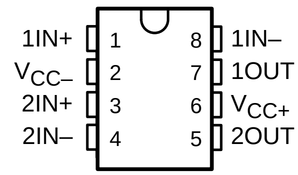
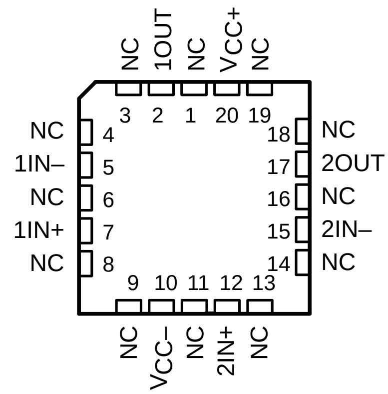
- **Single-Supply Operation**
  - **Input Voltage Range Extends to Ground**
  - **Output Swings to Ground While Sinking Current**
- **Input Offset Voltage**
  - **150 µV Max at 25°C for LT1013A**
- **Offset Voltage Temperature Coefficient**
  - **2.5 µV/°C Max for LT1013A**
- **Input Offset Current**
  - **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 T_A = 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)

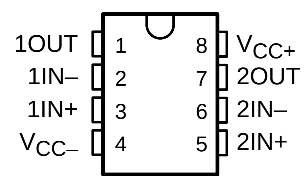


FK PACKAGE
(TOP VIEW)



NC – No internal connection

JG OR P PACKAGE
(TOP VIEW)



description

The LT1013 devices are dual precision operational amplifiers, featuring high gain, low supply current, low noise, and low-offset-voltage temperature coefficient.

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

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

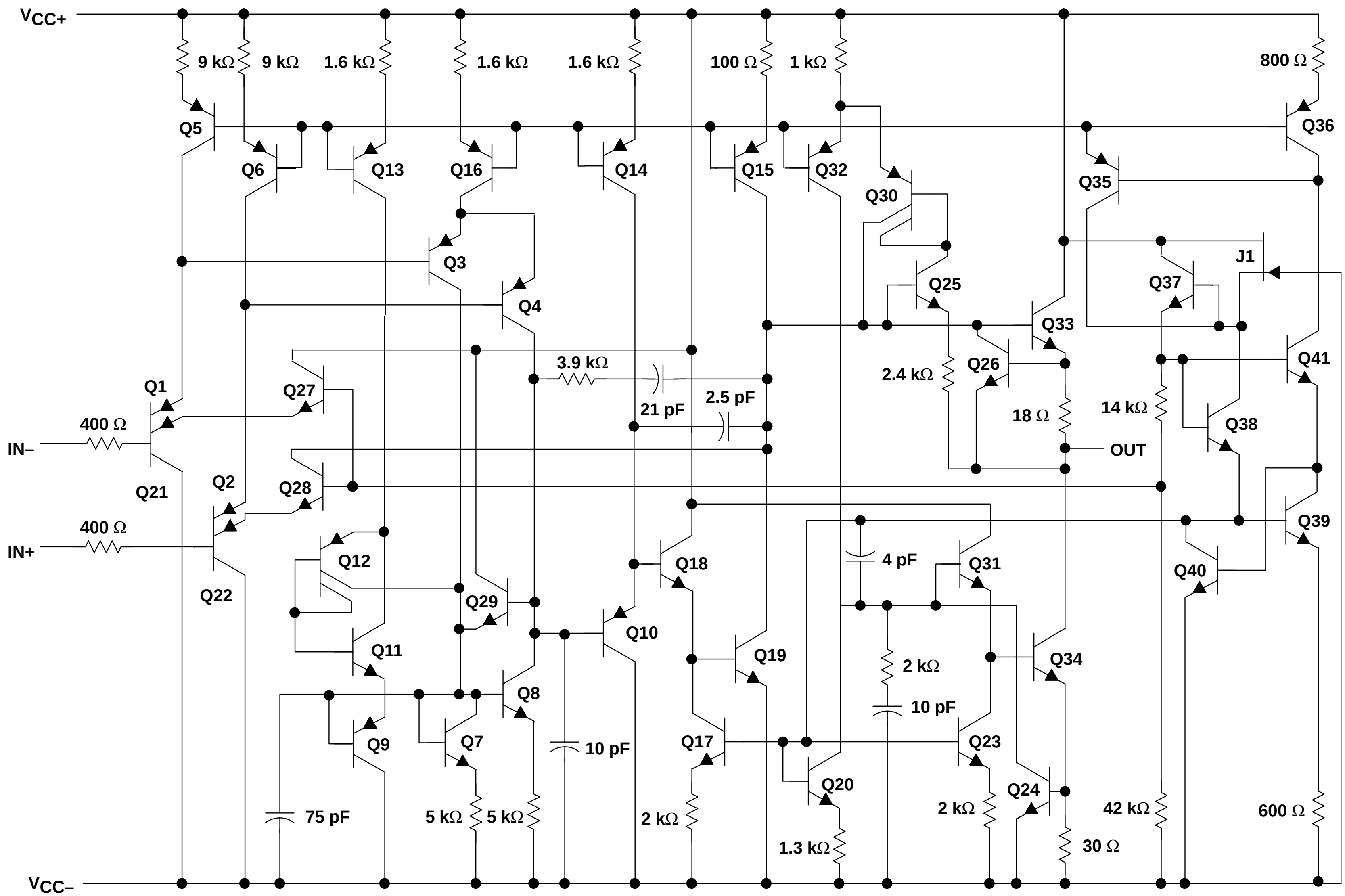
AVAILABLE OPTIONS

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

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

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.

schematic (each amplifier)



Component values are nominal.

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

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

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

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at IN+ with respect to IN–.
3. The output may be shorted to either supply.
4. The package thermal impedance is calculated in accordance with JESD 51-7.

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

PARAMETER		TEST CONDITIONS	T_A†	LT1013C			LT1013AC			LT1013DC			UNIT
				MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V_{IO}	Input offset voltage	R_S = 50 Ω	25°C		60	300		40	150		200	800	μV
			Full range			400			240			1000	
$\alpha_{V_{IO}}$	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	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} = –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+} = ±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			0.7			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_O = 1.4 V, V_{IC} = 0 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	LT1013C			LT1013AC			LT1013DC			UNIT
				MIN	TYP‡	MAX	MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V_{IO}	Input offset voltage	R_S = 50 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.
‡ All typical values are at T_A = 25°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, $V_{CC\pm}$ = ±15 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		60	300		40	150		200	800	µV
			Full range			550			300			1000	
$\alpha_{V_{IO}}$	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	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} = –14.9 V to 13 V	Full range	94			97			94			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±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			0.7			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+} = 5 V, V_{CC-} = 0, 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			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 –40°C to 105°C.
‡ All typical values are at T_A = 25°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/$\sqrt{Hz}$
		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/$\sqrt{Hz}$

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm15$ 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		60	300		40	150		200	800	µV
			Full range			550			300			1000	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage		Full range		0.5	2.5*		0.4	2*		0.5	2.5*	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
			Full range	–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	117		100	117		97	114		dB
		V_{IC} = –14.9 V to 13 V	Full range	94			97			94			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±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	

