

Quad Precision Op Amp (LT1014) Dual Precision Op Amp (LT1013)

FEATURES

- Single Supply Operation
 - Input Voltage Range Extends to Ground
 - Output Swings to Ground While Sinking Current
- Pin Compatible to 1458 and 324 with Precision Specs
- *Guaranteed* Offset Voltage: 150 μ V Max
- *Guaranteed* Low Drift: 2 μ V/ $^{\circ}$ C Max
- *Guaranteed* Offset Current: 0.8nA Max
- *Guaranteed* High Gain
 - 5mA Load Current: 1.5 Million Min
 - 17mA Load Current: 0.8 Million Min
- *Guaranteed* Low Supply Current: 500 μ A Max
- Low Voltage Noise, 0.1Hz to 10Hz: 0.55 μ V_{P-P}
- Low Current Noise—Better than OP-07, 0.07pA/ $\sqrt{\text{Hz}}$

APPLICATIONS

- Battery-Powered Precision Instrumentation
 - Strain Gauge Signal Conditioners
 - Thermocouple Amplifiers
 - Instrumentation Amplifiers
- 4mA to 20mA Current Loop Transmitters
- Multiple Limit Threshold Detection
- Active Filters
- Multiple Gain Blocks

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DESCRIPTION

The LT[®]1014 is the first precision quad operational amplifier which directly upgrades designs in the industry standard 14-pin DIP LM324/LM348/OP-11/4156 pin configuration. It is no longer necessary to compromise specifications, while saving board space and cost, as compared to single operational amplifiers.

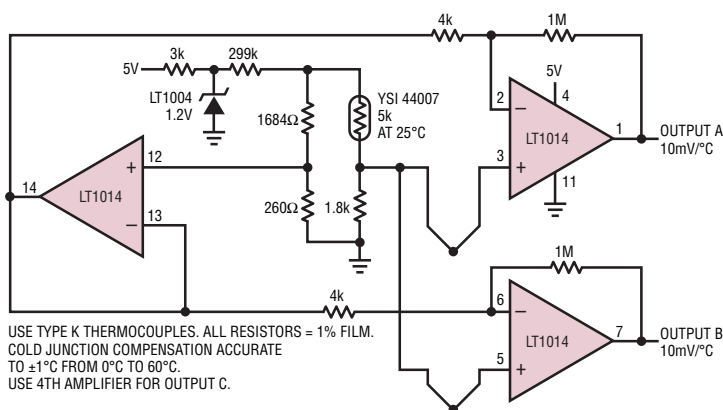
The LT1014's low offset voltage of 50 μ V, drift of 0.3 μ V/ $^{\circ}$ C, offset current of 0.15nA, gain of 8 million, common mode rejection of 117dB and power supply rejection of 120dB qualify it as four truly precision operational amplifiers. Particularly important is the low offset voltage, since no offset null terminals are provided in the quad configuration. Although supply current is only 350 μ A per amplifier, a new output stage design sources and sinks in excess of 20mA of load current, while retaining high voltage gain.

Similarly, the LT1013 is the first precision dual op amp in the 8-pin industry standard configuration, upgrading the performance of such popular devices as the MC1458/MC1558, LM158 and OP-221. The LT1013's specifications are similar to (even somewhat better than) the LT1014's.

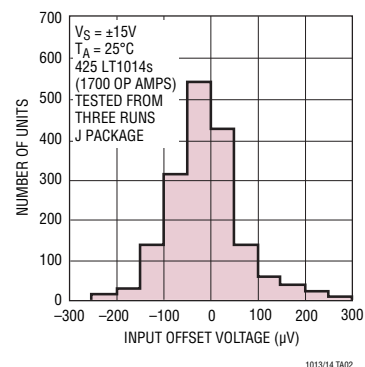
Both the LT1013 and LT1014 can be operated off a single 5V power supply: input common mode range includes ground; the output can also swing to within a few millivolts of ground. Crossover distortion, so apparent on previous single-supply designs, is eliminated. A full set of specifications is provided with ± 15 V and single 5V supplies.

TYPICAL APPLICATION

3-Channel Thermocouple Thermometer



LT1014 Distribution of Offset Voltage



LT1013/LT1014

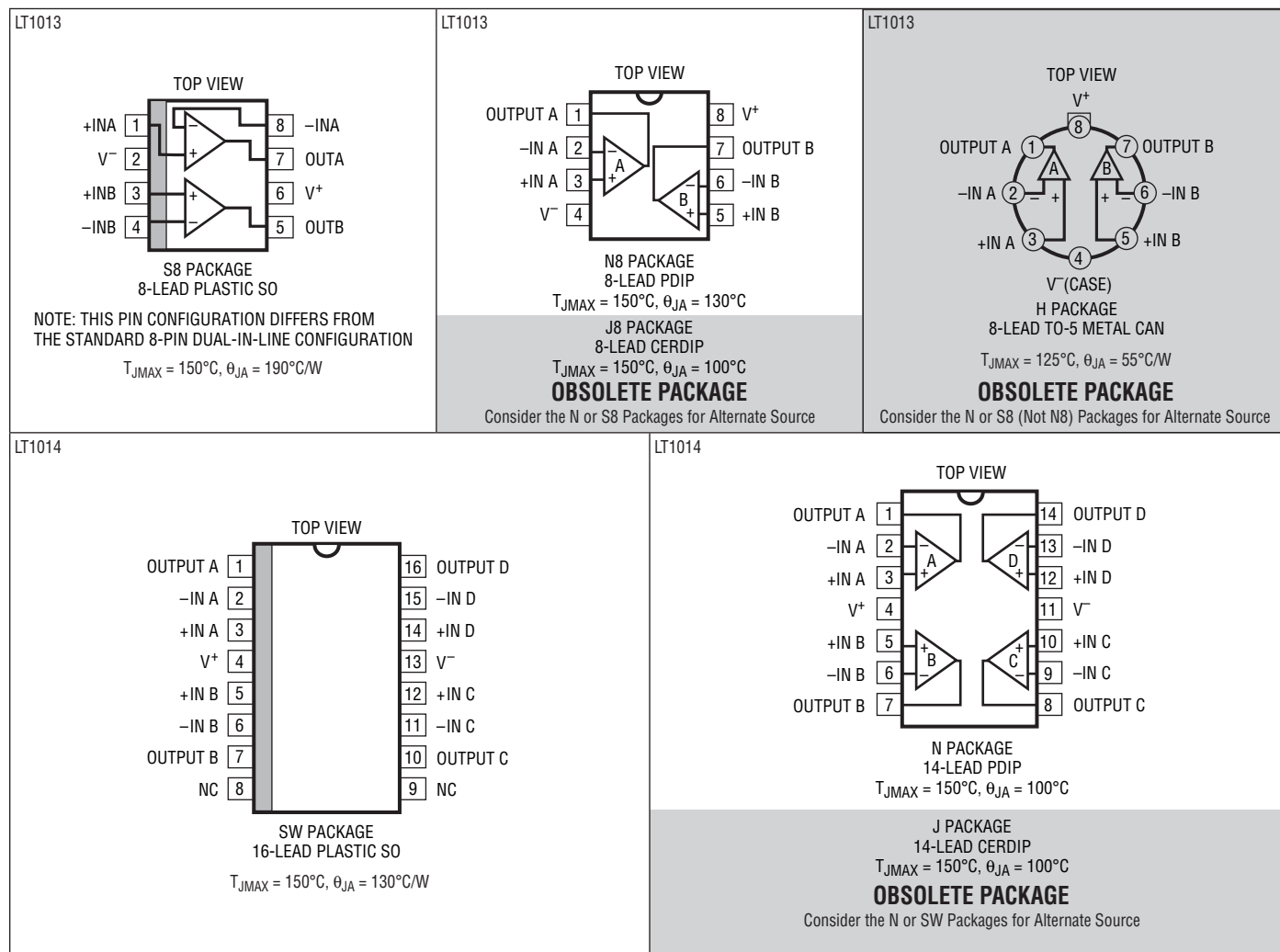
ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage $\pm 22\text{V}$
 Differential Input Voltage $\pm 30\text{V}$
 Input Voltage Equal to Positive Supply Voltage
 5V Below Negative Supply Voltage
 Output Short-Circuit Duration Indefinite
 Storage Temperature Range
 All Grades -65°C to 150°C

Lead Temperature (Soldering, 10 sec.) 300°C
 Operating Temperature Range

LT1013AM/LT1013M/
 LT1014AM/LT1014M -55°C to 125°C
 LT1013AC/LT1013C/LT1013D
 LT1014AC/LT1014C/LT1014D 0°C to 70°C
 LT1013I/ LT1014I -40°C to 85°C

PIN CONFIGURATION



ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT1013DS8#PBF	LT1013DS8#TRPBF	1013	8-Lead Plastic SO	0°C to 70°C
LT1013IS8#PBF	LT1013IS8#TRPBF	1013I	8-Lead Plastic SO	-40°C to 85°C
LT1013ACN8#PBF	LT1013ACN8#TRPBF	LT1013ACN8	8-Lead PDIP	0°C to 70°C
LT1013CN8#PBF	LT1013CN8#TRPBF	LT1013CN8	8-Lead PDIP	0°C to 70°C
LT1013DN8#PBF	LT1013DN8#TRPBF	LT1013DN8	8-Lead PDIP	0°C to 70°C
LT1013IN8#PBF	LT1013IN8#TRPBF	LT1013IN8	8-Lead PDIP	-40°C to 85°C
LT1014DSW#PBF	LT1014DSW#TRPBF	LT1014DSW	16-Lead Plastic SO	0°C to 70°C
LT1014ISW#PBF	LT1014ISW#TRPBF	LT1014ISW	16-Lead Plastic SO	-40°C to 85°C
LT1014ACN#PBF	LT1014ACN#TRPBF	LT1014ACN	14-Lead PDIP	0°C to 70°C
LT1014CN#PBF	LT1014CN#TRPBF	LT1014CN	14-Lead PDIP	0°C to 70°C
LT1014DN#PBF	LT1014DN#TRPBF	LT1014DN	14-Lead PDIP	0°C to 70°C
LT1014IN#PBF	LT1014IN#TRPBF	LT1014IN	14-Lead PDIP	-40°C to 85°C
LT1013AMJ8#PBF	LT1013AMJ8#TRPBF	LT1013AMJ8	8-Lead Cerdip	-55°C to 125°C (OBSOLETE)
LT1013MJ8#PBF	LT1013MJ8#TRPBF	LT1013MJ8	8-Lead Cerdip	-55°C to 125°C (OBSOLETE)
LT1013ACJ8#PBF	LT1013ACJ8#TRPBF	LT1013ACJ8	8-Lead Cerdip	0°C to 70°C (OBSOLETE)
LT1013CJ8#PBF	LT1013CJ8#TRPBF	LT1013CJ8	8-Lead Cerdip	0°C to 70°C (OBSOLETE)
LT1013AMH#PBF	LT1013AMH#TRPBF	LT1013AMH	8-Lead TO-5 Metal Can	-55°C to 125°C (OBSOLETE)
LT1013MH#PBF	LT1013MH#TRPBF	LT1013MH	8-Lead TO-5 Metal Can	-55°C to 125°C (OBSOLETE)
LT1013ACH#PBF	LT1013ACH#TRPBF	LT1013ACH	8-Lead TO-5 Metal Can	0°C to 70°C (OBSOLETE)
LT1013CH#PBF	LT1013CH#TRPBF	LT1013CH	8-Lead TO-5 Metal Can	0°C to 70°C (OBSOLETE)
LT1014AMJ#PBF	LT1014AMJ#TRPBF	LT1014AMJ	14-Lead Cerdip	-55°C to 125°C (OBSOLETE)
LT1014MJ#PBF	LT1014MJ#TRPBF	LT1014MJ	14-Lead Cerdip	-55°C to 125°C (OBSOLETE)
LT1014ACJ#PBF	LT1014ACJ#TRPBF	LT1014ACJ	14-Lead Cerdip	0°C to 70°C (OBSOLETE)
LT1014CJ#PBF	LT1014CJ#TRPBF	LT1014CJ	14-Lead Cerdip	0°C to 70°C (OBSOLETE)

Consult LTC Marketing for parts specified with wider operating temperature ranges.

Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreel/>

LT1013/LT1014

ELECTRICAL CHARACTERISTICS $T_A = 25^\circ\text{C}$. $V_S = \pm 15\text{V}$, $V_{CM} = 0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LT1013AM/AC LT1014AM/AC			LT1013C/D/I/M LT1014C/D/I/M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1013		40	150		60	300	μV
		LT1014		50	180		60	300	μV
		LT1013D/I, LT1014D/I					200	800	μV
									μV
	Long-Term Input Offset Voltage Stability			0.4			0.5		$\mu\text{V}/\text{Mo.}$
I_{SO}	Input Offset Current			0.15	0.8		0.2	1.5	nA
I_B	Input Bias Current			12	20		15	30	nA
e_n	Input Noise Voltage	0.1Hz to 10Hz		0.55			0.55		μV_{P-P}
e_n	Input Noise Voltage Density	$f_0 = 10\text{Hz}$		24			24		$\text{nV}/\sqrt{\text{Hz}}$
		$f_0 = 1000\text{Hz}$		22			22		$\text{nV}/\sqrt{\text{Hz}}$
i_n	Input Noise Current Density	$f_0 = 10\text{Hz}$		0.07			0.07		$\text{pA}/\sqrt{\text{Hz}}$
	Input Resistance – Differential Common Mode	(Note 2)	100	400 5		70	300 4		$\text{M}\Omega$ $\text{G}\Omega$
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 10\text{V}$, $R_L = 2\text{k}$	1.5	8.0		1.2	7.0		$\text{V}/\mu\text{V}$
		$V_O = \pm 10\text{V}$, $R_L = 600\Omega$	0.8	2.5		0.5	2.0		$\text{V}/\mu\text{V}$
	Input Voltage Range		13.5 –15.0	13.8 –15.3		13.5 –15.0	13.8 –15.3		V V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 13.5\text{V}$, -15.0V	100	117		97	114		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2\text{V}$ to $\pm 18\text{V}$	103	120		100	117		dB
	Channel Separation	$V_O = \pm 10\text{V}$, $R_L = 2\text{k}$	123	140		120	137		dB
V_{OUT}	Output Voltage Swing	$R_L = 2\text{k}$	± 13	± 14		± 12.5	± 14		V
	Slew Rate		0.2	0.4		0.2	0.4		$\text{V}/\mu\text{s}$
I_S	Supply Current	Per Amplifier		0.35	0.50		0.35	0.55	mA

$T_A = 25^\circ\text{C}$. $V_S^+ = 5\text{V}$, $V_S^- = 0\text{V}$, $V_{OUT} = 1.4\text{V}$, $V_{CM} = 0\text{V}$ unless otherwise noted

SYMBOL	PARAMETER	CONDITIONS	LT1013AM/AC LT1014AM/AC			LT1013C/D/I/M LT1014C/D/I/M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1013		60	250		90	450	μV
		LT1014		70	280		90	450	μV
		LT1013D/I, LT1014D/I					250	950	μV
									μV
I_{OS}	Input Offset Current			0.2	1.3		0.3	2.0	nA
I_B	Input Bias Current			15	35		18	50	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = 5\text{mV}$ to 4V , $R_L = 500\Omega$		1.0			1.0		$\text{V}/\mu\text{V}$
	Input Voltage Range		3.5	3.8 –0.3		3.5 0	3.8 –0.3		V V
V_{OUT}	Output Voltage Swing	Output Low, No Load		15	25		15	25	mV
		Output Low, 600Ω to Ground		5	10		5	10	mV
		Output Low, $I_{SINK} = 1\text{mA}$		220	350		220	350	mV
		Output High, No Load	4.0	4.4		4.0	4.4		V
		Output High, 600Ω to Ground	3.4	4.0		3.4	4.0		V
I_S	Supply Current	Per Amplifier		0.31	0.45		0.32	0.50	mA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range $-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$. $V_S = \pm 15\text{V}$, $V_{CM} = 0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1013AM			LT1014AM			LT1013M/LT1014M			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$ $-55^{\circ}\text{C} \leq T_A \leq 100^{\circ}\text{C}$ $V_{CM} = 0.1\text{V}, T_A = 125^{\circ}\text{C}$ $V_{CM} = 0\text{V}, T_A = 125^{\circ}\text{C}$	●	80	300		90	350		110	550		μV
			●	80	450		90	480		100	750		μV
				120	450		150	480		200	750		μV
				250	900		300	960		400	1500		μV
	Input Offset Voltage Drift	(Note 3)	●	0.4	2.0		0.4	2.0		0.5	2.5		$\mu\text{V}/^{\circ}\text{C}$
I_{OS}	Input Offset Current	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	0.3	2.5		0.3	2.8		0.4	5.0		nA
			●	0.6	6.0		0.7	7.0		0.9	10.0		nA
I_B	Input Bias Current	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	15	30		15	30		18	45		nA
			●	20	80		25	90		28	120		nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 10\text{V}, R_L = 2\text{k}$	●	0.5	2.0		0.4	2.0		0.25	2.0		$\text{V}/\mu\text{V}$
CMRR	Common Mode Rejection	$V_{CM} = 13.0\text{V}, -14.9\text{V}$	●	97	114		96	114		94	113		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2\text{V to } \pm 18\text{V}$	●	100	117		100	117		97	116		dB
V_{OUT}	Output Voltage Swing	$R_L = 2\text{k}$ $V_S = 5\text{V}, 0\text{V}$ $R_L = 600\Omega$ to Ground Output Low Output High	●	± 12	± 13.8		± 12	± 13.8		± 11.5	± 13.8		V
			●		6	15		6	15		6	18	mV
			●	3.2	3.8		3.2	3.8		3.1	3.8		V
I_S	Supply Current Per Amplifier	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	0.38	0.60		0.38	0.60		0.38	0.7		mA
			●	0.34	0.55		0.34	0.55		0.34	0.65		mA

LT1013/LT1014

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ for LT1013I, LT1014I, $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$ for LT1013C, LT1013D, LT1014C, LT1014D. $V_S = \pm 15\text{V}$, $V_{CM} = 0\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LT1013AC			LT1014AC			LT1013C/D/I LT1014C/D/I			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	LT1013D/I, LT1014D/I $V_S = 5\text{V}$, 0V ; $V_O = 1.4\text{V}$ LT1013D/I, LT1014D/I $V_S = 5\text{V}$, 0V ; $V_O = 1.4\text{V}$	●		55	240		65	270		80	400	μV
			●								230	1000	μV
			●		75	350		85	380		110	570	μV
			●								280	1200	μV
	Average Input Offset Voltage Drift	(Note 3) LT1013D/I, LT1014D/I	●		0.3	2.0		0.3	2.0		0.4	2.5	$\mu\text{V}/^{\circ}\text{C}$
			●								0.7	5.0	$\mu\text{V}/^{\circ}\text{C}$
I_{OS}	Input Offset Current	$V_S = 5\text{V}$, 0V ; $V_O = 1.4\text{V}$	●		0.2	1.5		0.2	1.7		0.3	2.8	nA
			●		0.4	3.5		0.4	4.0		0.5	6.0	nA
I_B	Input Bias Current	$V_S = 5\text{V}$, 0V ; $V_O = 1.4\text{V}$	●		13	25		13	25		16	38	nA
			●		18	55		20	60		24	90	nA
A_{VOL}	Large-Signal Voltage Gain	$V_O = \pm 10\text{V}$, $R_L = 2\text{k}$	●	1.0	5.0		1.0	5.0		0.7	4.0		$\text{V}/\mu\text{V}$
CMRR	Common Mode Rejection Ratio	$V_{CM} = 13.0\text{V}$, -15.0V	●	98	116		98	116		94	113		dB
PSRR	Power Supply Rejection Ratio	$V_S = \pm 2\text{V}$ to $\pm 18\text{V}$	●	101	119		101	119		97	116		dB
V_{OUT}	Output Voltage Swing	$R_L = 2\text{k}$ $V_S = 5\text{V}$, 0V ; $R_L = 600\Omega$ Output Low Output High	●	± 12.5	± 13.9		± 12.5	± 13.9		± 12.0	± 13.9		V
			●		6	13		6	13		6	13	mV
			●	3.3	3.9		3.3	3.9		3.2	3.9		V
I_S	Supply Current per Amplifier	$V_S = 5\text{V}$, 0V ; $V_O = 1.4\text{V}$	●		0.36	0.55		0.36	0.55		0.37	0.60	mA
			●		0.32	0.50		0.32	0.50		0.34	0.55	mA

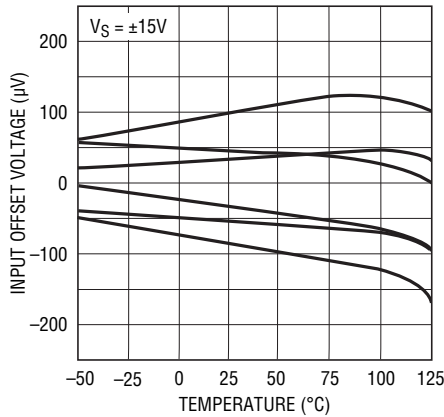
Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Rating condition for extended periods may affect device reliability and lifetime.

Note 2: This parameter is guaranteed by design and is not tested. Typical parameters are defined as the 60% yield of parameter distributions of individual amplifiers; i.e., out of 100 LT1014s (or 100 LT1013s) typically 240 op amps (or 120) will be better than the indicated specification.

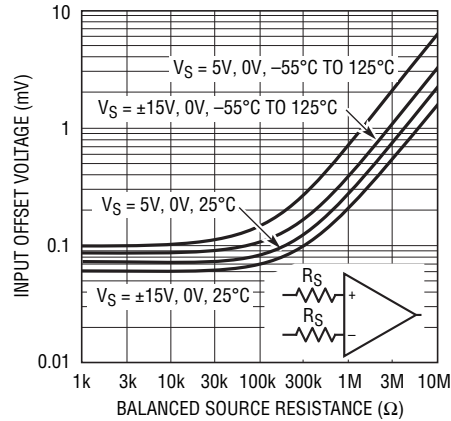
Note 3: This parameter is not 100% tested.

