

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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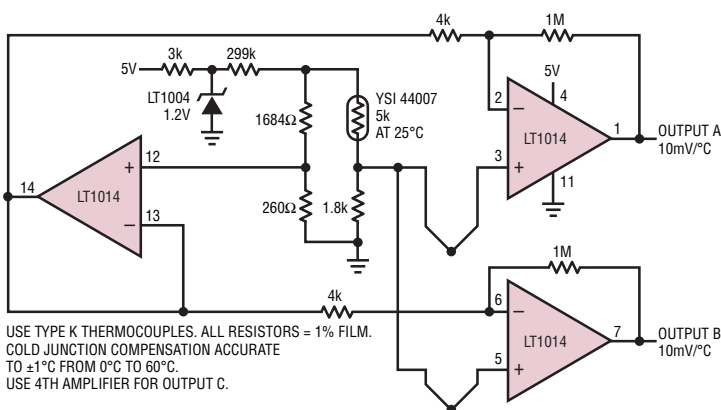
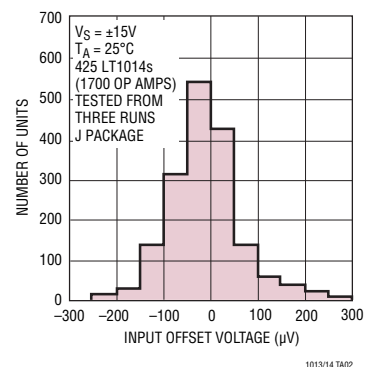
DESCRIPTION

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


1013/14 10A2

10134fd

LT1013/LT1014

ABSOLUTE MAXIMUM RATINGS (Note 1)

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

Lead Temperature (Soldering, 10 sec.) $300^{\circ}C$
 Operating Temperature Range

LT1013AM/LT1013M/
 LT1014AM/LT1014M $-55^{\circ}C$ to $125^{\circ}C$
 LT1013AC/LT1013C/LT1013D
 LT1014AC/LT1014C/LT1014D $0^{\circ}C$ to $70^{\circ}C$
 LT1013I/ LT1014I $-40^{\circ}C$ to $85^{\circ}C$

PIN CONFIGURATION

<p>LT1013</p> <p>TOP VIEW</p> <p>+INA 1 8 -INA V⁻ 2 7 OUTA +INB 3 6 V⁺ -INB 4 5 OUTB</p> <p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p>NOTE: THIS PIN CONFIGURATION DIFFERS FROM THE STANDARD 8-PIN DUAL-IN-LINE CONFIGURATION</p> <p>$T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 190^{\circ}C/W$</p>	<p>LT1013</p> <p>TOP VIEW</p> <p>OUTPUT A 1 8 V⁺ -IN A 2 7 OUTPUT B +IN A 3 6 -IN B V⁻ 4 5 +IN B</p> <p>N8 PACKAGE 8-LEAD PDIP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 130^{\circ}C$</p> <p>J8 PACKAGE 8-LEAD CERDIP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 100^{\circ}C$</p> <p>OBSOLETE PACKAGE</p> <p>Consider the N or S8 Packages for Alternate Source</p>	<p>LT1013</p> <p>TOP VIEW</p> <p>V⁺ 8 OUTPUT A 1 7 OUTPUT B -IN A 2 6 -IN B +IN A 3 5 +IN B V⁻ (CASE) 4</p> <p>H PACKAGE 8-LEAD TO-5 METAL CAN</p> <p>$T_{JMAX} = 125^{\circ}C$, $\theta_{JA} = 55^{\circ}C/W$</p> <p>OBSOLETE PACKAGE</p> <p>Consider the N or S8 (Not N8) Packages for Alternate Source</p>
<p>LT1014</p> <p>TOP VIEW</p> <p>OUTPUT A 1 16 OUTPUT D -IN A 2 15 -IN D +IN A 3 14 +IN D V⁺ 4 13 V⁻ +IN B 5 12 +IN C -IN B 6 11 -IN C OUTPUT B 7 10 OUTPUT C NC 8 9 NC</p> <p>SW PACKAGE 16-LEAD PLASTIC SO</p> <p>$T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 130^{\circ}C/W$</p>	<p>LT1014</p> <p>TOP VIEW</p> <p>OUTPUT A 1 14 OUTPUT D -IN A 2 13 -IN D +IN A 3 12 +IN D V⁺ 4 11 V⁻ +IN B 5 10 +IN C -IN B 6 9 -IN C OUTPUT B 7 8 OUTPUT C</p> <p>N PACKAGE 14-LEAD PDIP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 100^{\circ}C$</p> <p>J PACKAGE 14-LEAD CERDIP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 100^{\circ}C$</p> <p>OBSOLETE PACKAGE</p> <p>Consider the N or SW Packages for Alternate Source</p>	

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/tapeandreeel/>

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
	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			$\mu\text{V}_{\text{P-P}}$
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	
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
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	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 $V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$ LT1013D/I, LT1014D/I $V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	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	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	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	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	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	$V_{CM} = 13.0\text{V}, -15.0\text{V}$	●	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	$R_L = 2\text{k}$ $V_S = 5\text{V}, 0\text{V}; R_L = 600\Omega$ 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	$V_S = 5\text{V}, 0\text{V}; V_O = 1.4\text{V}$	●	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	

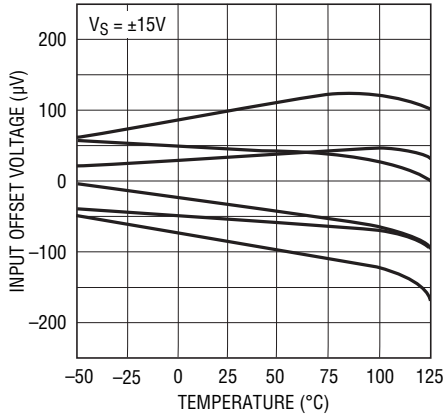
Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Rating condition for extended periods may affect device reliability and lifetime.

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.

