA
			Full range			−90			−55			−90	
V <sub>ICR</sub>	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 <sub>OM</sub>	Maximum-peak output voltage swing	Output low, No load	25°C		15	25		15	25		15	25	mV
		Output low, R <sub>L</sub> = 600 Ω to GND	25°C		5	10		5	10		5	10	
			Full range			13			13			13	
		Output low, I <sub>sink</sub> = 1 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 <sub>L</sub> = 600 Ω to GND	25°C	3.4	4		3.4	4		3.4	4		
			Full range		3.2			3.3			3.2		
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>O</sub> = 5 mV to 4 V, R <sub>L</sub> = 500 Ω	25°C		1			1			1	V/μV	
I <sub>CC</sub>	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	

$^\dagger$  Full range is  $-0^\circ\text{C}$  to  $70^\circ\text{C}$ .

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		V/ $\mu\text{s}$
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		24		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		pA/ $\sqrt{\text{Hz}}$

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

PARAMETER	TEST CONDITIONS	$T_A^\dagger$	LT1013I			LT1013AI			LT1013DI			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		$\mu V$
		Full range		550		300		1000				
$\alpha_{VIO}$ Temperature coefficient of input offset voltage		Full range	0.4	2.5		0.3	2		0.7	5		$\mu V/^\circ C$
Long-term drift of input offset voltage		25°C	0.5			0.4			0.5			$\mu V/mo$
$I_{IO}$ 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				
$I_{IB}$ Input bias current		25°C	–15	–30		–12	–20		–15	–30		nA
		Full range		–38		–25		–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		–15 to 13.5	–15.3 to 13.8		V
		Full range	–15 to 13			–15 to 13			–15 to 13			
$V_{OM}$ Maximum peak output voltage swing	$R_L = 2 k\Omega$	25°C	$\pm 12.5$	$\pm 14$		$\pm 13$	$\pm 14$		$\pm 12.5$	$\pm 14$		V
		Full range	$\pm 12$			$\pm 12.5$			$\pm 12$			
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L = 600 \Omega$	25°C	0.5	0.2		0.8	2.5		0.5	2		V/ $\mu V$
	$V_O = \pm 10$ V, $R_L = 2 k\Omega$	25°C	1.2	7		1.5	8		1.2	7		
		Full range	0.7			1			0.7			
CMRR Common-mode rejection ratio	$V_{IC} = -15$ V to 13.5 V	25°C	97	114		100	117		97	114		dB
	$V_{IC} = -14.9$ V to 13 V	Full range	94			97			94			
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 2$ V to $\pm 18$ V	25°C	100	117		103	120		100	117		dB
		Full range	97			101			97			
Channel separation	$V_O = \pm 10$ V, $R_L = 2 k\Omega$	25°C	120	137		123	140		120	137		dB
$r_{id}$ Differential input resistance		25°C	70	300		100	400		70	300		M $\Omega$
$r_{ic}$ Common-mode input resistance		25°C	4			5			4			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		0.55		0.6				

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

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

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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 <sub>A</sub> <sup>†</sup>	LT1013I			LT1013AI			LT1013DI			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>IO</sub>	Input offset voltage	R <sub>S</sub> = 50 Ω	25°C		90	450		60	250		250	950	μV
			Full range			570			350			1200	
I <sub>IO</sub>	Input offset current		25°C		0.3	2		0.2	1.3		0.3	2	nA
			Full range			6			3.5			6	
I <sub>IB</sub>	Input bias current		25°C		−18	−50		−15	−35		−18	−50	nA
			Full range			−90			−55			−90	
V <sub>ICR</sub>	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 <sub>OM</sub>	Maximum-peak output voltage swing	Output low, No load	25°C		15	25		15	25		15	25	mV
		Output low, R <sub>L</sub> = 600 Ω to GND	25°C		5	10		5	10		5	10	
			Full range			13			13			13	
		Output low, I <sub>sink</sub> = 1 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 <sub>L</sub> = 600 Ω to GND	25°C	3.4	4		3.4	4		3.4	4		
			Full range		3.2			3.3			3.2		
A <sub>VD</sub>	Large-signal differential voltage amplification	V <sub>O</sub> = 5 mV to 4 V, R <sub>L</sub> = 500 Ω	25°C		1			1			1	V/μV	
I <sub>CC</sub>	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	

$^\dagger$  Full range is –40°C to 105°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		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	$T_A^\dagger$	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				
$\alpha_{VIO}$ 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			$\mu\text{V}/\text{mo}$
$I_{IO}$ 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  $T_A = 25^\circ\text{C}$ .

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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	$T_A^\dagger$	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, $I_{\text{sink}} = 1\text{ mA}$	25°C		220	350		220	350		220	350	V/ $\mu\text{V}$
	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		
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV}$ to $4\text{ V}$ , $R_L = 500\ \Omega$	25°C		1			1			1		mA
$I_{CC}$ Supply current per amplifier		25°C		0.32	0.5		0.31	0.45		0.32	0.5	
		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		V/ $\mu\text{s}$
$V_n$	Equivalent input noise voltage	$f = 10\text{ Hz}$		24		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		pA/ $\sqrt{\text{Hz}}$

# LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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electrical characteristics at  $V_{CC+} = 5\text{ V}$ ,  $V_{CC-} = 0$ ,  $V_O = 1.4\text{ V}$ ,  $V_{IC} = 0$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	LT1013Y			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$		250	950	$\mu\text{V}$
$I_{IO}$ Input offset current			0.3	2	nA
$I_{IB}$ Input bias current			-18	-50	nA
$V_{ICR}$ Common-mode input voltage range		0 to 3.5	0.3 to 3.8		V
$V_{OM}$ Maximum peak output voltage swing	Output low, No load		15	25	mV
	Output low, $R_L = 600\ \Omega$ to GND		5	10	
	Output low, $I_{\text{sink}} = 1\text{ mA}$		220	350	
	Output high, No load		4	4.4	V
	Output high, $R_L = 600\ \Omega$ to GND		3.4	4	
$A_{VD}$ Large-signal differential voltage amplification	$V_O = 5\text{ mV}$ to $4\text{ V}$ , $R_L = 500\ \Omega$		1		$\text{V}/\mu\text{V}$
$I_{CC}$ Supply current per amplifier			0.32	0.5	mA

electrical characteristics at  $V_{CC+} = \pm 15\text{ V}$ ,  $V_{IC} = 0$ ,  $T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER	TEST CONDITIONS	LT1013Y			UNIT
		MIN	TYP	MAX	
$V_{IO}$ Input offset voltage	$R_S = 50\ \Omega$		200	800	$\mu\text{V}$
	Long-term drift of input offset voltage		0.5		$\mu\text{V}/\text{mo}$
$I_{IO}$ Input offset current			0.2	1.5	nA
$I_{IB}$ Input bias current			-15	-30	nA
$V_{ICR}$ Common-mode input voltage range		-15 to 13.5	-15.3 to 13.8		V
$V_{OM}$ Maximum peak output voltage swing	$R_L = 2\text{ k}\Omega$	$\pm 12.5$	$\pm 14$		V
$A_{VD}$ Large-signal differential voltage amplification	$V_O = \pm 10\text{ V}$ , $R_L = 600\ \Omega$	0.5	2		$\text{V}/\mu\text{V}$
	$R_L = 2\ \Omega$	1.2	7		dB
CMRR Common-mode rejection ratio	$V_{IC} = -15\text{ V}$ to $13.5\text{ V}$	97	114		
$k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ )	$V_{CC\pm} = \pm 2\text{ V}$ to $\pm 18\text{ V}$	100	117		dB
	Channel separation	$V_O = \pm 10\text{ V}$ , $R_L = 2\ \Omega$	120	137	dB
$r_{id}$ Differential input resistance		70	300		$\text{M}\Omega$
$r_{ic}$ Common-mode input resistance			4		$\text{G}\Omega$
$I_{CC}$ Supply current per amplifier			0.35	0.55	mA

