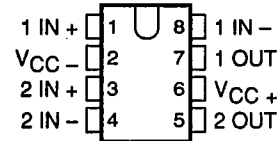


NOTICE
SEE ORDER OF DATA FOR ERRATA INFORMATION

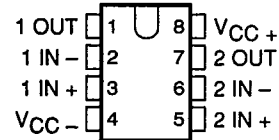
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- **Single-Supply Operation:**
Input Voltage Range Extends to Ground
Output Swings to Ground While Sinking Current
- **Input Offset Voltage ... 150 μ V Max at 25°C for LT1013A**
- **Offset Voltage Temperature Coefficient ... 2 μ V/°C Max for LT1013A**
- **Input Offset Current ... 0.8 nA Max at 25°C for LT1013A**
- **High Gain ... 1.5 V/ μ V Min ($R_L = 2$ k Ω), 0.8 V/ μ V Min ($R_L = 600$ k Ω) for LT1013A**
- **Low Supply Current ... 0.5 mA Max at 25°C for LT1013A**
- **Low Peak-To-Peak Noise Voltage ... 0.55 μ V Typ**
- **Low Current Noise ... 0.07 pA/ $\sqrt{\text{Hz}}$ Typ**

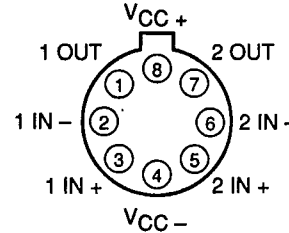
D PACKAGE
(TOP VIEW)



JG OR P PACKAGE
(TOP VIEW)



L PACKAGE
(TOP VIEW)



Pin 4 of the L package is in electrical contact with the case.

description

The LT1013 is a precision dual operational amplifier featuring low offset voltage temperature coefficient, high gain, low supply current, and low noise. It is offered in an 8-pin industry-standard configuration in JG and P package types as well as in a D package with a special pinout.

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 ± 15 -V and single 5-V supplies.

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

AVAILABLE OPTIONS

TA	V _{IO} max AT 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C to 70°C	150 μ V to 800 μ V	— — LT1013DD	LT1013ACJG LT1013CJG LT1013DJG	LT1013ACL LT1013CL LT1013DL	— LT1013CP LT1013DP
-40°C to 105°C	150 μ V to 800 μ V	— — LT1013DID	LT1013AIJG LT1013IJG LT1013DIJG	— — —	— LT1013IP LT1013DIP
-55°C to 125°C	150 μ V to 800 μ V	— — LT1013DMD	— LT1013MJG LT1013DMJG	LT1013AML LT1013ML LT1013DML	— LT1013MP LT1013DMP

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

PRODUCTION DATA documents contain information 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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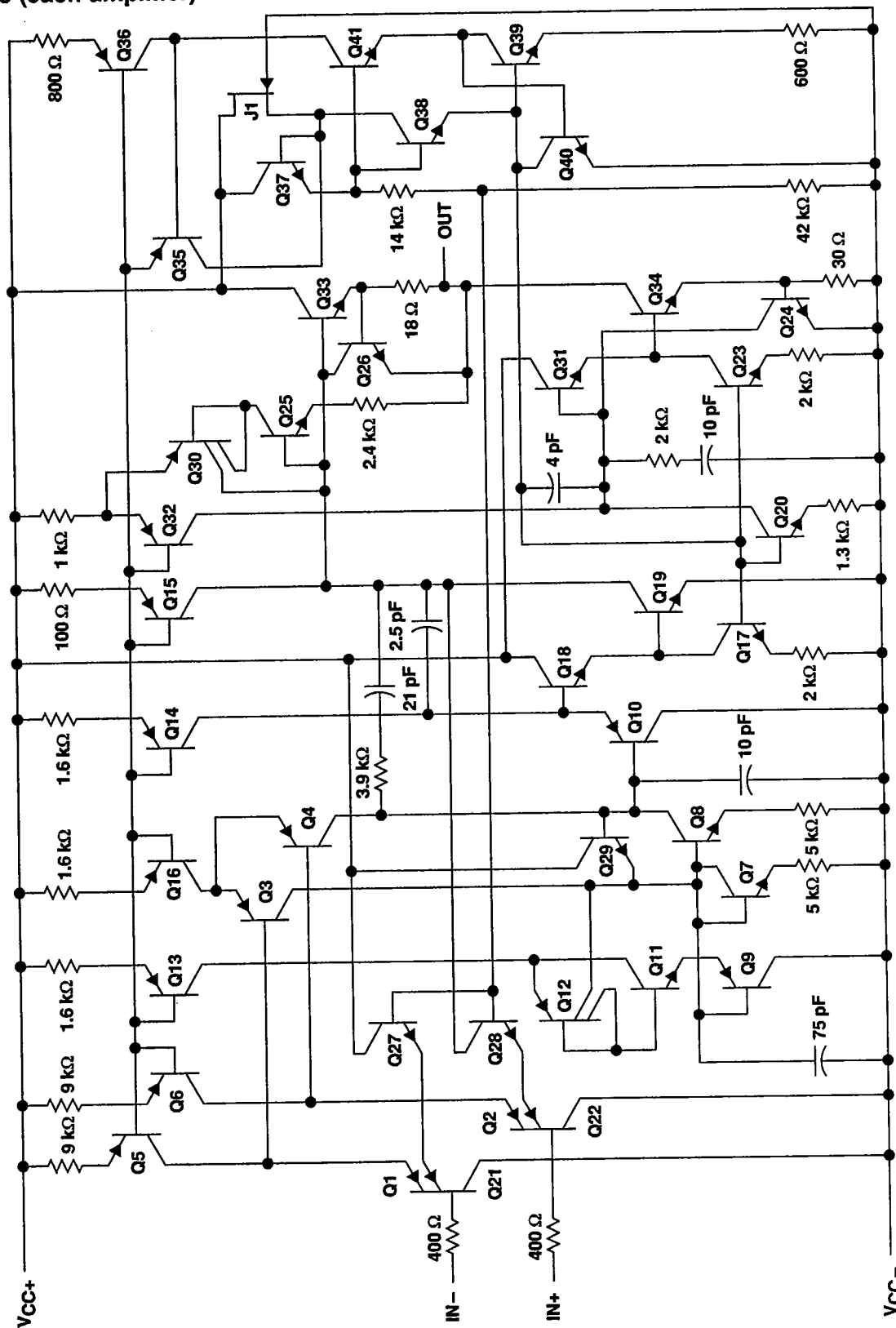
LT1013, LT1013A, LT1013D
 DUAL PRECISION OPERATIONAL AMPLIFIERS

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schematic (each amplifier)



Resistor values are nominal.

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)	± 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°C (see Note 3)	unlimited
Operating free-air temperature range, T_A : LT1013M, LT1013AM, LT1013DM	-55°C to 125°C
LT1013I, LT1013AI, LT1013DI	-40°C to 105°C
LT1013C, LT1013AC, LT1013D	0°C to 70°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: JG or L package	300°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.

LT1013M, LT1013AM, LT1014DM
 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_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 Full range	60	300	300	40	150	150	200	800	1000	μV
α_{VIO} Temperature coefficient of input offset voltage		Full range	0.5	2.5	2.5	0.4	2	2	0.5	2.5	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 Full range	0.2	1.5	1.5	0.15	0.8	0.8	0.2	1.5	1.5	nA
I_{IB} Input bias current		25°C Full range	-15	-30	-30	-12	-20	-20	-15	-30	-30	nA
V_{ICR} Common-mode input voltage range		25°C	-15	-15.3	-15.3	-15	-15.3	-15.3	-15	-15.3	-15.3	V
		-55°C to 105°C	to	to	to	to	to	to	to	to	to	
		105°C to 125°C	13.5	13.8	13.8	13.5	13.8	13.8	13.5	13.8	13.8	
			-15			-15			-15			
V_{OM} Maximum peak output voltage swing	$R_L = 2\ \text{k}\Omega$	25°C Full range	± 12.5	± 14	± 14	± 13	± 14	± 14	± 12.5	± 14	± 14	V
A_{VD} Large-signal differential voltage amplification	$V_O = \pm 10\ \text{V}$	25°C	0.5	2	2	0.8	2.5	2.5	0.5	2	2	$\text{V}/\mu\text{V}$
	$V_O = \pm 10\ \text{V}$	25°C	1.2	7	7	1.5	8	8	1.2	7	7	
CMRR Common-mode rejection ratio	$V_{IC} = -15\ \text{V}$ to $13.5\ \text{V}$	25°C	97	114	114	100	117	117	97	114	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	117	103	120	120	100	117	117	dB
		Full range	97			100			97			
r_{id} Channel separation	$V_O = \pm 10\ \text{V}$, $R_L = 2\ \text{k}\Omega$	25°C	120	137	137	123	140	140	120	137	137	dB
r_{ic} Differential input resistance		25°C	70	300	300	100	400	400	70	300	300	$\text{M}\Omega$
Common-mode input resistance		25°C	4			5			4			$\text{G}\Omega$
I_{CC} Supply current per amplifier		25°C	0.35	0.55	0.55	0.35	0.5	0.5	0.35	0.55	0.55	mA
	Full range	Full range	0.7			0.6			0.7			

†Full range is -55°C to 125°C.
 ‡All typical values are at $T_A = 25^\circ\text{C}$.