TYPICAL PERFORMANCE CHARACTERISTICS

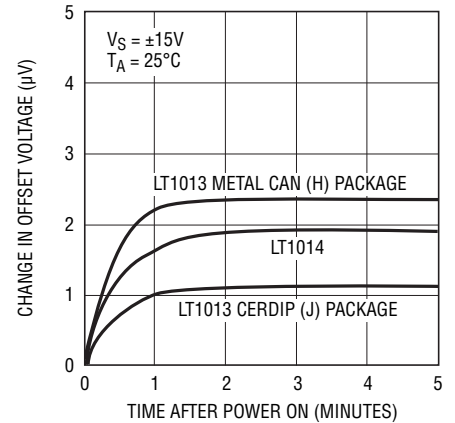
Offset Voltage Drift with Temperature of Representative Units



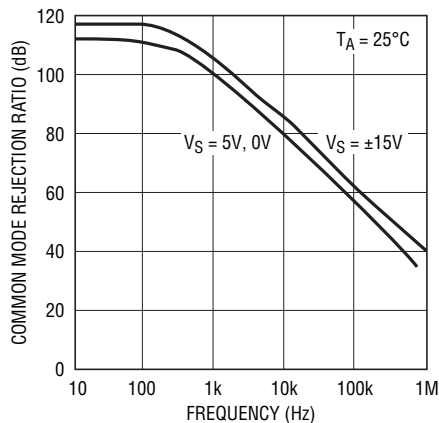
Offset Voltage vs Balanced Source Resistance



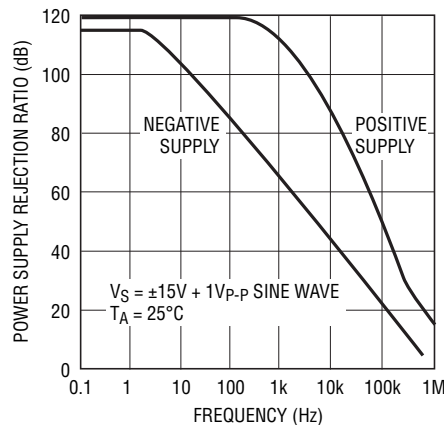
Warm-Up Drift



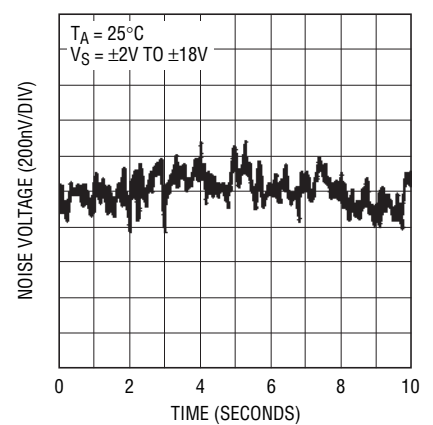
Common Mode Rejection Ratio vs Frequency



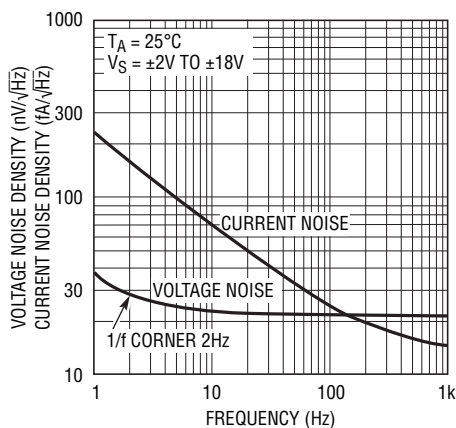
Power Supply Rejection Ratio vs Frequency



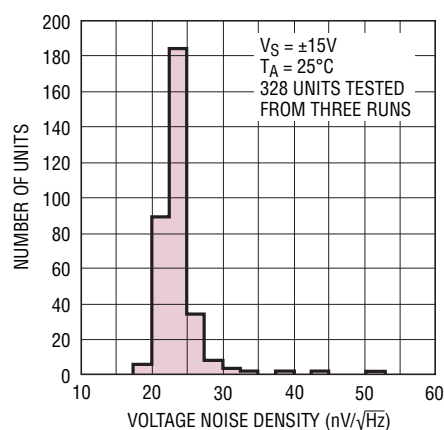
0.1Hz to 10Hz Noise



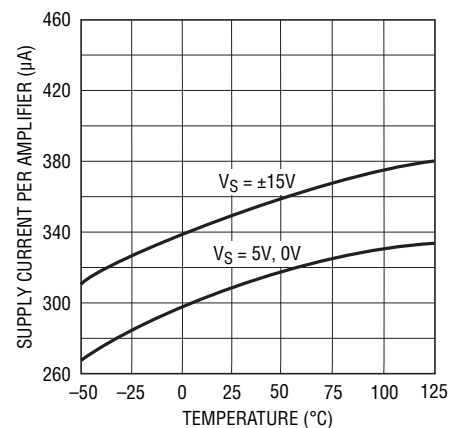
Noise Spectrum



10Hz Voltage Noise Distribution

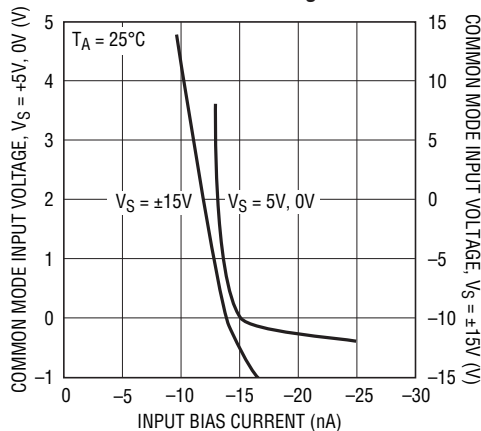


Supply Current vs Temperature

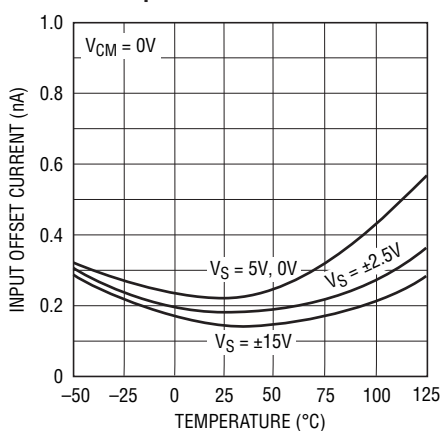


TYPICAL PERFORMANCE CHARACTERISTICS

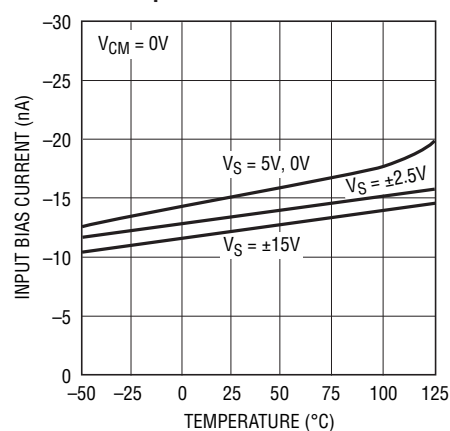
Input Bias Current vs Common Mode Voltage



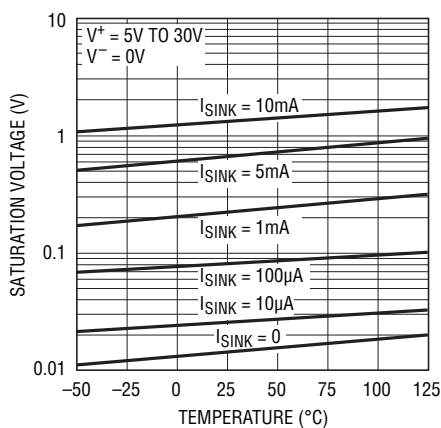
Input Offset Current vs Temperature



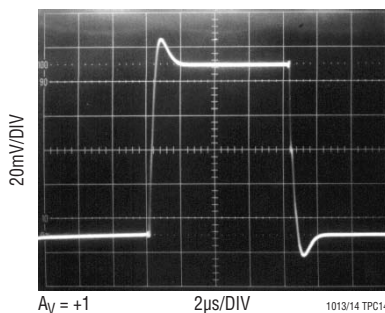
Input Bias Current vs Temperature



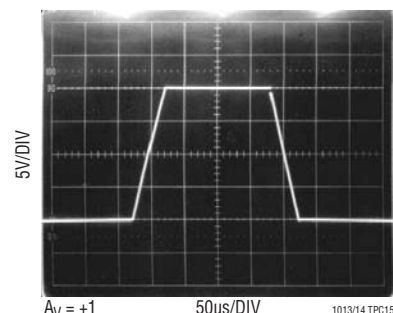
Output Saturation vs Sink Current vs Temperature



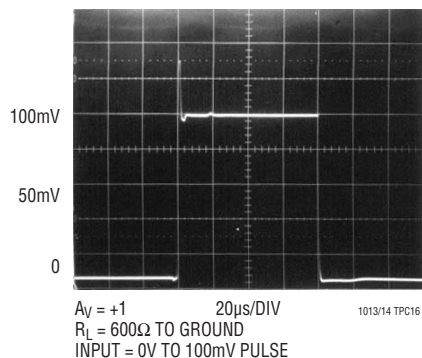
Small-Signal Transient Response, $V_S = \pm 15V$



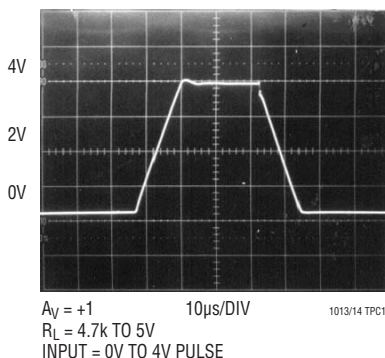
Large-Signal Transient Response, $V_S = \pm 15V$



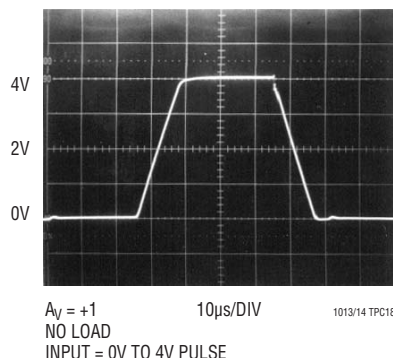
Small-Signal Transient Response, $V_S = 5V, 0V$



Large-Signal Transient Response, $V_S = 5V, 0V$

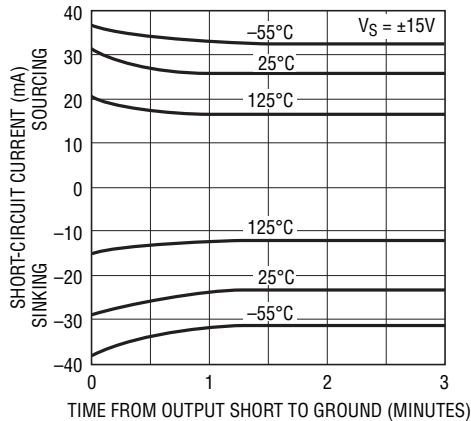


Large-Signal Transient Response, $V_S = 5V, 0V$



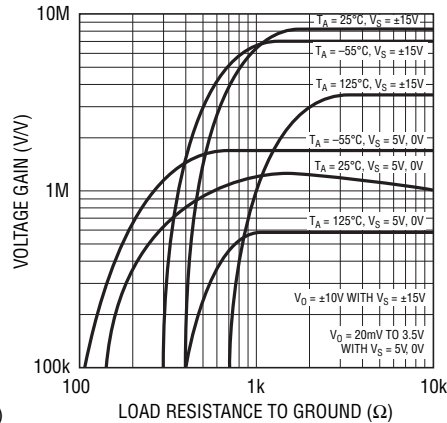
TYPICAL PERFORMANCE CHARACTERISTICS

Output Short-Circuit Current
vs Time



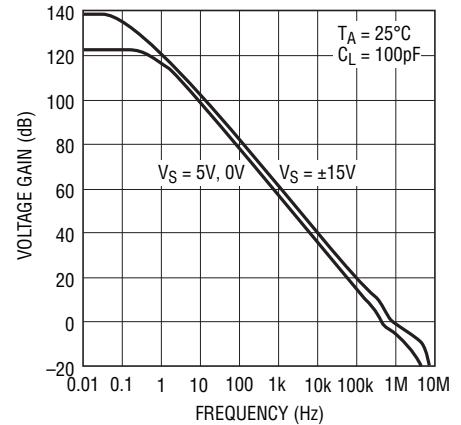
1013/14 TPC19

Voltage Gain vs Load Resistance



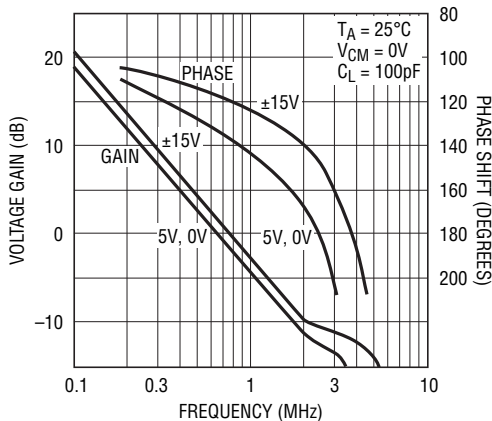
1013/14 TPC20

Voltage Gain vs Frequency



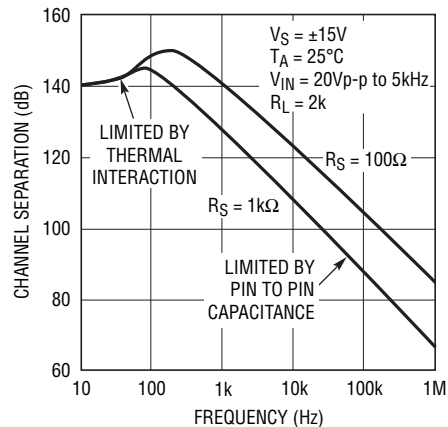
1013/14 TPC21

Gain, Phase vs Frequency



1013/14 TPC22

Channel Separation
vs Frequency



1013/14 TPC23

APPLICATIONS INFORMATION

Single Supply Operation

The LT1013/LT1014 are fully specified for single supply operation, i.e., when the negative supply is 0V. Input common mode range includes ground; the output swings within a few millivolts of ground. Single supply operation, however, can create special difficulties, both at the input and at the output. The LT1013/LT1014 have specific circuitry which addresses these problems.