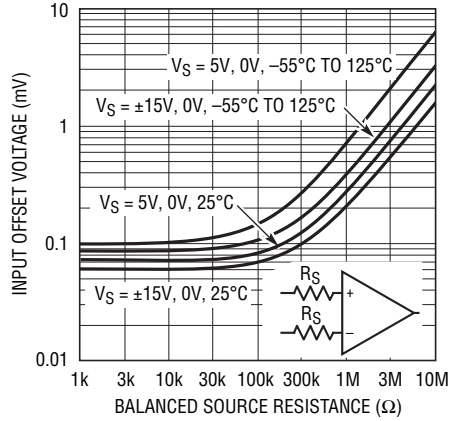
TYPICAL PERFORMANCE CHARACTERISTICS

Offset Voltage Drift with Temperature of Representative Units



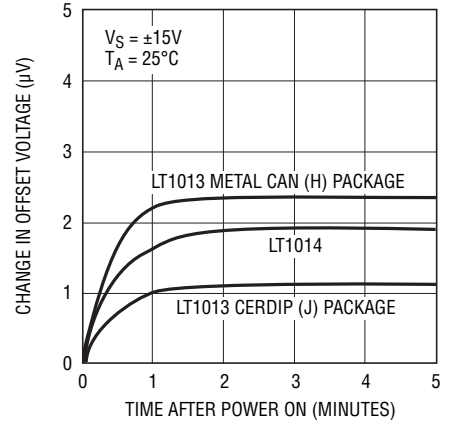
1013/14 TPC01

Offset Voltage vs Balanced Source Resistance



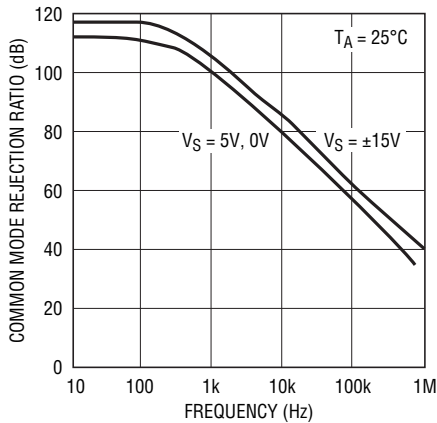
1013/14 TPC02

Warm-Up Drift



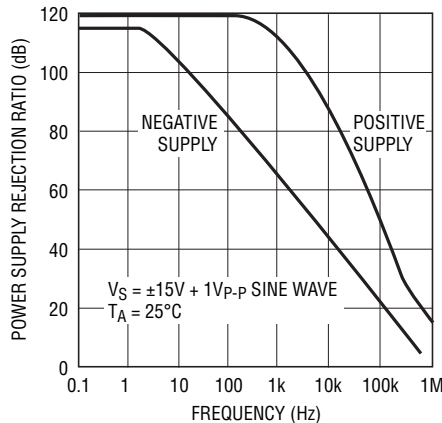
1013/14 TPC03

Common Mode Rejection Ratio vs Frequency



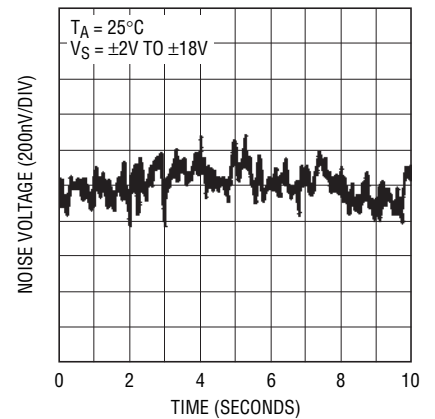
1013/14 TPC04

Power Supply Rejection Ratio vs Frequency



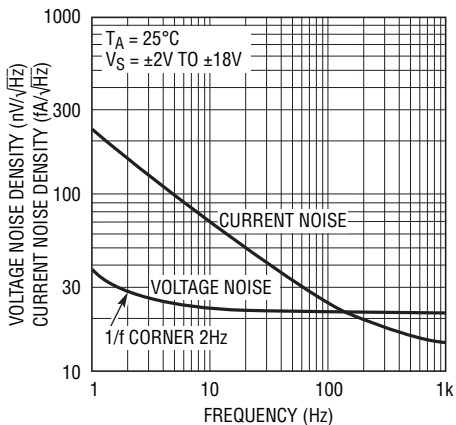
1013/14 TPC05

0.1Hz to 10Hz Noise



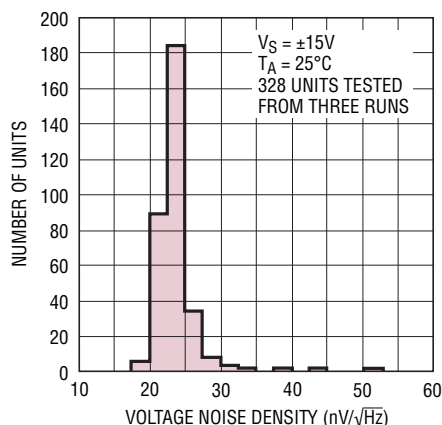
1013/14 TPC06

Noise Spectrum



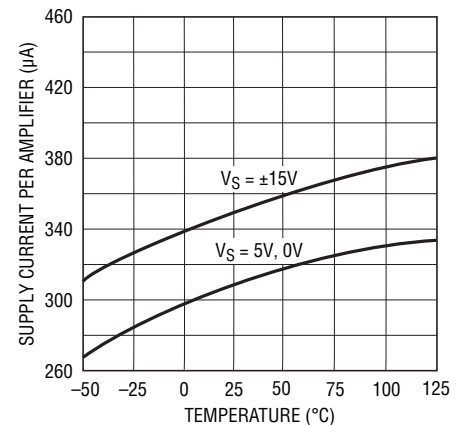
1013/14 TPC07

10Hz Voltage Noise Distribution



1013/14 TPC08

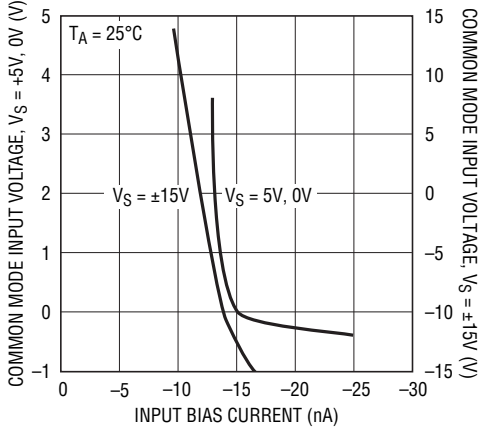
Supply Current vs Temperature



1013/14 TPC09

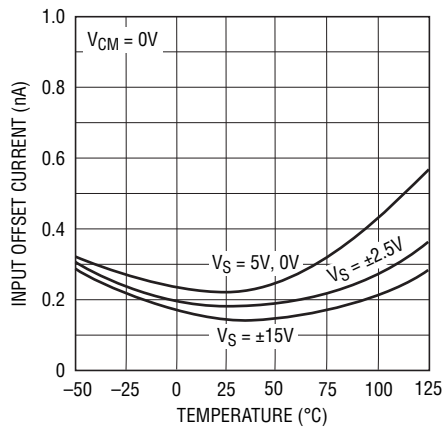
TYPICAL PERFORMANCE CHARACTERISTICS

Input Bias Current vs Common Mode Voltage



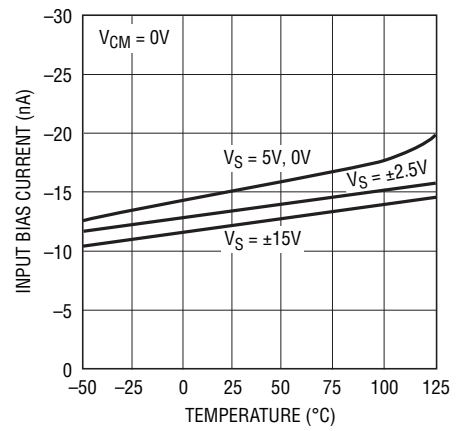
1013/14 TPC10

Input Offset Current vs Temperature



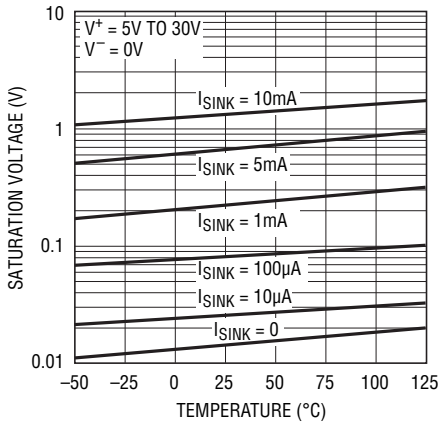
1013/14 TPC11

Input Bias Current vs Temperature



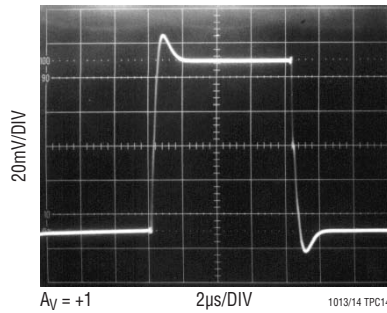
1013/14 TPC12

Output Saturation vs Sink Current vs Temperature

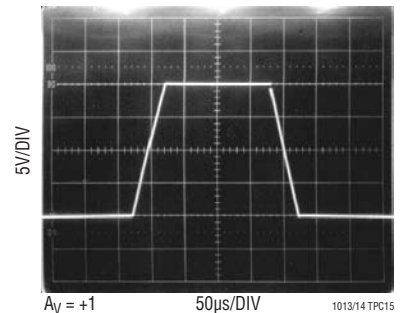


1013/14 TPC13

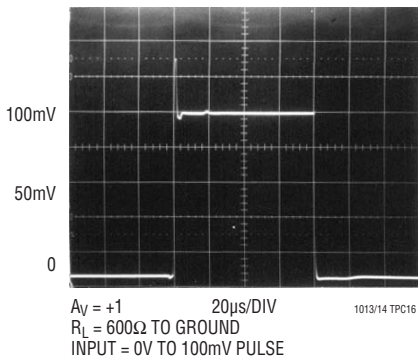
Small-Signal Transient Response, $V_S = \pm 15\text{V}$



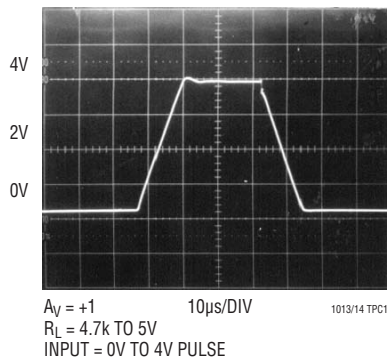
Large-Signal Transient Response, $V_S = \pm 15\text{V}$



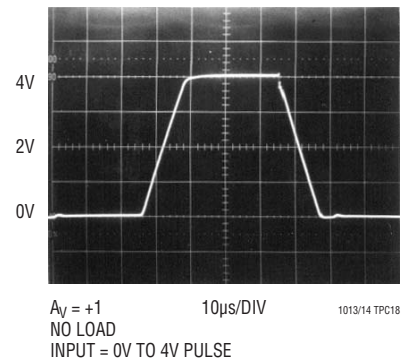
Small-Signal Transient Response, $V_S = 5\text{V}, 0\text{V}$



Large-Signal Transient Response, $V_S = 5\text{V}, 0\text{V}$

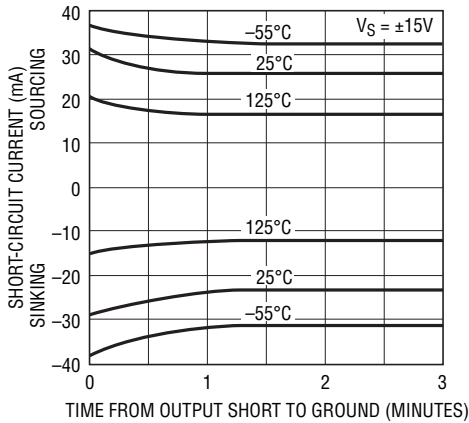


Large-Signal Transient Response, $V_S = 5\text{V}, 0\text{V}$



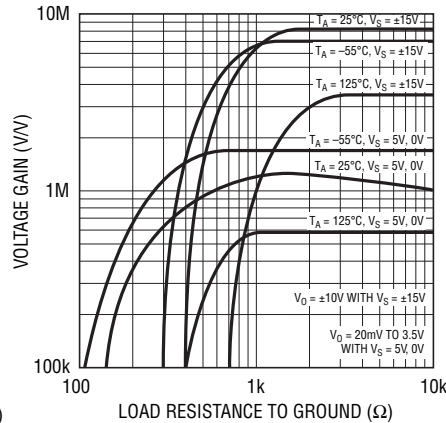
TYPICAL PERFORMANCE CHARACTERISTICS

Output Short-Circuit Current vs Time



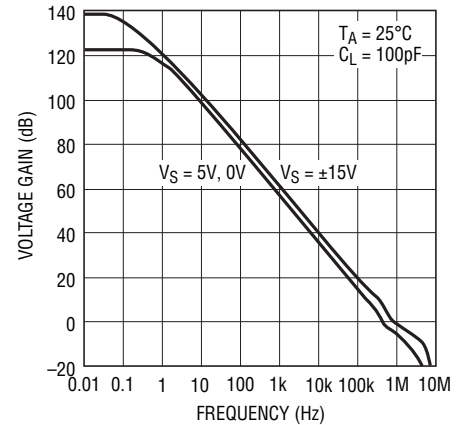
1013/14 TPC19

Voltage Gain vs Load Resistance



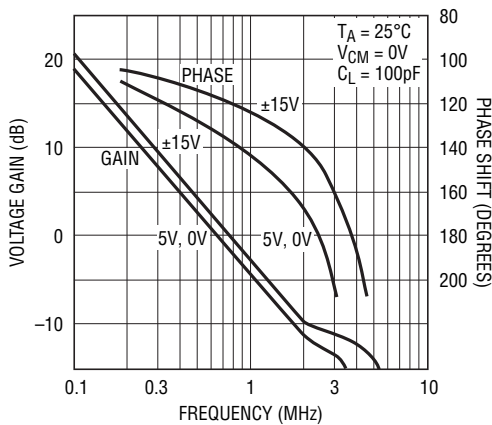
1013/14 TPC20

Voltage Gain vs Frequency



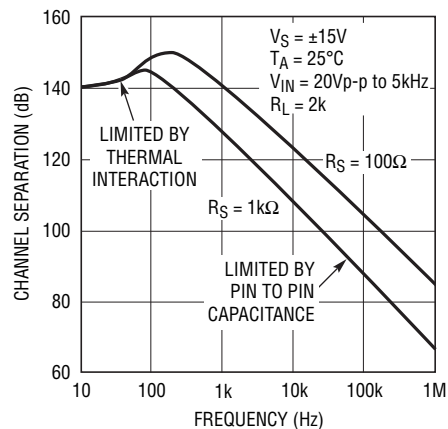
1013/14 TPC21

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 400 Ω 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.

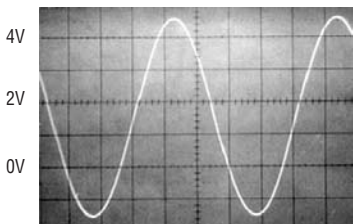
In dual supply operations, the output stage is crossover distortion-free.

Comparator Applications

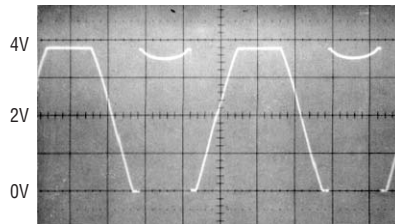
The single supply operation of the LT1013/LT1014 lends itself to its use as a precision comparator with TTL compatible output:

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.