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electrical characteristics at specified free-air temperature, $V_{CC+} = 5V$, $V_{CC-} = 0V$, $V_O = 1.4V$, $V_{IC} = 0$ (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 Ω	25°C	90	450	60	250	250	950				μV
		-55°C to 105°C		750		450		1200				
		125°C	400	1500	250	900	800	2000				
		125°C	200	750	120	450	560	1200				
I _{IO} Input offset current	R _S = 50 Ω, V _{IC} = 0.1 V	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	-0.3	0	-0.3	0	-0.3				V
		-55°C to 105°C	to	to	to	to	to	to				
		105°C to 125°C	3.5	3.8	3.5	3.8	3.5	3.8				
			0		0		0					
V _{OM} Maximum peak output voltage swing	Output low, No load Output low, R _L = 600 Ω to GND Output low, I _{sink} = 1 mA Output high, No load Output high, R _L = 600 Ω to GND	25°C	15	25	15	25	15	25				mV
		25°C	5	10	5	10	5	10				
		Full range		18		15		18				
		25°C	220	350	220	350	220	350				
		25°C	4	4.4	4	4.4	4	4.4				
		25°C	3.4	4	3.4	4	3.4	4				
A _{VD} Large-signal differential voltage amplification	V _O = 5 mV to 4 V, R _L = 500 Ω	Full range	3.1		3.2		3.1					V/μV
		25°C	1		1		1					
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.

operating characteristics, $V_{CC±} = ±15V$, $V_{IC} = 0$, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		V/μs
V _n Equivalent input noise voltage	f = 10 Hz		24		nV/√Hz
V _{N(PP)} Peak-to-peak equivalent input noise voltage	f = 1 kHz		22		μV
	f = 0.1 Hz to 10 Hz		0.55		
I _n Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

LT1013I, LT1013AI, LT1013DI
 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 _A [†]	LT1013I			LT1013AI			LT1013DI			UNIT
			MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	
V _{IO}	R _S = 50 Ω	25°C	60	300	MAX	40	150	MAX	200	800	μV	
		Full range		550		300		1000				
α _{VIO}	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 _{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	-15.3		-15	-15.3		-15	-15.3	V	
		Full range		to		to			to			
			13.5	13.8		13.5	13.8		13.5	13.8		
			-15			-15			-15			
			to			to			to			
			13			13			13			
V _{OM}	Maximum peak output voltage swing	25°C	±12.5	±14		±13	±14		±12.5	±14	V	
		Full range										
			0.5	2		0.8	2.5		0.5	2		
AVD	Large-signal differential voltage amplification	25°C	1.2	7		1.5	8		1.2	7	V/μV	
		Full range				1			0.7			
CMRR	Common-mode rejection ratio	25°C	97	114		100	117		97	114	dB	
		Full range				97			94			
kSVR	Supply-voltage rejection ratio (ΔV _{CC} / ΔV _{IO})	25°C	100	117		103	120		100	117	dB	
		Full range				101			97			
r _{id}	Differential input resistance	25°C	120	137		123	140		120	137	MΩ	
		Full range				100	400		70	300		
r _{ic}	Common-mode input resistance	25°C	4			5			4		GΩ	
I _{CC}	Supply current per amplifier	25°C	0.35	0.55		0.35	0.5		0.35	0.55	mA	
		Full range		0.6		0.55			0.6			

[†]Full range is -40°C to 105°C.
[‡]All typical values are at T_A = 25°C.

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

PARAMETER	TEST CONDITIONS	TA†	LT1013I			LT1013AI			LT1013DI			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO} Input offset voltage	R _S = 50 Ω	25°C	90	450	450	60	250	250	250	950	μV	
		Full range		750	750	450	1200	1200	1200	1200		
I _{IO} Input offset current		25°C	0.3	2	2	0.2	1.3	1.3	0.3	2	nA	
		Full range		6	6	3.5	6	6	3.5	6		
I _{IB} Input bias current		25°C	-18	-50	-50	-15	-35	-35	-18	-50	nA	
		Full range		-90	-90	-55	-90	-90	-55	-90		
V _{ICR} Common-mode input voltage range		25°C	0	-0.3	-0.3	0	-0.3	-0.3	0	-0.3	V	
		Full range	3.5	3.8	3.8	3.5	3.8	3.8	3.5	3.8		
V _{OM} Maximum peak output voltage swing	Output low, No load	25°C	15	25	25	15	25	25	15	25	mV	
		25°C	5	10	10	5	10	10	5	10		
		Full range		13	13	13	13	13	13	13		
		25°C	220	350	350	220	350	350	220	350		
		25°C	4	4.4	4.4	4	4.4	4.4	4	4.4		
		25°C	3.4	4	4	3.4	4	4	3.4	4		
A _{VD} Large-signal differential voltage amplification	V _O = 5 mV to 4 V, R _L = 500 Ω	25°C	1	1	1	1	1	1	1	V/μV		
		Full range	0.32	0.5	0.55	0.31	0.45	0.5	0.32		0.5	
I _{CC} Supply current per amplifier		25°C	0.32	0.5	0.55	0.31	0.45	0.5	0.32	0.5	mA	
		Full range		0.55	0.55	0.5	0.55	0.55	0.5	0.55		

†Full range is -40°C to 105°C.

operating characteristics, $V_{CC±} = ±15V$, $V_{IC} = 0$, $T_A = 25°C$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		V/μs
V _n Equivalent input noise voltage	f = 10 Hz		24		nV/√Hz
V _{N(PP)} Peak-to-peak equivalent input noise voltage	f = 1 kHz		22		μV
	f = 0.1 Hz to 10 Hz		0.55		
I _n Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

DUAL PRECISION OPERATIONAL AMPLIFIERS

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

PARAMETER	TEST CONDITIONS	T _A [†]	LT1013C			LT1013AC			LT1013D			UNIT
			MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	MIN	TYP [‡]	MAX	
V _{IO}	R _S = 50 Ω	25°C	60	300	40	150	200	800				μV
		Full range		400		240		1000				
α _{VIO}	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 _{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	-15.3	-15	-15.3	-15	-15.3				V
		Full range		to		to		to				
			13.5	13.8	13.5	13.8	13.5	13.8				
			-15		-15		-15					
			to		to		to					
			13		13		13					
V _{OM}	Maximum peak output voltage swing	25°C	±12.5	±14	±13	±14	±12.5	±14				V
		Full range										
A _{VD}	Large-signal differential voltage amplification	25°C	0.5	0.2	0.8	2.5	0.5	0.2				V/μV
	V _O = ±10 V, R _L = 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	25°C	97	114	100	117	97	114				dB
	V _{IC} = -15 V to 13.5 V	Full range		94		98		94				
k _{SVR}	Supply-voltage rejection ratio (ΔV _{CC} / ΔV _{IO})	25°C	100	117	103	120	100	117				dB
	V _{CC±} = ±2 V to ±18 V	Full range		97		101		97				
r _{id}	Channel separation	25°C	120	137	123	140	120	137				dB
	V _O = ±10 V, R _L = 2 kΩ	25°C	70	300	100	400	70	300				MΩ
r _{ic}	Differential input resistance	25°C										GΩ
	Common-mode input resistance	25°C	4		5		4					
I _{CC}	Supply current per amplifier	25°C	0.35	0.55	0.35	0.5	0.35	0.55				mA
		Full range		0.6		0.55		0.6				

[†]Full range is 0°C to 70°C.
[‡]All typical values are at T_A = 25°C.