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

PARAMETER	TEST CONDITIONS	LT1013Y			UNIT
		MIN	TYP	MAX	
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, LT1013Y

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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 Large signal	19, 21 20, 22, 23
	Phase shift	vs Frequency	9



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# TYPICAL CHARACTERISTICS†

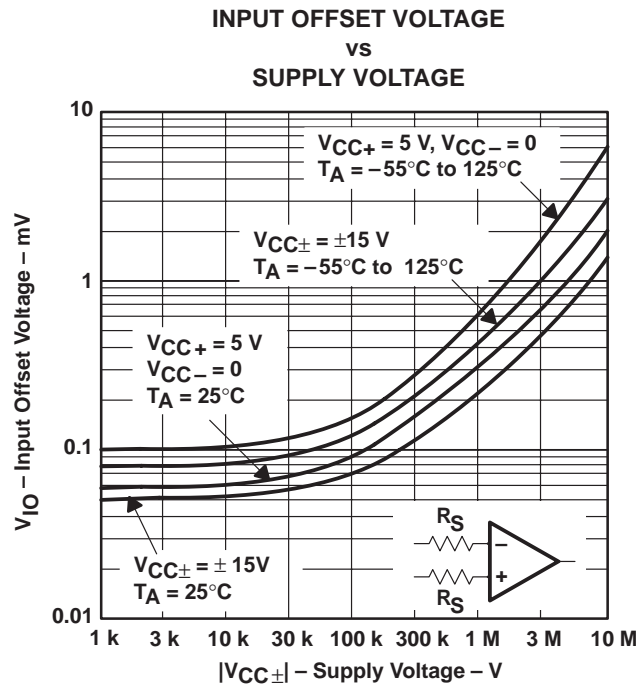


Figure 1

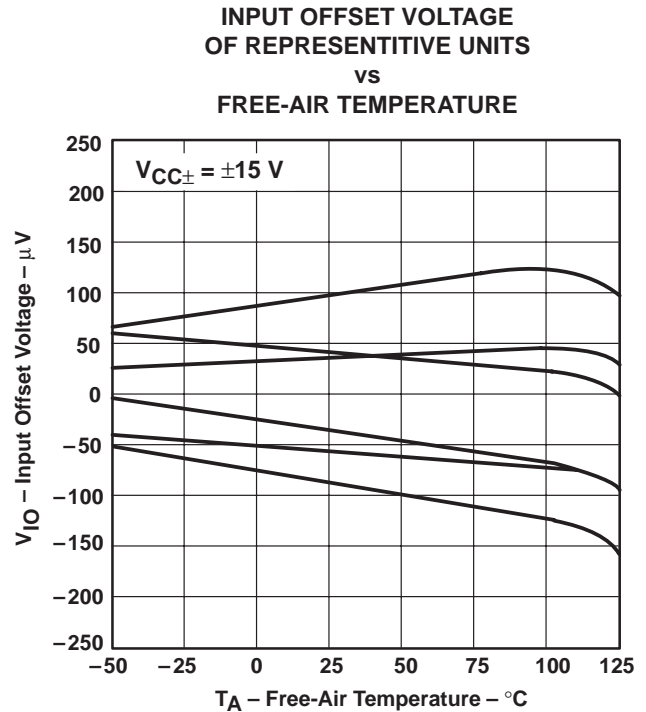


Figure 2

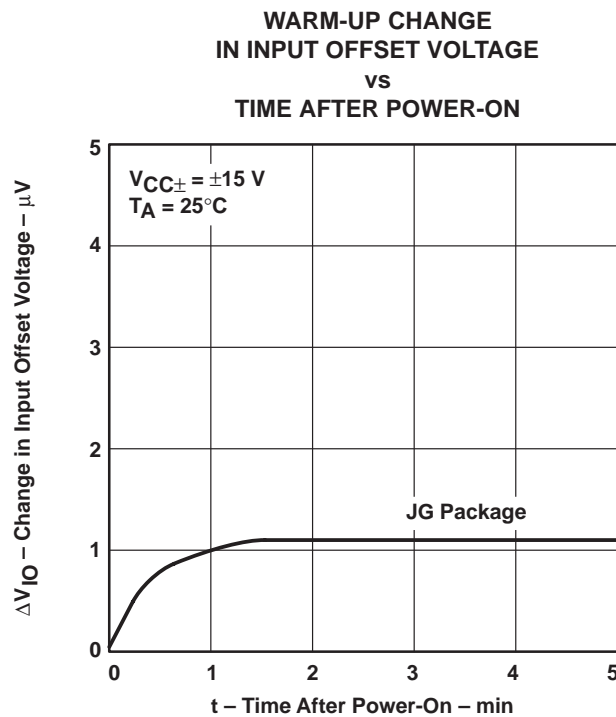


Figure 3

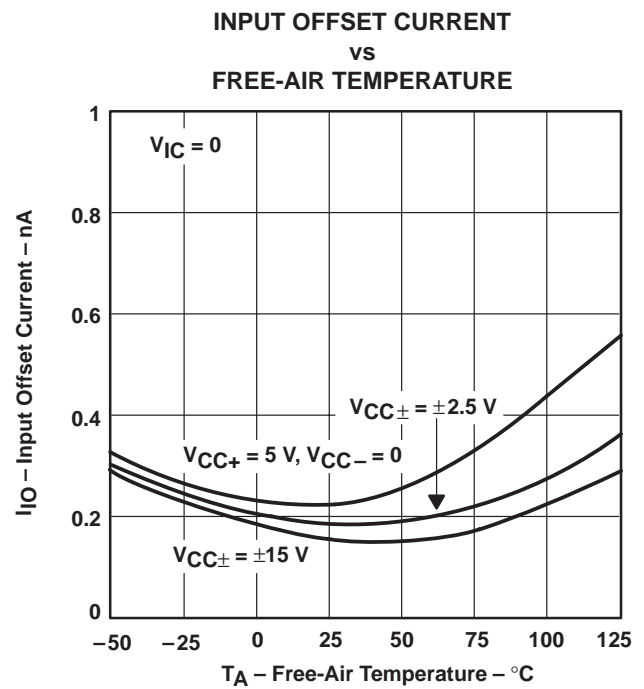


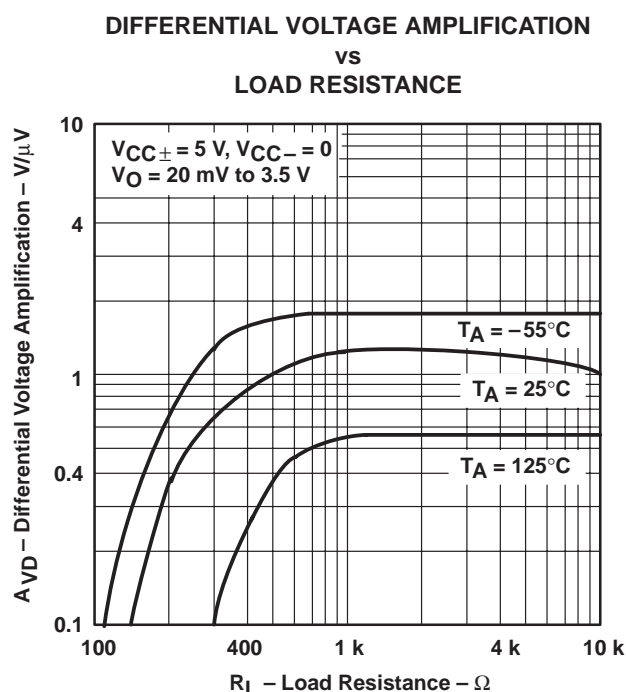
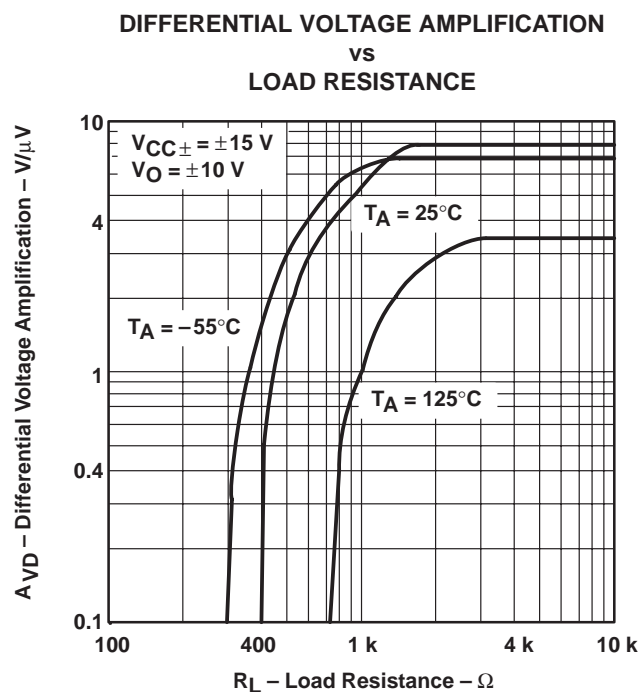
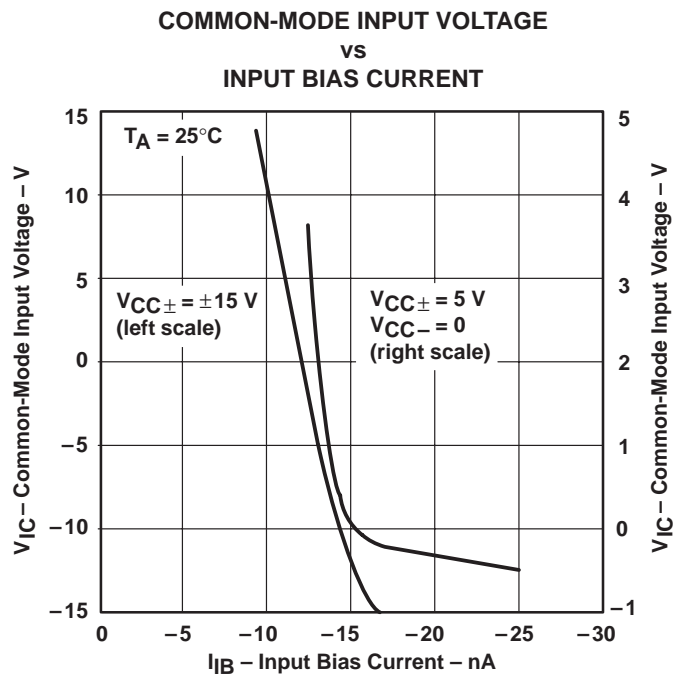
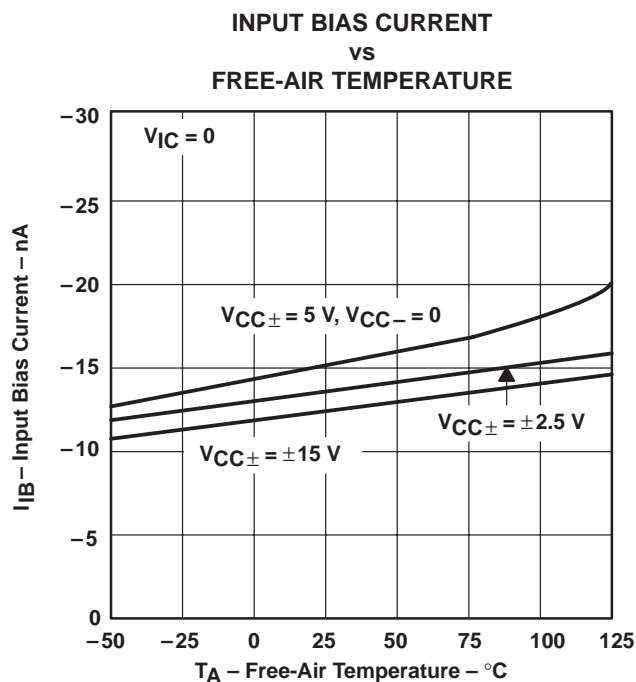
Figure 4

