LT1013, LT1013A, LT1013D
DUAL PRECISION OPERATIONAL AMPLIFIERS

TEXAS INSTR (LIN/INTFC)

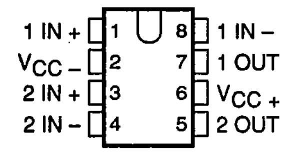
NOTICE
SEE ORDER OF DATA FOR ERRATA INFORMATION

D3237, MAY 1988 – REVISED JULY 1989

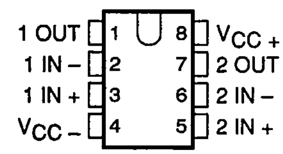
T- 79-10

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

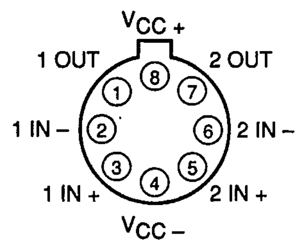
D PACKAGE
(TOP VIEW)



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

T_A	V_{IO} max AT 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C	150 μV	—	LT1013ACJG	LT1013ACL	—
to	300 μV	—	LT1013CJG	LT1013CL	LT1013CP
70°C	800 μV	LT1013DD	LT1013DJG	LT1013DL	LT1013DP
− 40°C	150 μV	—	LT1013AIJG	—	—
to	300 μV	—	LT1013IJG	—	LT1013IP
105°C	800 μV	LT1013DID	LT1013DIJG	—	LT1013DIP
− 55°C	150 μV	—	—	LT1013AML	—
to	300 μV	—	LT1013MJG	LT1013ML	LT1013MP
125°C	800 μV	LT1013DMD	LT1013DMJG	LT1013DML	LT1013DMP

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

25E D ■ 8961724 0080609 4 ■

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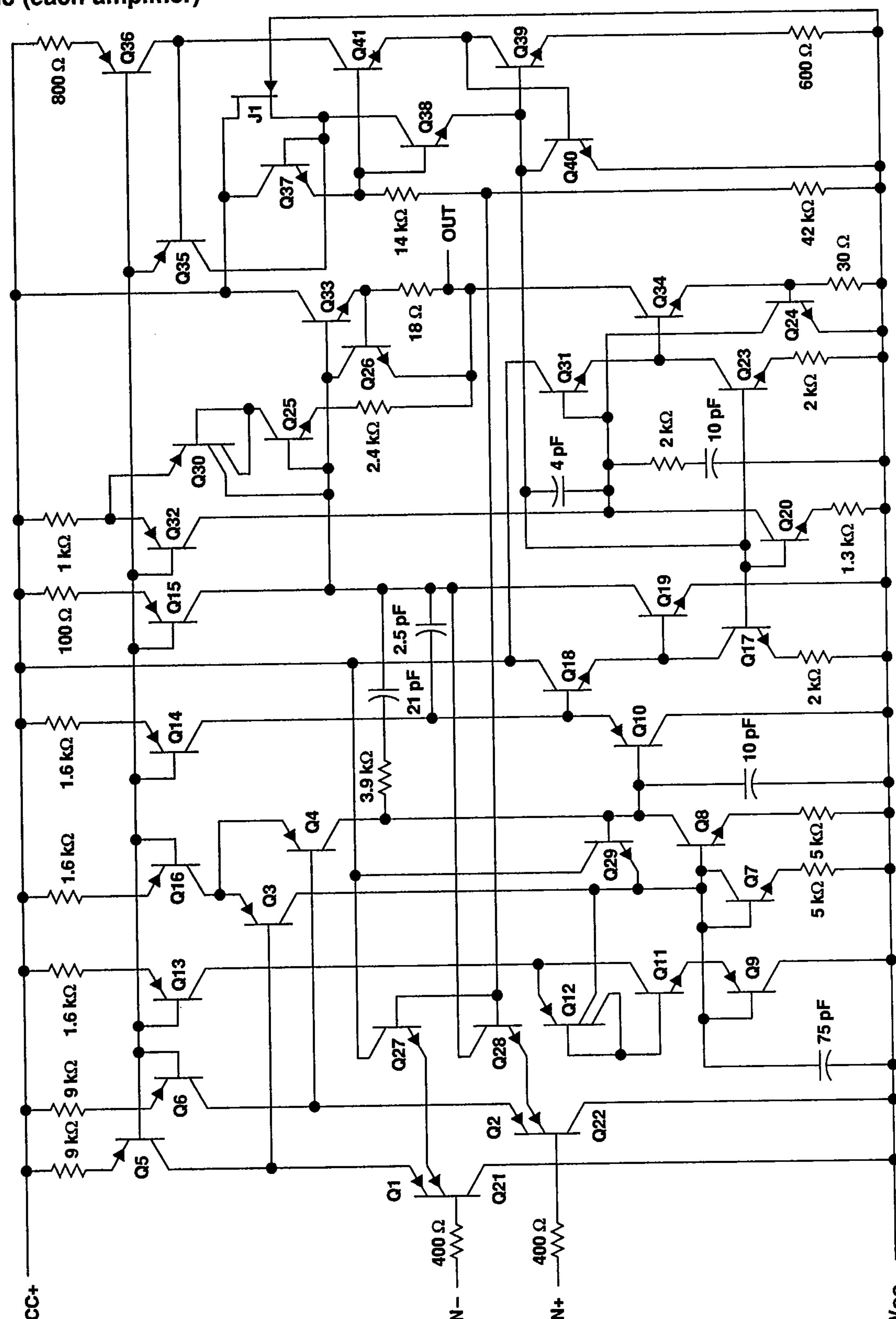
schematic (each amplifier)



Resistor values are nominal.

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

Supply voltage, V_{CC+} (see Note 1)		22 V
Supply voltage, V_{CC-} (see Note 1)		−22 V
Differential input voltage (see Note 2)		±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.

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

	PARAMETER	TEST CONDITIONS	T_A†	LT1013M MIN	LT1013M TYP‡	LT1013M MAX	LT1013AM MIN	LT1013AM TYP‡	LT1013AM MAX	LT1013DM MIN	LT1013DM TYP‡	LT1013DM MAX	UNIT
V_{IO}	Input offset voltage	R_S = 50 Ω	25°C		60	300		40	150		200	800	µV
			Full range			550			300			1000	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		0.5	2.5		0.4	2		0.5	2.5	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			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
			−55°C to 105°C	−15 to 13			−15 to 13			−15 to 13			
			105°C to 125°C	−14.9 to 13			−14.9 to 13			−14.9 to 13			
V_{OM}	Maximum peak output voltage swing	R_L = 2 kΩ	25°C	±12.5	±14		±13	±14		±12.5	±14		V
			Full range	±11.5			±12			±11.5			
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L = 600 Ω	25°C	0.5	2		0.8	2.5		0.5	2		V/µV
		V_O = ±10 V, R_L = 2 kΩ	25°C	1.2	7		1.5	8		1.2	7		
			Full range	0.25			0.5			0.25			
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 (ΔV_{CC} / ΔV_{IO})	$V_{CC\pm}$ = ±2 V to ±18 V	25°C	100	117		103	120		100	117		dB
			Full range	97			100			97			
	Channel separation	V_O = ±10 V, R_L = 2 kΩ	25°C	120	137		123	140		120	137		dB
r_{id}	Differential input resistance		25°C	70	300		100	400		70	300		MΩ
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			0.7			0.6			0.7	

†Full range is −55°C to 125°C.
‡All typical values are at T_A = 25°C.