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

PARAMETER	TEST CONDITIONS	T _A [†]	LT1013C			LT1013AC			LT1013D			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V _{IO} Input offset voltage	R _S = 50 Ω	25°C	90	450		60	250	250	950		μV	
		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	-0.3		0	-0.3	0	-0.3		V	
		Full range		to		to	to	to	to			
			3.5	3.8		3.5	3.8		3.5	3.8		
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 Ω to GND	25°C	5	10		5	10	5	10			
	Output low, I _{sink} = 1 mA	Full range		13		13		13				
	Output high, No load	25°C	220	350		220	350	220	350			
	Output high, R _L = 600 Ω to GND	25°C	4	4.4		4	4.4	4	4.4			
A _{VD} Large-signal differential voltage amplification	V _O = 5 mV to 4 V, R _L = 500 Ω	25°C	1			1		1			V/μV	
		Full range		3.2		3.3		3.2				
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 0°C to 70°C.

operating characteristics, $V_{CC±} = ±15V$, $V_{IC} = 0$, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR Slew rate		0.2	0.4		V/μs
V _n Equivalent input noise voltage	f = 10 Hz		24		nV/√Hz
	f = 1 kHz		22		
V _{N(PP)} Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz		0.55		μV
	f = 10 Hz		0.07		
I _n Equivalent input noise current					pA/√Hz

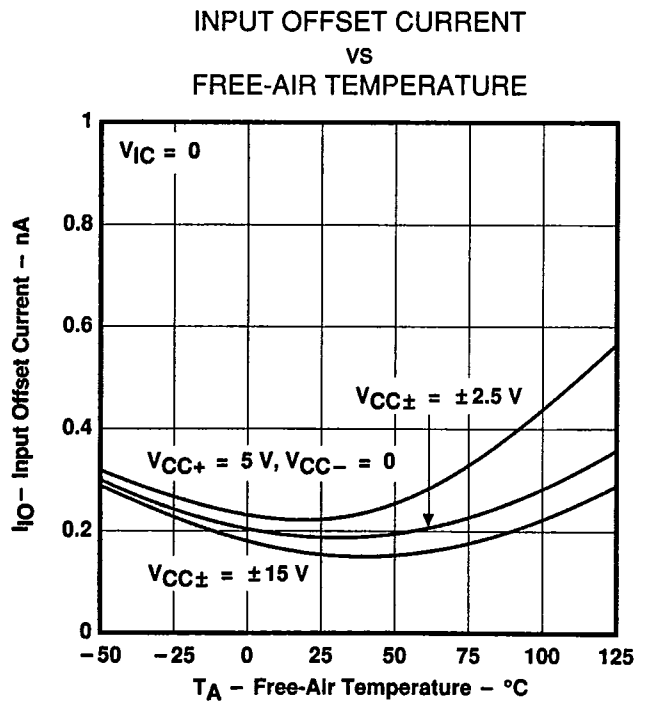
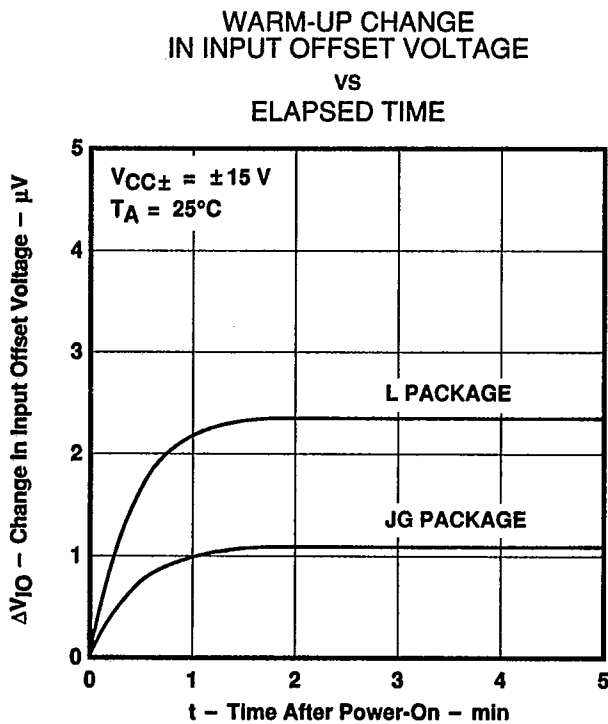
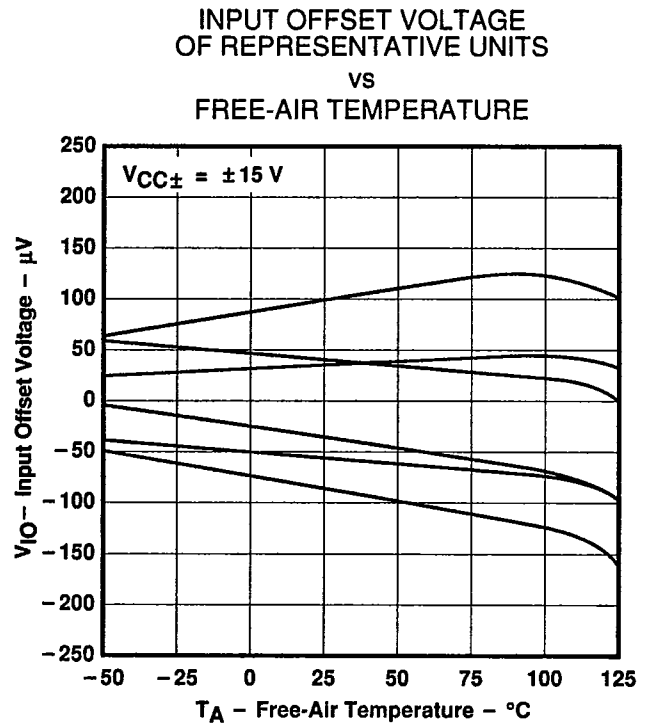
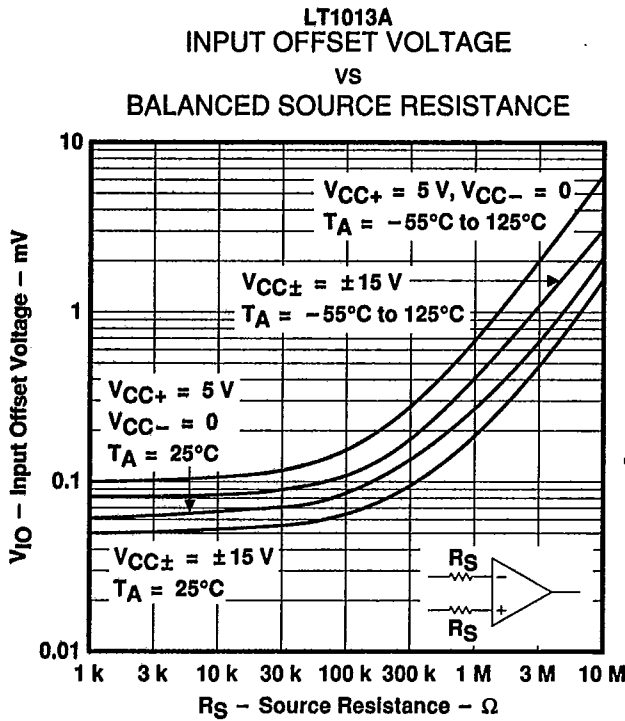
TYPICAL CHARACTERISTICS

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V_{IC}	Common-mode input voltage	vs Input bias current	6
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	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	19, 21
		Large-signal	20, 22, 23
	Phase shift	vs Frequency	9

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†

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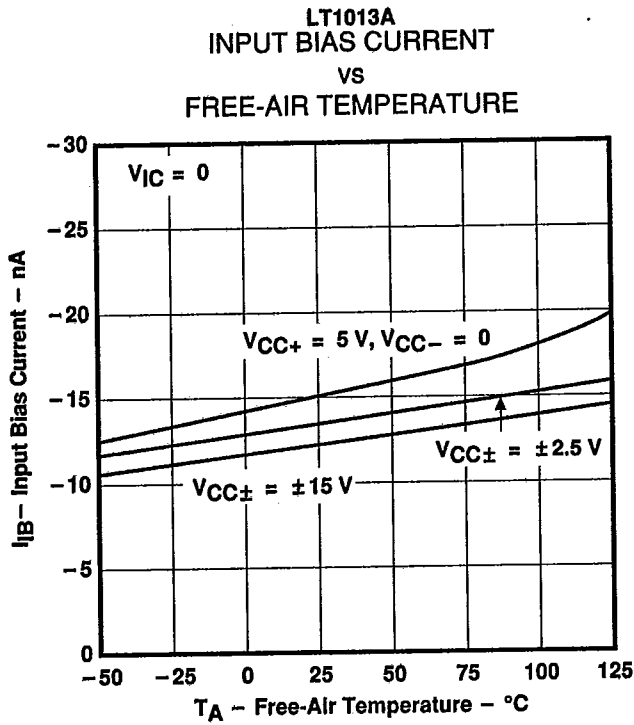