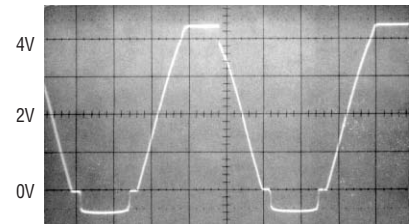
Voltage Follower with Input Exceeding the Negative Common Mode Range



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

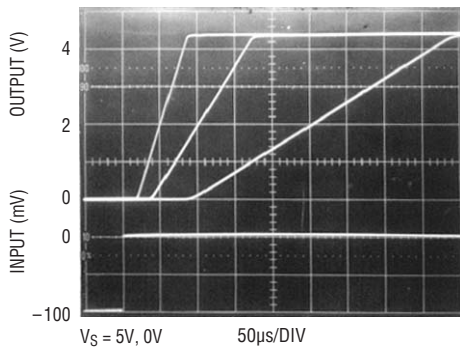


LM324, LM358, OP-20
EXHIBIT OUTPUT PHASE
REVERSAL



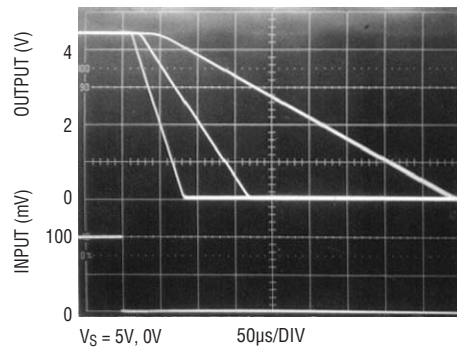
LT1013/LT1014
NO PHASE REVERSAL

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

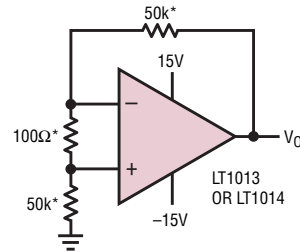
Low Supply Operation

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 290µA, 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

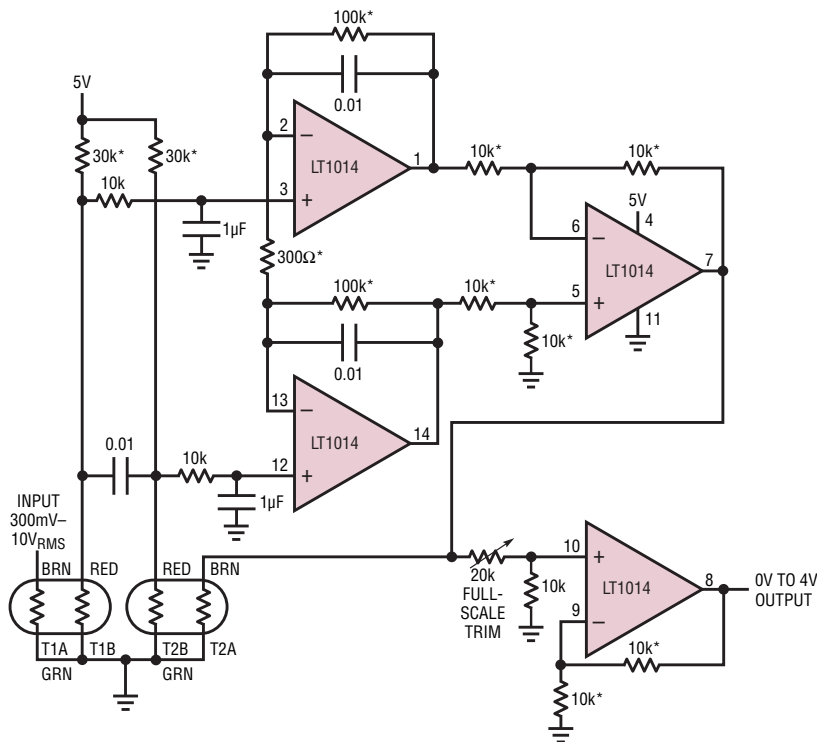


* RESISTOR MUST HAVE LOW THERMOELECTRIC POTENTIAL.
 ** THIS CIRCUIT IS ALSO USED AS THE BURN-IN CONFIGURATION, WITH SUPPLY VOLTAGES INCREASED TO ±20V.
 $V_O = 1000V_{OS}$

LT1013/14 F06

TYPICAL APPLICATIONS

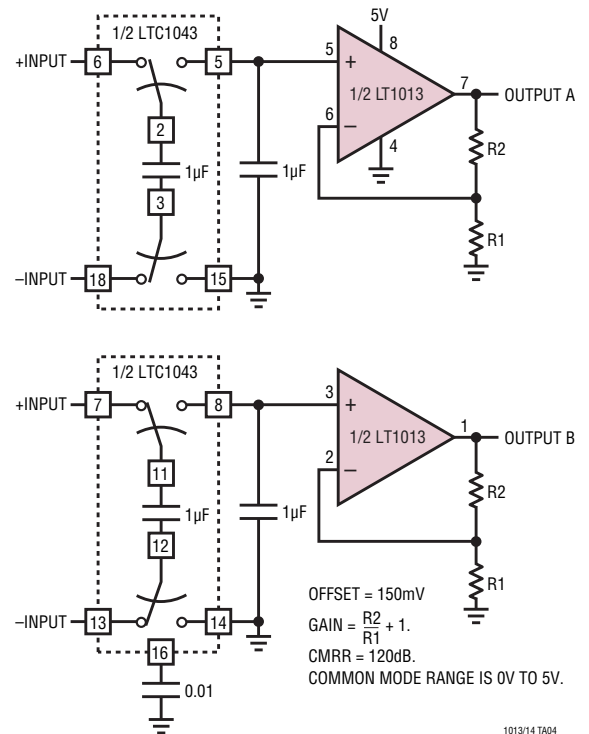
50MHz Thermal RMS-to-DC Converter



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

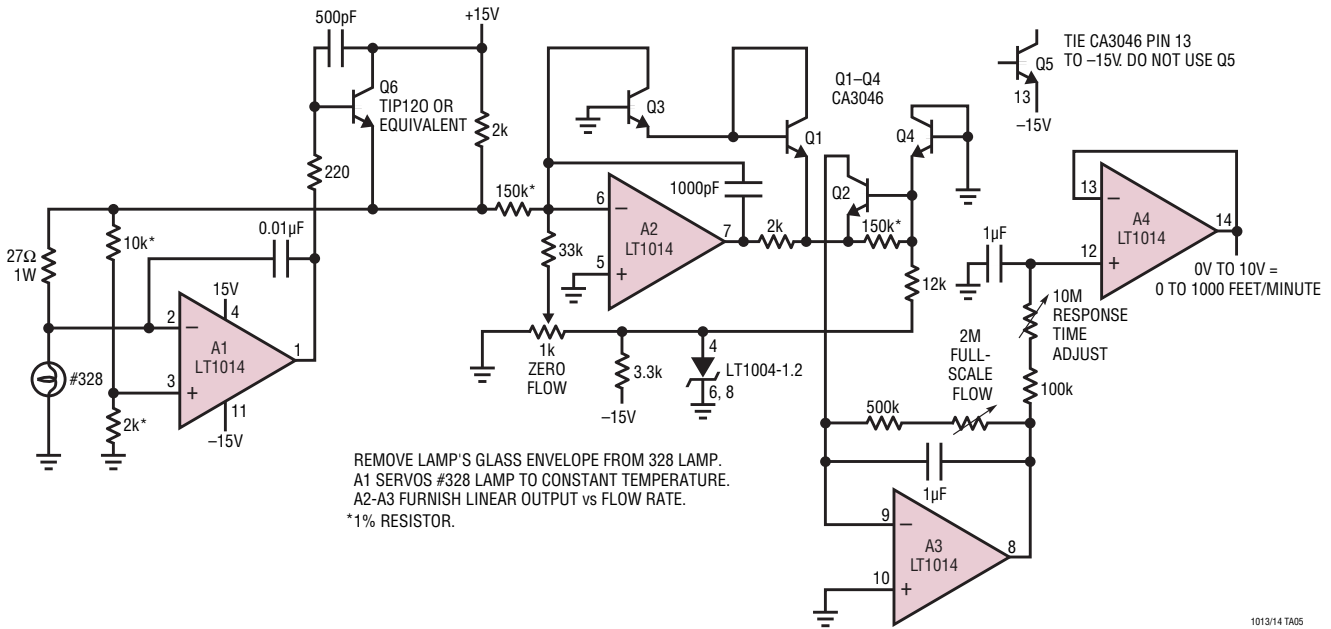


OFFSET = 150mV
 $GAIN = \frac{R_2}{R_1} + 1$
 CMRR = 120dB.
 COMMON MODE RANGE IS 0V TO 5V.