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electrical characteristics at specified free-air temperature, V_{CC+} = 5 V, V_{CC-} = 0 V, V_O = 1.4 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 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	
		R_S = 50 Ω, V_{IC} = 0.1 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
			−55°C to 105°C	0 to 3			0 to 3			0 to 3			
			105°C to 125°C	0.1 to 3			0.1 to 3			0.1 to 3			
V_{OM}	Maximum peak output voltage swing	Output low, No load	25°C		15	25		15	25		15	25	mV
		Output low, R_L = 600 Ω to GND	25°C		5	10		5	10		5	10	
			Full range			18			15			18	
		Output low, I_{sink} = 1 mA	25°C		220	350		220	350		220	350	
		Output high, No load	25°C	4	4.4		4	4.4		4	4.4		V
		Output high, R_L = 600 Ω to GND	25°C	3.4	4		3.4	4		3.4	4		
			Full range	3.1			3.2			3.1			
A_{VD}	Large-signal differential voltage amplification	V_O = 5 mV to 4 V, R_L = 500 Ω	25°C		1			1			1		V/μV
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, $V_{CC\pm}$ = ±15 V, 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
I_n	Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

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

PARAMETER		TEST CONDITIONS	T_A†	LT1013I MIN	LT1013I TYP‡	LT1013I MAX	LT1013AI MIN	LT1013AI TYP‡	LT1013AI MAX	LT1013DI MIN	LT1013DI TYP‡	LT1013DI MAX	UNIT
V_{IO}	Input offset voltage	R_S = 50 Ω	25°C		60	300		40	150		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 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 kΩ	25°C	±12.5	±14		±13	±14		±12.5	±14		V
			Full range	±12			±12.5			±12			
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L = 600 Ω	25°C	0.5	2		0.8	2.5		0.5	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	V_{IC} = −15 V to 13.5 V	25°C	97	114		100	117		97	114		dB
		V_{IC} = −15 V to 13 V	Full range	94			97			94			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC} / \Delta V_{IO}$)	$V_{CC\pm}$ = ±2 V to ±15 V	25°C	100	117		103	120		100	117		dB
			Full range	97			101			97			
	Channel separation	V_O = ±10 V, R_L = 2 kΩ	25°C	120	137		123	140		120	137		dB
r_{id}	Differential input resistance		25°C	70	300		100	400		70	300		MΩ
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.

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electrical characteristics at specified free-air temperature, V_{CC+} = 5 V, V_{CC-} = 0 V, V_O = 1.4 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 Ω	25°C		90	450		60	250		250	950	µV
			Full range			750			450			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 Ω to GND	25°C		5	10		5	10		5	10	
			Full range			13			13			13	
		Output low, I_{sink} = 1 mA	25°C		220	350		220	350		220	350	
		Output high, No load	25°C	4	4.4		4	4.4		4	4.4		V
		Output high, R_L = 600 Ω 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 mV to 4 V, R_L = 500 Ω	25°C		1			1			1		V/µV
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°C to 105°C.

operating characteristics, $V_{CC\pm}$ = ±15 V, 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
I_n	Equivalent input noise current	f = 10 Hz		0.07		pA/√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†	LT1013C MIN	LT1013C TYP‡	LT1013C MAX	LT1013AC MIN	LT1013AC TYP‡	LT1013AC MAX	LT1013D MIN	LT1013D TYP‡	LT1013D MAX	UNIT
V_{IO}	Input offset voltage	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 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 kΩ	25°C	±12.5	±14		±13	±14		±12.5	±14		V
			Full range	±12			±12.5			±12			
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L = 600 Ω	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	V_{IC} = −15 V to 13.5 V	25°C	97	114		100	117		97	114		dB
		V_{IC} = −15 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 ±18 V	25°C	100	117		103	120		100	117		dB
			Full range	97			101			97			
	Channel separation	V_O = ±10 V, R_L = 2 kΩ	25°C	120	137		123	140		120	137		dB
r_{id}	Differential input resistance		25°C	70	300		100	400		70	300		MΩ
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 0°C to 70°C.
‡All typical values are at T_A = 25°C.

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

	PARAMETER	TEST CONDITIONS	T_A†	LT1013C MIN	LT1013C TYP	LT1013C MAX	LT1013AC MIN	LT1013AC TYP	LT1013AC MAX	LT1013D MIN	LT1013D TYP	LT1013D MAX	UNIT
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 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 Ω to GND	25°C		5	10		5	10		5	10	
			Full range			13			13			13	
		Output low, I_{sink} = 1 mA	25°C		220	350		220	350		220	350	
		Output high, No load	25°C	4	4.4		4	4.4		4	4.4		V
		Output high, R_L = 600 Ω 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 mV to 4 V, R_L = 500 Ω	25°C		1			1			1		V/µV
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, $V_{CC\pm}$ = ±15 V, 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
I_n	Equivalent input noise current	f = 10 Hz		0.07		pA/√Hz

TYPICAL CHARACTERISTICS

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table of graphs

			FIGURE
V_{IO}	Input offset voltage	vs Source resistance	1
		vs Temperature	2
ΔV_{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	19, 21
		Large-signal	20, 22, 23
	Phase shift	vs Frequency	9