* On products compliant to MIL-PRF-38535, Class B, this parameter is not production tested.
† Full range is –55°C to 125°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_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
			Full range		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
			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			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.
‡ All typical values are at T_A = 25°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

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	vs Supply voltage	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

TYPICAL CHARACTERISTICS†

INPUT OFFSET VOLTAGE vs SUPPLY VOLTAGE

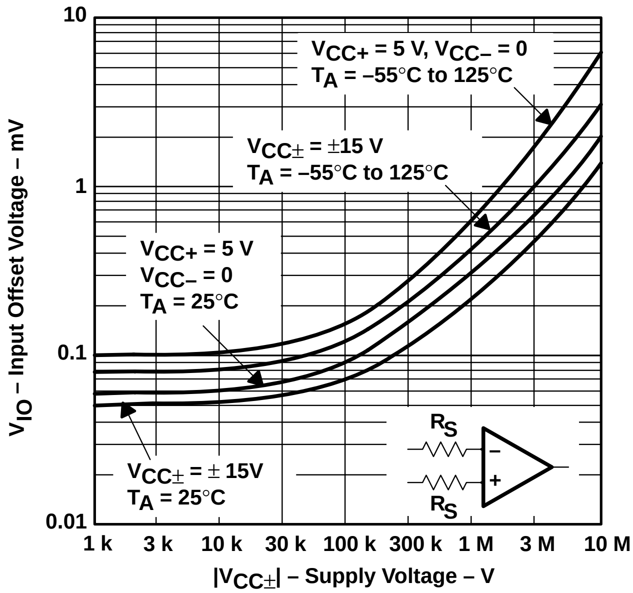


Figure 1

INPUT OFFSET VOLTAGE OF REPRESENTATIVE UNITS vs FREE-AIR TEMPERATURE

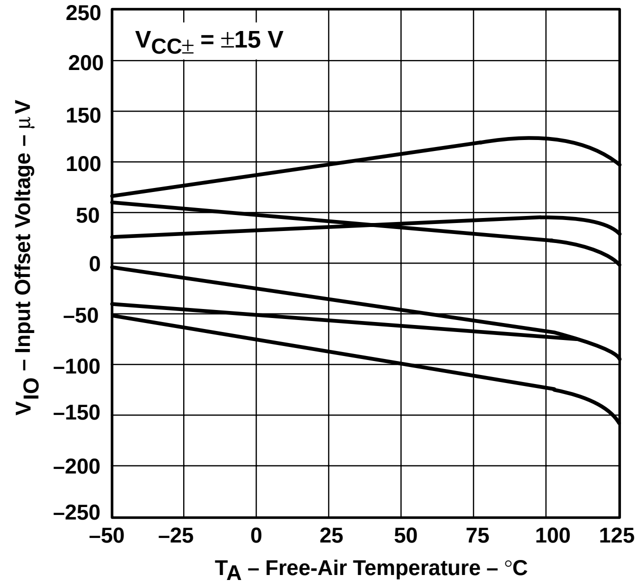


Figure 2

WARM-UP CHANGE IN INPUT OFFSET VOLTAGE vs TIME AFTER POWER-ON

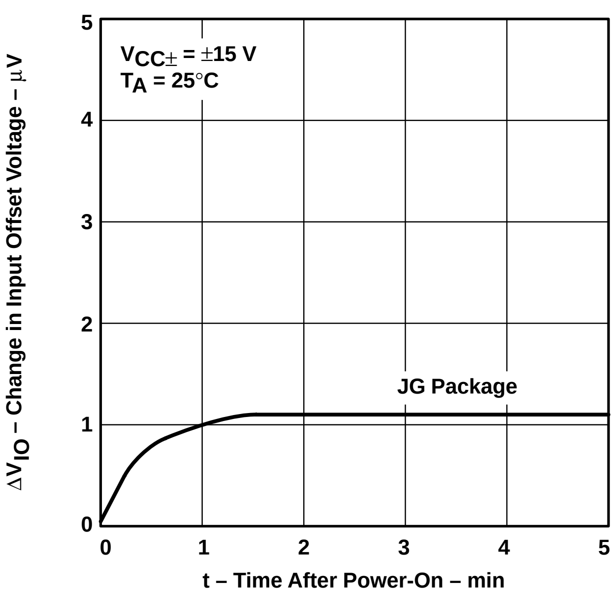


Figure 3