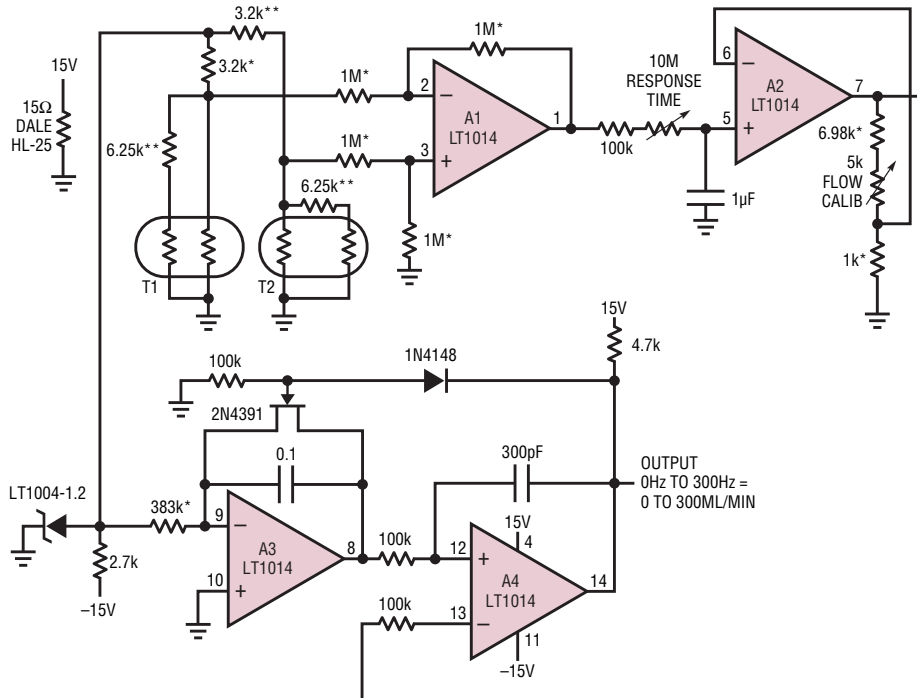
1013/14 TA04

TYPICAL APPLICATIONS

Hot-Wire Anemometer



Liquid Flowmeter



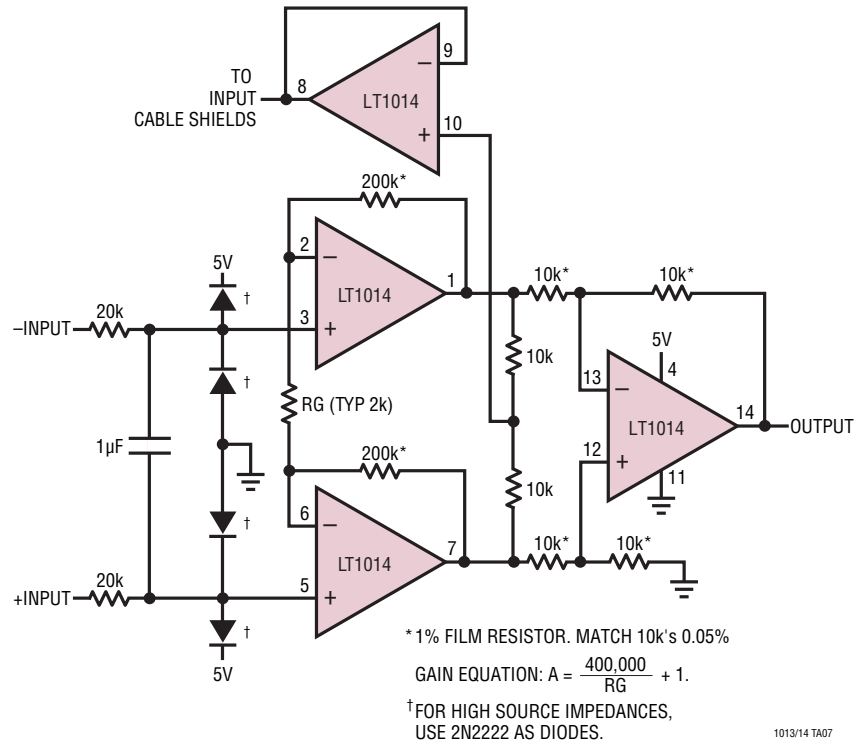
* 1% FILM RESISTOR.
 ** SUPPLIED WITH YSI THERMISTOR NETWORK.
 T1, T2 YSI THERMISTOR NETWORK = #44201.
 FLOW IN PIPE IS INVERSELY PROPORTIONAL TO RESISTANCE OF T1-T2 TEMPERATURE DIFFERENCE.
 A1-A2 PROVIDE GAIN. A3-A4 PROVIDE LINEARIZED FREQUENCY OUTPUT.