FIGURE 5

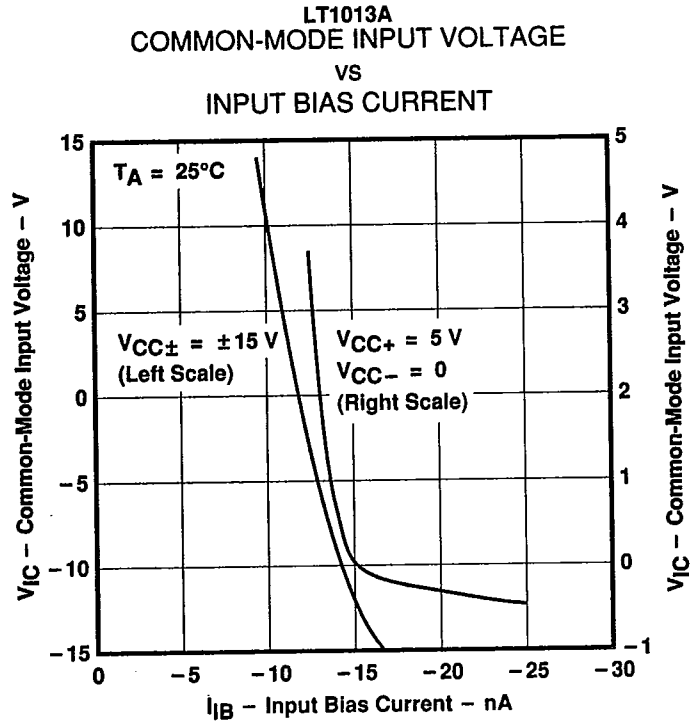


FIGURE 6

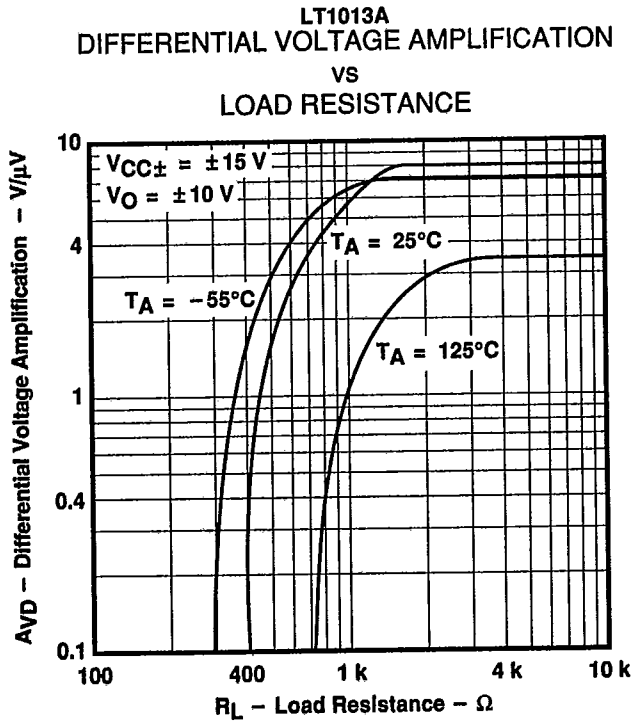


FIGURE 7

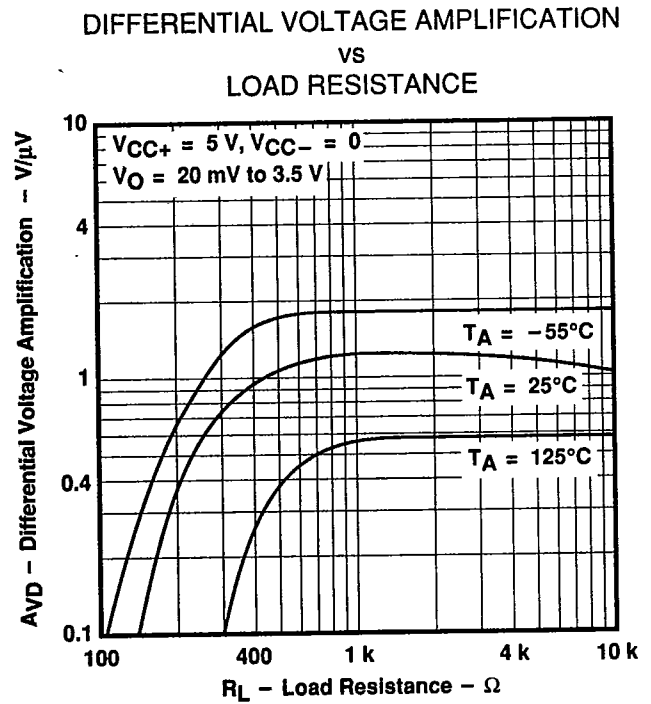


FIGURE 8

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

TEXAS INSTR (LIN/INTFC)