INPUT OFFSET CURRENT vs FREE-AIR TEMPERATURE

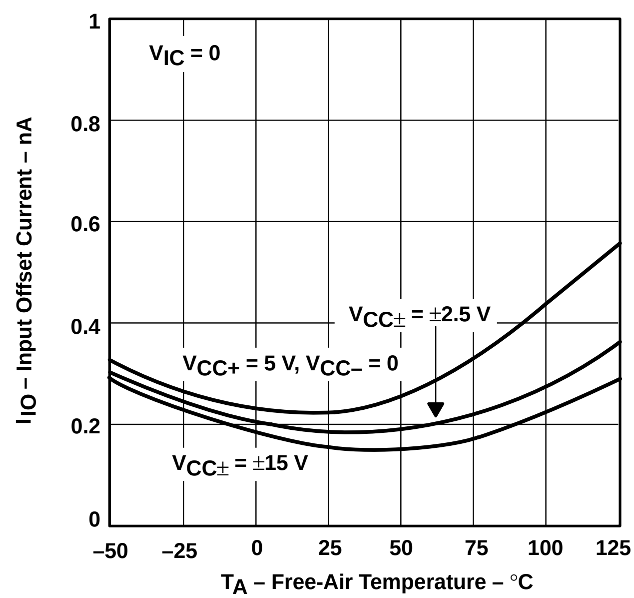


Figure 4

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

TYPICAL CHARACTERISTICS†

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

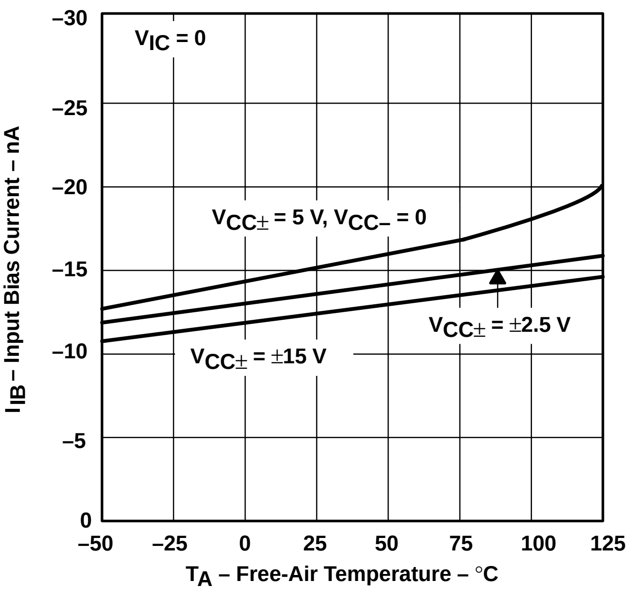


Figure 5

COMMON-MODE INPUT VOLTAGE
vs
INPUT BIAS CURRENT

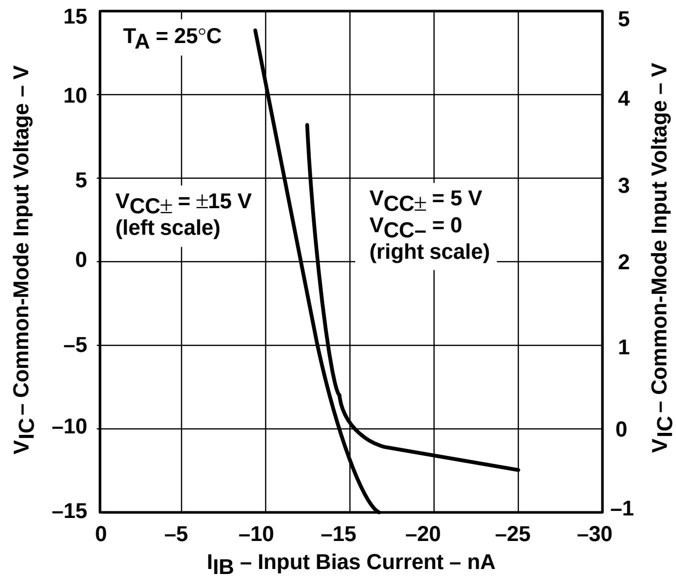


Figure 6

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
LOAD RESISTANCE

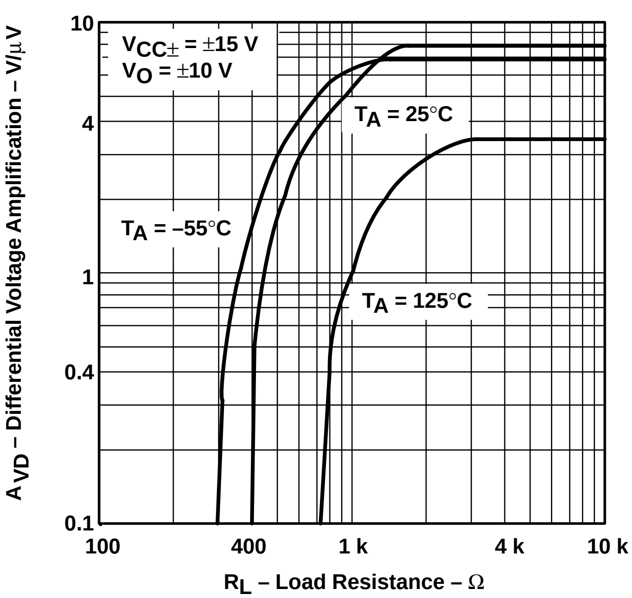


Figure 7

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
LOAD RESISTANCE

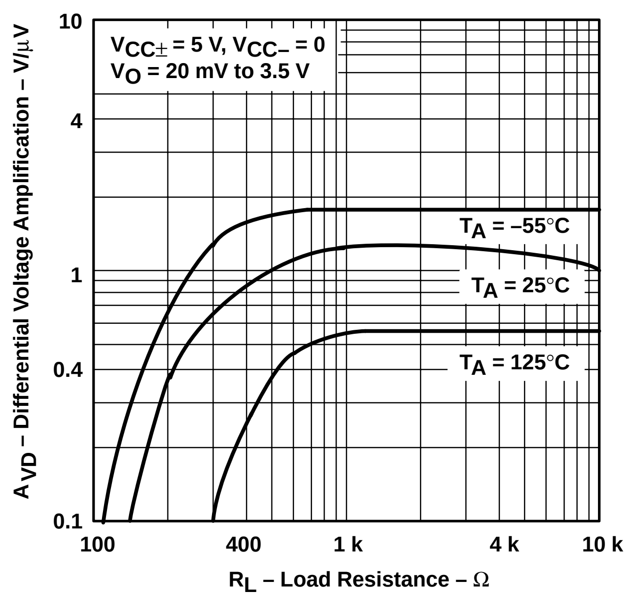


Figure 8

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

TYPICAL CHARACTERISTICS†

DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

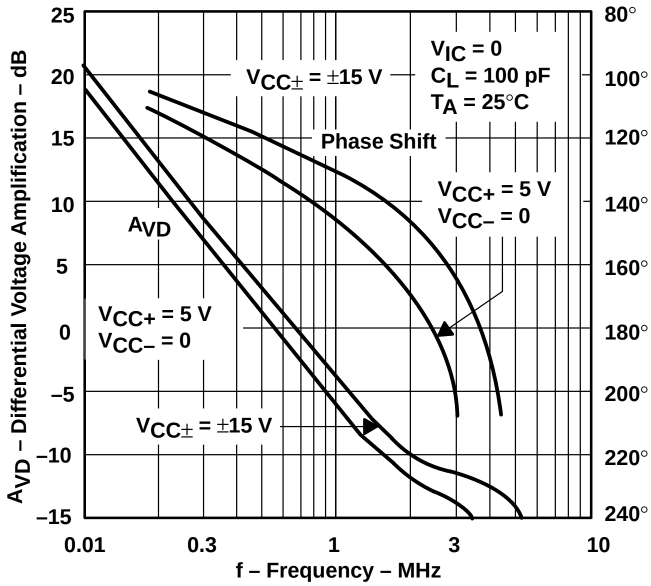


Figure 9

DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY

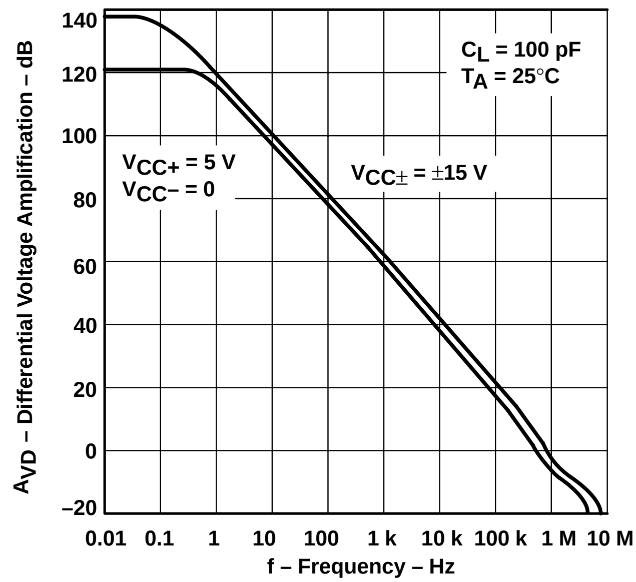


Figure 10

CHANNEL SEPARATION vs FREQUENCY

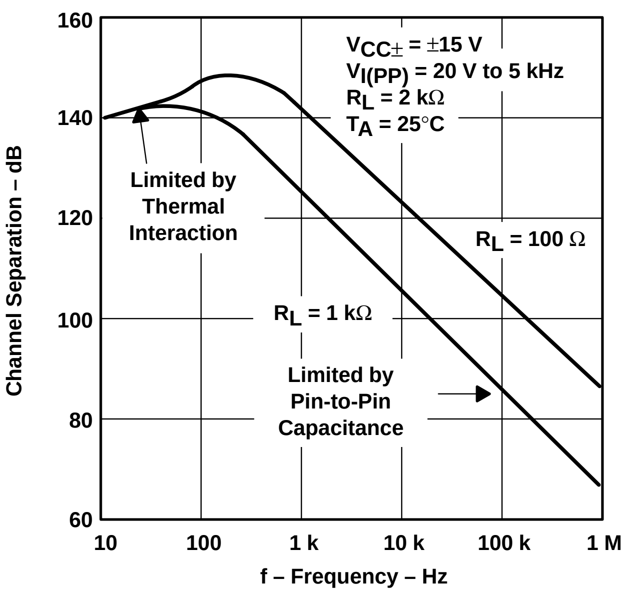


Figure 11