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

# LT1013, LT1013A, LT1013D, LT1013Y 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†

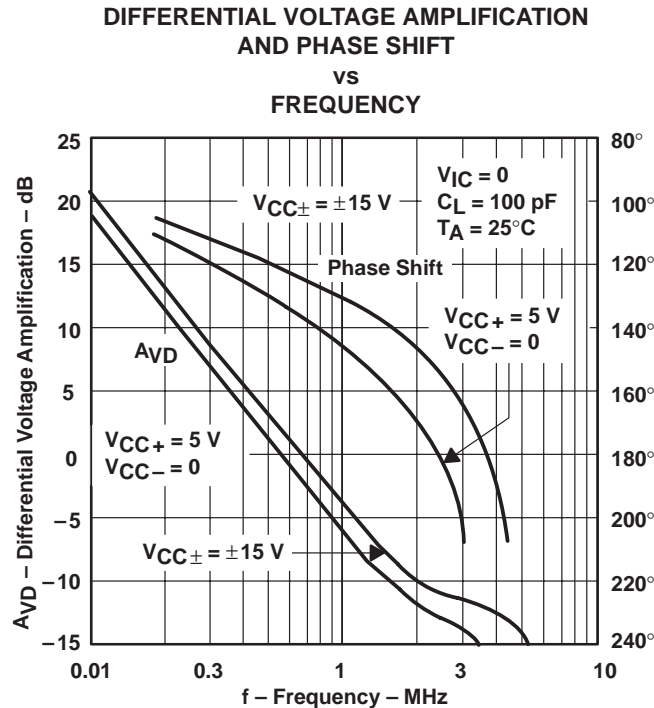


Figure 9

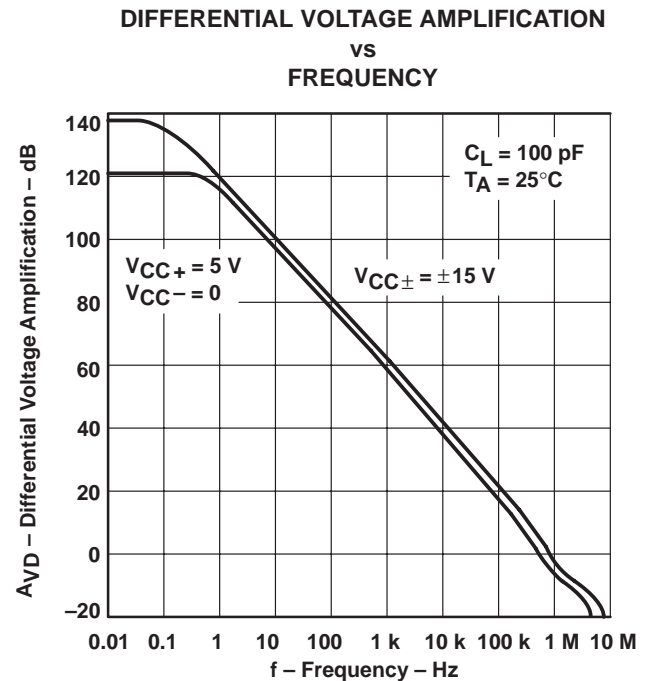


Figure 10

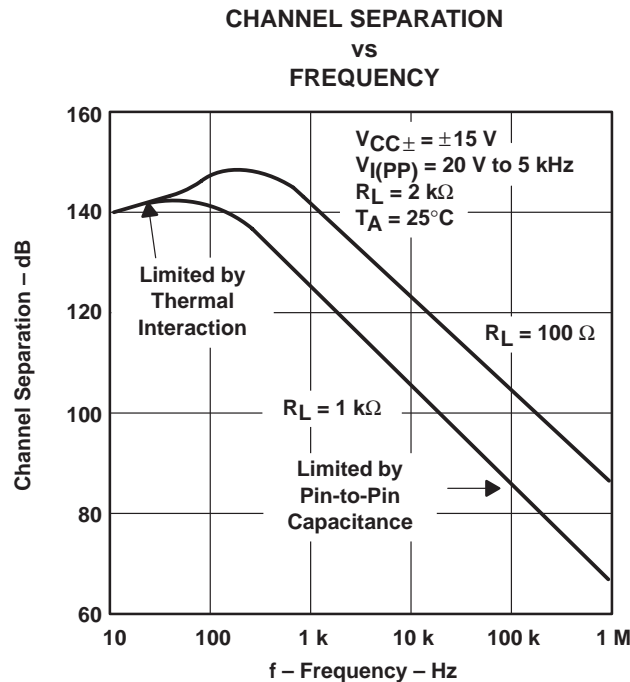


Figure 11

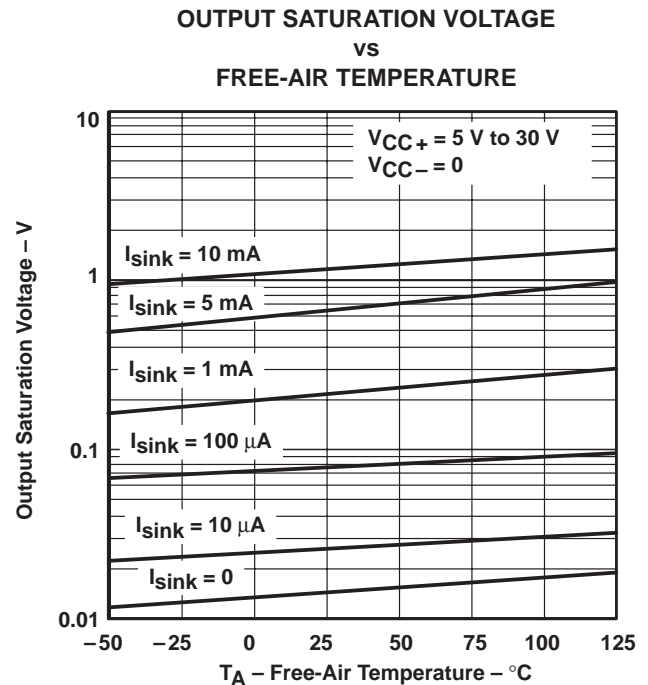


Figure 12

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

LT1013, LT1013A, LT1013D, LT1013Y  
DUAL PRECISION OPERATIONAL AMPLIFIERS

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TYPICAL CHARACTERISTICS†

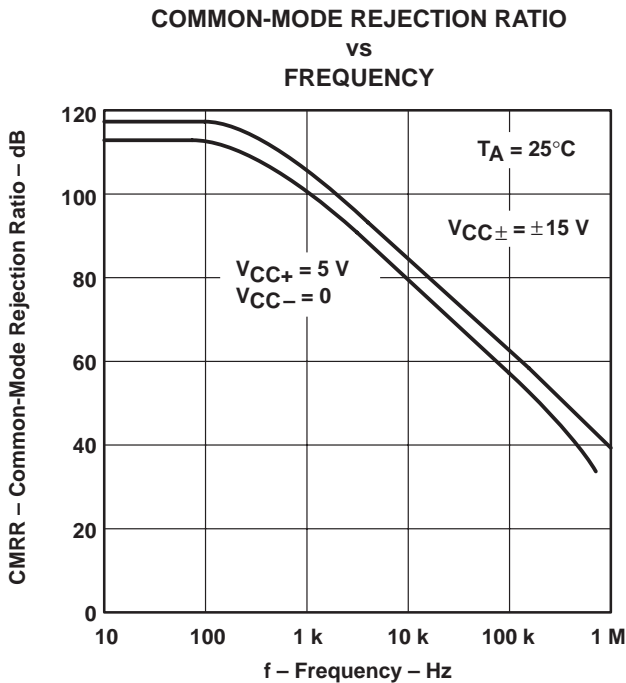


Figure 13

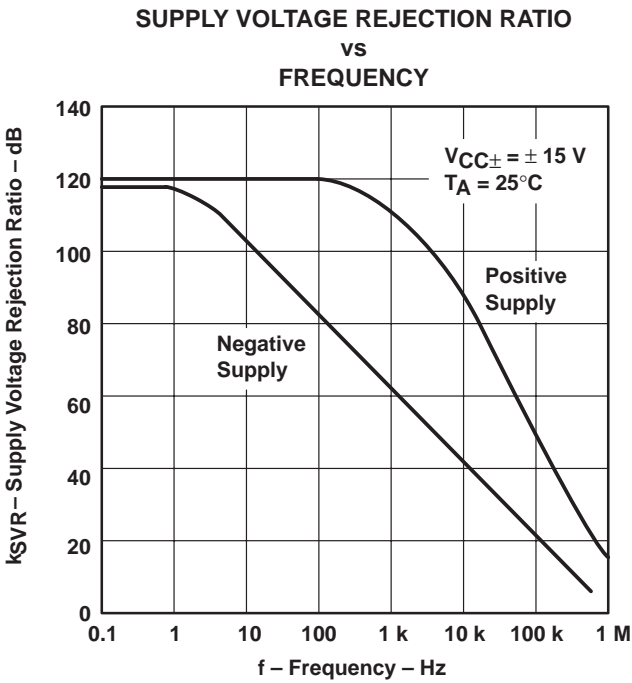


Figure 14

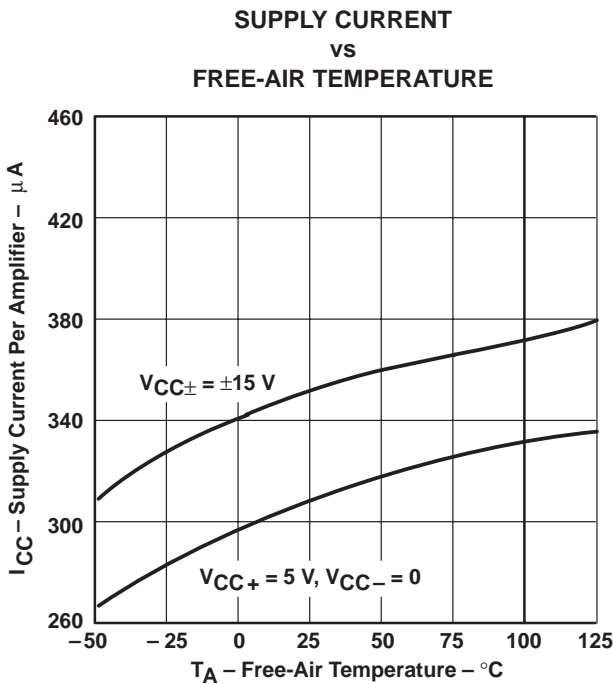


Figure 15