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TYPICAL CHARACTERISTICS†

LT1013A
INPUT OFFSET VOLTAGE
vs
BALANCED SOURCE RESISTANCE

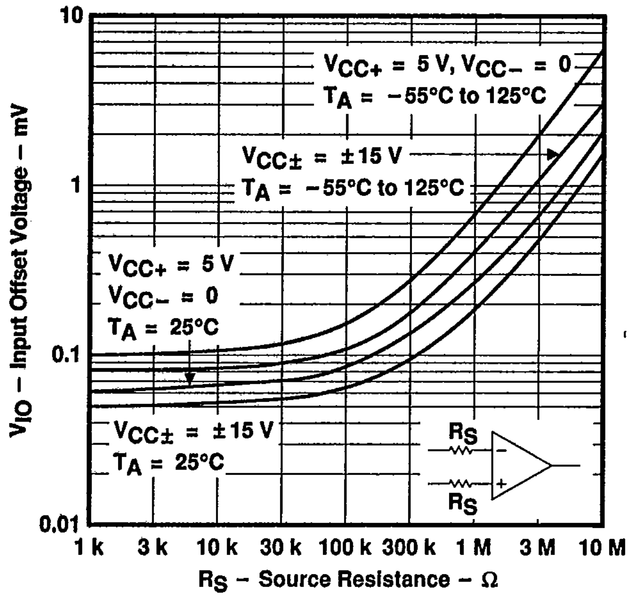

FIGURE 1

INPUT OFFSET VOLTAGE
OF REPRESENTATIVE UNITS
vs
FREE-AIR TEMPERATURE

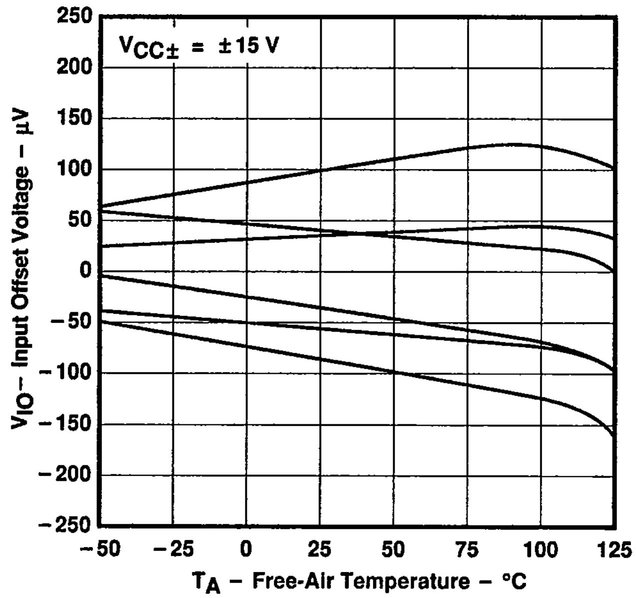

FIGURE 2

WARM-UP CHANGE
IN INPUT OFFSET VOLTAGE
vs
ELAPSED TIME

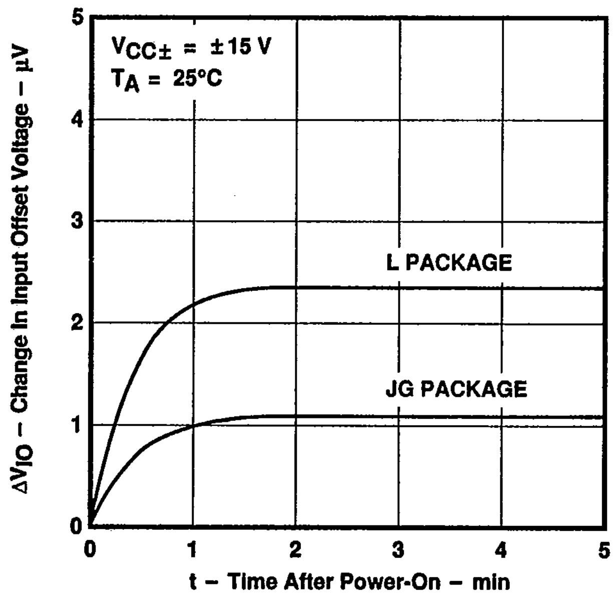

FIGURE 3

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

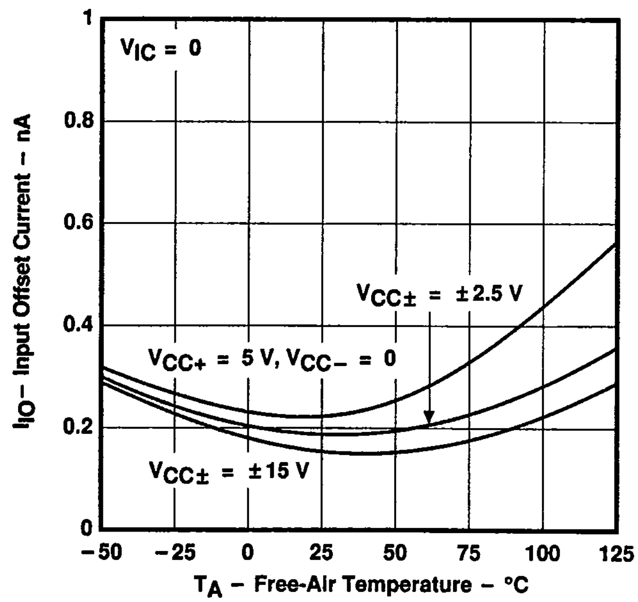

FIGURE 4

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

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TYPICAL CHARACTERISTICS†

LT1013A
INPUT BIAS CURRENT
VS
FREE-AIR TEMPERATURE

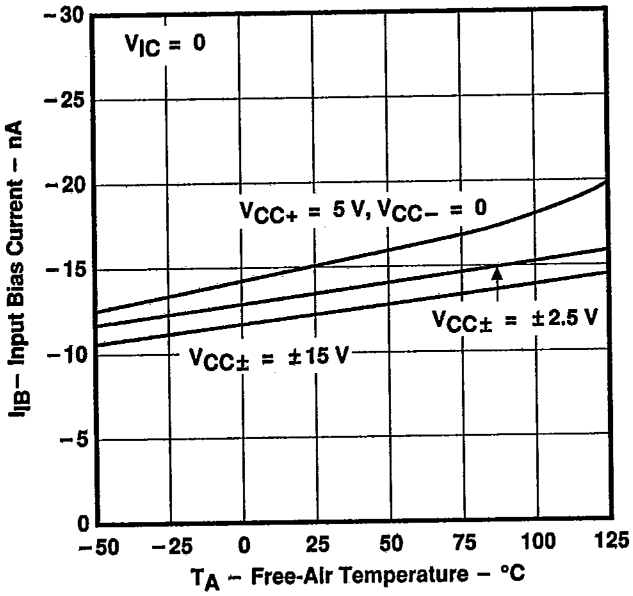

FIGURE 5

LT1013A
COMMON-MODE INPUT VOLTAGE
VS
INPUT BIAS CURRENT

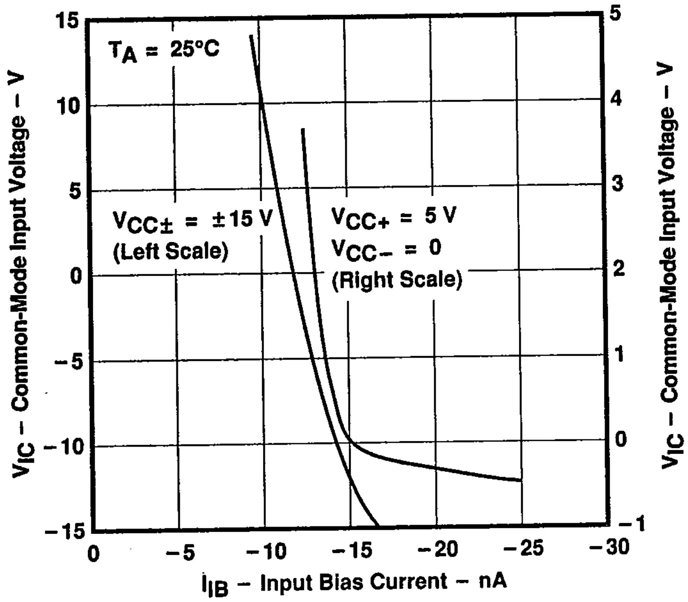

FIGURE 6

LT1013A
DIFFERENTIAL VOLTAGE AMPLIFICATION