1013/14 TA06

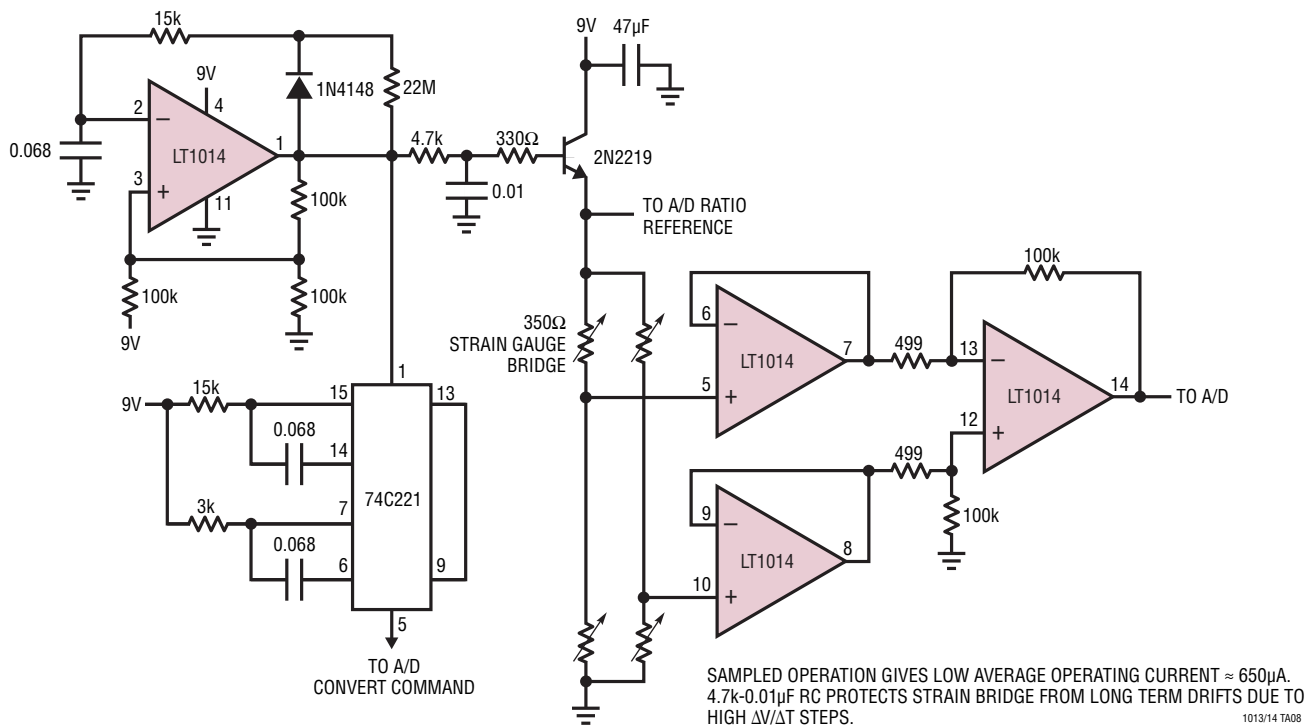
10134fd

TYPICAL APPLICATIONS

5V Powered Precision Instrumentation Amplifier

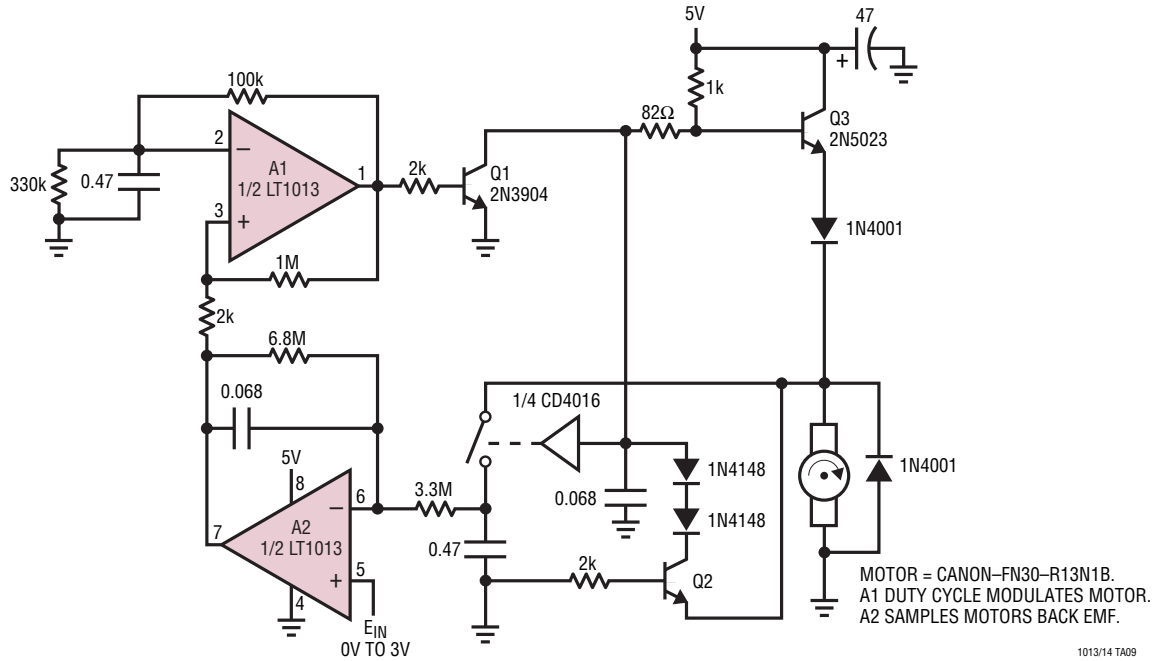


9V Battery Powered Strain Gauge Signal Conditioner

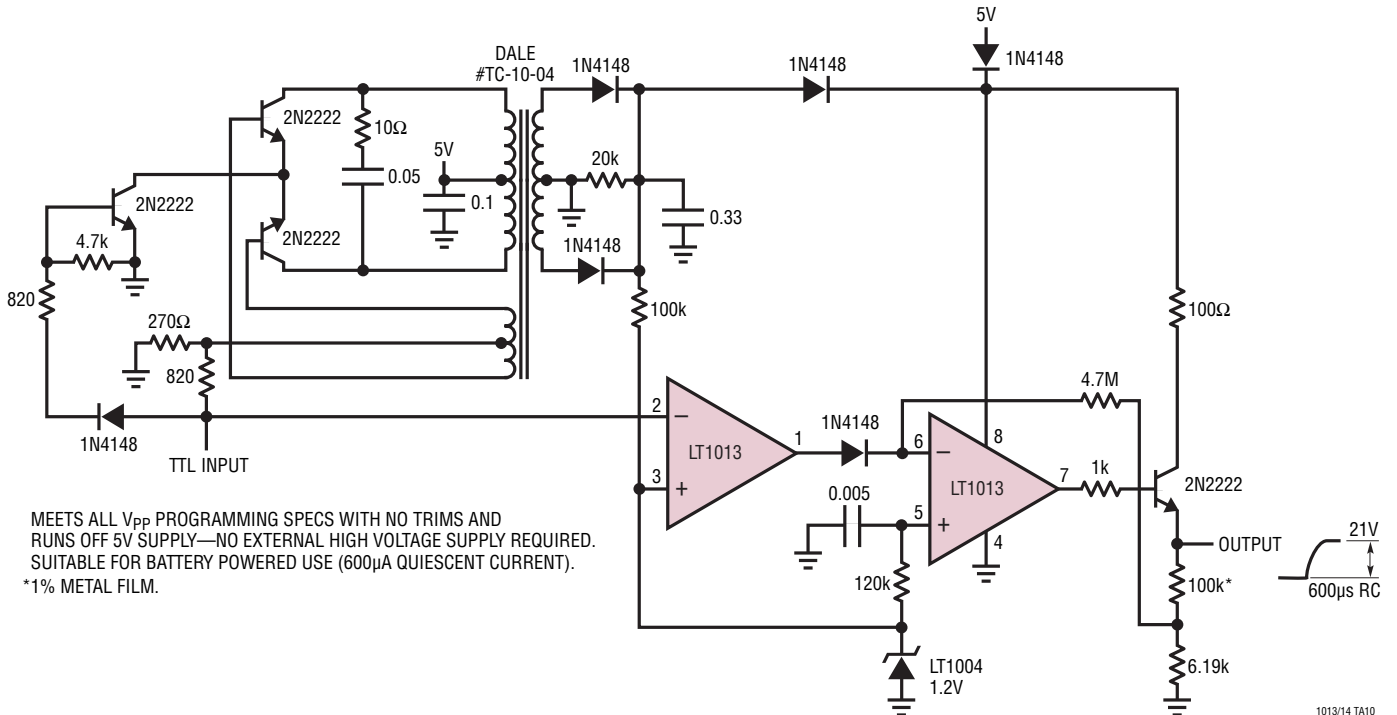


TYPICAL APPLICATIONS

5V Powered Motor Speed Controller No Tachometer Required

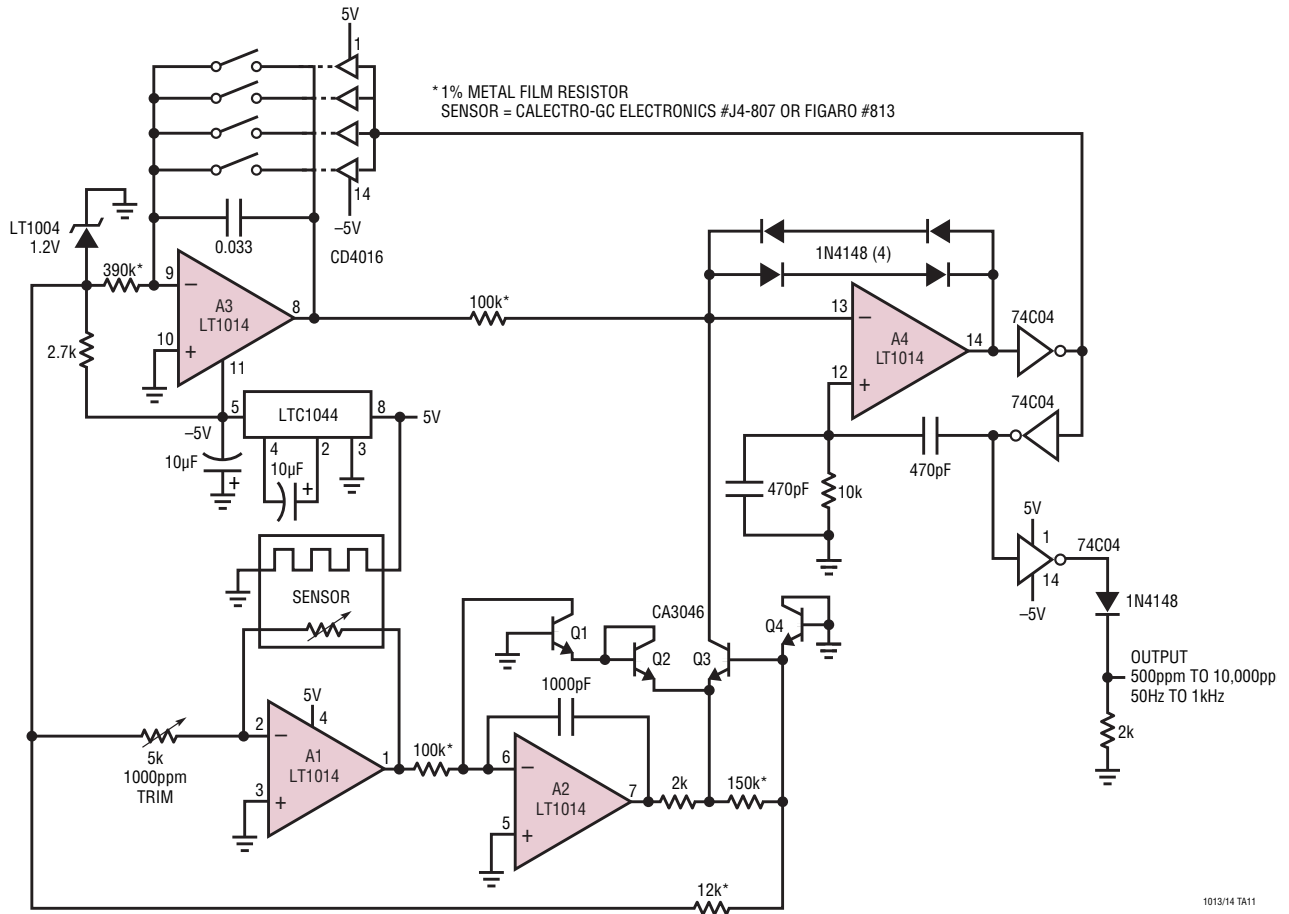


5V Powered EEPROM Pulse Generator



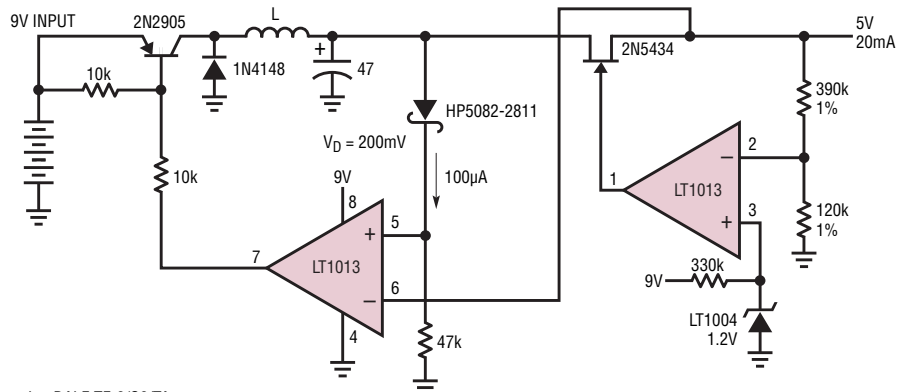
TYPICAL APPLICATIONS

Methane Concentration Detector with Linearized Output



1013/14 TA11

Low Power 9V to 5V Converter

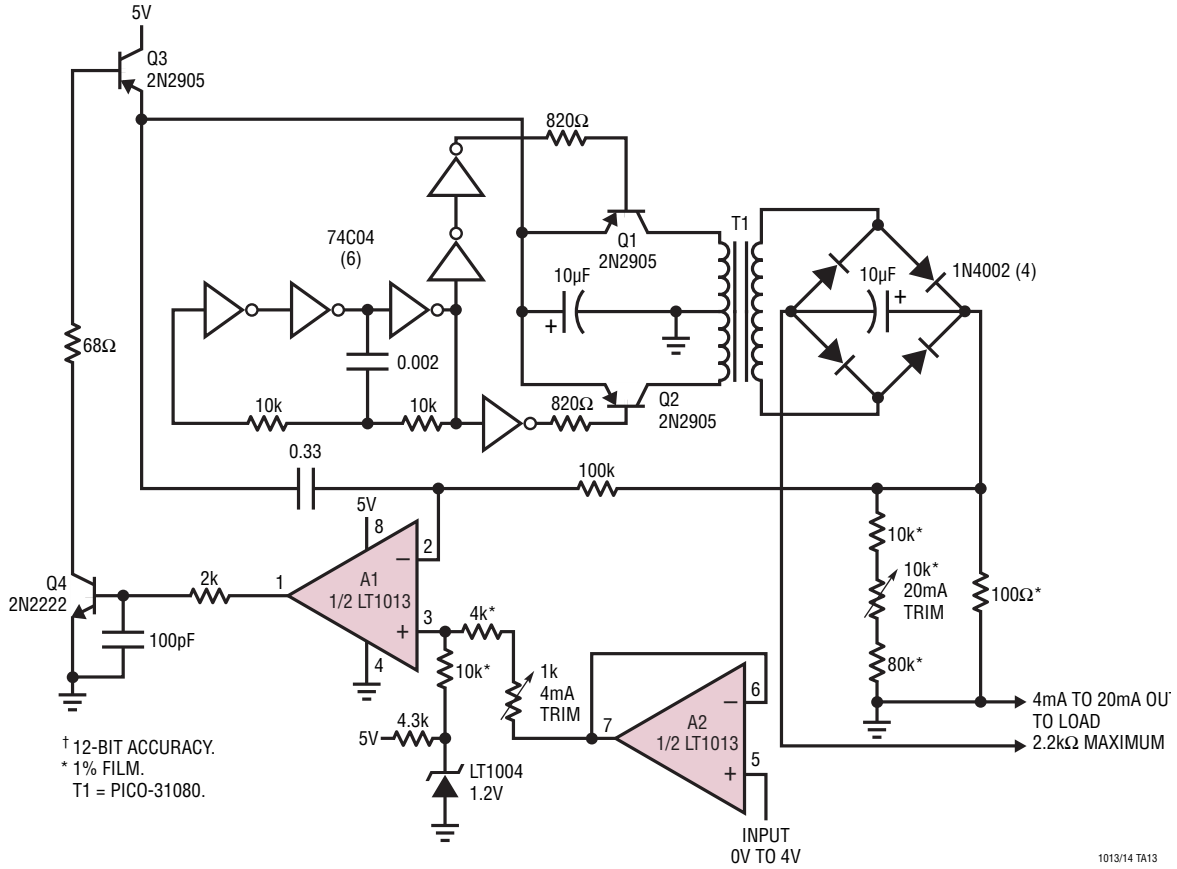


L = DALE TE-3/Q3/TA.
SHORT CIRCUIT CURRENT = 30mA.
≈ 75% EFFICIENCY.
SWITCHING PREREGULATOR CONTROLS DROP ACROSS FET TO 200mV.