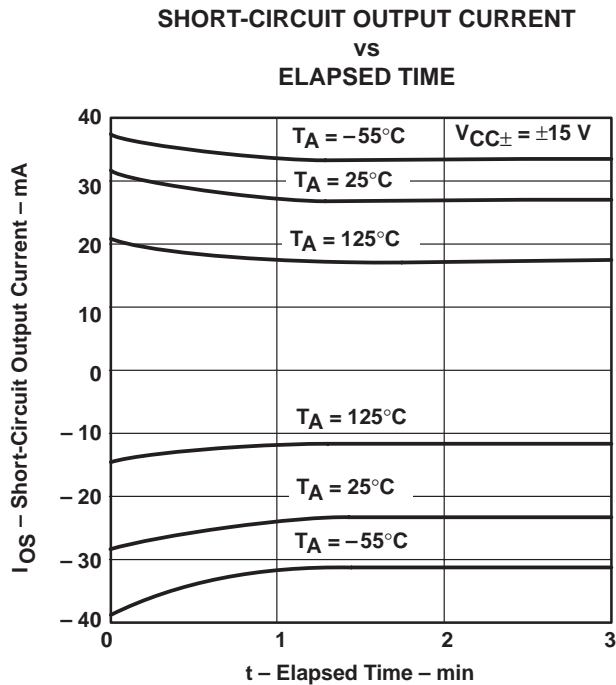


Figure 16

† 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

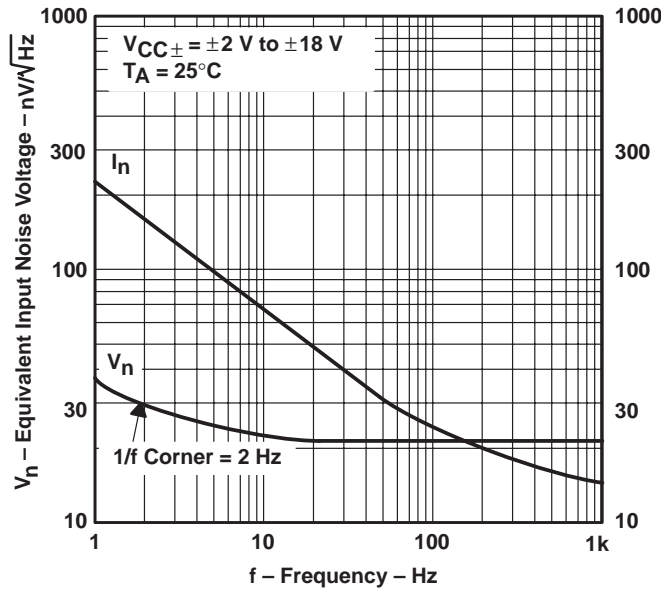


Figure 17

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

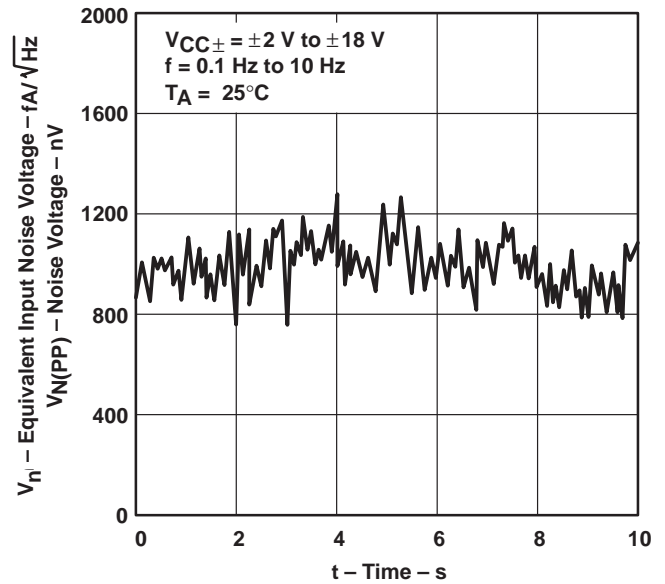


Figure 18

VOLTAGE-FOLLOWER  
SMALL-SIGNAL  
PULSE RESPONSE

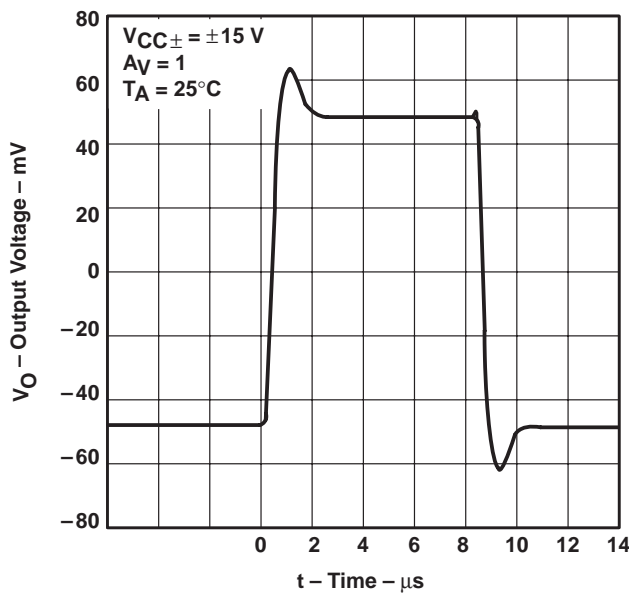


Figure 19

VOLTAGE-FOLLOWER  
LARGE-SIGNAL  
PULSE-RESPONSE

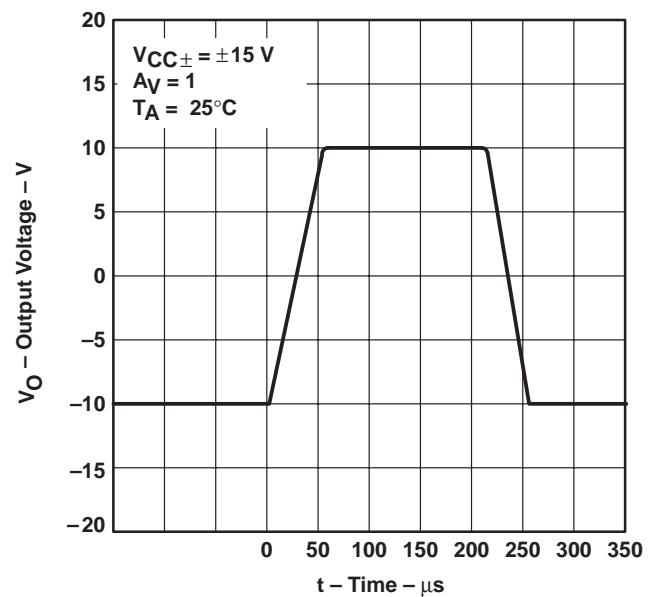


Figure 20

# LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

**VOLTAGE-FOLLOWER  
SMALL-SIGNAL  
PULSE RESPONSE**

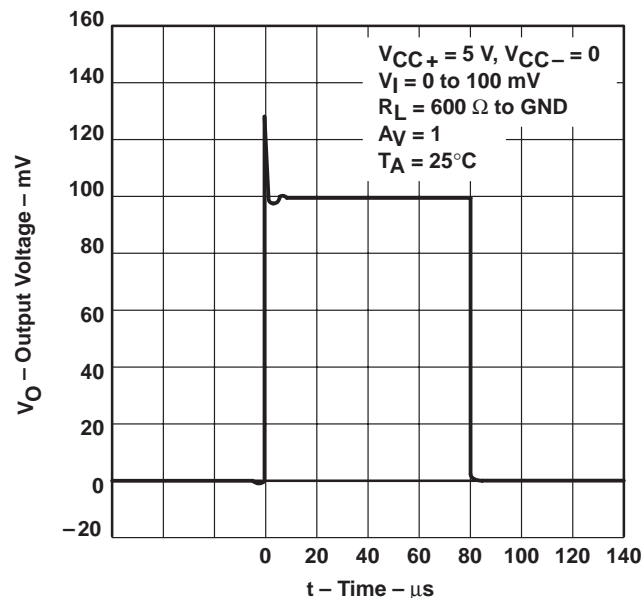


Figure 21

**VOLTAGE-FOLLOWER  
LARGE-SIGNAL  
PULSE RESPONSE**

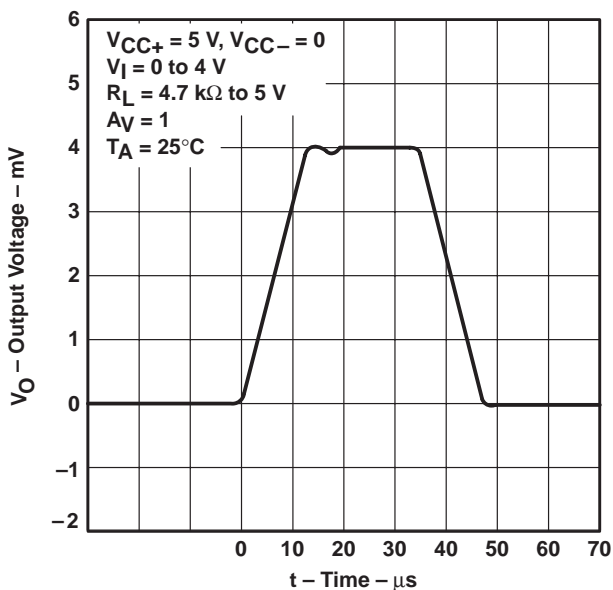


Figure 22