VS
LOAD RESISTANCE

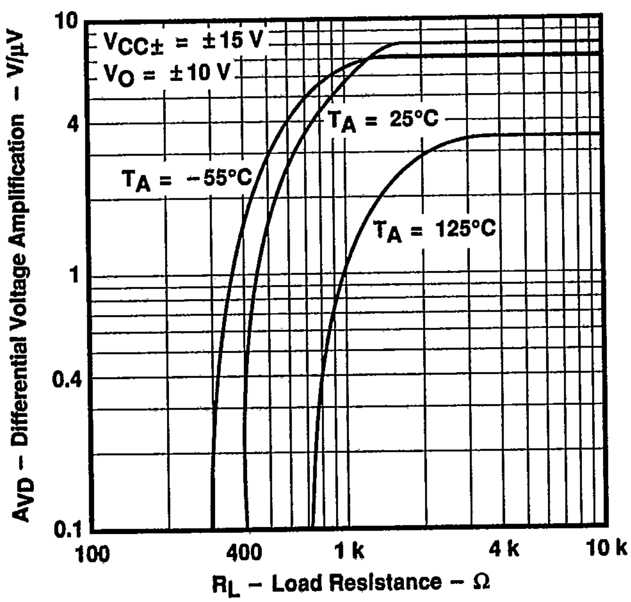

FIGURE 7

DIFFERENTIAL VOLTAGE AMPLIFICATION
VS
LOAD RESISTANCE

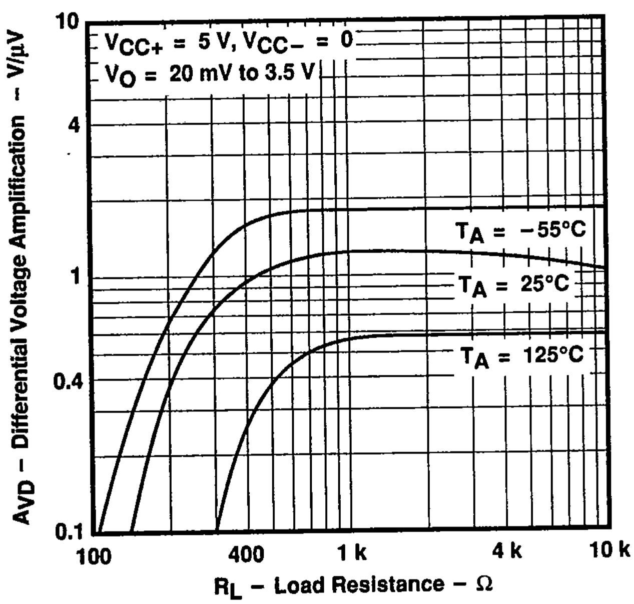

FIGURE 8

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

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TYPICAL CHARACTERISTICS†

DIFFERENTIAL VOLTAGE AMPLIFICATION and PHASE SHIFT vs FREQUENCY

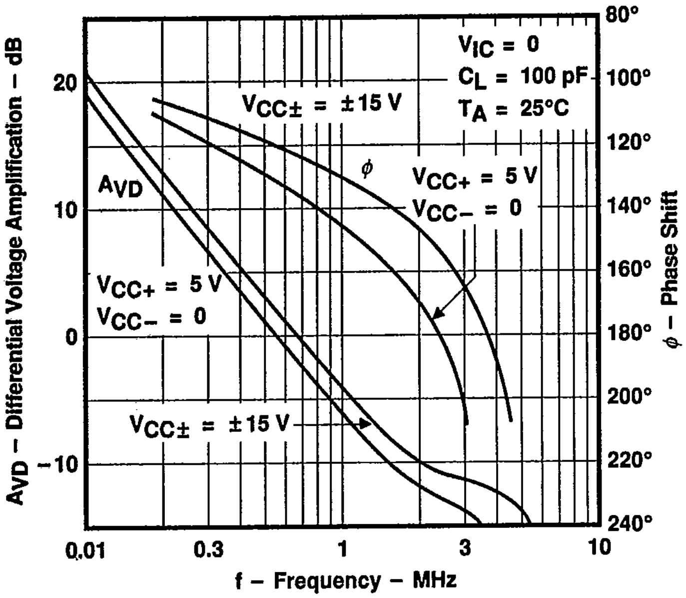

FIGURE 9

DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY

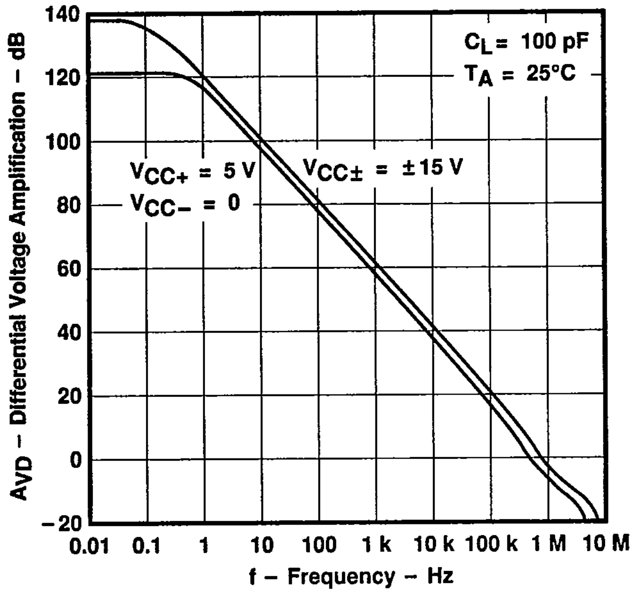

FIGURE 10

CHANNEL SEPARATION vs FREQUENCY

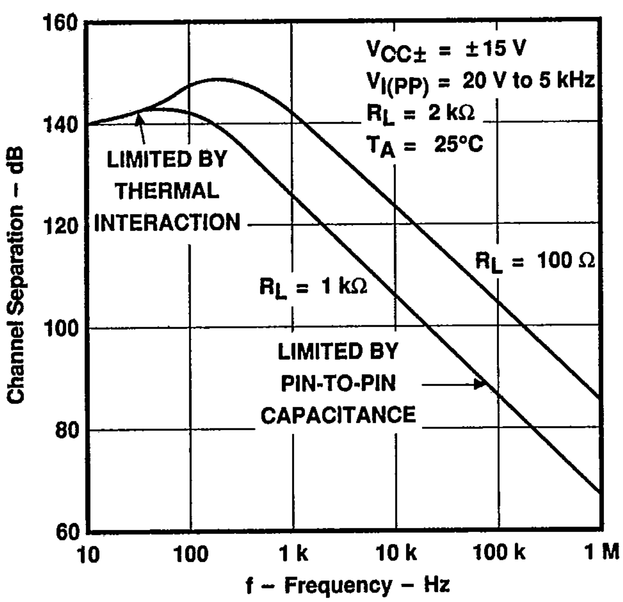

FIGURE 11

OUTPUT SATURATION VOLTAGE vs FREE-AIR TEMPERATURE

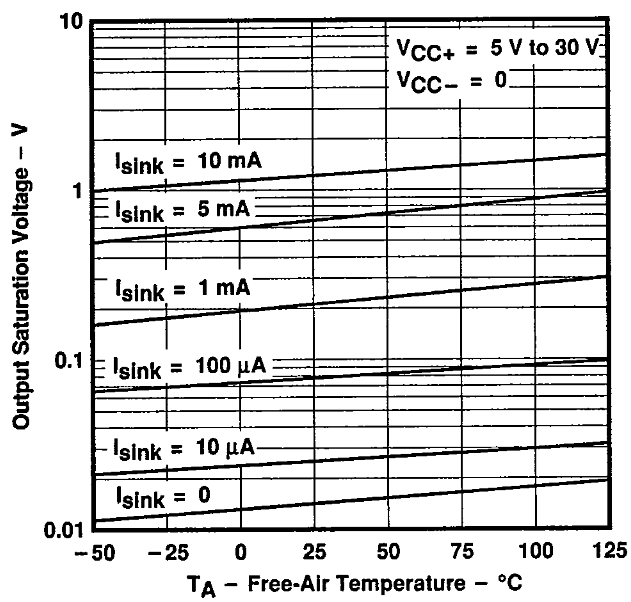

FIGURE 12

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

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TYPICAL CHARACTERISTICS†

LT1013A