At the input, the driving signal can fall below 0V—advertently or on a transient basis. If the input is more than a few hundred millivolts below ground, two distinct

problems can occur on previous single supply designs, such as the LM124, LM158, OP-20, OP-21, OP-220, OP-221, OP-420:

a) When the input is more than a diode drop below ground, unlimited current will flow from the substrate (V^- terminal) to the input. This can destroy the unit. On the LT1013/LT1014, the 400Ω resistors, in series with the input (see Schematic Diagram), protect the devices even when the input is 5V below ground.

APPLICATIONS INFORMATION

b) When the input is more than 400mV below ground (at 25°C), the input stage saturates (transistors Q3 and Q4) and phase reversal occurs at the output. This can cause lock-up in servo systems. Due to a unique phase reversal protection circuitry (Q21, Q22, Q27, Q28), the LT1013/LT1014's outputs do not reverse, as illustrated below, even when the inputs are at -1.5V.

There is one circumstance, however, under which the phase reversal protection circuitry does not function: when the other op amp on the LT1013, or one specific amplifier of the other three on the LT1014, is driven hard into negative saturation at the output.

Phase reversal protection does not work on amplifier:

A when D's output is in negative saturation. B's and C's outputs have no effect.

B when C's output is in negative saturation. A's and D's outputs have no effect.

C when B's output is in negative saturation. A's and D's outputs have no effect.

D when A's output is negative saturation. B's and C's outputs have no effect.

At the output, the aforementioned single supply designs either cannot swing to within 600mV of ground (OP-20) or cannot sink more than a few microamperes while swinging to ground (LM124, LM158). The LT1013/LT1014's all-NPN output stage maintains its low output resistance and high gain characteristics until the output is saturated.

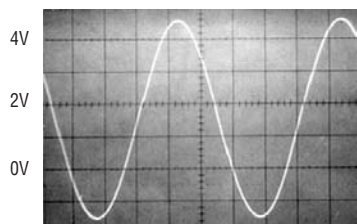
In dual supply operations, the output stage is crossover distortion-free.

Comparator Applications

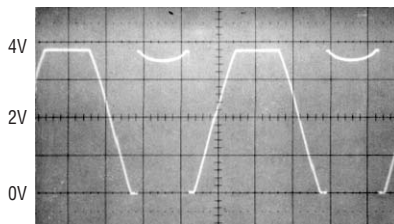
The single supply operation of the LT1013/LT1014 lends itself to its use as a precision comparator with TTL compatible output:

In systems using both op amps and comparators, the LT1013/LT1014 can perform multiple duties; for example, on the LT1014, two of the devices can be used as op amps and the other two as comparators.

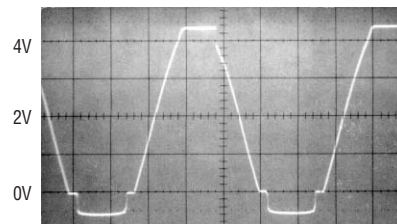
Voltage Follower with Input Exceeding the Negative Common Mode Range



6V_{P-P} INPUT, -1.5V TO 4.5V

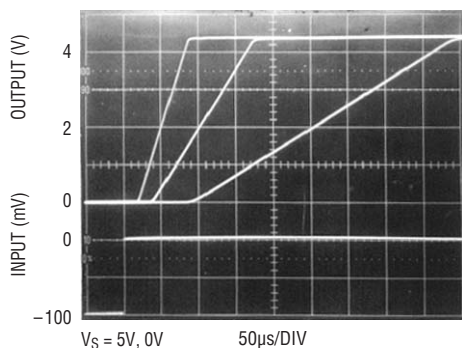


LM324, LM358, OP-20
EXHIBIT OUTPUT PHASE
REVERSAL



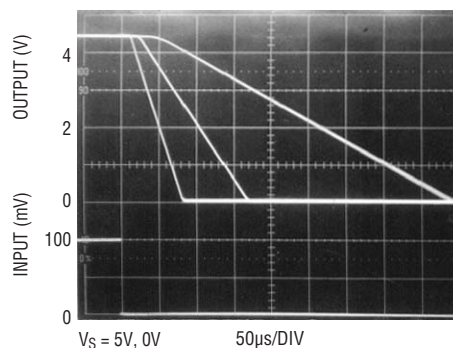
LT1013/LT1014
NO PHASE REVERSAL

Comparator Rise Response Time 10mV, 5mV, 2mV Overdrives



V_S = 5V, 0V 50µs/DIV

Comparator Fall Response Time to 10mV, 5mV, 2mV Overdrives



V_S = 5V, 0V 50µs/DIV

APPLICATIONS INFORMATION

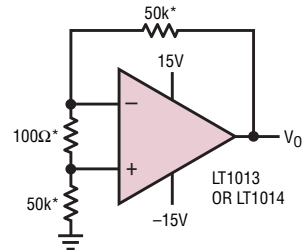
Low Supply Operation

The minimum supply voltage for proper operation of the LT1013/LT1014 is 3.4V (three Ni-Cad batteries). Typical supply current at this voltage is 290 μ A, therefore power dissipation is only one milliwatt per amplifier.

Noise Testing

For applications information on noise testing and calculations, please see the LT1007 or LT1008 data sheet.

Test Circuit for Offset Voltage and Offset Drift with Temperature

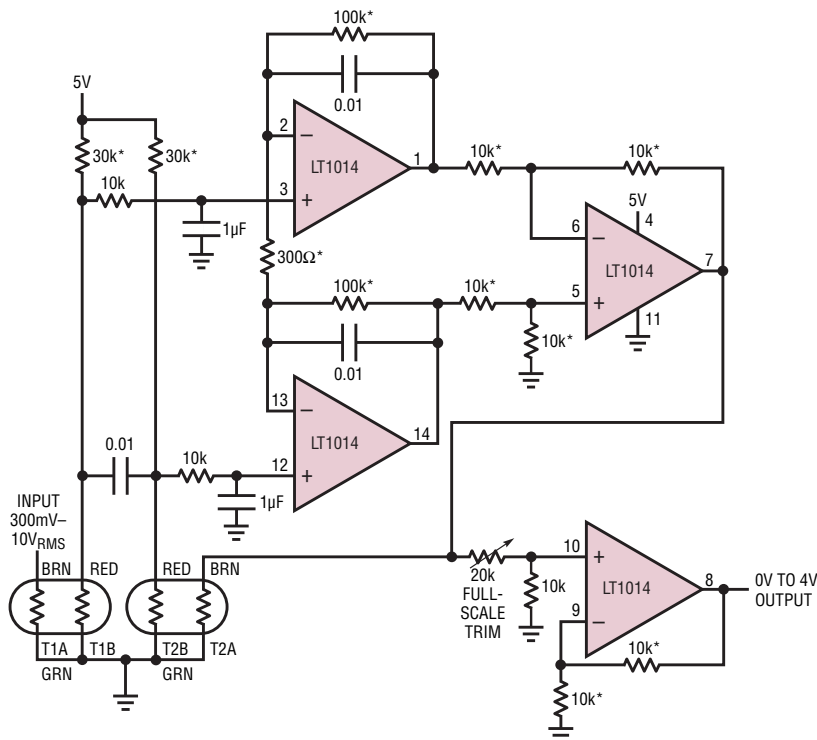


*RESISTOR MUST HAVE LOW THERMOELECTRIC POTENTIAL.
 **THIS CIRCUIT IS ALSO USED AS THE BURN-IN CONFIGURATION, WITH SUPPLY VOLTAGES INCREASED TO ± 20 V.
 $V_O = 1000V_{OS}$

LT1013/14 F06

TYPICAL APPLICATIONS

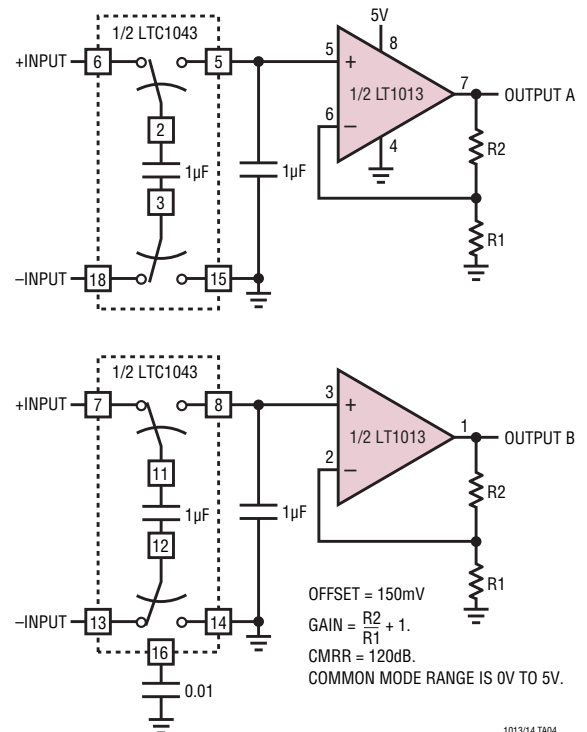
50MHz Thermal RMS-to-DC Converter



2% ACCURACY, DC-50MHz.
 100:1 CREST FACTOR CAPABILITY.
 * 0.1% RESISTOR.
 T1-T2 = YELLOW SPRINGS INST. CO. THERMISTOR COMPOSITE #44018.
 ENCLOSE T1 AND T2 IN STYROFOAM.
 7.5mW DISSIPATION.

1013/14 TA03

5V Single Supply Dual Instrumentation Amplifier



OFFSET = 150mV
 GAIN = $\frac{R_2}{R_1} + 1$.
 CMRR = 120dB.
 COMMON MODE RANGE IS 0V TO 5V.

1013/14 TA04

TYPICAL APPLICATIONS

27Ω 1W

10k*

0.01μF

15V

A1 LT1014

2k*

-15V

500pF

Q6 TIP120 OR EQUIVALENT

2k

150k*

33k

1k ZERO FLOW

3.3k

-15V

Q3

Q1-Q4 CA3046

Q1

Q2

1000pF

2k

150k*

12k

1μF

10M RESPONSE TIME ADJUST

2M FULL-SCALE FLOW

100k

500k

1μF

A3 LT1014

9

10

8

A4 LT1014

13

12

14

0V TO 10V = 0 TO 1000 FEET/MINUTE

TIE CA3046 PIN 13 TO -15V. DO NOT USE Q5

Q5

13

-15V

REMOVE LAMP'S GLASS ENVELOPE FROM 328 LAMP.
A1 SERVOES #328 LAMP TO CONSTANT TEMPERATURE.
A2-A3 FURNISH LINEAR OUTPUT vs FLOW RATE.
*1% RESISTOR.

15V

15Ω DALE HL-25

3.2k**

3.2k*

6.25k**

T1

T2

1M*

1M*

1M*

A1 LT1014

10M RESPONSE TIME

100k

1μF

A2 LT1014

6.98k*

5k FLOW CALIB

1k*

15V

4.7k

1N4148

100k

2N4391

0.1

383k*

2.7k

-15V

A3 LT1014

300pF

15V

100k

100k

A4 LT1014

15V

-15V

OUTPUT 0Hz TO 300Hz = 0 TO 300ML/MIN

LT1004-1.2

FLOW → T1

PIPE

15Ω HEATER RESISTOR

T2

FLOW →

* 1% FILM RESISTOR.