TYPICAL CHARACTERISTICS†

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DIFFERENTIAL VOLTAGE AMPLIFICATION
and PHASE SHIFT
VS
FREQUENCY

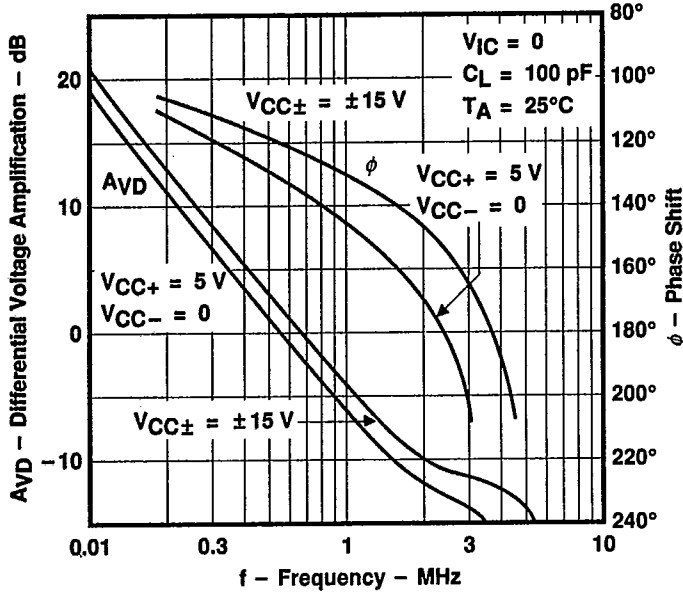


FIGURE 9

DIFFERENTIAL VOLTAGE AMPLIFICATION
VS
FREQUENCY

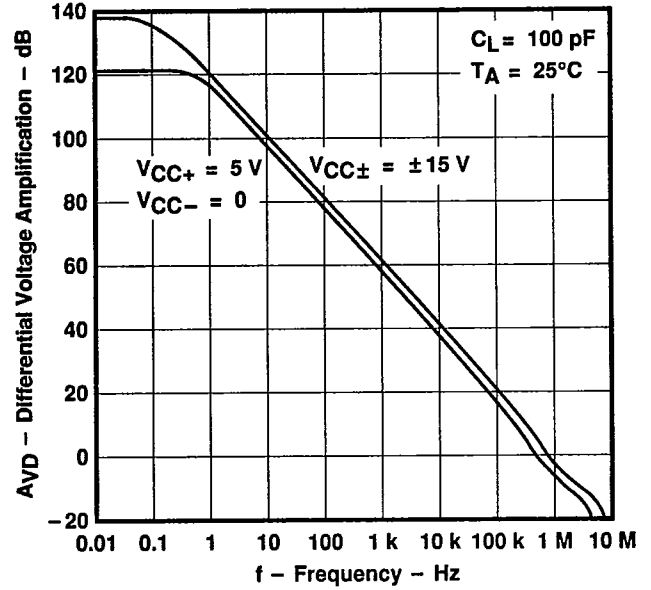


FIGURE 10

CHANNEL SEPARATION
VS
FREQUENCY

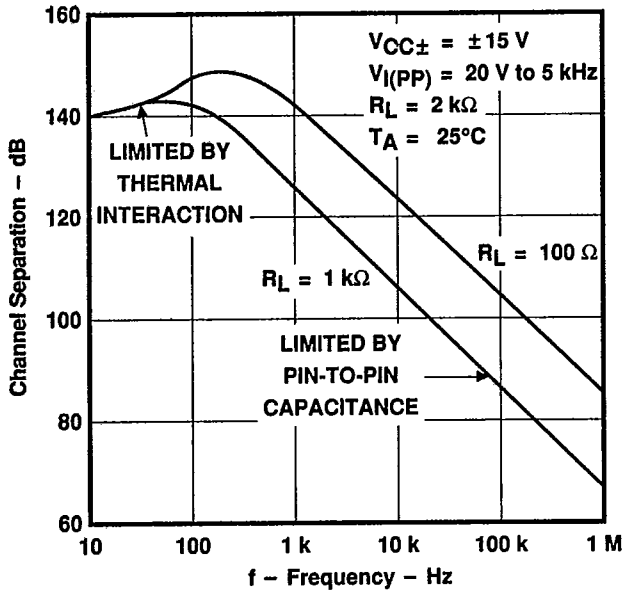


FIGURE 11

OUTPUT SATURATION VOLTAGE
VS
FREE-AIR TEMPERATURE

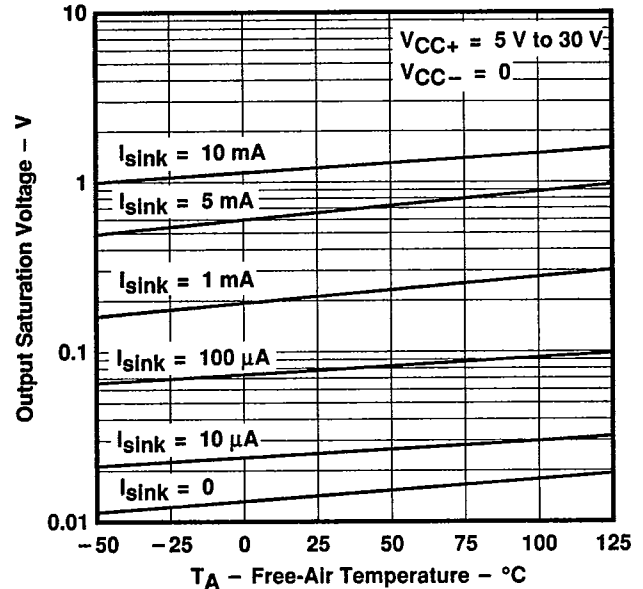


FIGURE 12

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

TYPICAL CHARACTERISTICS†

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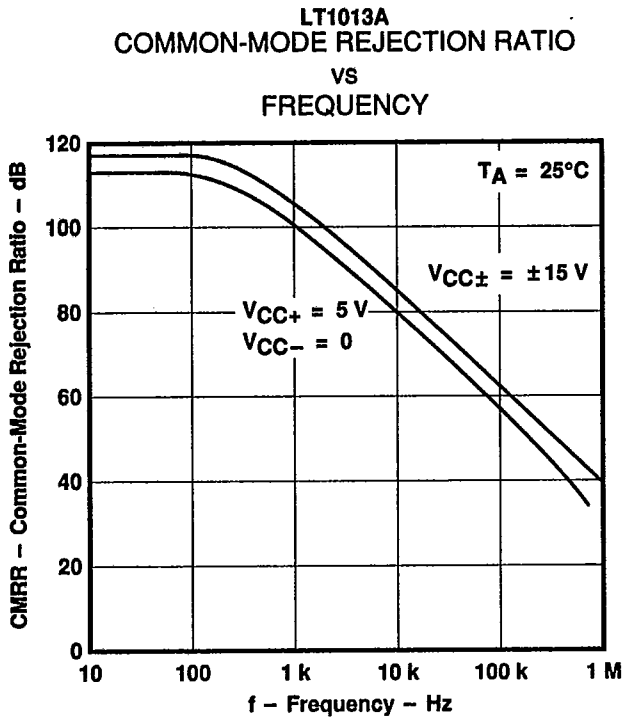