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

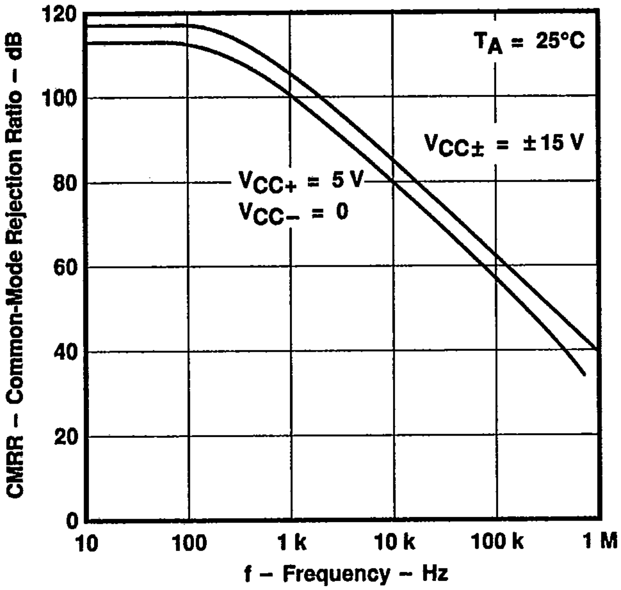


FIGURE 13

SUPPLY VOLTAGE REJECTION RATIO
vs
FREQUENCY

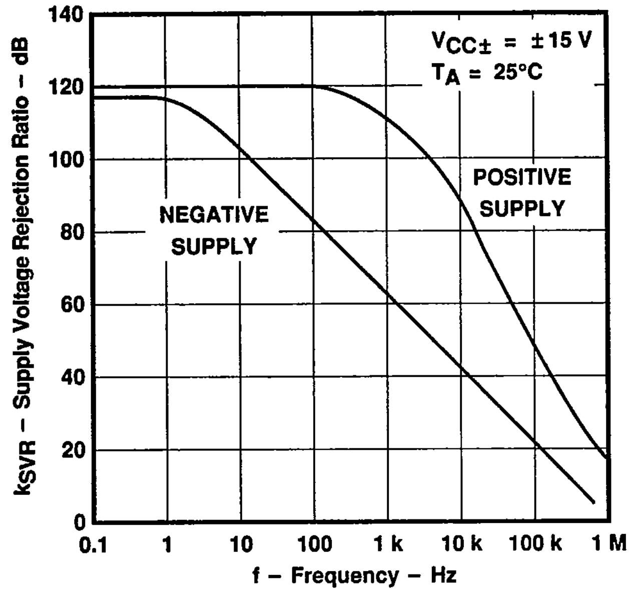


FIGURE 14

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

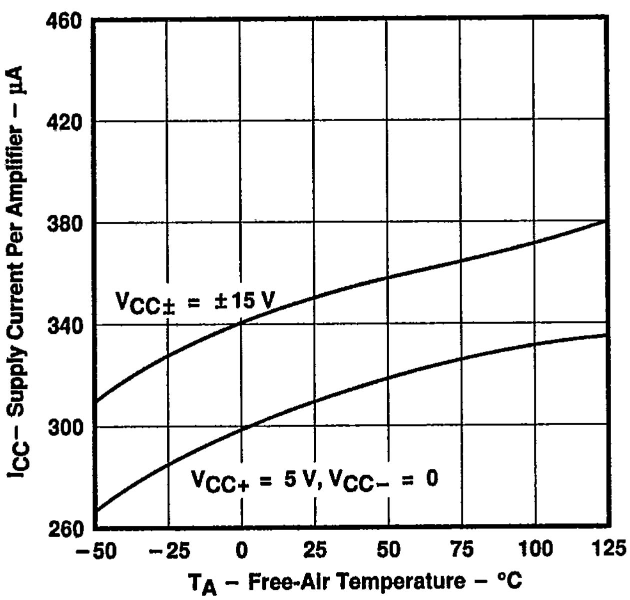


FIGURE 15

SHORT-CIRCUIT OUTPUT CURRENT
vs
ELAPSED TIME

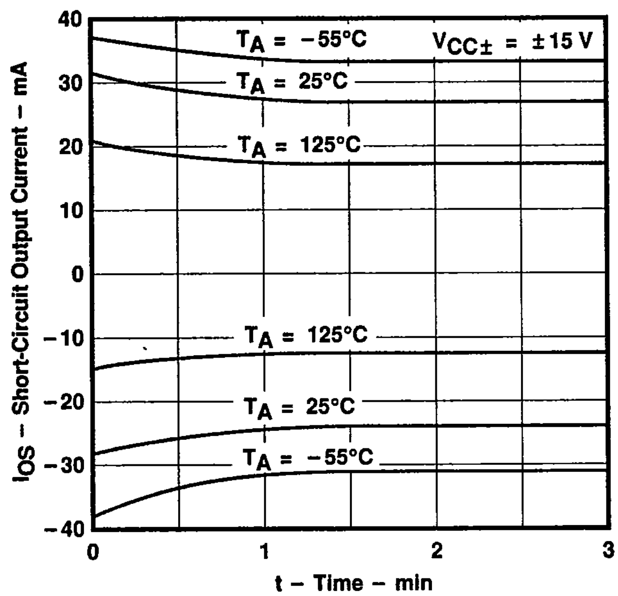


FIGURE 16

†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

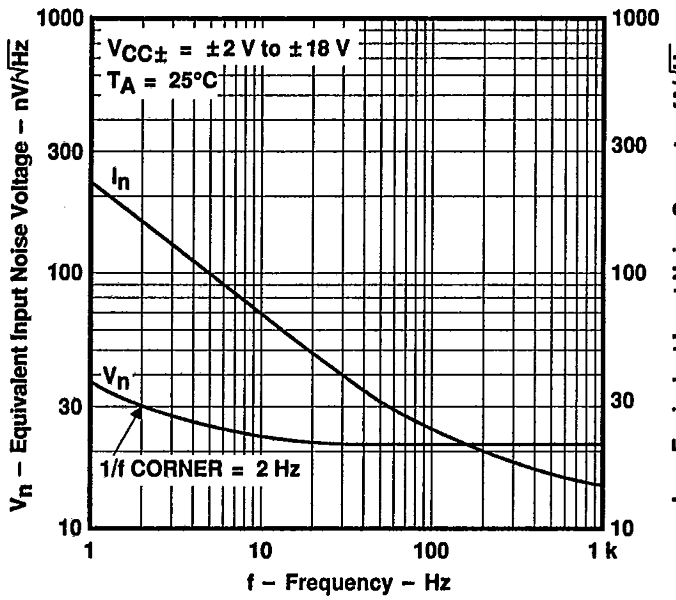


FIGURE 17

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

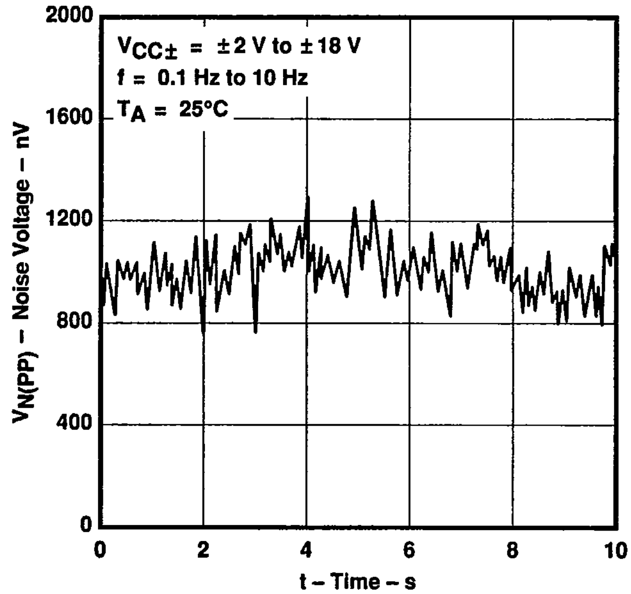


FIGURE 18

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

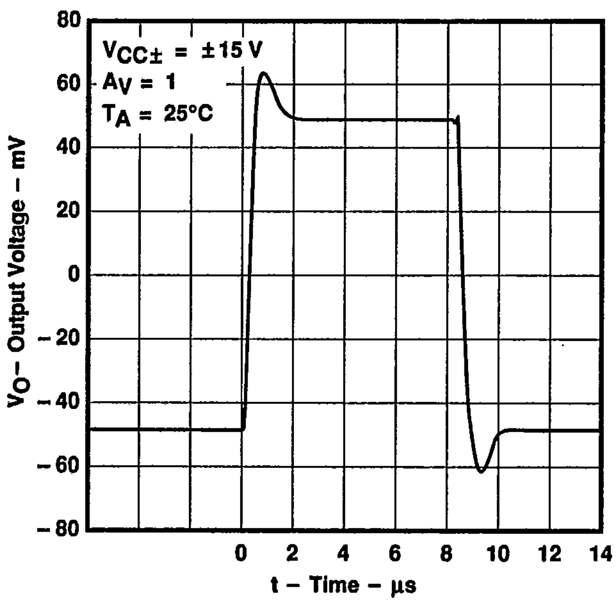


FIGURE 19

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

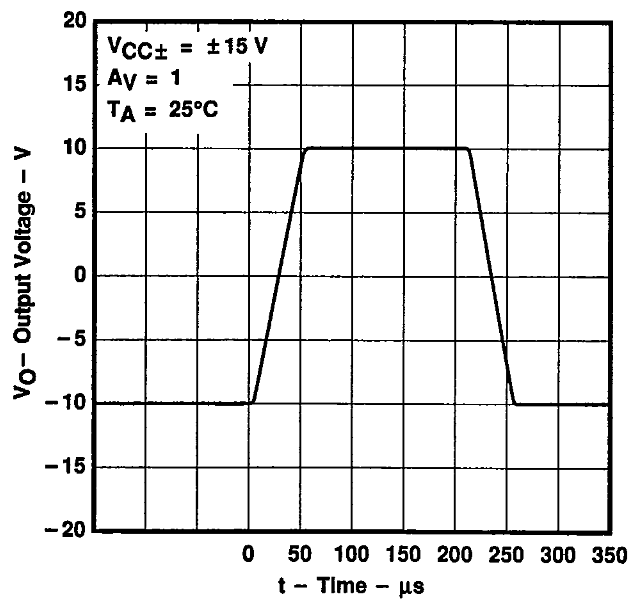


FIGURE 20

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

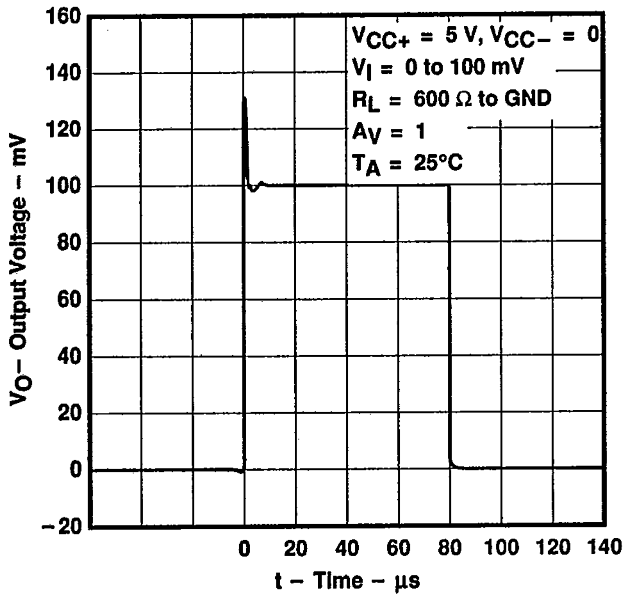