** SUPPLIED WITH YSI THERMISTOR NETWORK

FLOW IN PIPE IS INVERSELY PROPORTIONAL TO

* 1% FILM RESISTOR.
 ** SUPPLIED WITH YSI THERMISTOR NETWORK.
 T1, T2 YSI THERMISTOR NETWORK = #44201.
 FLOW IN PIPE IS INVERSELY PROPORTIONAL TO
 RESISTANCE OF T1-T2 TEMPERATURE DIFFERENCE.
 A1-A2 PROVIDE GAIN. A3-A4 PROVIDE LINEARIZED
 FREQUENCY OUTPUT.

The circuit diagram shows three LT1014 operational amplifiers configured as follows:

- Op-Amp 1 (Top):** Non-inverting input (+) is connected to pin 9 (V_{CC}). Inverting input (-) is connected to pin 8 (TO INPUT CABLE SHIELDS). Output (pin 10) is connected to the non-inverting input of Op-Amp 2.
- Op-Amp 2 (Middle):** Non-inverting input (+) is connected to pin 1. Inverting input (-) is connected to pin 2. The output (pin 1) is connected to a network of resistors leading to the final output.
- Op-Amp 3 (Bottom):** Non-inverting input (+) is connected to pin 5. Inverting input (-) is connected to pin 6. The output (pin 7) is connected to a network of resistors leading to the final output.

Input Stage:

- +INPUT:** Connected through a 20k resistor to the non-inverting input of Op-Amp 3 (pin 5).
- INPUT:** Connected through a 20k resistor to the non-inverting input of Op-Amp 2 (pin 3).

Biasing and Reference:

- A 5V supply is connected to pins 4 and 11.
- Diodes are used to clamp the inputs to the 5V rail and ground.
- A resistor R_G (TYP 2k) connects the inverting inputs of Op-Amps 2 and 3 (pins 2 and 6).

Output Stage:

- The outputs of Op-Amps 2 and 3 (pins 1 and 7) are combined through a network of resistors (10k*, 10k, 10k*) to produce the final **OUTPUT** at pin 14.

Resistor Values:

- 20k: Input resistors.
- 10k*: Matched 1% film resistors.
- 10k: Standard 10k resistors.
- 200k*: Matched 1% film resistors.
- R_G: Typical 2k resistor.

Gain Equation:

$$A = \frac{400,000}{R_G} + 1$$

Notes:

- * 1% FILM RESISTOR. MATCH 10k's 0.05%
- † FOR HIGH SOURCE IMPEDANCES, USE 2N2222 AS DIODES.

1013/14 TA07

0.068

9V

15k

47μF

9V

22M

1N4148

4.7k

330Ω

0.01

2N2219

TO A/D RATIO REFERENCE

100k

100k

9V

15k

0.068

3k

0.068

74C221

TO A/D CONVERT COMMAND

350Ω

STRAIN GAUGE BRIDGE

LT1014

LT1014

LT1014

100k

499

499

100k

TO A/D

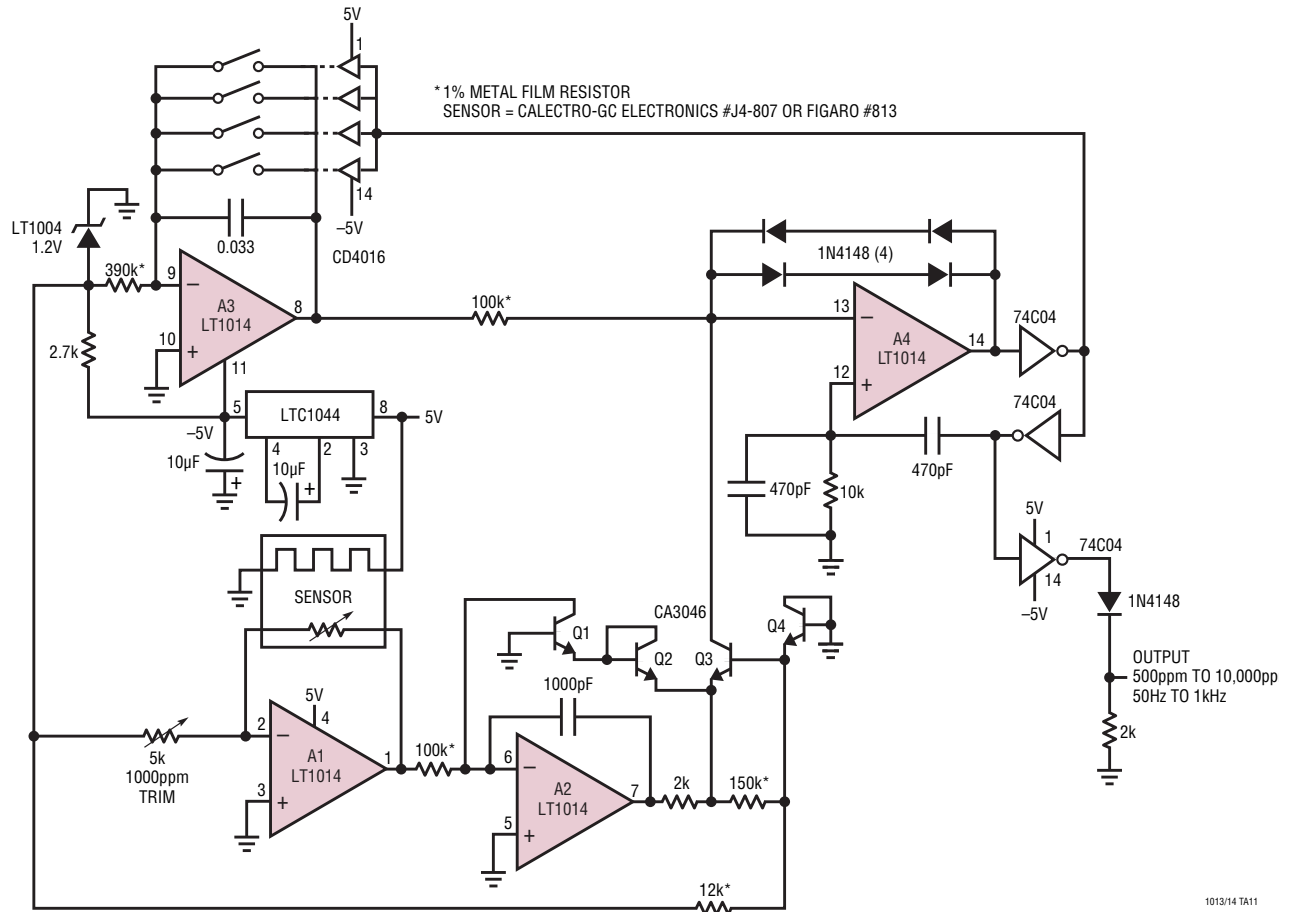
SAMPLED OPERATION GIVES LOW AVERAGE OPERATING CURRENT
4.7k-0.01μF RC PROTECTS STRAIN BRIDGE FROM LONG TERM DRIFT
HIGH ΔV/ΔT STEPS

[illegible]

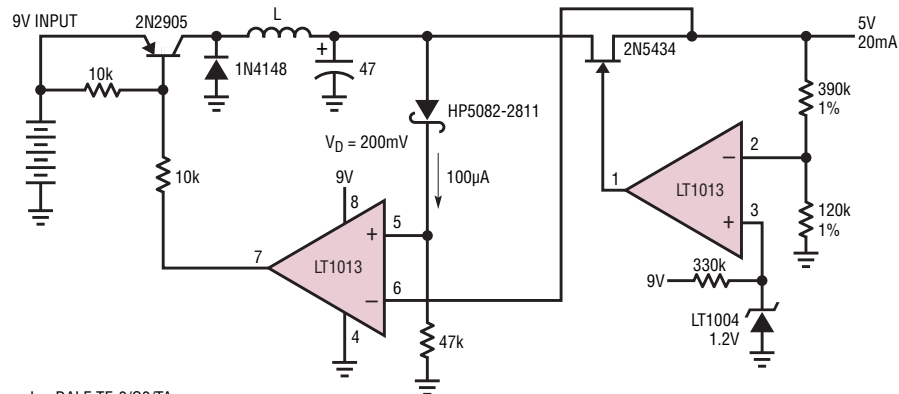
MEETS ALL V_{pp} PROGRAMMING SPECS WITH NO TRIMS AND RUNS OFF 5V SUPPLY—NO EXTERNAL HIGH VOLTAGE SUPPLY REQUIRED. SUITABLE FOR BATTERY POWERED USE (600µA QUIESCENT CURRENT). *1% METAL FILM.

TYPICAL APPLICATIONS

Methane Concentration Detector with Linearized Output



Low Power 9V to 5V Converter



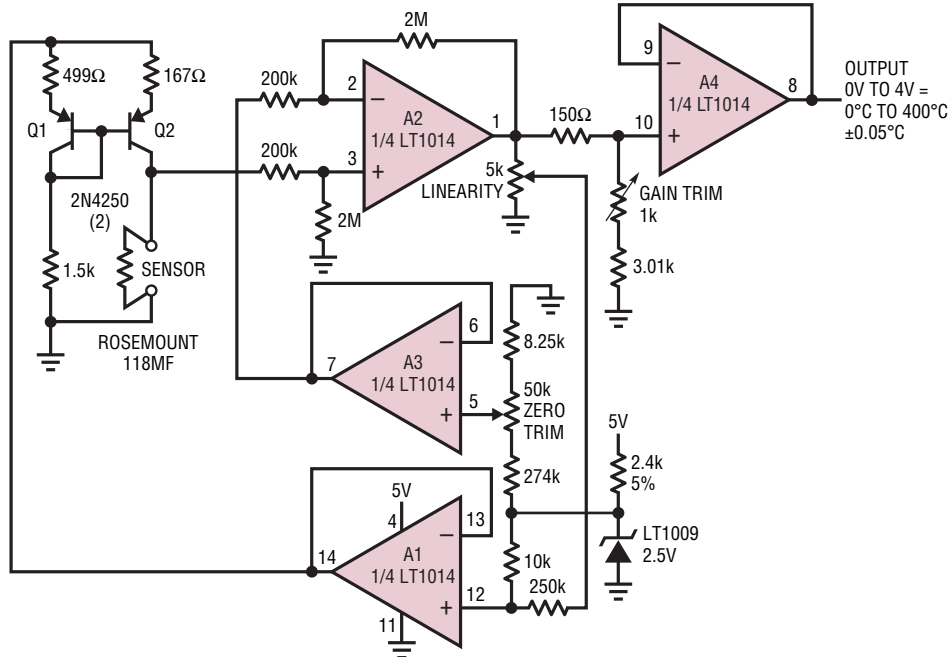
L = DALE TE-3/Q3/TA.
SHORT CIRCUIT CURRENT = 30mA.
≈ 75% EFFICIENCY.
SWITCHING PREREGULATOR CONTROLS DROP ACROSS FET TO 200mV.