FIGURE 13

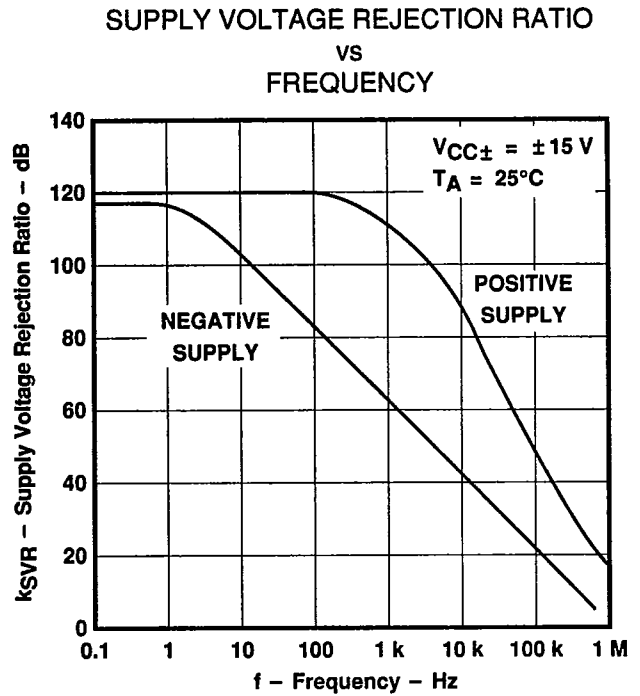


FIGURE 14

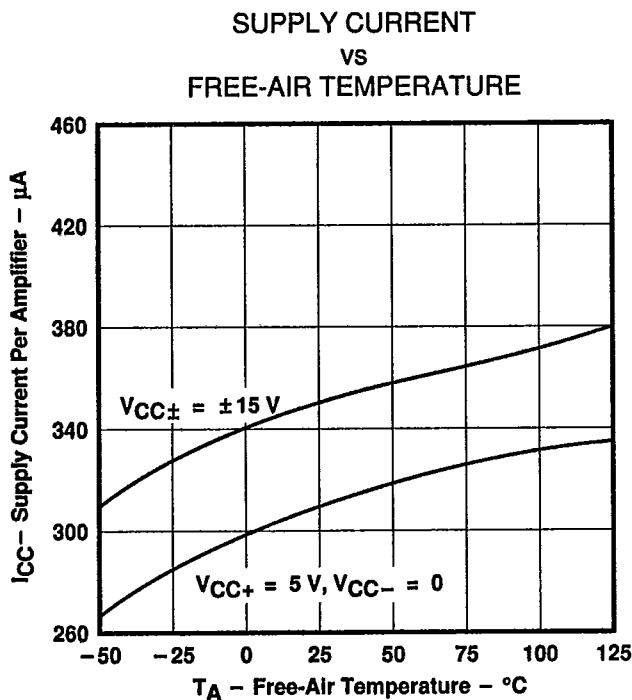


FIGURE 15

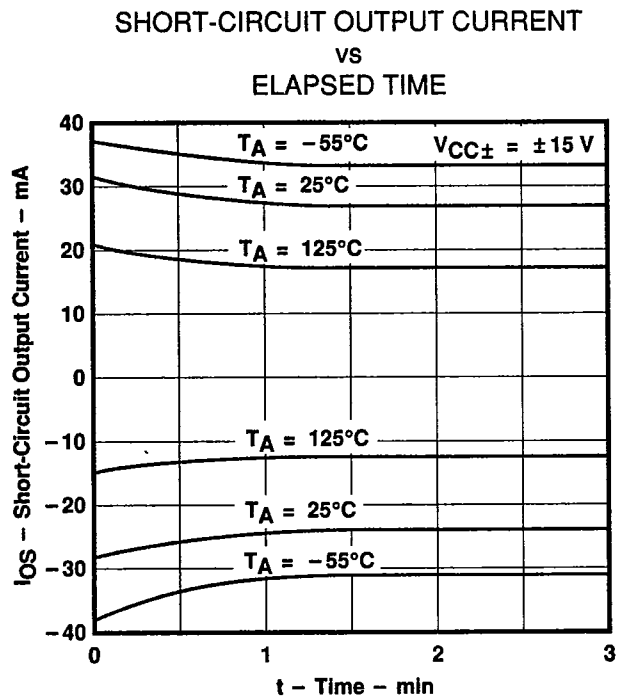


FIGURE 16

†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

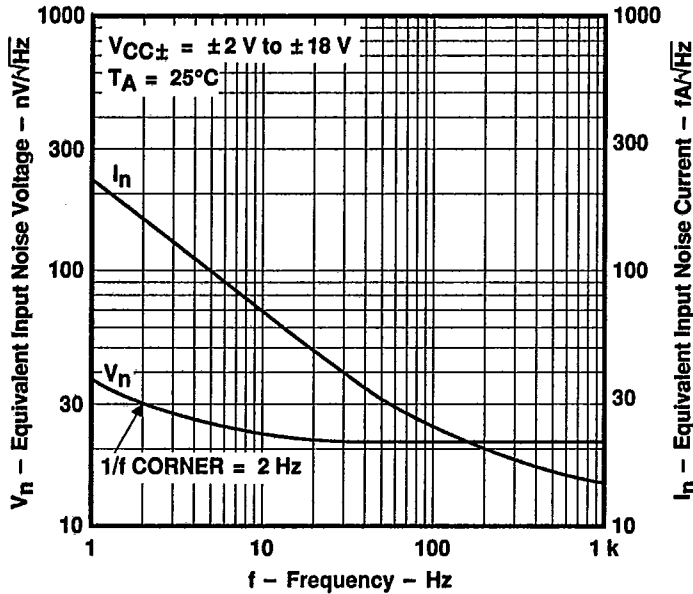


FIGURE 17

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

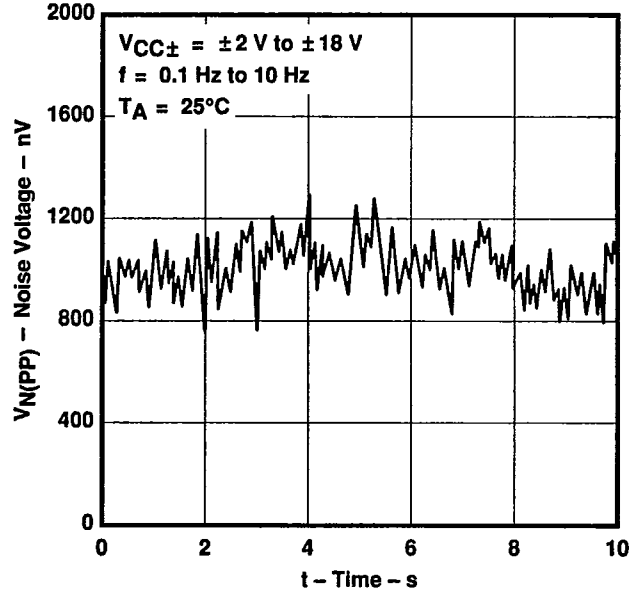


FIGURE 18

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

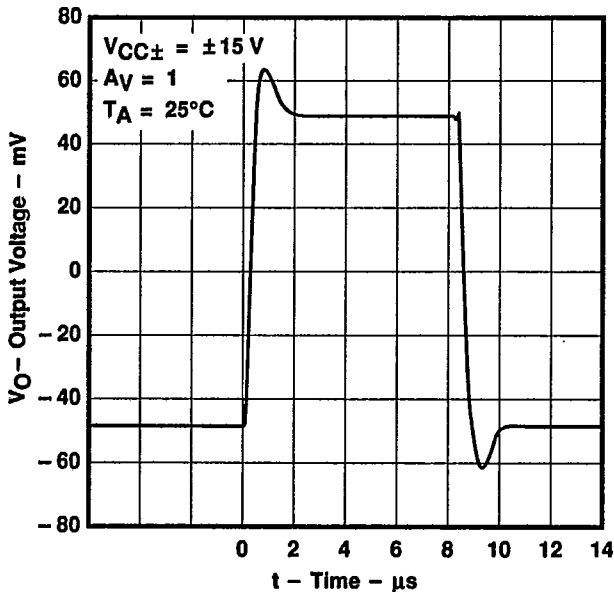


FIGURE 19

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

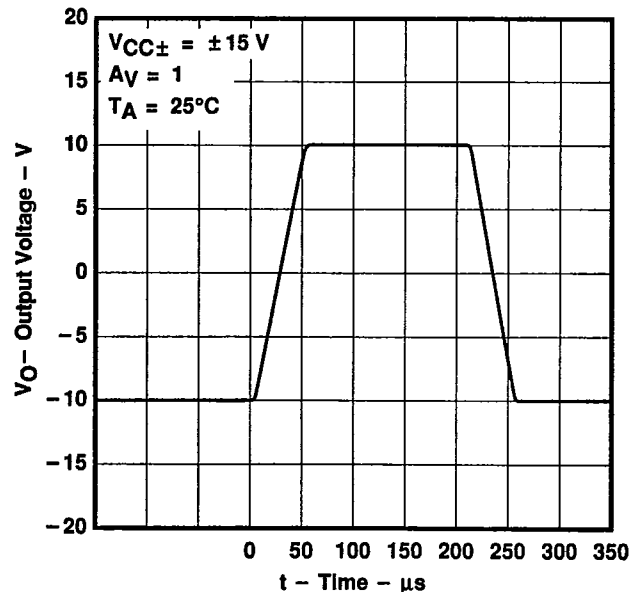


FIGURE 20

TYPICAL CHARACTERISTICS

T-79-10

VOLTAGE-FOLLOWER
 SMALL-SIGNAL
 PULSE RESPONSE

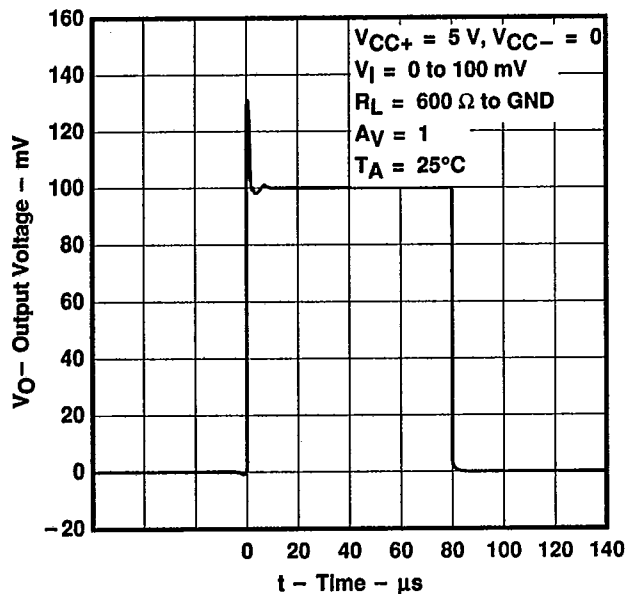


FIGURE 21

VOLTAGE-FOLLOWER
 LARGE-SIGNAL
 PULSE RESPONSE

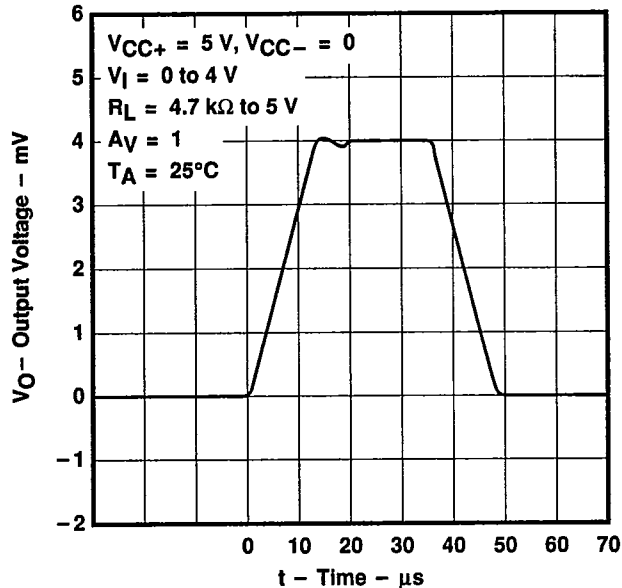


FIGURE 22

VOLTAGE-FOLLOWER
 LARGE-SIGNAL
 PULSE RESPONSE

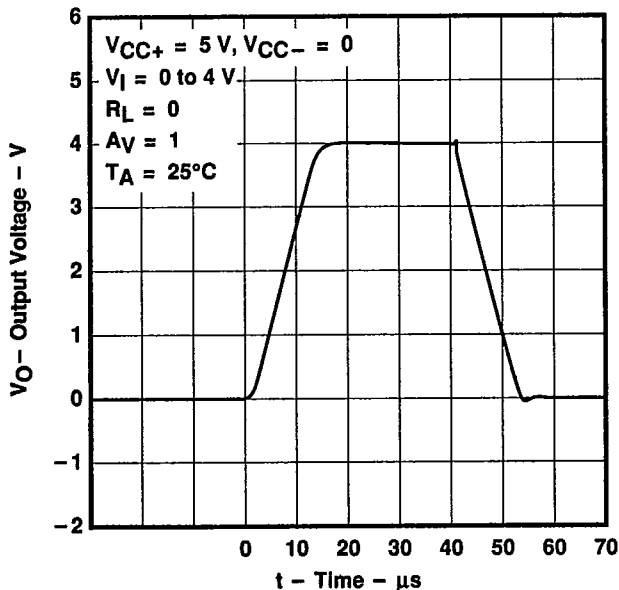


FIGURE 23

TYPICAL APPLICATION DATA

T-79-10

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 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 op amps, 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- Ω 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 op amps 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, 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 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.