OUTPUT SATURATION VOLTAGE vs FREE-AIR TEMPERATURE

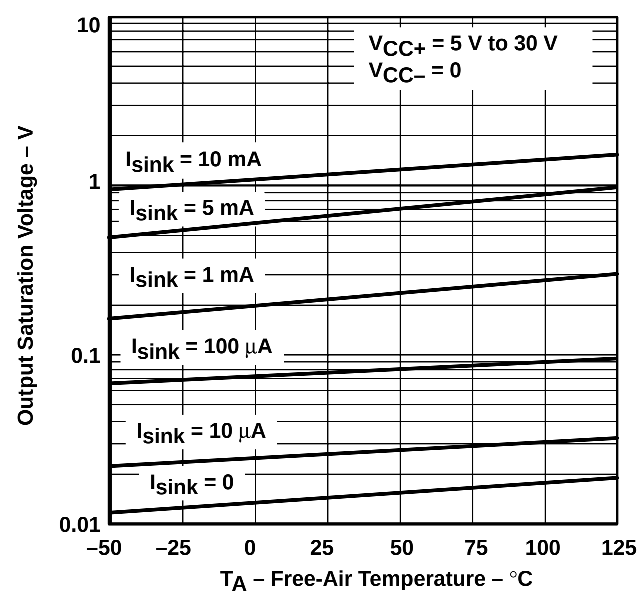


Figure 12

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

TYPICAL CHARACTERISTICS†

COMMON-MODE REJECTION RATIO vs FREQUENCY

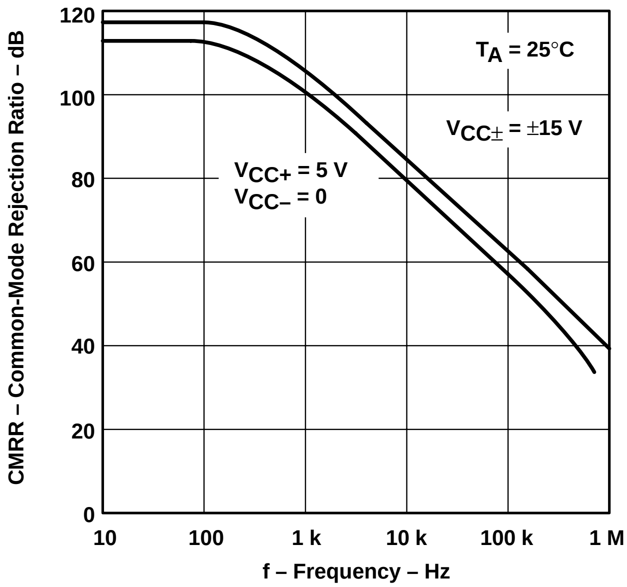


Figure 13

SUPPLY-VOLTAGE REJECTION RATIO vs FREQUENCY

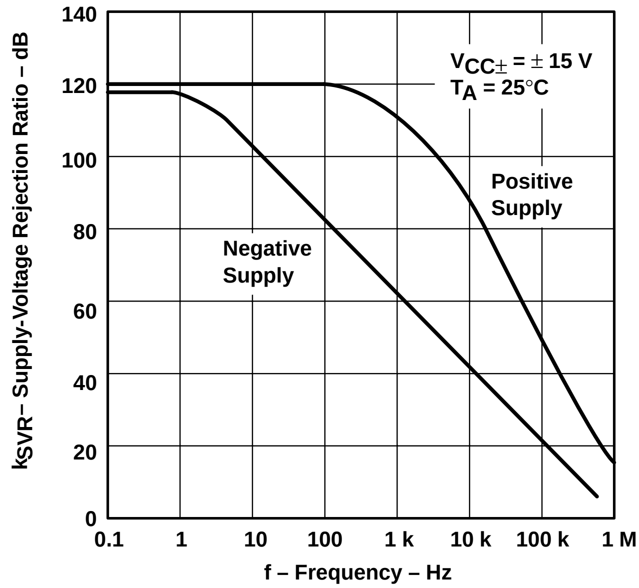


Figure 14

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

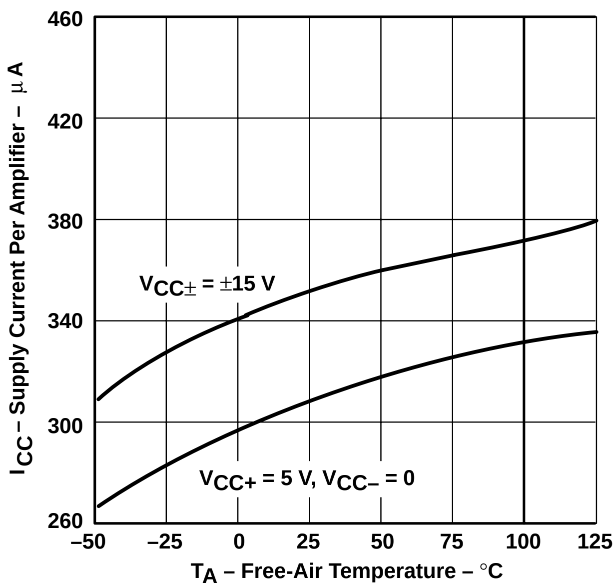


Figure 15

SHORT-CIRCUIT OUTPUT CURRENT vs ELAPSED TIME

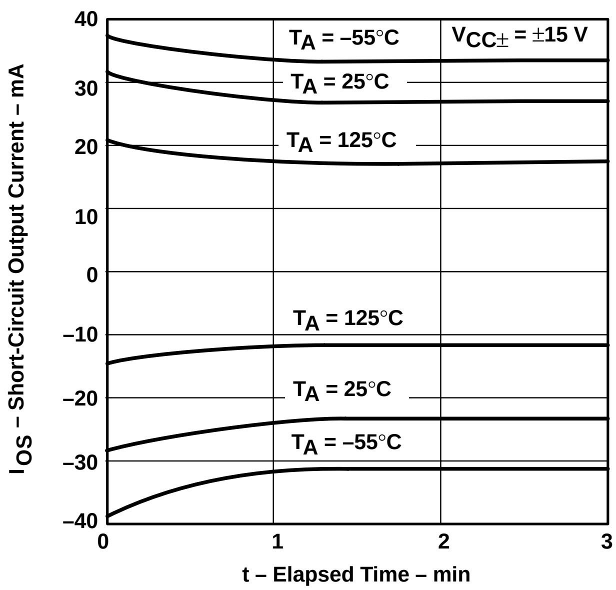


Figure 16

† 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

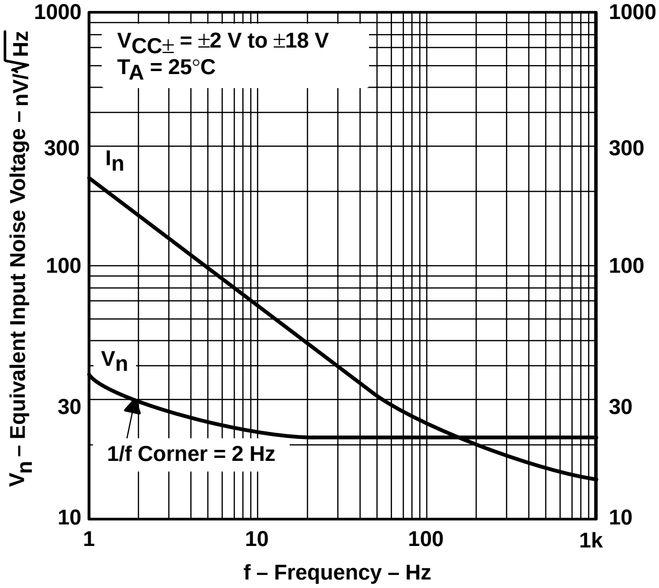


Figure 17

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

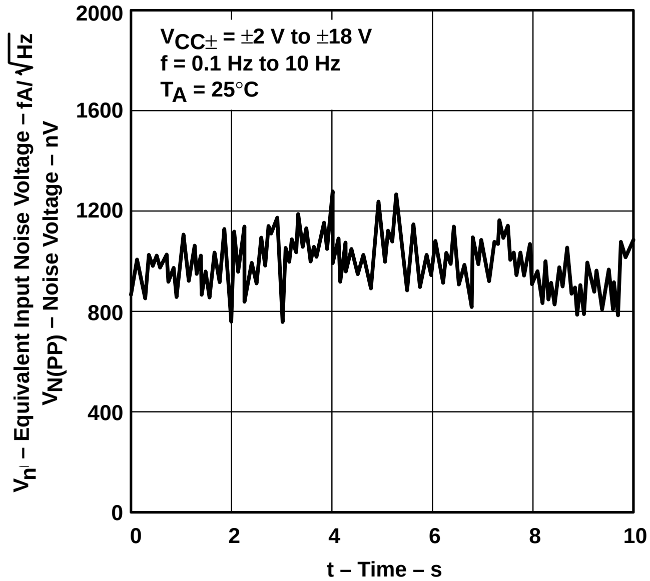


Figure 18

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

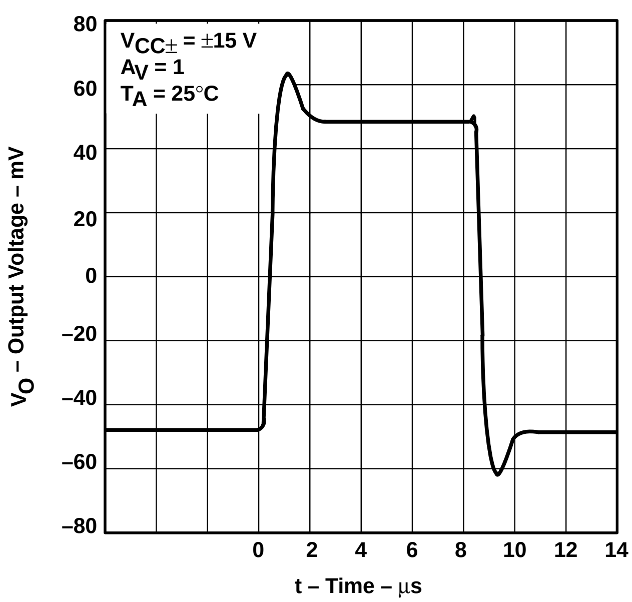


Figure 19

VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE

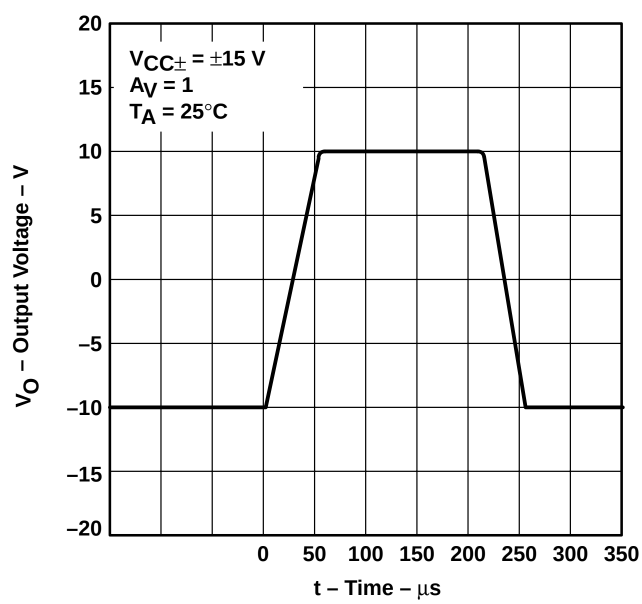