1013/14 TA12

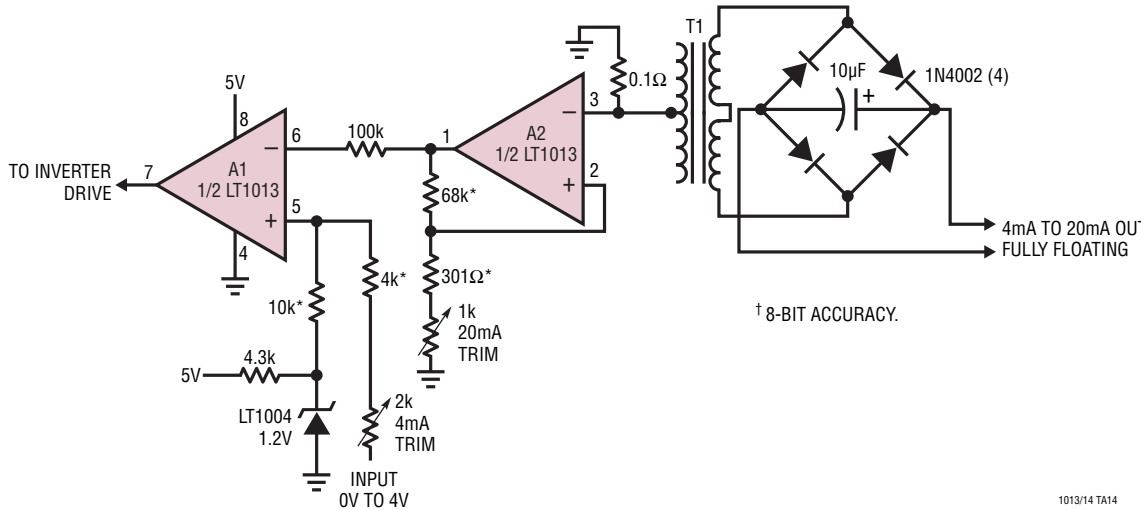
TYPICAL APPLICATIONS

5V Powered 4mA to 20mA Current Loop Transmitter†



1013/14 TA13

Fully Floating Modification to 4mA-20mA Current Loop†

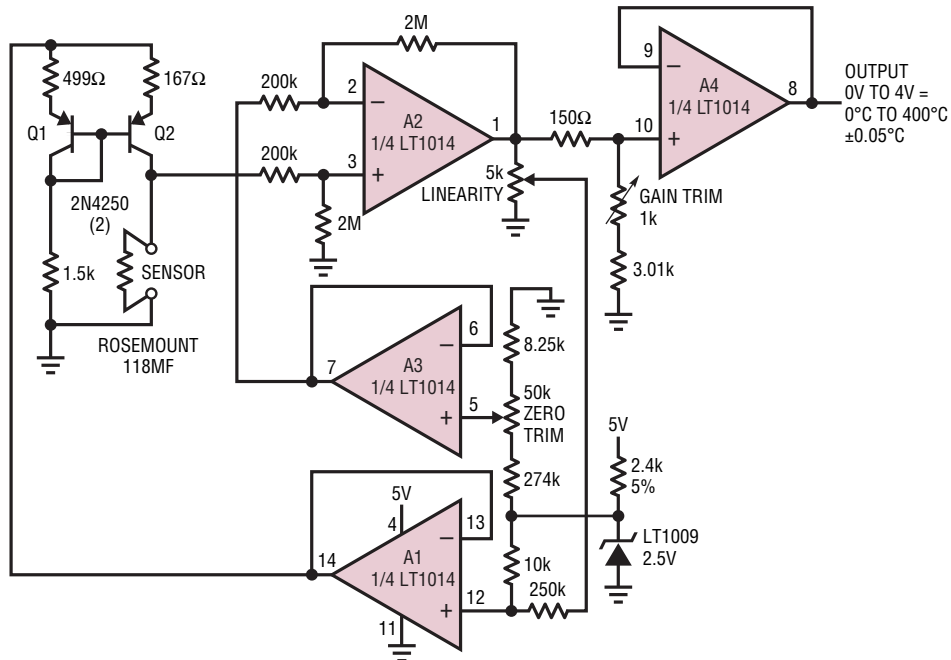


1013/14 TA14

10134fd

TYPICAL APPLICATIONS

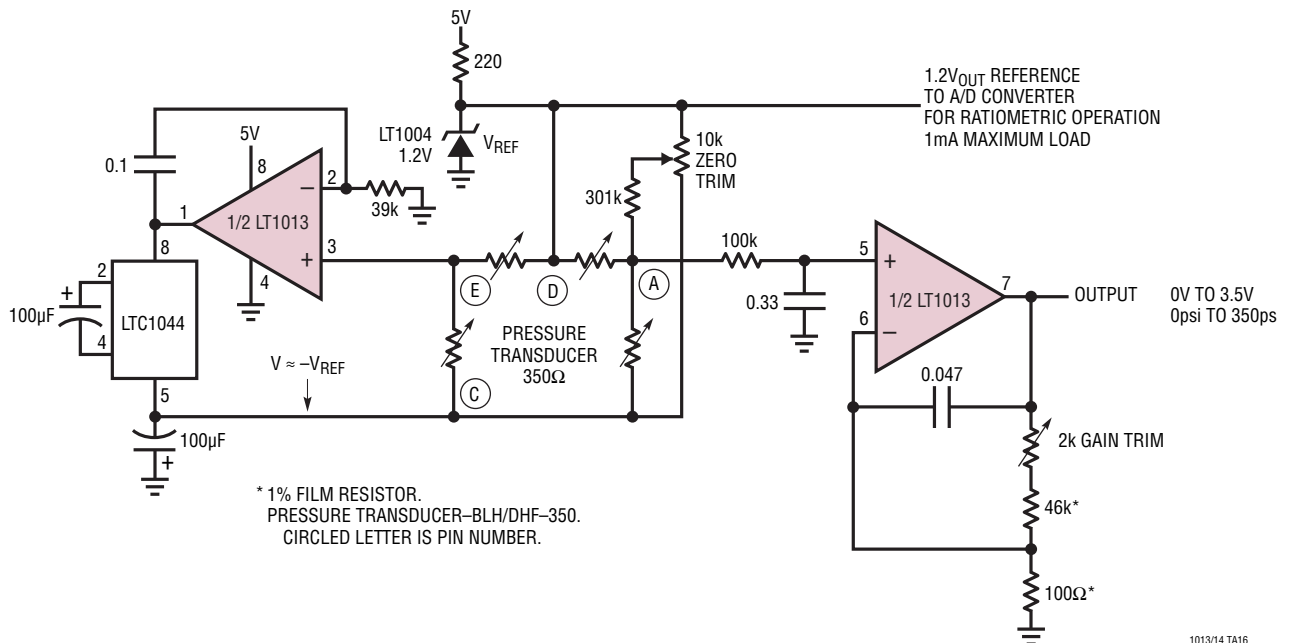
5V Powered, Linearized Platinum RTD Signal Conditioner



ALL RESISTORS ARE TRW-MAR-6 METAL FILM.
 RATIO MATCH 2M-200K ± 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

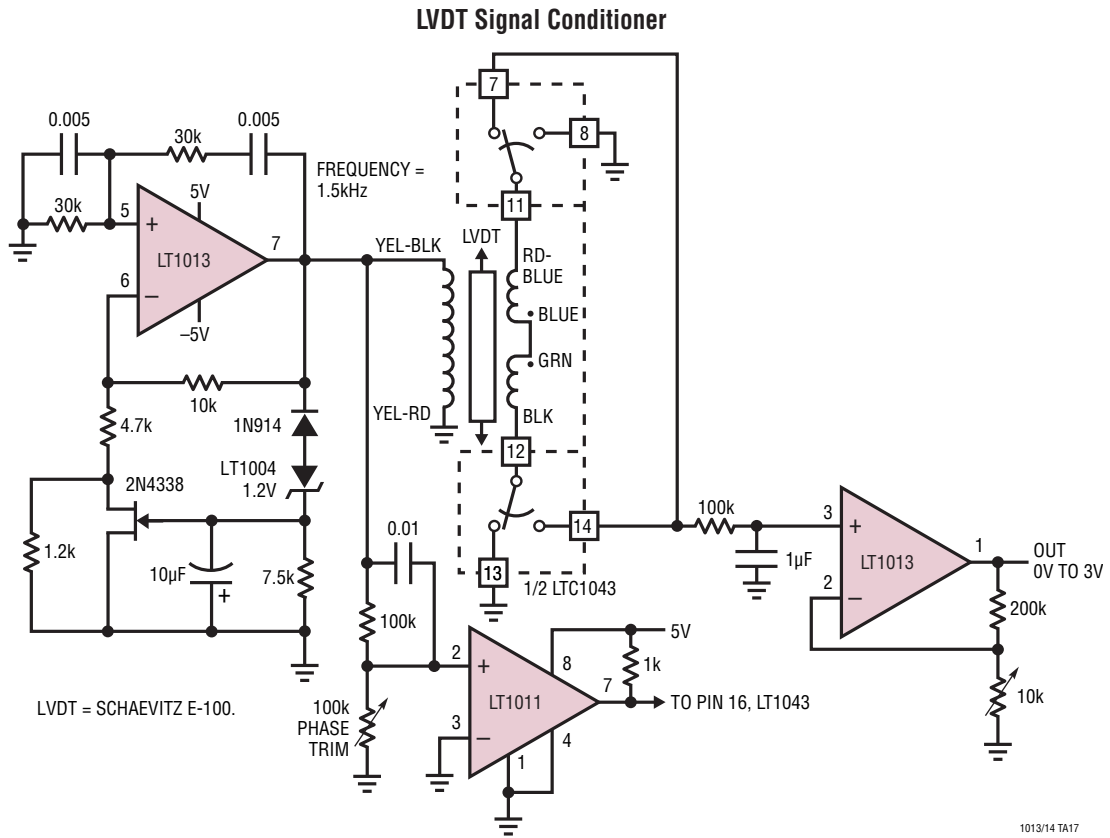


* 1% FILM RESISTOR.
 PRESSURE TRANSDUCER-BLH/DHF-350.
 CIRCLED LETTER IS PIN NUMBER.