**VOLTAGE-FOLLOWER  
LARGE-SIGNAL  
PULSE RESPONSE**

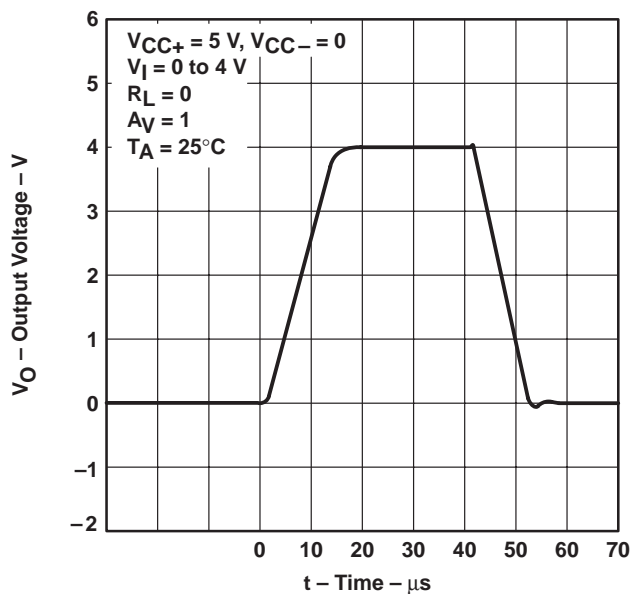


Figure 23

## 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 will flow 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) 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 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 2's output is in negative saturation or on amplifier 2 when 1's 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.

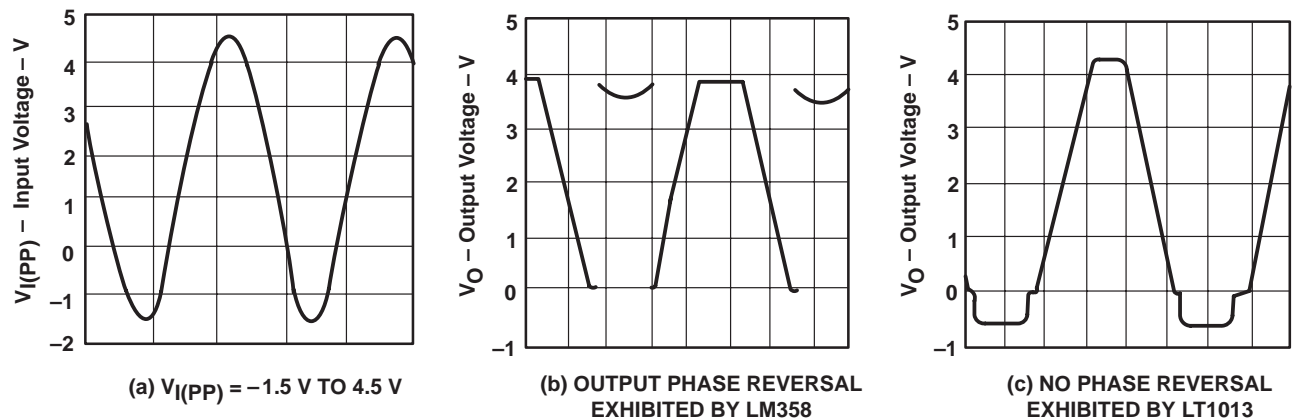


Figure 24. Voltage-Follower Response With Input Exceeding the Negative Common-Mode Input Voltage Range

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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. Refer to Figures 25 and 26.