Figure 20

TYPICAL CHARACTERISTICS

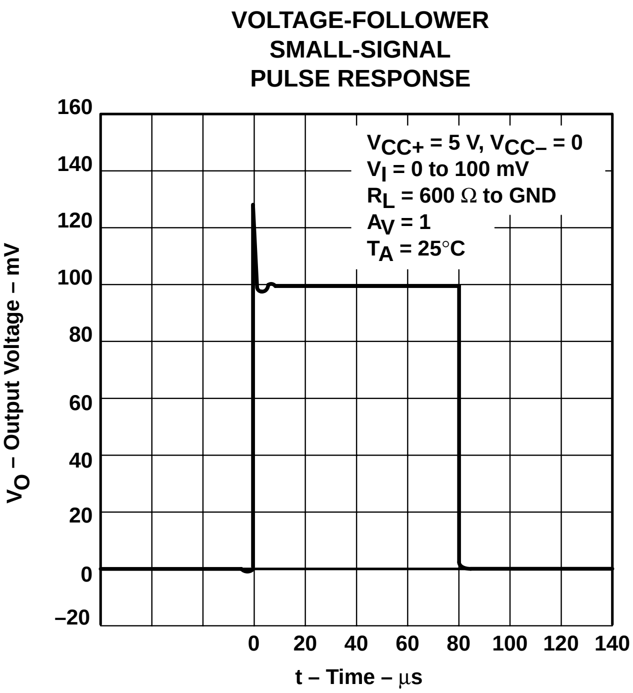


Figure 21

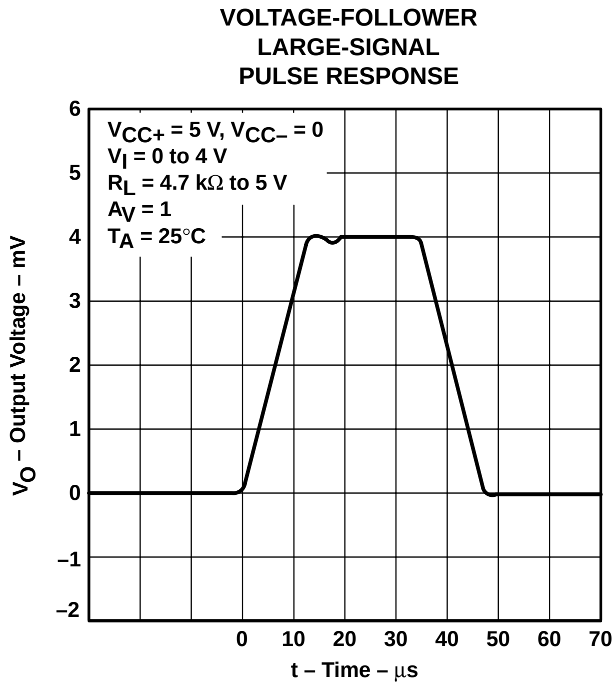


Figure 22

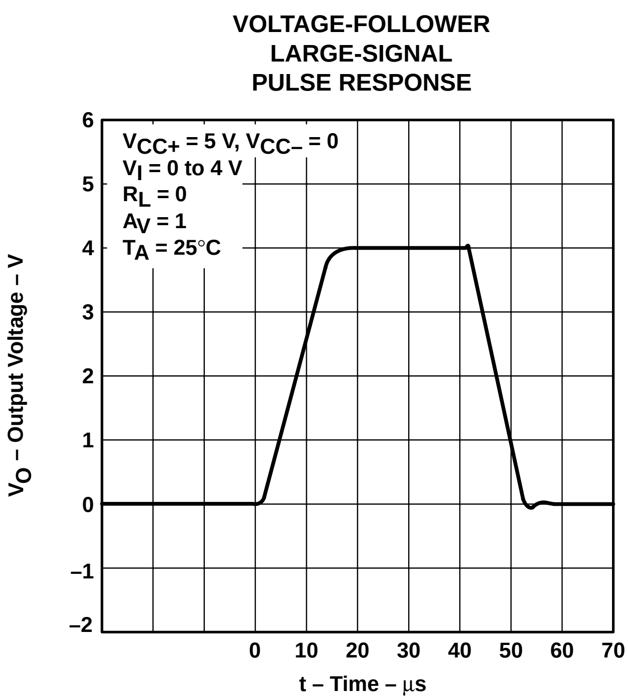


Figure 23

APPLICATION INFORMATION

single-supply operation

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

Furthermore, the LT1013 has specific circuitry that addresses the difficulties of single-supply operation, both at the input and at the output. At the input, the driving signal can fall below 0 V, either inadvertently or on a transient basis. If the input is more than a few hundred millivolts below ground, the LT1013 is designed to deal with the following two problems that can occur:

1. On many other operational amplifiers, when the input is more than a diode drop below ground, unlimited current flows from the substrate (V_{CC-} terminal) to the input, which can destroy the unit. On the LT1013, the 400-Ω resistors in series with the input [see *schematic (each amplifier)*] protect the device, even when the input is 5 V below ground.