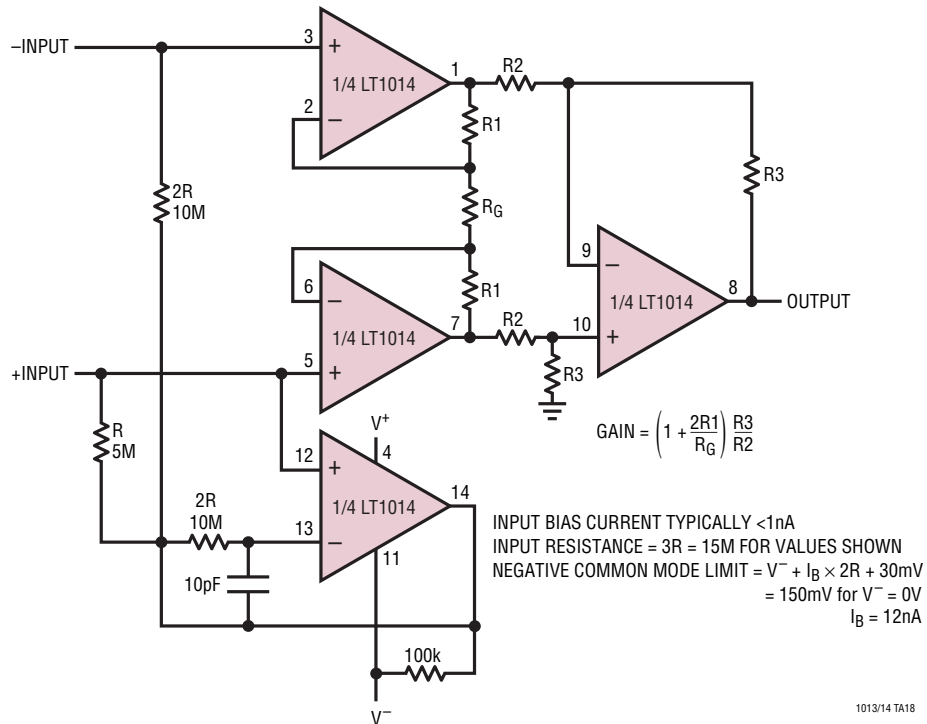
1013/14 TA16

10134fd

TYPICAL APPLICATIONS

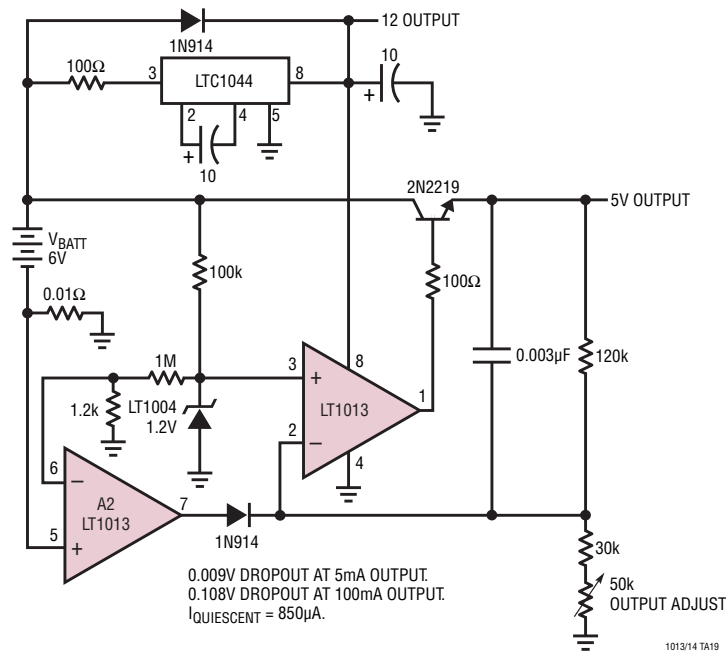


Triple Op Amp Instrumentation Amplifier with Bias Current Cancellation

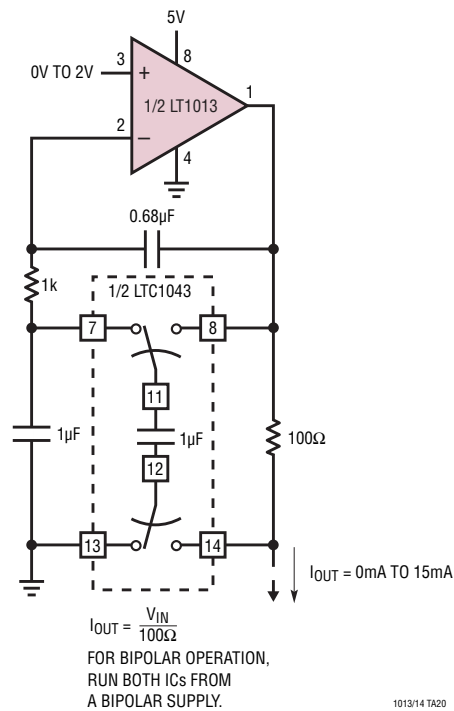


TYPICAL APPLICATIONS

Low Dropout Regulator for 6V Battery

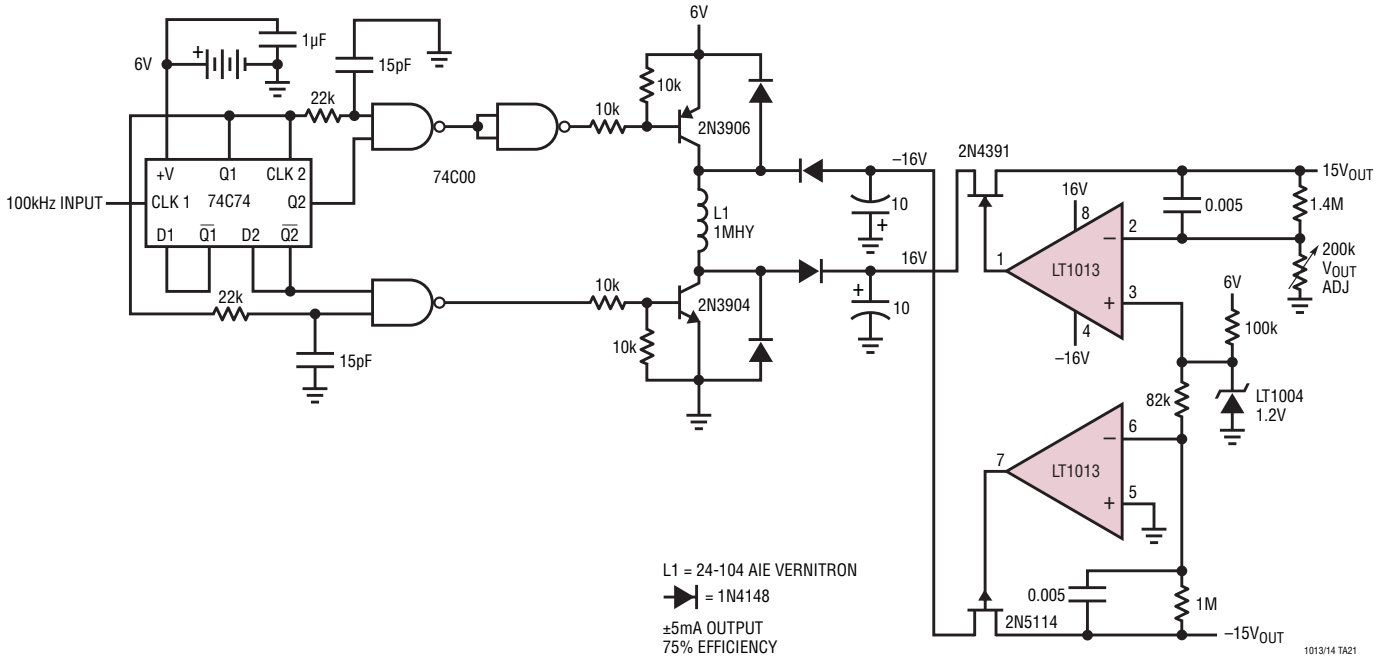


Voltage Controlled Current Source with Ground Referred Input and Output

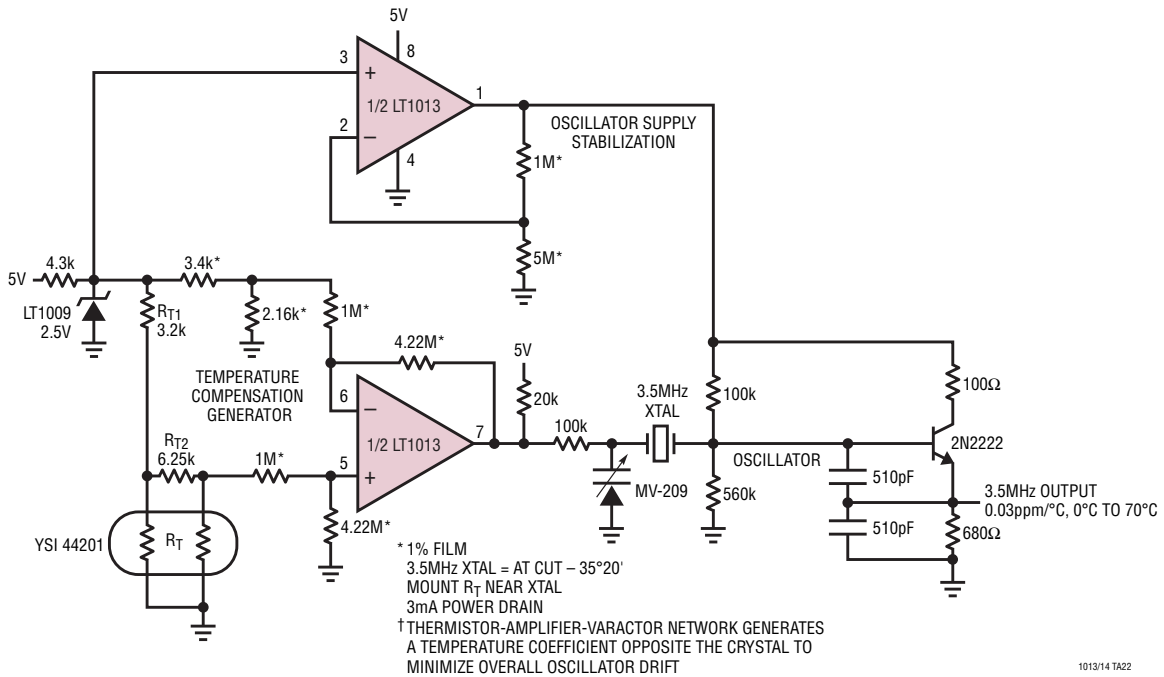


TYPICAL APPLICATIONS

6V to ±15V Regulating Converter

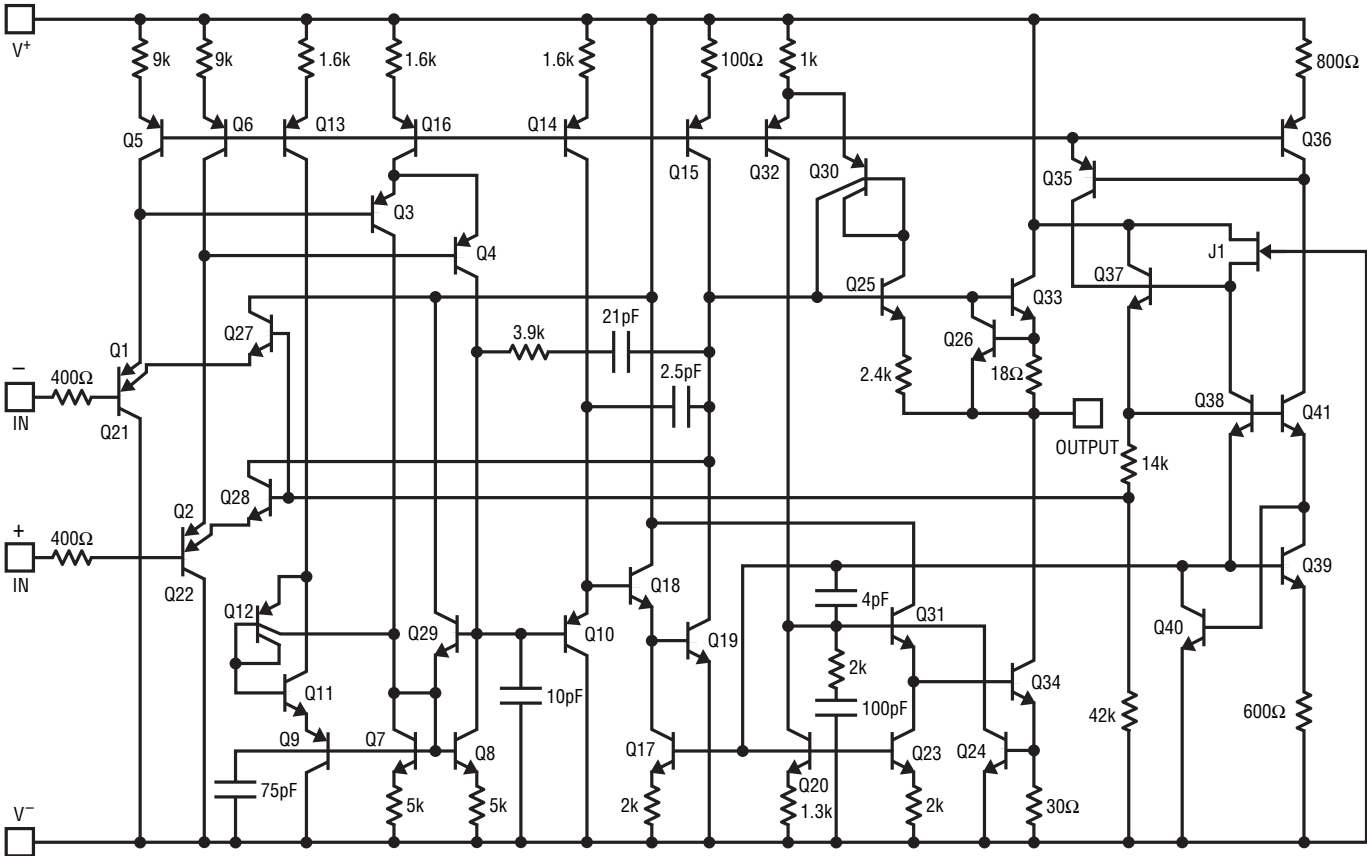


Low Power, 5V Driven, Temperature Compensated Crystal Oscillator (TXCO)[†]