FIGURE 21

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

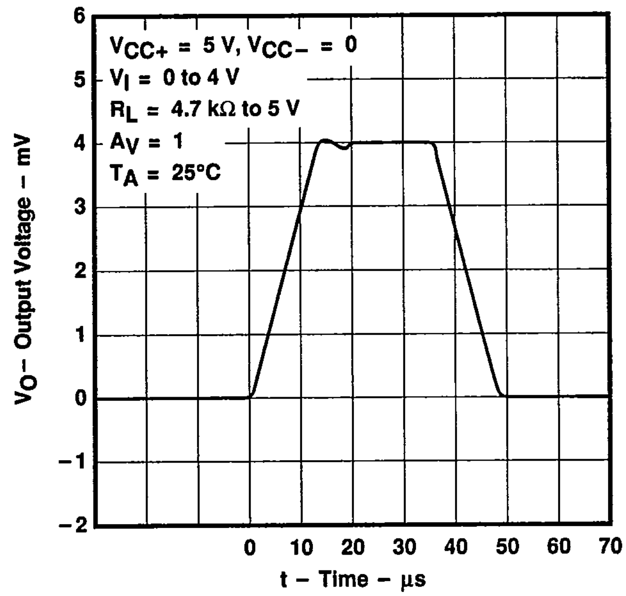


FIGURE 22

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

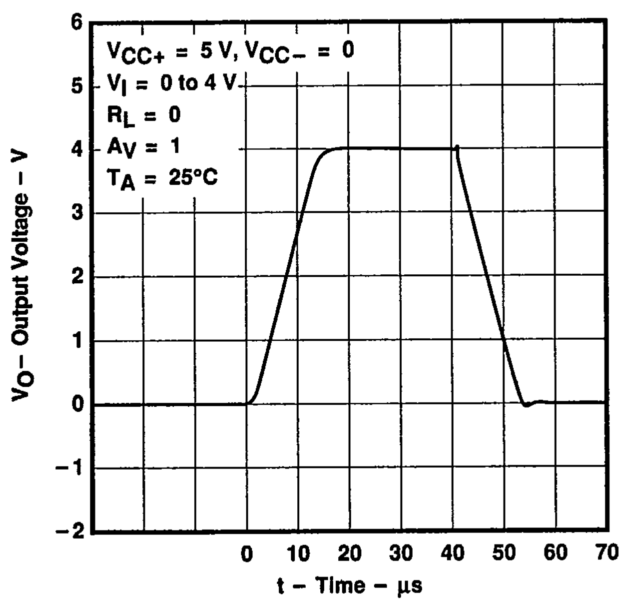


FIGURE 23

TYPICAL APPLICATION DATA

single-supply operation

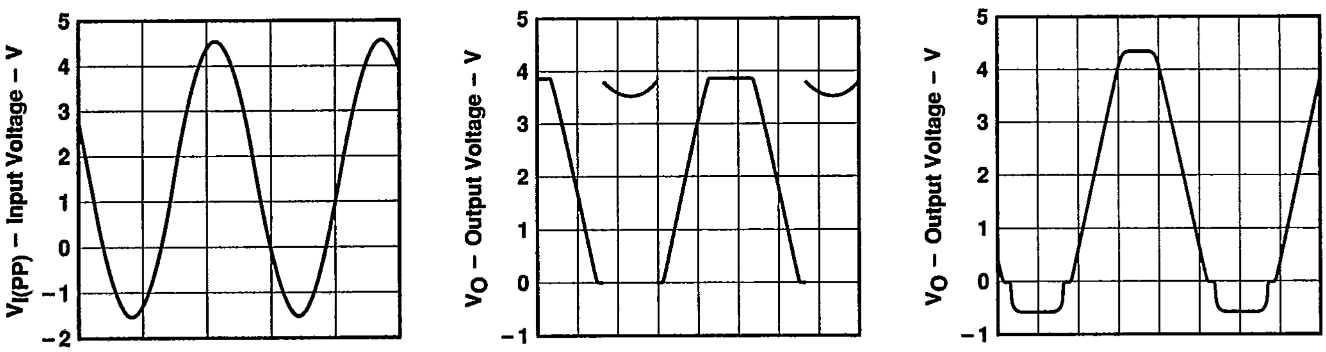
The LT1013 is fully specified for single-supply operation (V_{CC-} = 0). The common-mode input voltage range includes ground, and the output swings within a few millivolts of ground.

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°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.



(a) $V_{I(PP)}$ = −1.5 V to 4.5 V

(b) OUTPUT PHASE REVERSAL EXHIBITED BY LM358

(c) NO PHASE REVERSAL EXHIBITED BY LT1013

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

TYPICAL APPLICATION DATA T 79-10

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.