1013/14 TA12

[illegible]

TYPICAL APPLICATIONS

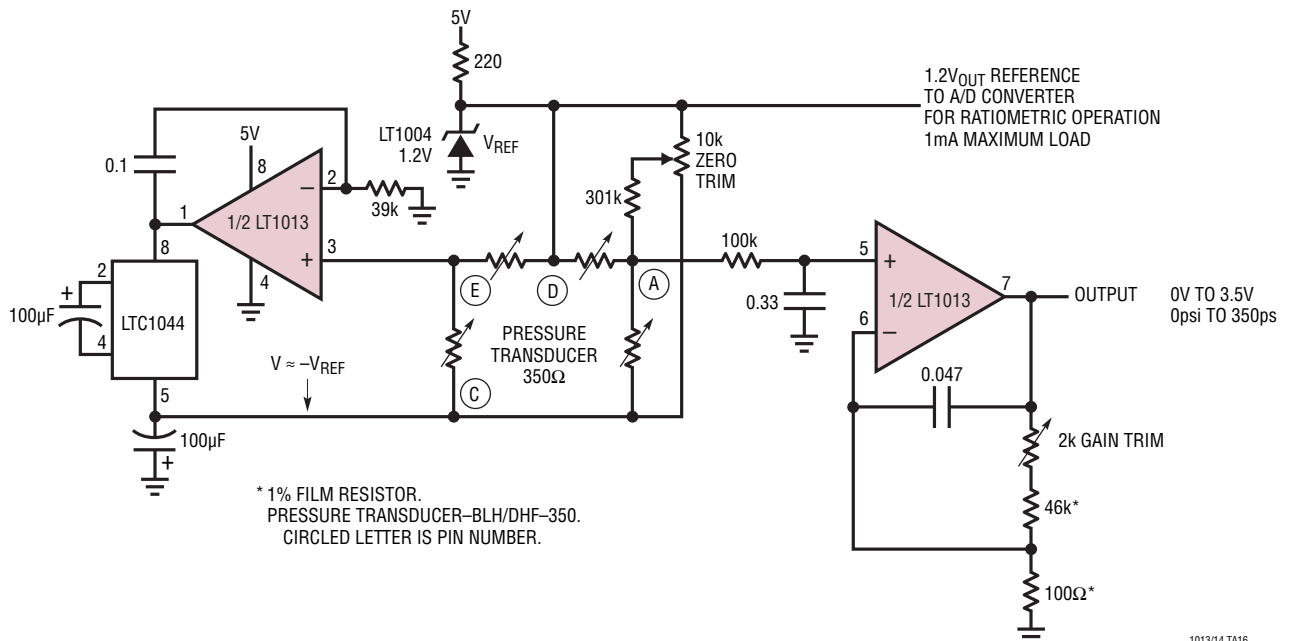
5V Powered, Linearized Platinum RTD Signal Conditioner



ALL RESISTORS ARE TRW-MAR-6 METAL FILM.
RATIO MATCH 2M-200K $\pm 0.01\%$.
TRIM SEQUENCE:
SET SENSOR TO 0° VALUE.
ADJUST ZERO FOR 0V OUT.
SET SENSOR TO 100°C VALUE.
ADJUST GAIN FOR 1.000V OUT.
SET SENSOR TO 400°C.
ADJUST LINEARITY FOR 4.000V OUT, REPEAT AS REQUIRED.

1013/14 TA15

Strain Gauge Bridge Signal Conditioner

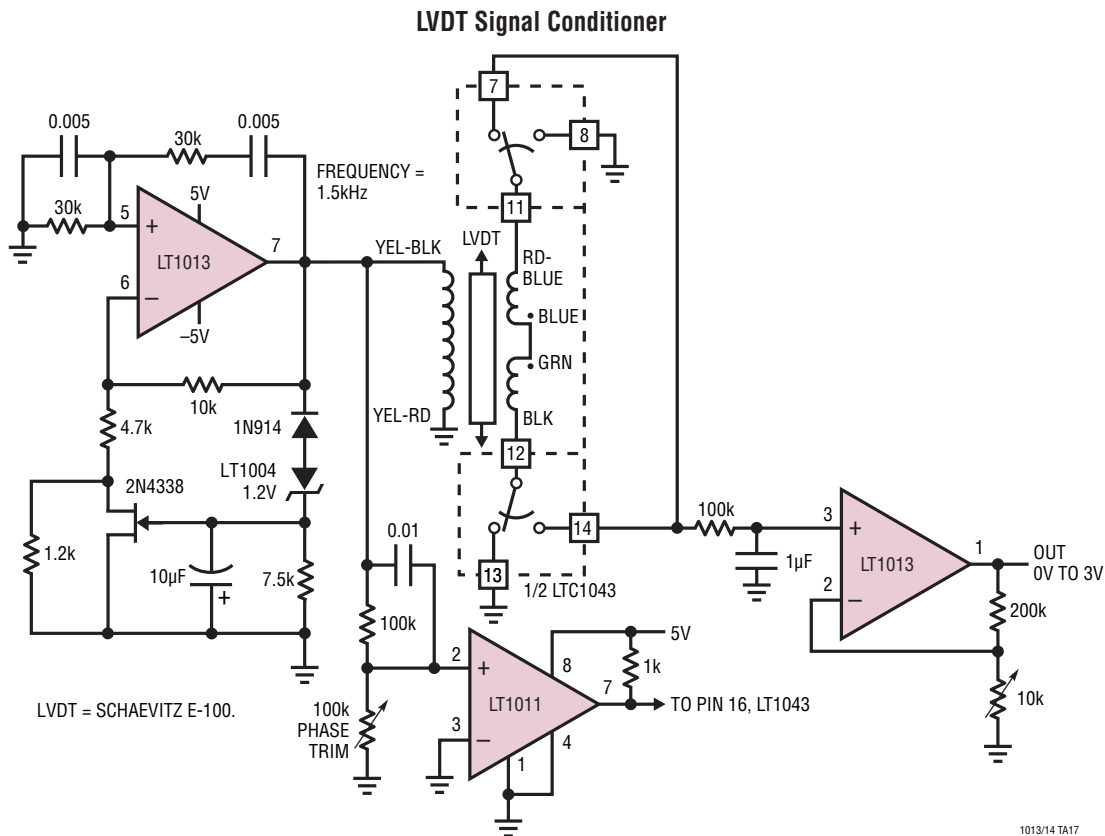


* 1% FILM RESISTOR.
PRESSURE TRANSDUCER-BLH/DHF-350.
CIRCLED LETTER IS PIN NUMBER.