SCHEMATIC DIAGRAM

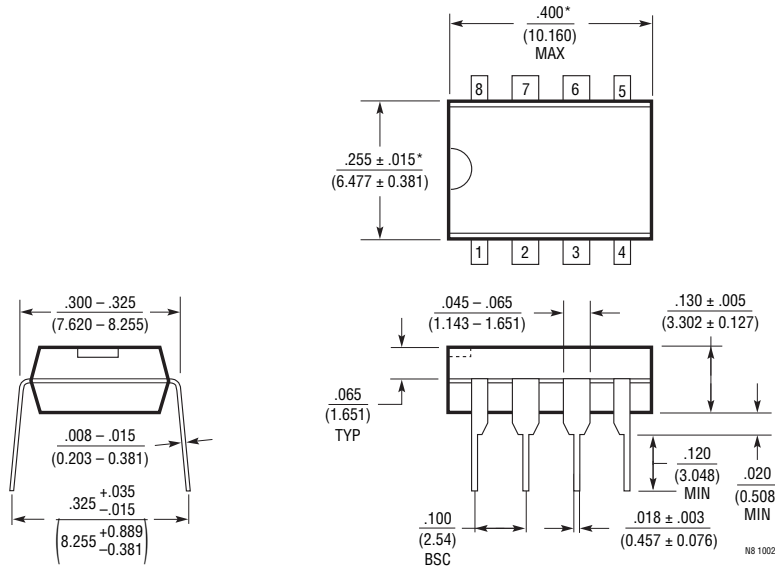
1/2 LT1013, 1/4 LT1014



1013/14 SD

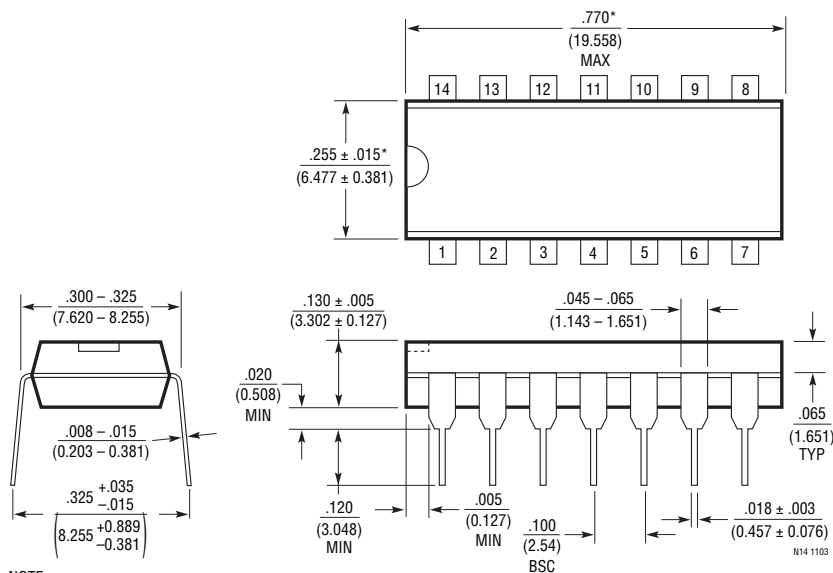
PACKAGE DESCRIPTION

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



NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

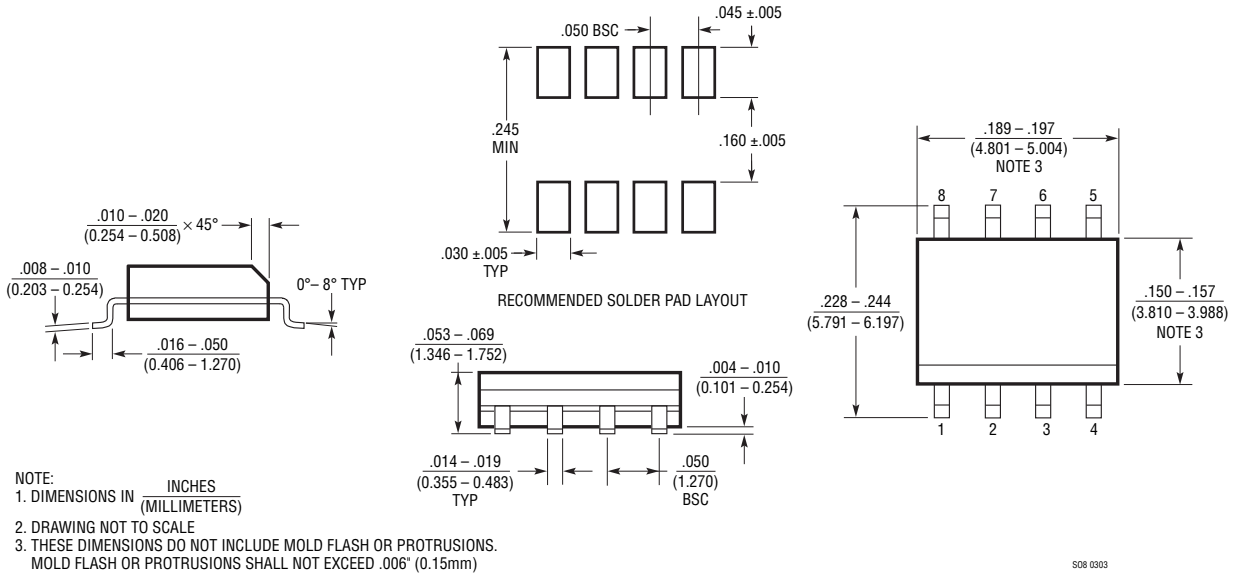
N Package 14-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)



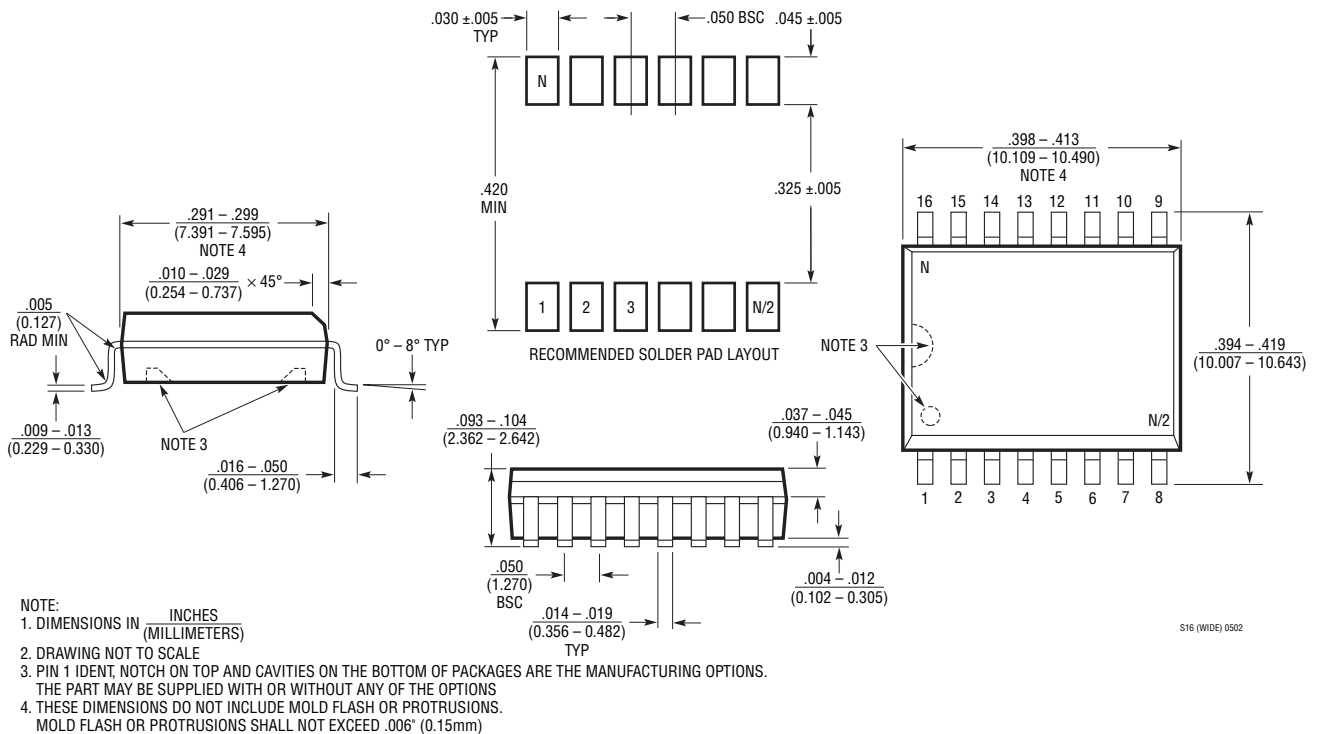
NOTE:
1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

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)



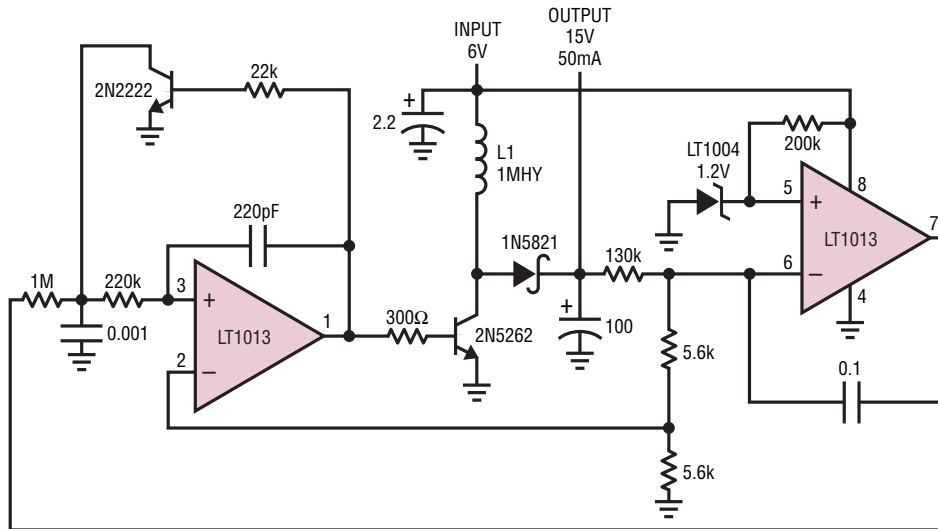
REVISION HISTORY (Revision history begins at Rev D)

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

LT1013/LT1014

TYPICAL APPLICATION

Step-Up Switching Regulator for 6V Battery



LT = AIE-VERNITRON 24-104
78% EFFICIENCY

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}

10134fd

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