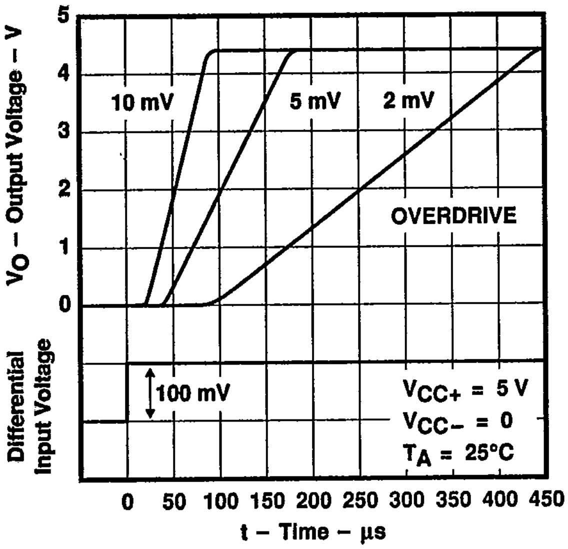


FIGURE 25. LOW- TO HIGH-LEVEL OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

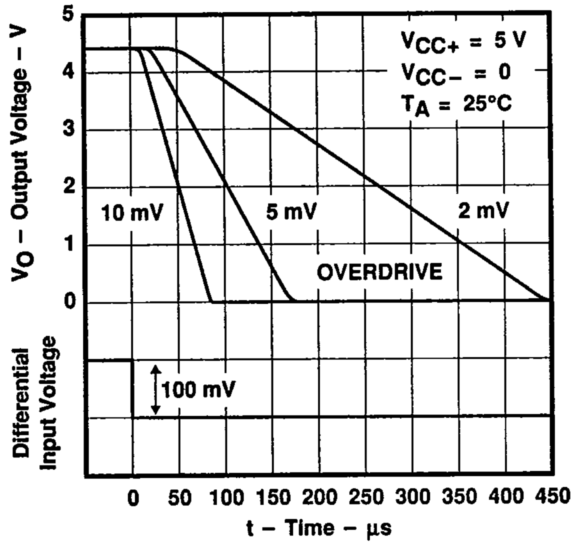


FIGURE 26. HIGH- TO LOW-LEVEL OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

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 µA; therefore, power dissipation is only 1 mW per amplifier.

offset voltage and noise testing

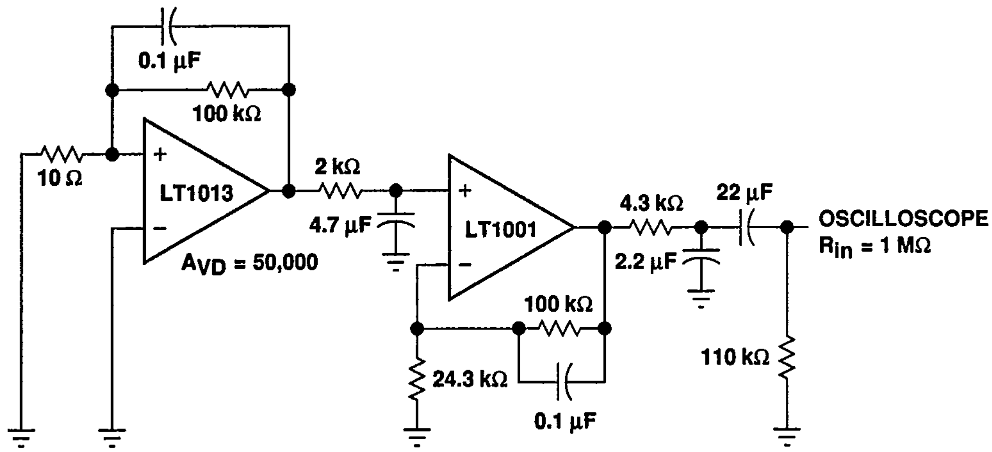
The test circuit for measuring input offset voltage and its temperature coefficient is shown in Figure 30. This circuit with supply voltages increased to ±20 V is also used as the burn-in configuration.

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.

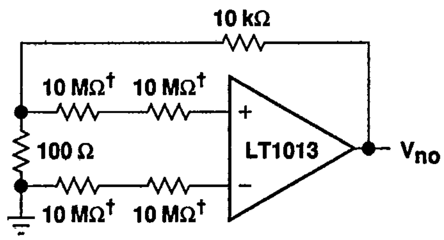
Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.

offset voltage and noise testing (continued)



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

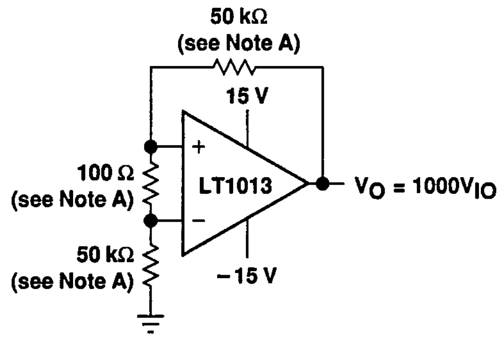
FIGURE 27. 0.1-Hz TO 10-Hz PEAK-TO-PEAK NOISE TEST CIRCUIT



†Metal film resistor.

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

FIGURE 28. NOISE CURRENT TEST CIRCUIT AND FORMULA



NOTE A: Resistors must have low thermoelectric potential.

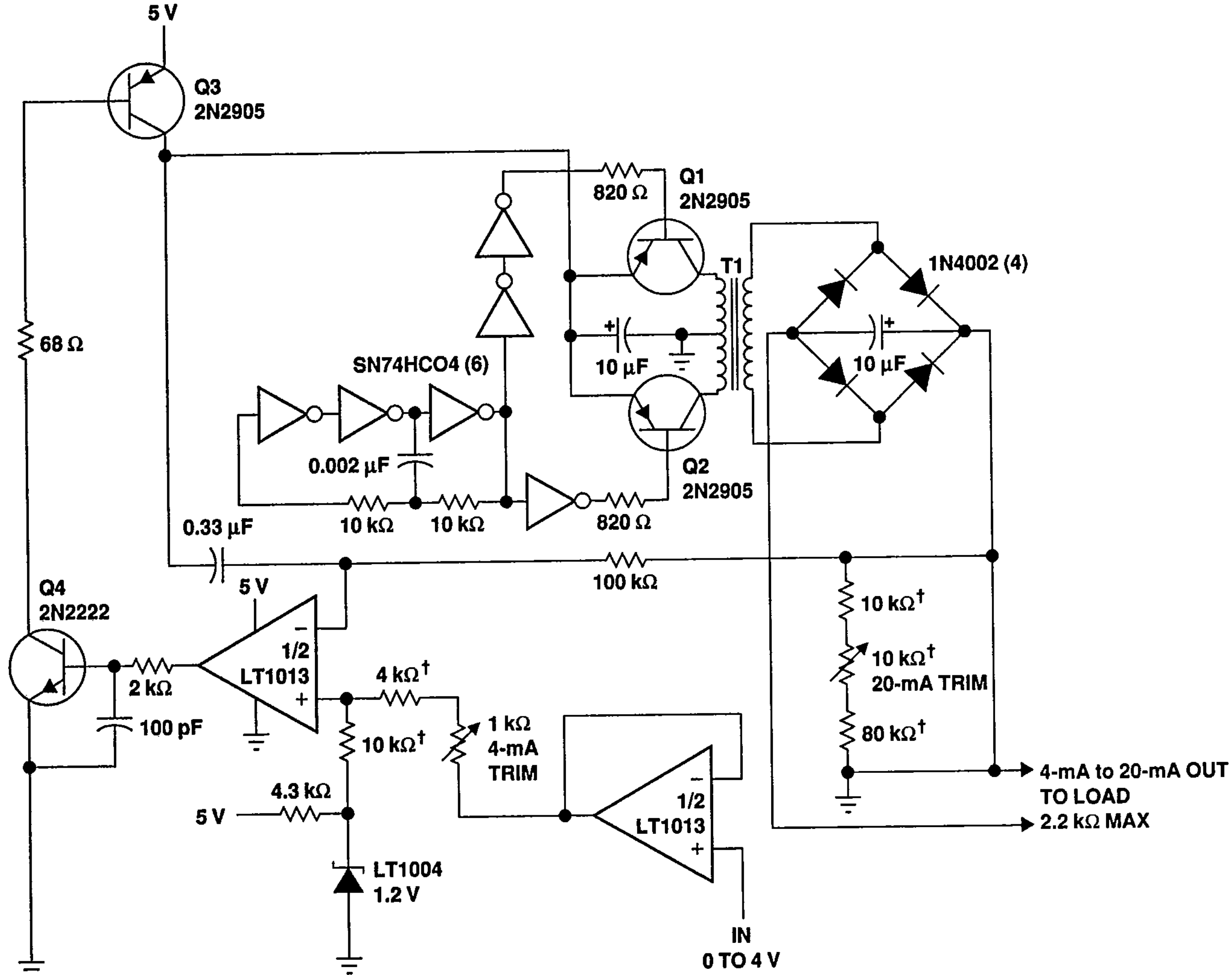
FIGURE 29. TEST CIRCUIT FOR V_{IO} AND α_{VIO}