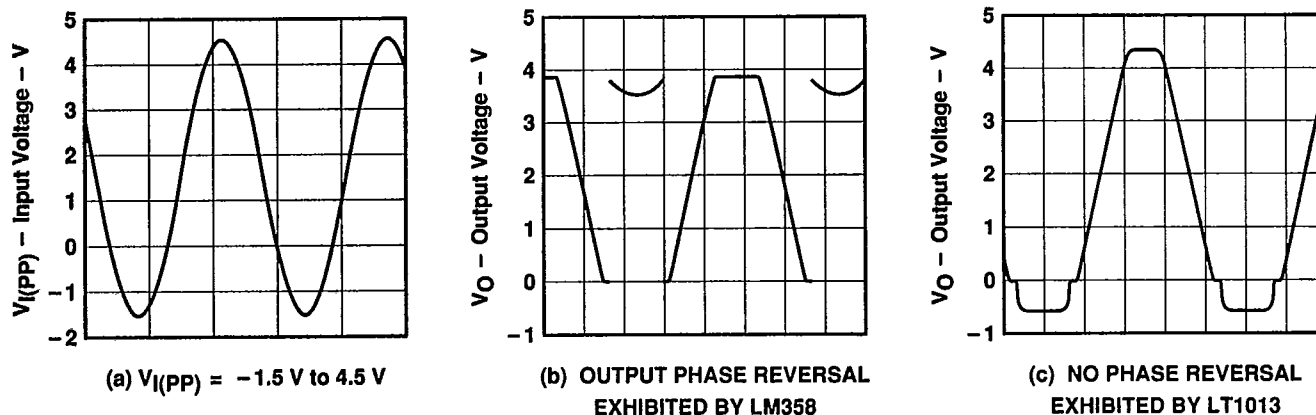


FIGURE 24. VOLTAGE-FOLLOWER PULSE RESPONSE WITH INPUT EXCEEDING THE NEGATIVE COMMON-MODE INPUT VOLTAGE RANGE

TYPICAL APPLICATION DATA

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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.

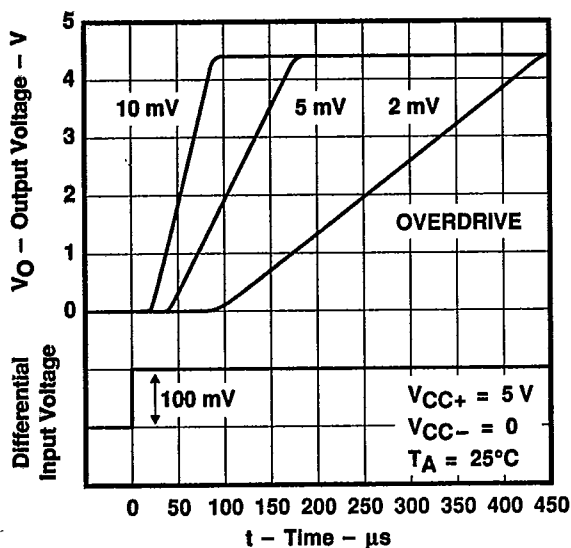


FIGURE 25. LOW- TO HIGH-LEVEL OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

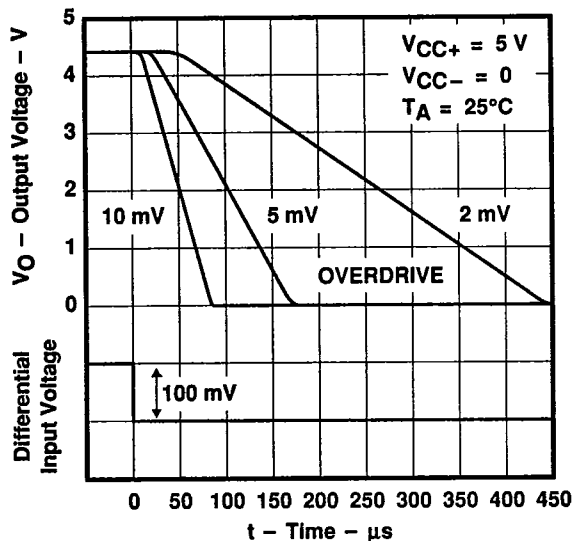


FIGURE 26. HIGH- TO LOW-LEVEL OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

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 μ 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 ± 20 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 contributions 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.

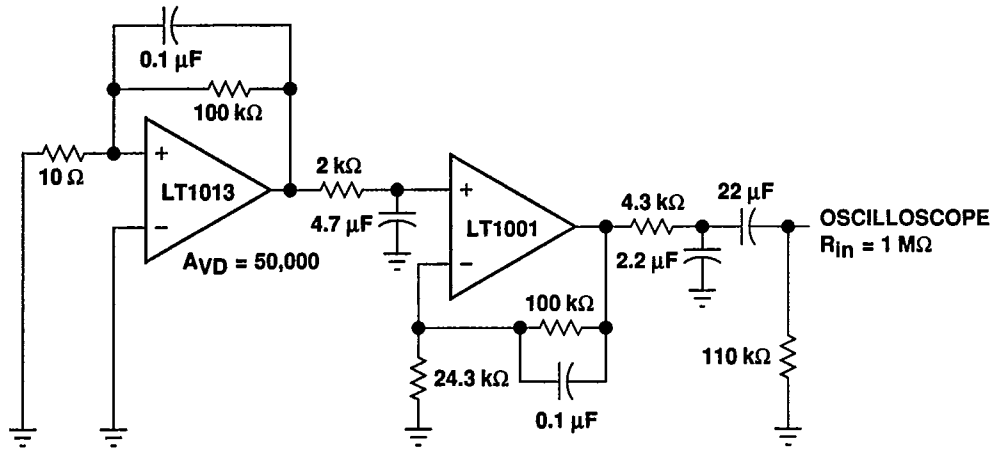
Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.

TEXAS INSTR (LIN/INTFC)

TYPICAL APPLICATION DATA

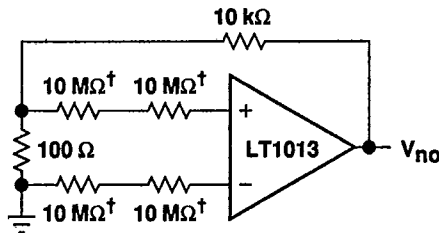
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offset voltage and noise testing (continued)



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

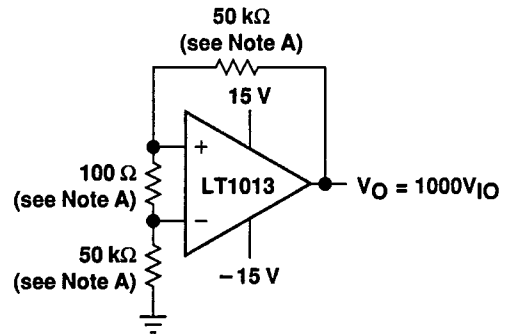
FIGURE 27. 0.1-Hz TO 10-Hz PEAK-TO-PEAK NOISE TEST CIRCUIT



† Metal film resistor.