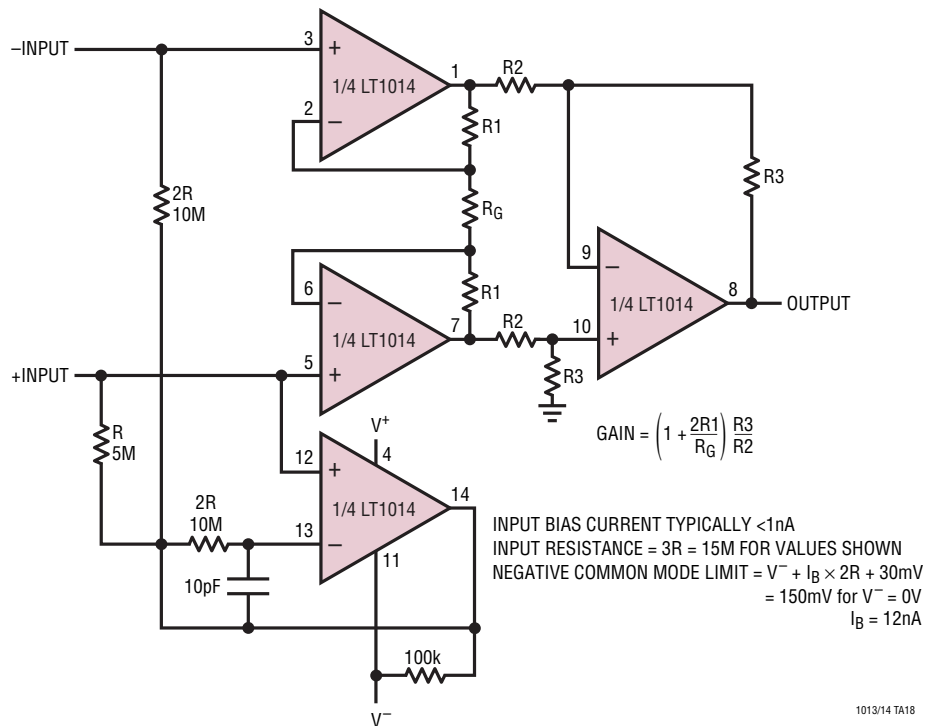
1013/14 TA16

10134fd

TYPICAL APPLICATIONS

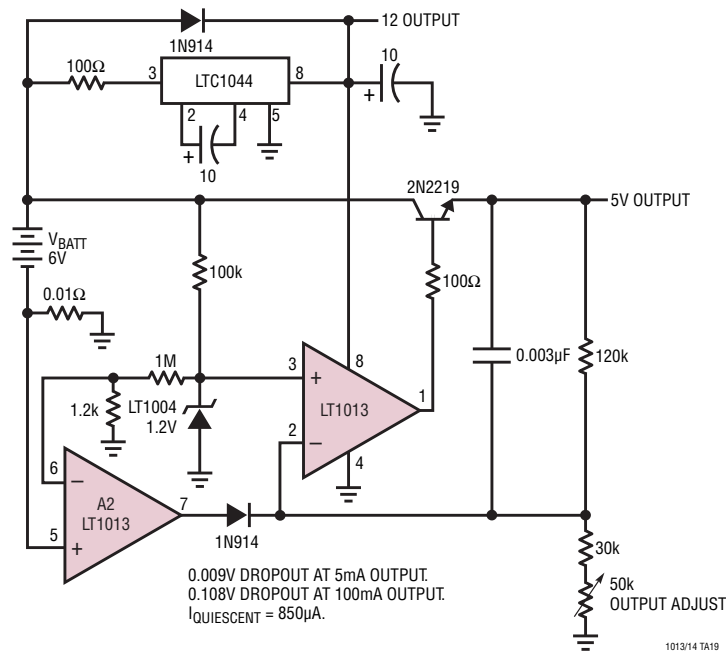


Triple Op Amp Instrumentation Amplifier with Bias Current Cancellation

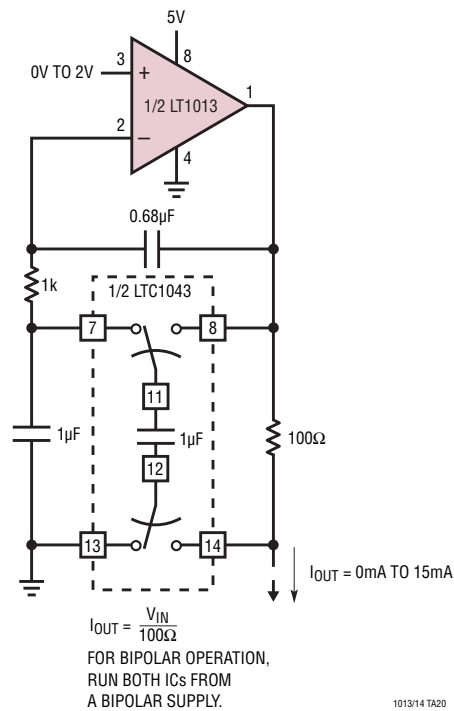


TYPICAL APPLICATIONS

Low Dropout Regulator for 6V Battery

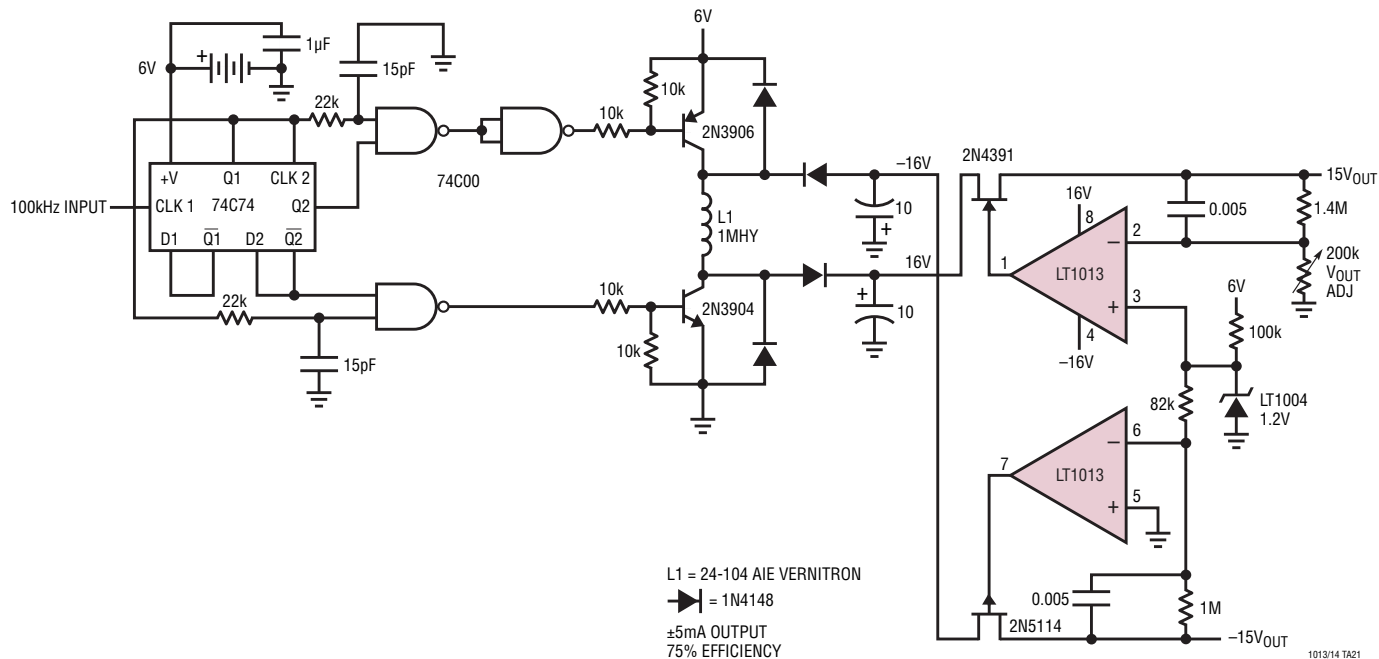


Voltage Controlled Current Source with Ground Referred Input and Output

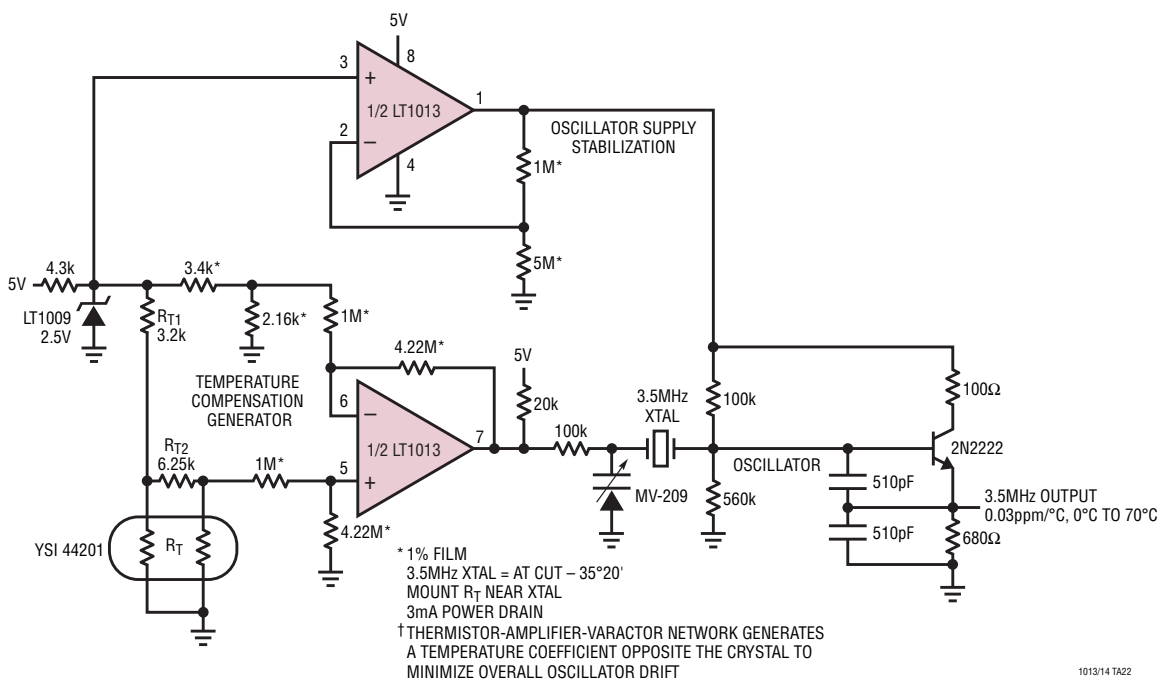


TYPICAL APPLICATIONS

6V to $\pm 15V$ Regulating Converter

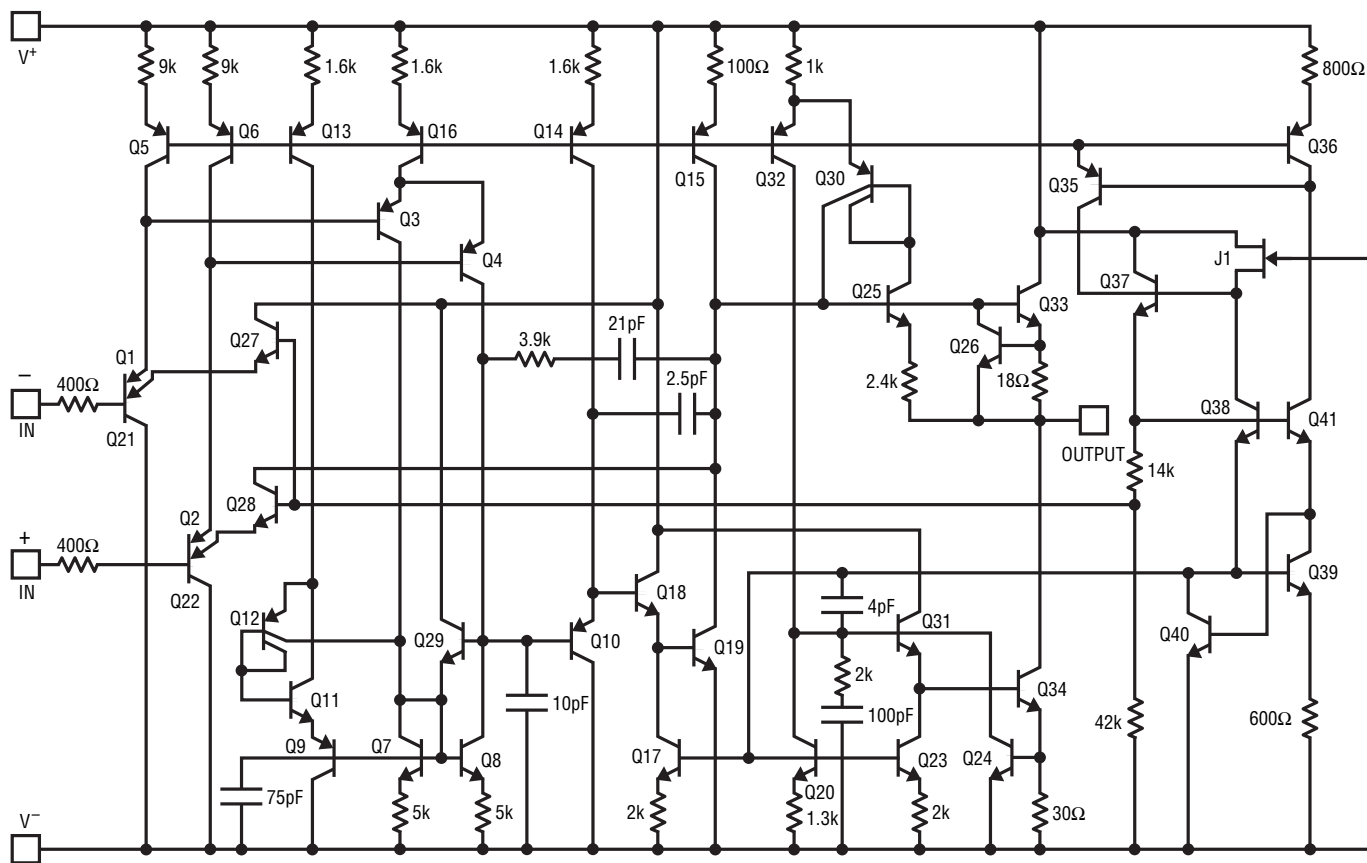


Low Power, 5V Driven, Temperature Compensated Crystal Oscillator (TXCO)[†]



SCHEMATIC DIAGRAM

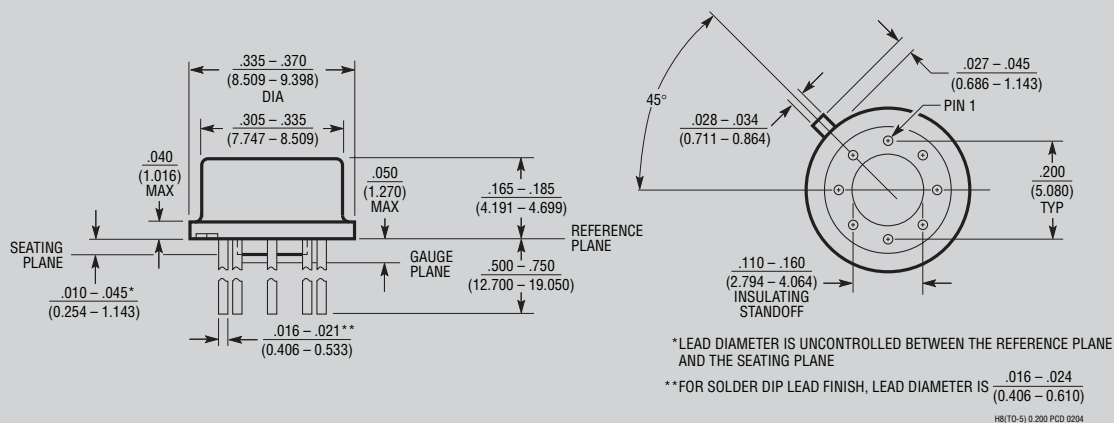
1/2 LT1013, 1/4 LT1014



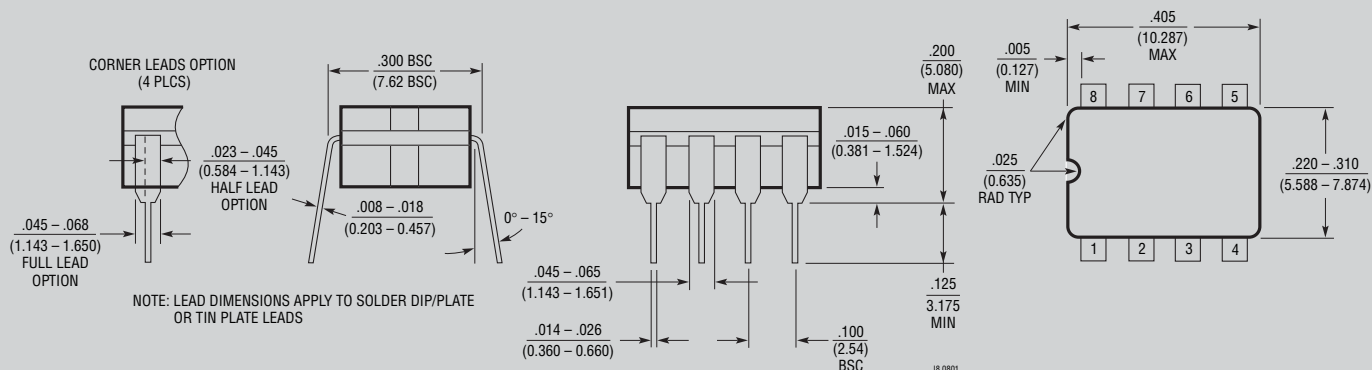
1013/14 SD

PACKAGE DESCRIPTION

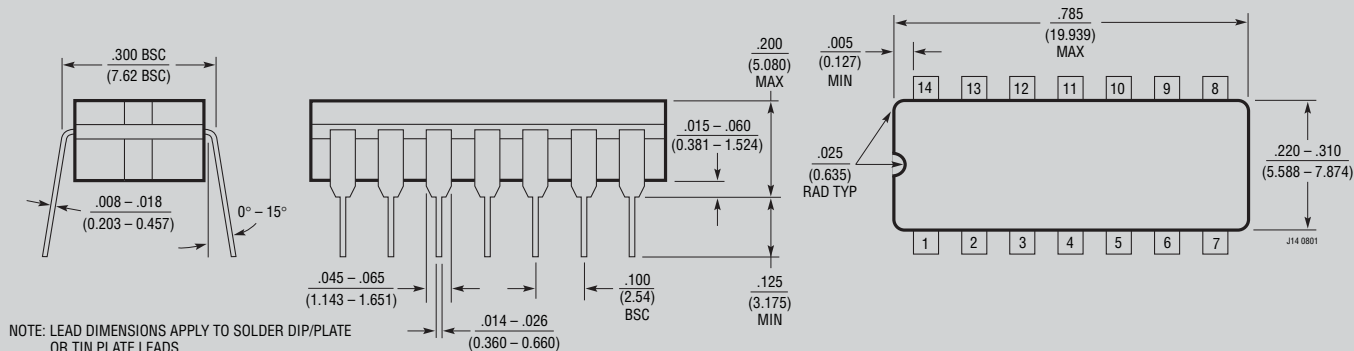
H Package 8-Lead TO-5 Metal Can (.200 Inch PCD) (Reference LTC DWG # 05-08-1320)