2. When the input is more than 400 mV below ground (at T_A = 25°C), the input stage of similar type operational amplifiers saturates and phase reversal occurs at the output. This can cause lockup in servo systems. Because of a unique phase-reversal protection circuitry (Q21, Q22, Q27, and Q28), the LT1013 outputs do not reverse, even when the inputs are at –1.5 V (see Figure 24).

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

At the output, other single-supply designs either cannot swing to within 600 mV of ground or cannot sink more than a few microamperes while swinging to ground. The all-npn output stage of the LT1013 maintains its low output resistance and high-gain characteristics until the output is saturated. In dual-supply operations, the output stage is free of crossover distortion.

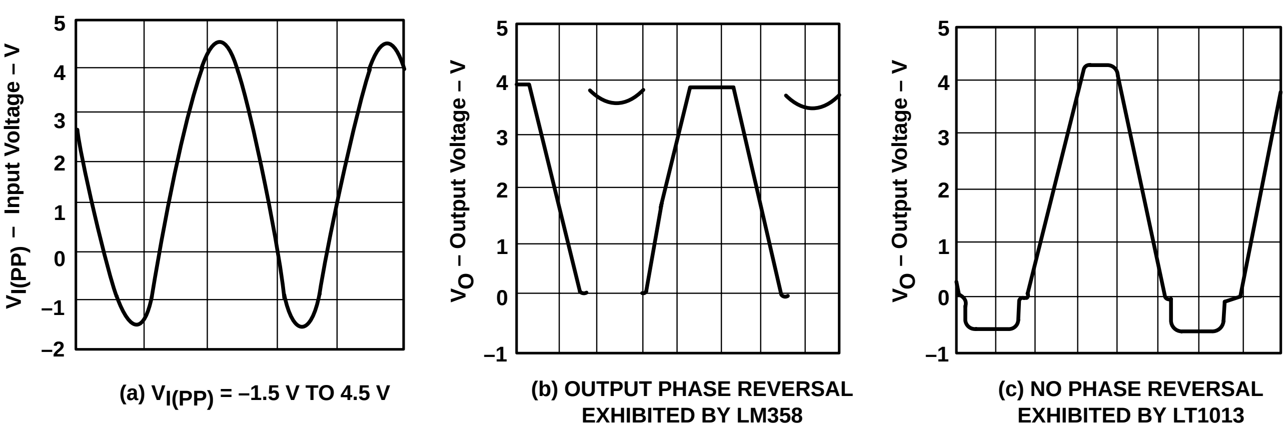


Figure 24. Voltage-Follower Response With Input Exceeding the Negative Common-Mode Input Voltage Range