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

FIGURE 28. NOISE CURRENT TEST CIRCUIT AND FORMULA



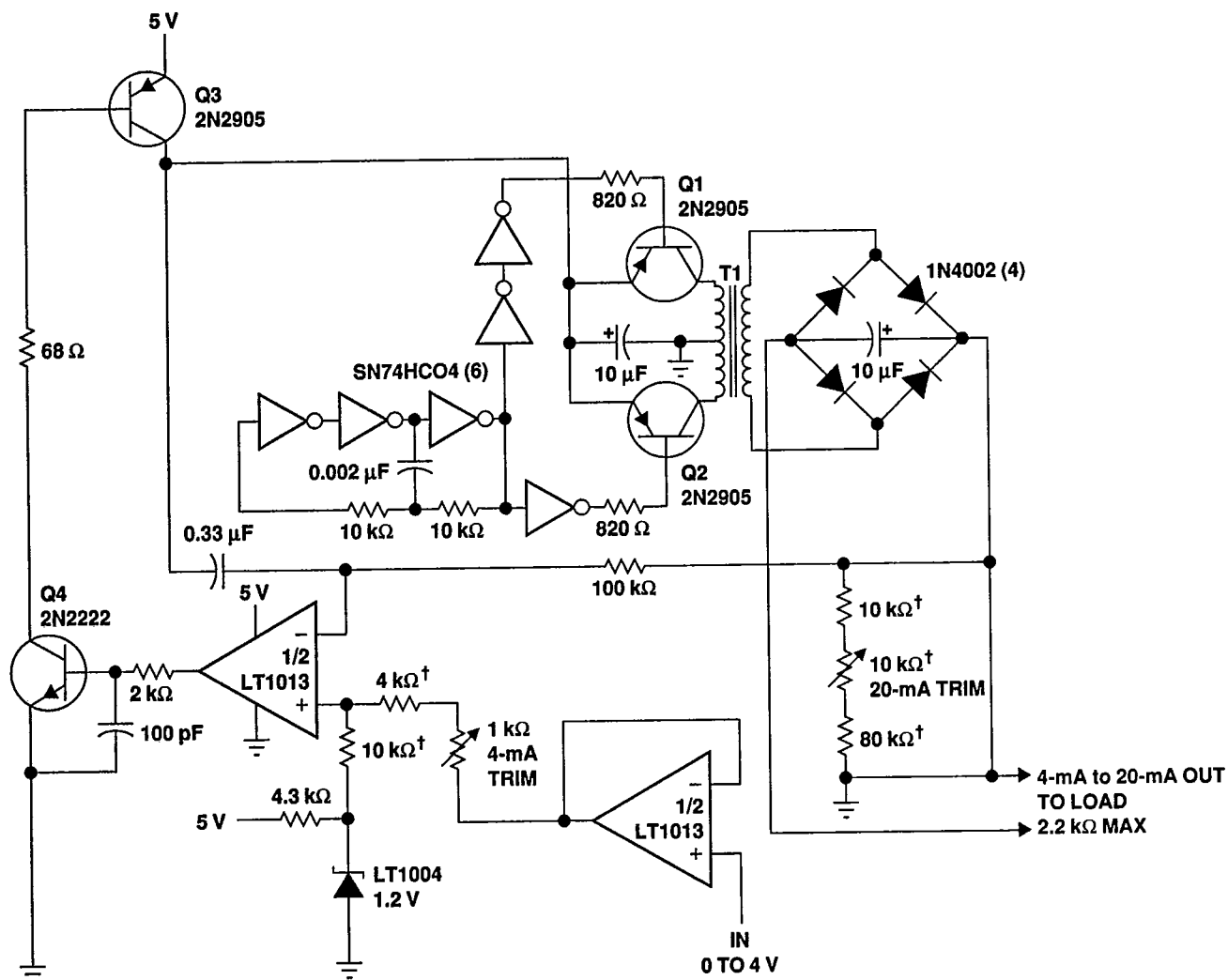
NOTE A: Resistors must have low thermoelectric potential.

FIGURE 29. TEST CIRCUIT FOR V_{IO} AND αV_{IO}

TYPICAL APPLICATION DATA

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typical applications



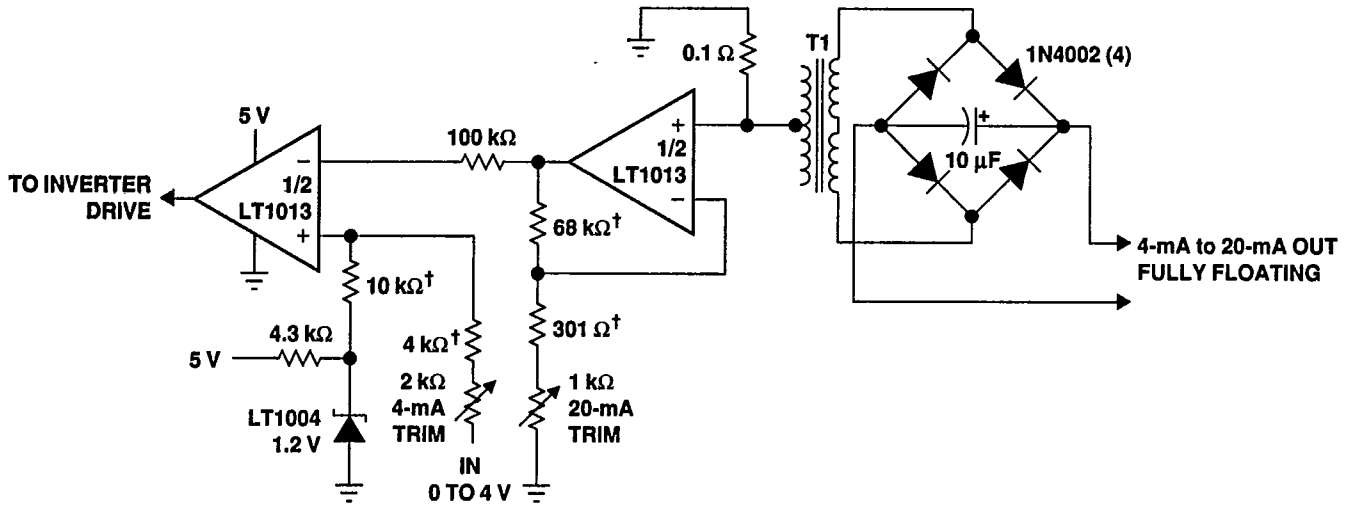
†1% film resistor. Match 10-kΩ resistors 0.05%.

NOTE A: T1 = PICO-31080.

FIGURE 30. 5-V POWERED 4-mA – 20-mA CURRENT LOOP TRANSMITTER WITH 12-BIT ACCURACY

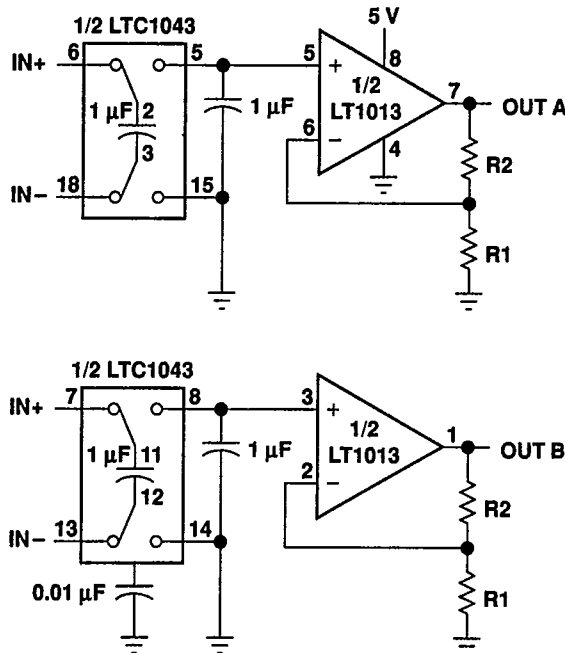
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TYPICAL APPLICATION DATA



†1% film resistor

FIGURE 31. FULLY FLOATING MODIFICATION TO 4-mA - 20-mA CURRENT LOOP TRANSMITTER WITH 8-BIT ACCURACY

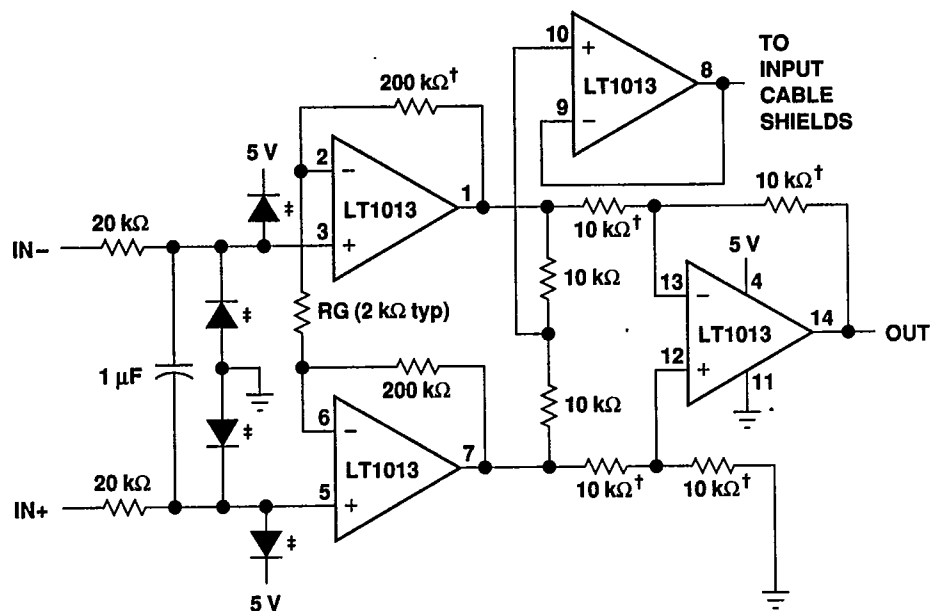


NOTE A: $V_{IO} = 150 \mu\text{V}$, $A_{VD} = (R1/R2) + 1$, $\text{CMRR} = 120 \text{ dB}$, $V_{ICR} = 0 \text{ to } 5 \text{ V}$.

FIGURE 32. 5-V SINGLE-SUPPLY DUAL INSTRUMENTATION AMPLIFIER

TYPICAL APPLICATION DATA

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†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 POWERED PRECISION INSTRUMENTATION AMPLIFIER