25E D 8961724 0080627 6
TEXAS INSTR (LIN/INTFC)

T-79-10

TYPICAL APPLICATION DATA

typical applications

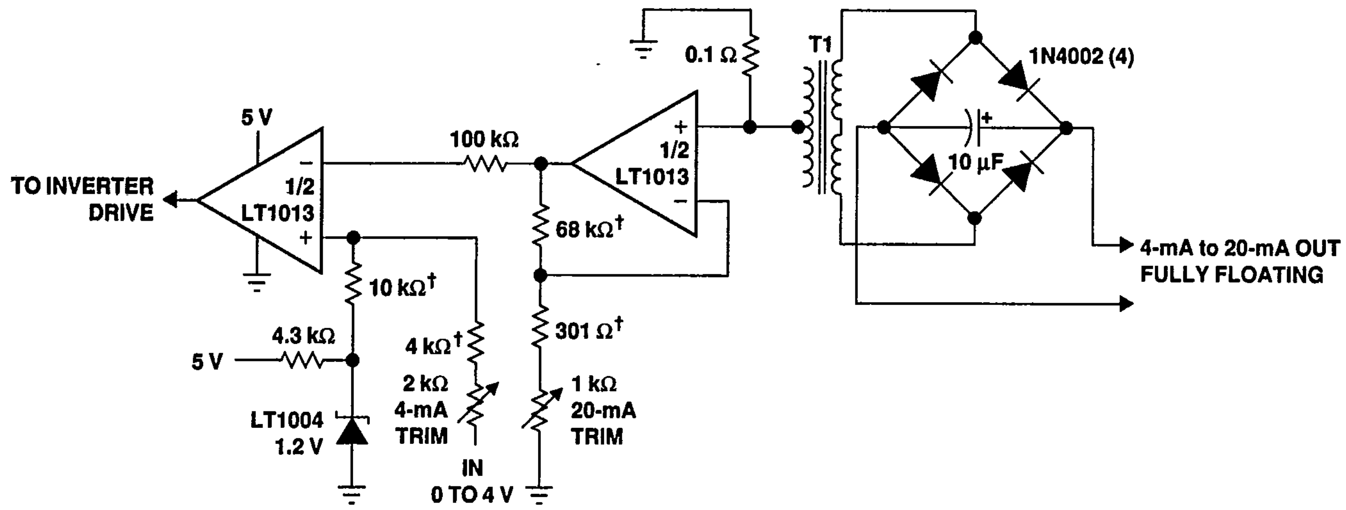


†1% film resistor. Match 10-kΩ resistors 0.05%.
NOTE A: T1 = PICO-31080.

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

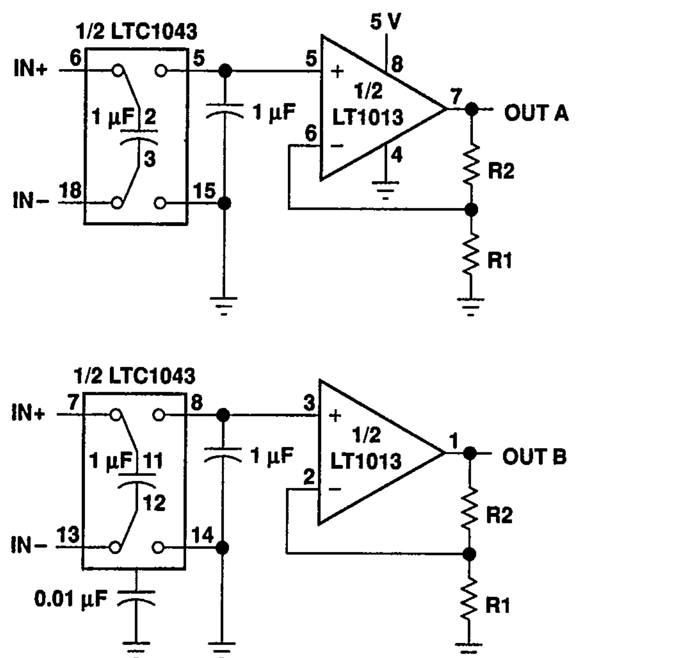
1440 E-07

TYPICAL APPLICATION DATA



†1% film resistor

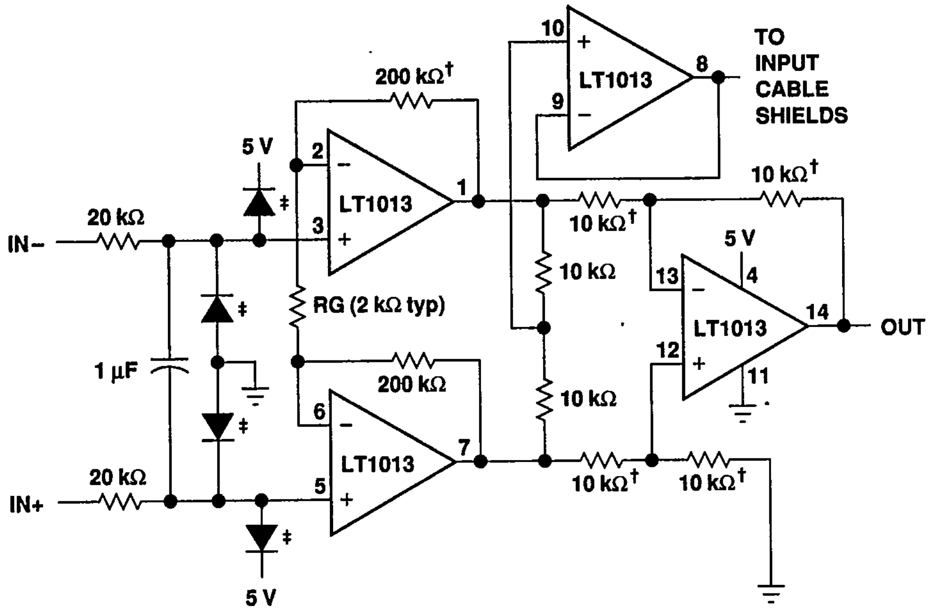
FIGURE 31. FULLY FLOATING MODIFICATION TO 4-mA – 20-mA CURRENT LOOP TRANSMITTER WITH 8-BIT ACCURACY



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

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

TYPICAL APPLICATION DATA



†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

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265