APPLICATION INFORMATION

comparator applications

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

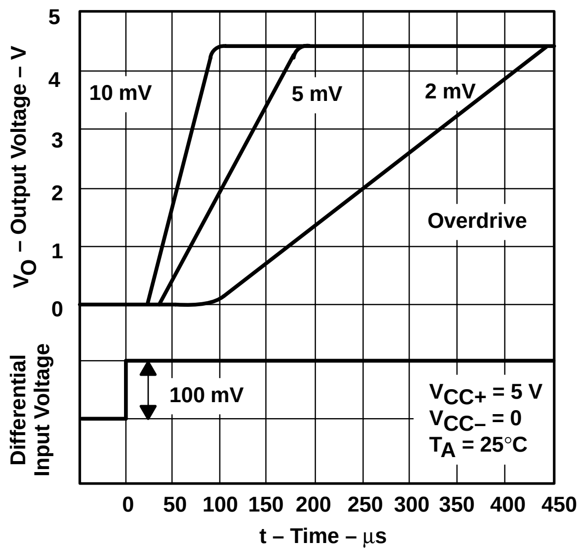


Figure 25. Low-to-High-Level Output Response for Various Input Overdrives

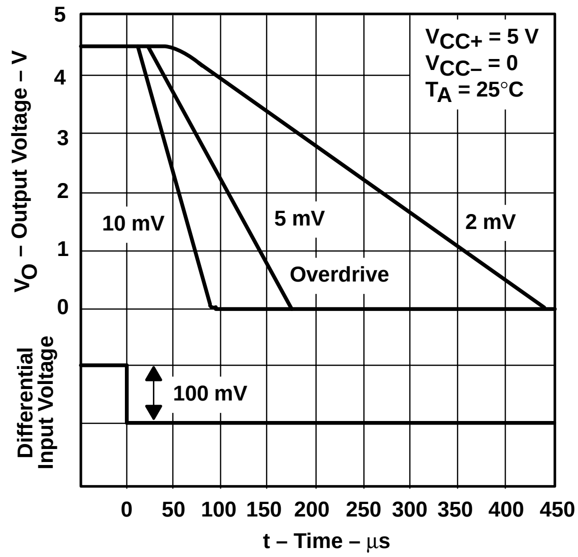


Figure 26. High-to-Low-Level Output Response for Various Input Overdrives

low-supply operation

The minimum supply voltage for proper operation of the LT1013 is 3.4 V (three NiCad batteries). Typical supply current at this voltage is 290 µA; therefore, power dissipation is only 1 mW per amplifier.

offset voltage and noise testing

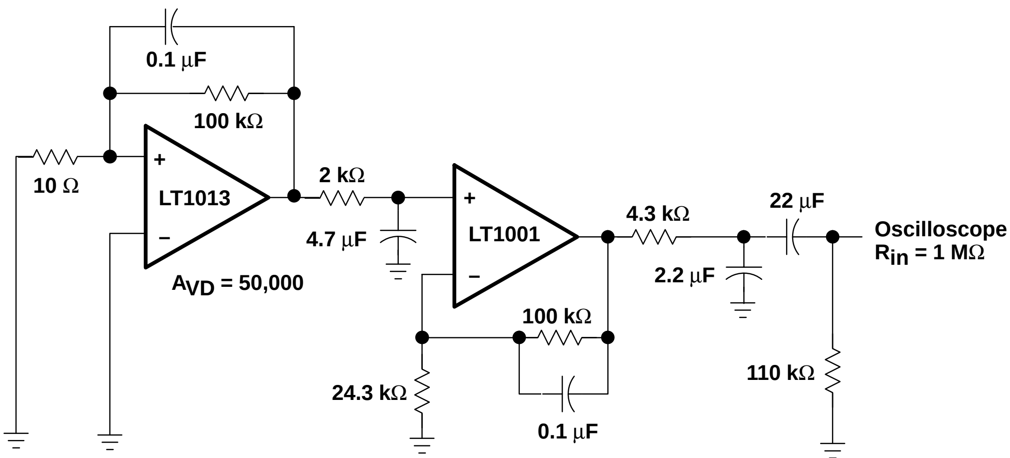
The test circuit for measuring input offset voltage and its temperature coefficient is shown in Figure 30. This circuit, with supply voltages increased to ±20 V, also is used as the burn-in configuration.

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

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

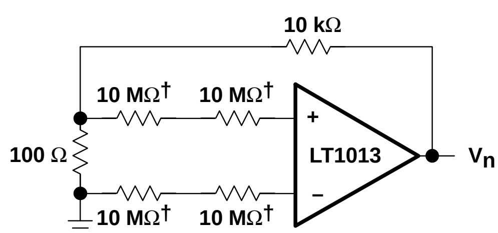
Current noise is measured by the circuit and formula shown in Figure 28. The noise of the source resistors is subtracted.

APPLICATION INFORMATION



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

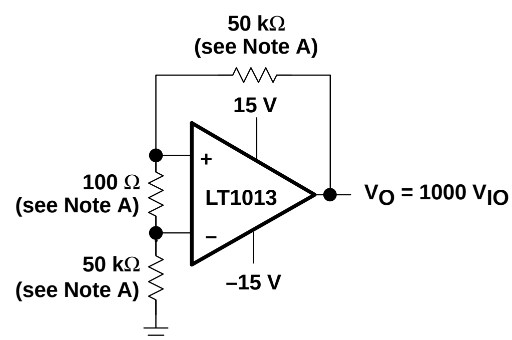
Figure 27. 0.1-Hz to 10-Hz Peak-to-Peak Noise Test Circuit