J8 Package 8-Lead Cerdip (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



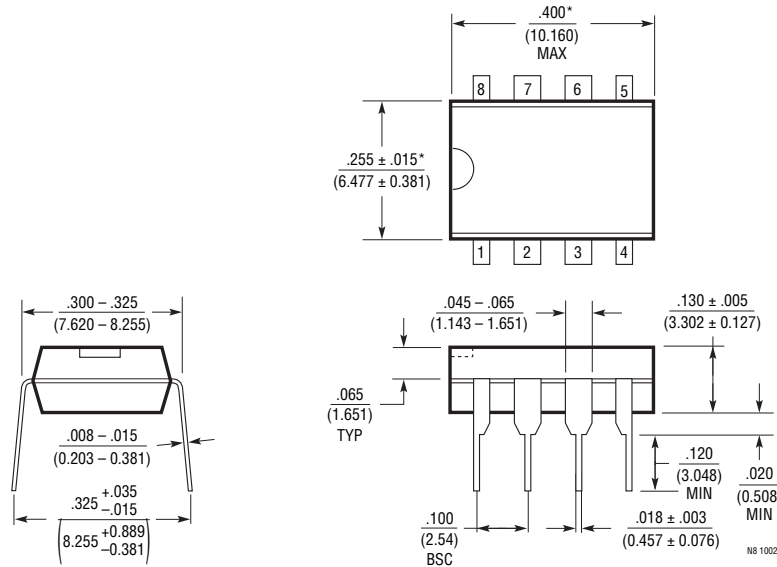
J Package 14-Lead Cerdip (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



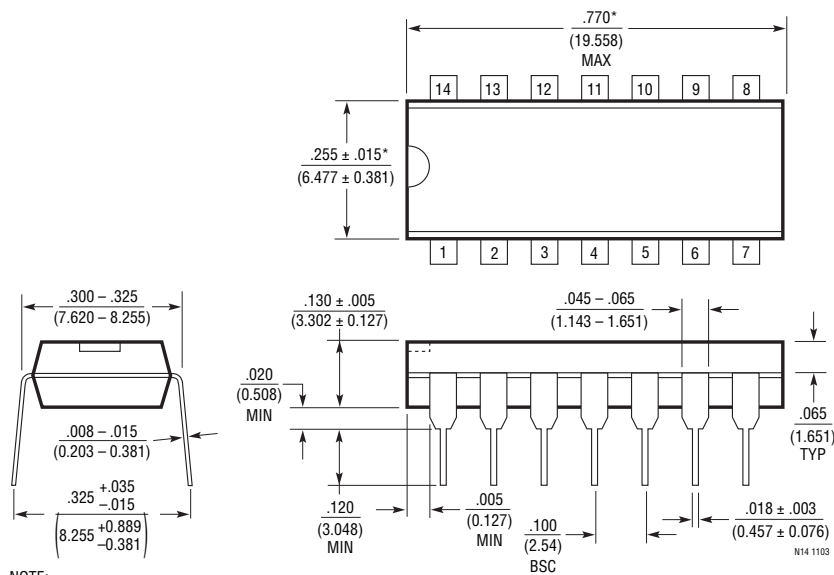
OBSOLETE PACKAGES

PACKAGE DESCRIPTION

N8 Package 8-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)

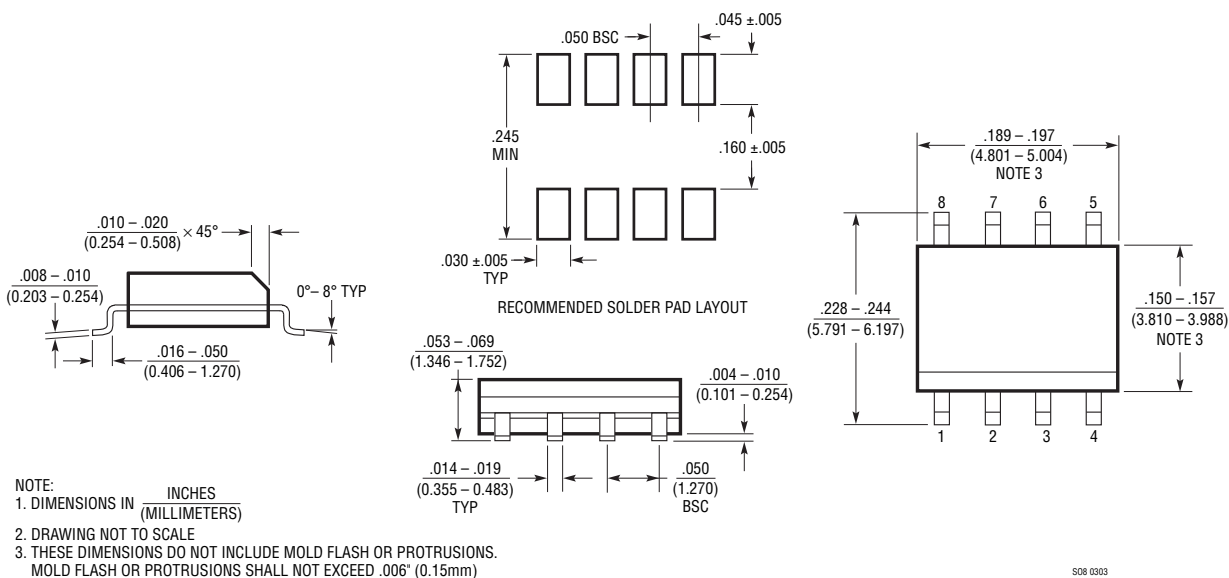


N Package 14-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)

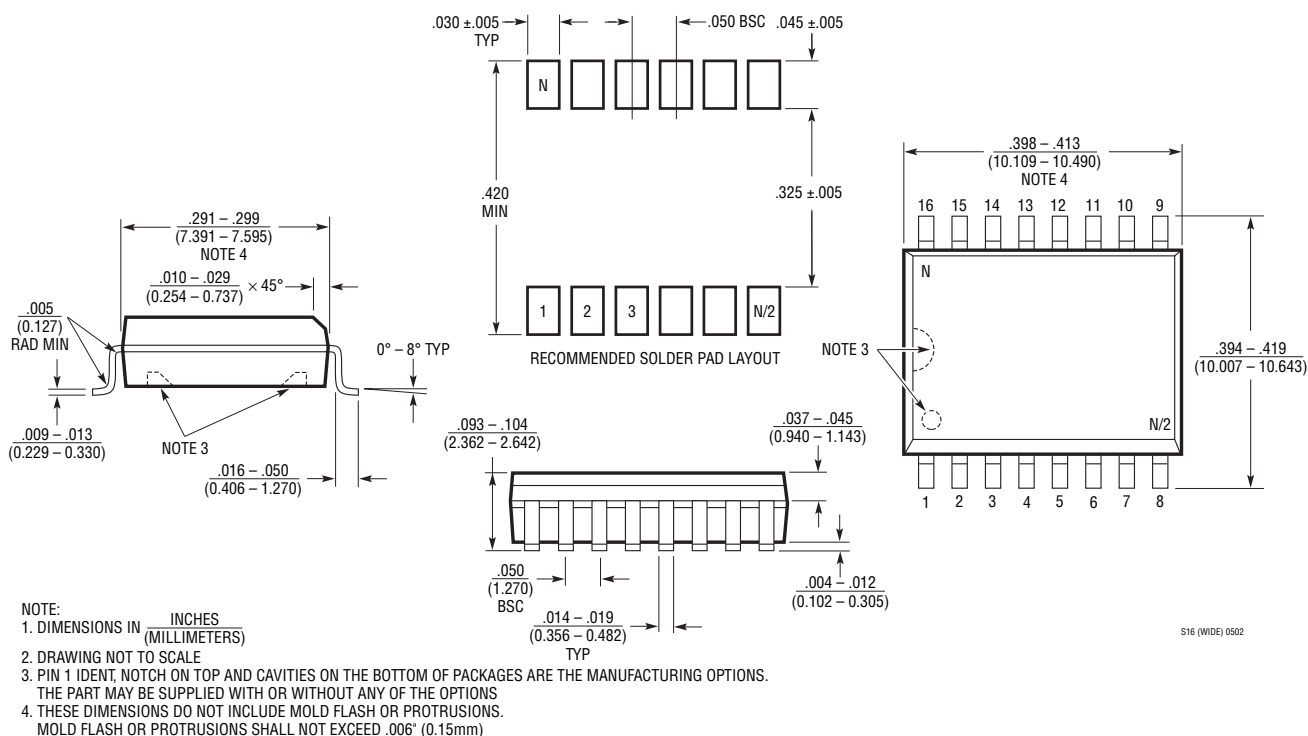


PACKAGE DESCRIPTION

S6 Package 6-Lead Plastic TSOT-23 (Reference LTC DWG # 05-08-1636)



SW Package XX-Lead Plastic Small Outline (Wide .300 Inch) (Reference LTC DWG # 05-08-1620)



REVISION HISTORY (Revision history begins at Rev D)

REV	DATE	DESCRIPTION	PAGE NUMBER
D	05/10	Updates to Typical Application "Hot-Wire Anemometer"	12
		Updated Related Parts	26

TYPICAL APPLICATION

The circuit diagram shows a 100 Hz sine wave generator. It consists of two LT1013 operational amplifiers. The first op-amp is configured as a voltage follower with a 1MΩ input resistor and a 220kΩ feedback resistor. Its non-inverting input is connected to a 220pF capacitor, which is in turn connected to a 2N2222 transistor. The transistor's base is connected to a 22kΩ resistor, and its emitter is grounded. The output of the first op-amp is connected to the base of a 2N5262 transistor through a 300Ω resistor. The 2N5262 transistor's emitter is grounded, and its collector is connected to the non-inverting input of the second op-amp. The second op-amp is configured as a voltage follower with a 130kΩ feedback resistor. Its non-inverting input is connected to a 1N5821 diode, which is in turn connected to a 100pF capacitor. The diode's anode is connected to a 2.2μF capacitor, and its cathode is connected to a 5.6kΩ resistor. The output of the second op-amp is connected to a 5.6kΩ resistor, which is in turn connected to a 0.1μF capacitor. The circuit is powered by a 6V input and a 15V output, with a 50mA current limit. Various other components include a 220kΩ resistor, a 220pF capacitor, a 2N2222 transistor, a 2N5262 transistor, a 1N5821 diode, a 100pF capacitor, a 5.6kΩ resistor, and a 0.1μF capacitor.

1013/14 TA23

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT2078/LT2079	Dual/Quad 50µA Single Supply Precision Amplifier	50µA Max I _S , 70µV Max V _{OS}
LT2178/LT2179	Dual/Quad 17µA Single Supply Precision Amplifier	17µA Max I _S , 70µV Max V _{OS}
LTC6081/LTC6082	Dual/Quad 400µA Precision Rail-to-Rail Amplifier	V _S = 2.7V to 6V, 400µA Max I _S , 70µV V _{OS} 0.8µV/°C TCV _{OS}
LTC6078/LTC6079	Dual/Quad 72µA Precision Rail-to-Rail Amplifier	V _S = 2.7V to 6V, 72µA Max I _S , 25µV V _{OS} 0.7µV/°C TCV _{OS}