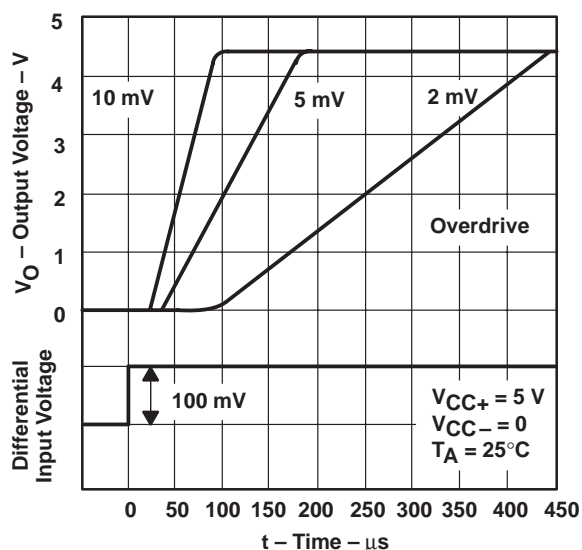


Figure 25. Low-to-High-Level Output Response for Various Input Overdrives

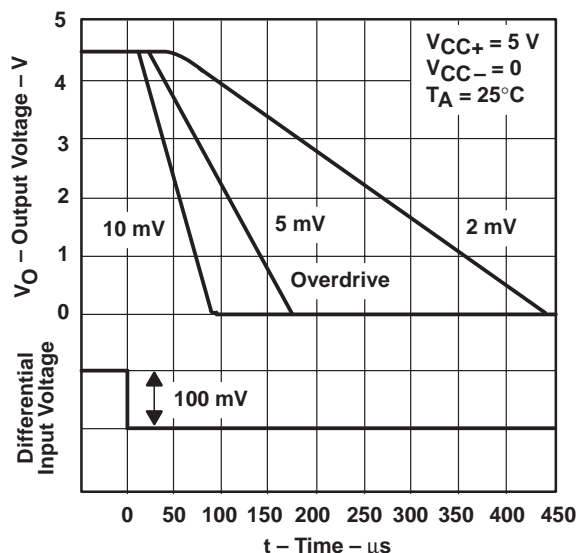


Figure 26. High-to-Low-Level Output Response for Various Input Overdrives

#### low-supply operation

The minimum supply voltage for proper operation of the LT1013 is 3.4 V (three Ni-Cad batteries). Typical supply current at this voltage is 290  $\mu\text{A}$ ; 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  $\pm 20\text{ V}$  is also used as the burn-in configuration.

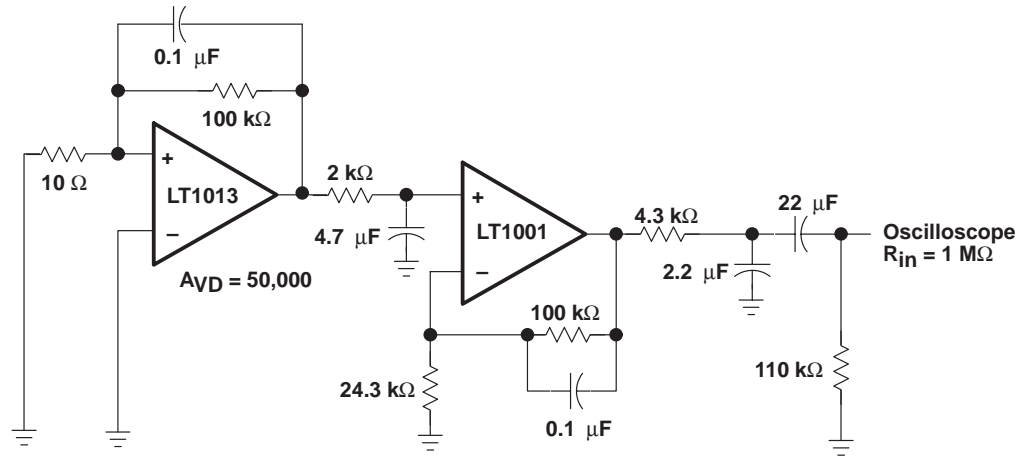
The peak-to-peak equivalent input noise voltage of the LT1013 is measured using the test circuit shown in Figure 27. The frequency response of the noise tester indicates that the 0.1-Hz corner is defined by only one zero. The test time to measure 0.1-Hz to 10-Hz noise should not exceed 10 seconds, as 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.

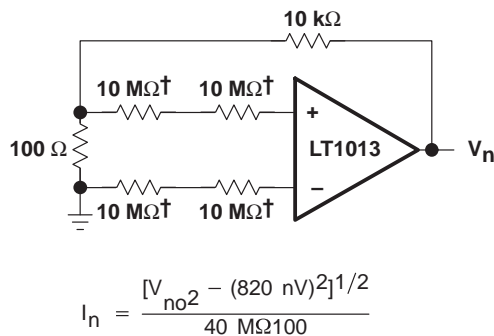
## APPLICATION INFORMATION

### offset voltage and noise testing (continued)



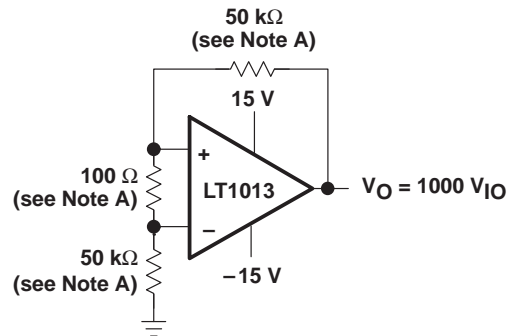
NOTE A: All capacitor values are for nonpolarized capacitors only.