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

† Metal-film resistor

Figure 28. Noise-Current Test Circuit and Formula

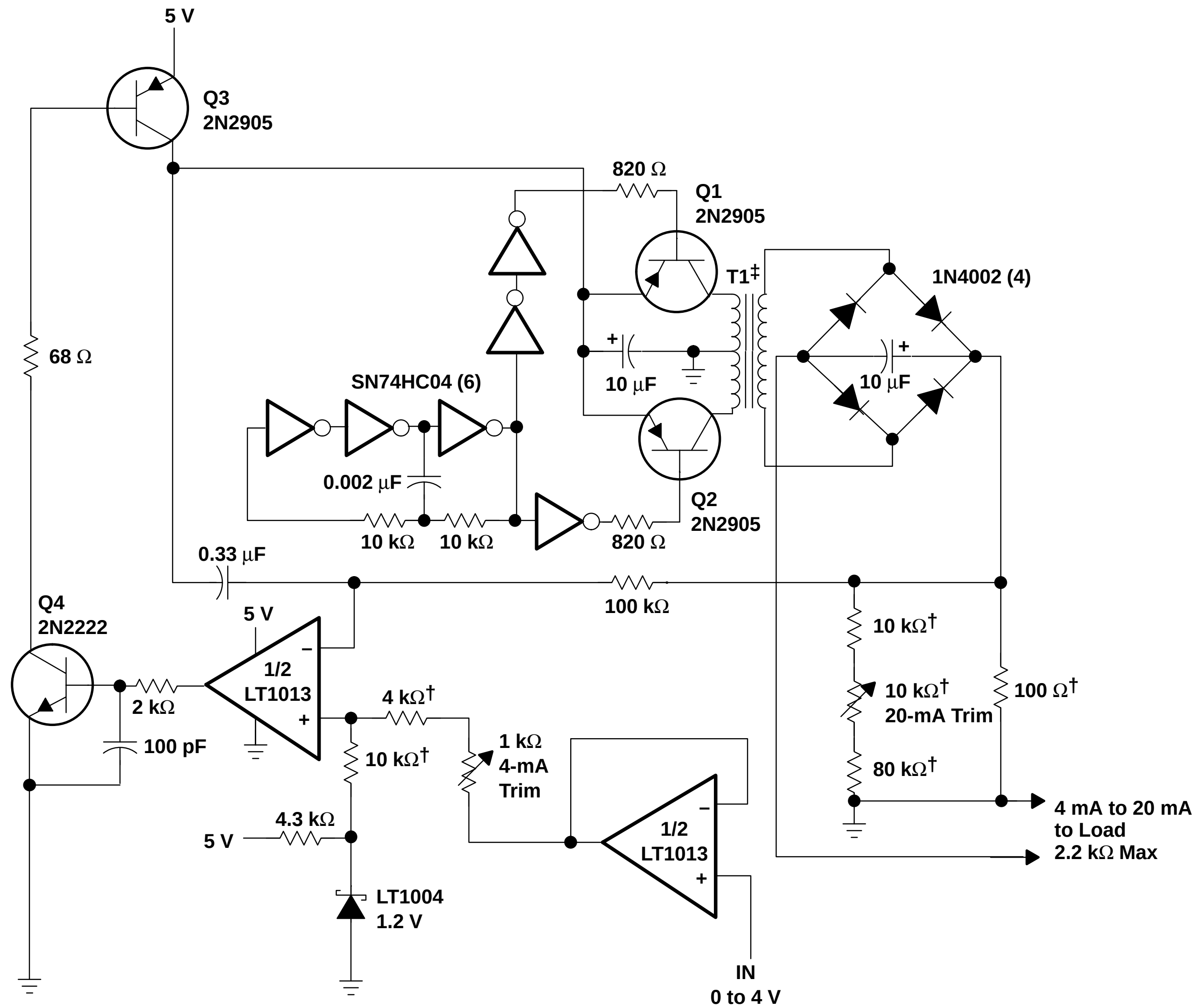


NOTE A: Resistors must have low thermoelectric potential.

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

APPLICATION INFORMATION

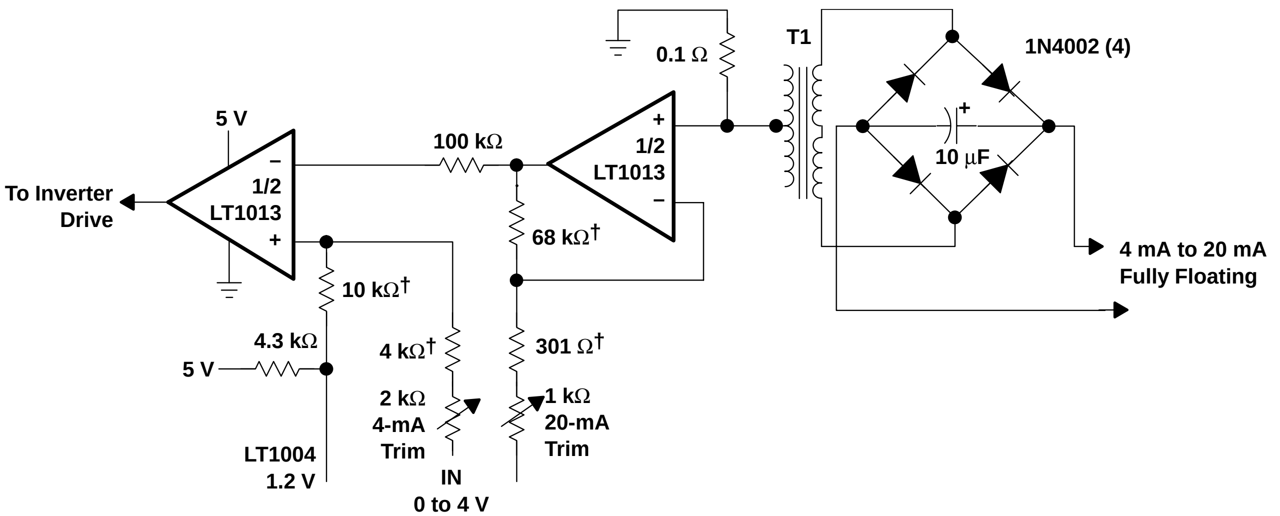
typical applications



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

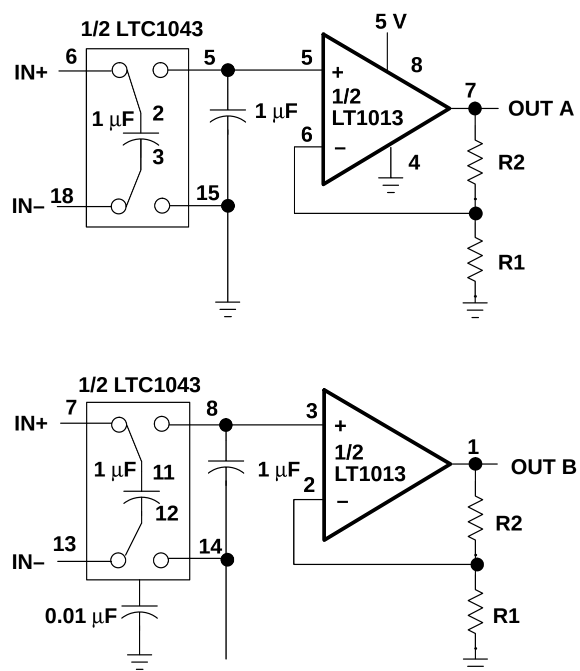
Figure 30. 5-V 4-mA to 20-mA Current Loop Transmitter With 12-Bit Accuracy

APPLICATION INFORMATION



† 1% film resistor

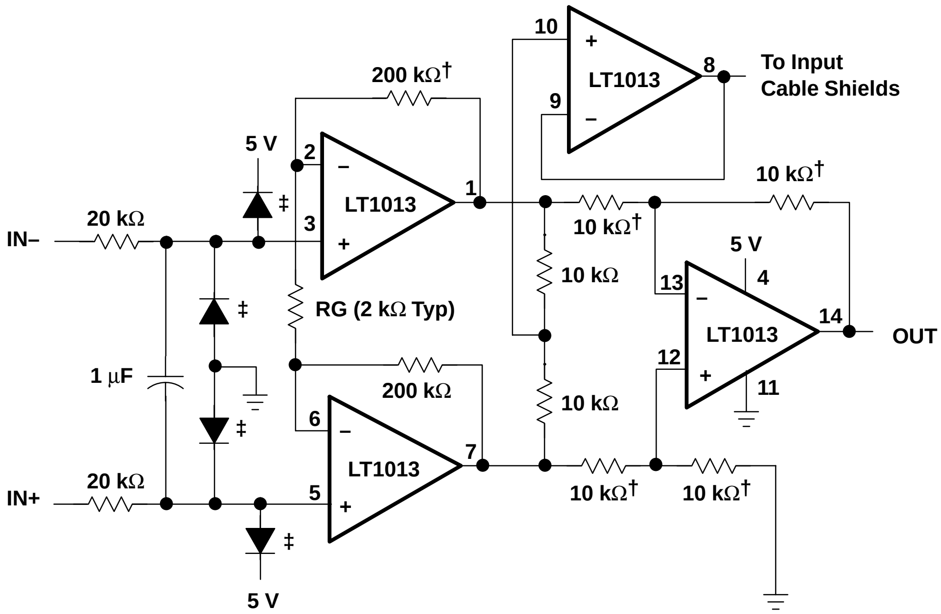
Figure 31. Fully Floating Modification to 4-mA to 20-mA Current Loop Transmitter With 8-Bit Accuracy



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

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

APPLICATION INFORMATION



† 1% film resistor. Match 10-kΩ resistors to within 0.05%.
‡ For high source impedances, use 2N2222 diodes.
NOTE A: A_{VD} = (400,000/RG) + 1

Figure 33. 5-V Precision Instrumentation Amplifier

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