**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

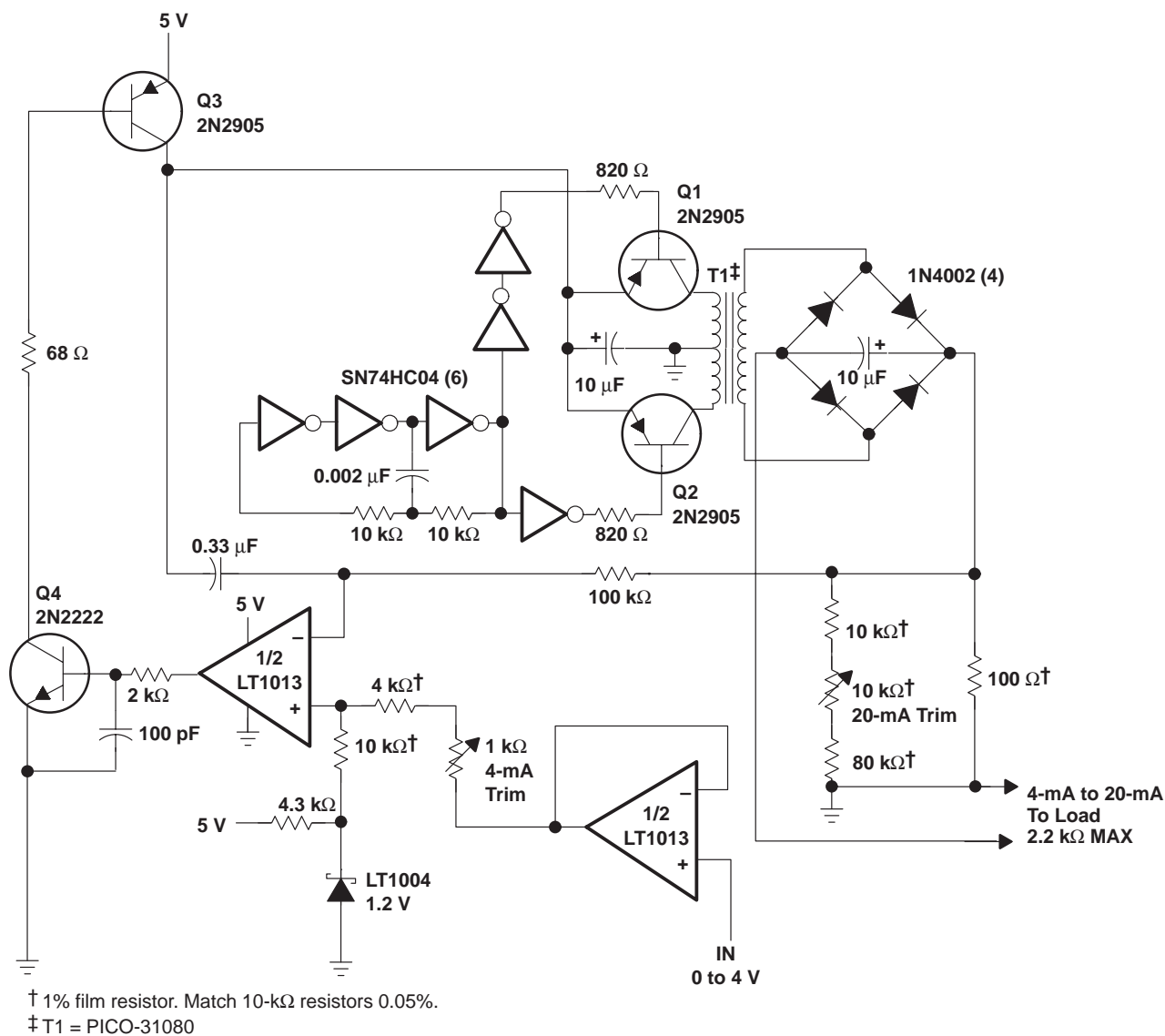
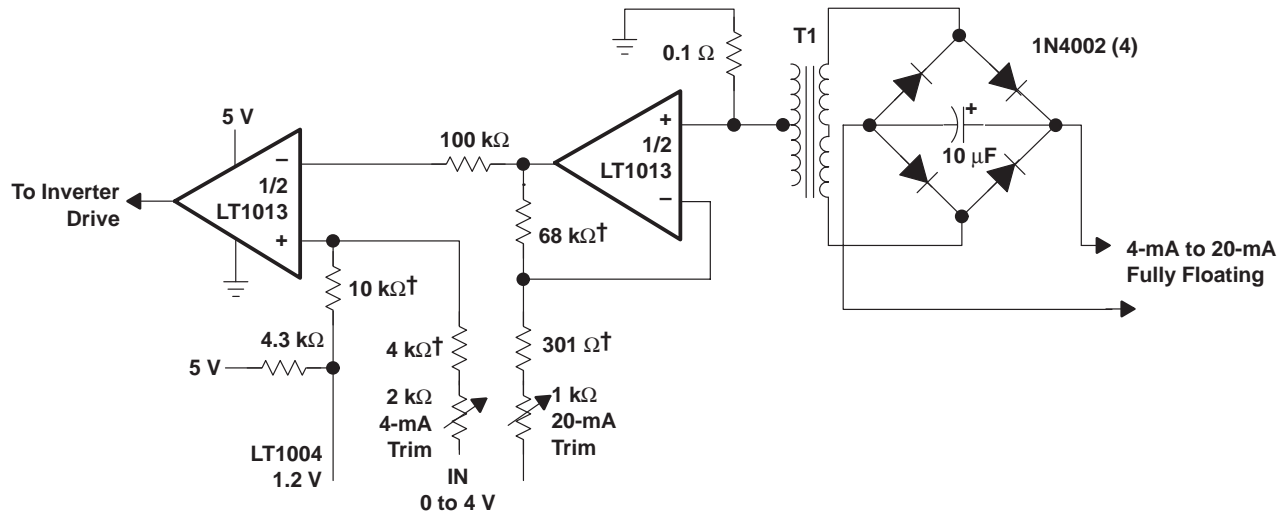


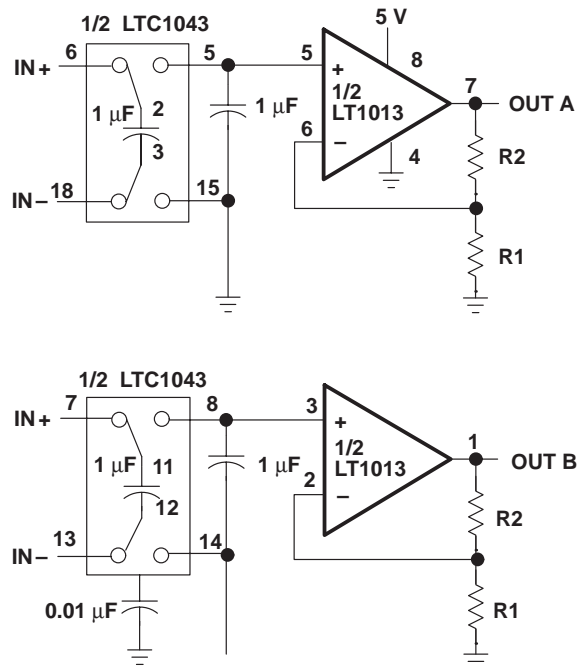
Figure 30. 5-V 4-mA – 20-mA Current Loop Transmitter With 12-Bit Accuracy

# APPLICATION INFORMATION



† 1% film resistor

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



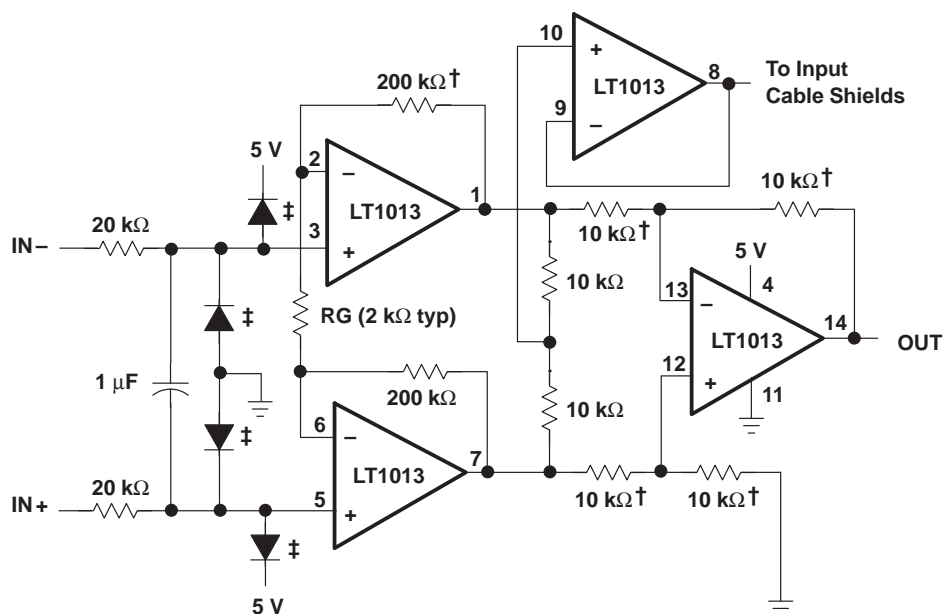
NOTE A:  $V_{IO} = 150 \mu V$ ,  $A_{VD} = (R1/R2) + 1$ ,  $CMRR = 120 \text{ dB}$ ,  $V_{ICR} = 0 \text{ to } 5 \text{ V}$

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

# LT1013, LT1013A, LT1013D, LT1013Y DUAL PRECISION OPERATIONAL AMPLIFIERS

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## APPLICATION INFORMATION



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

‡ For high source impedances, use 2N2222 as diodes.

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

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



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