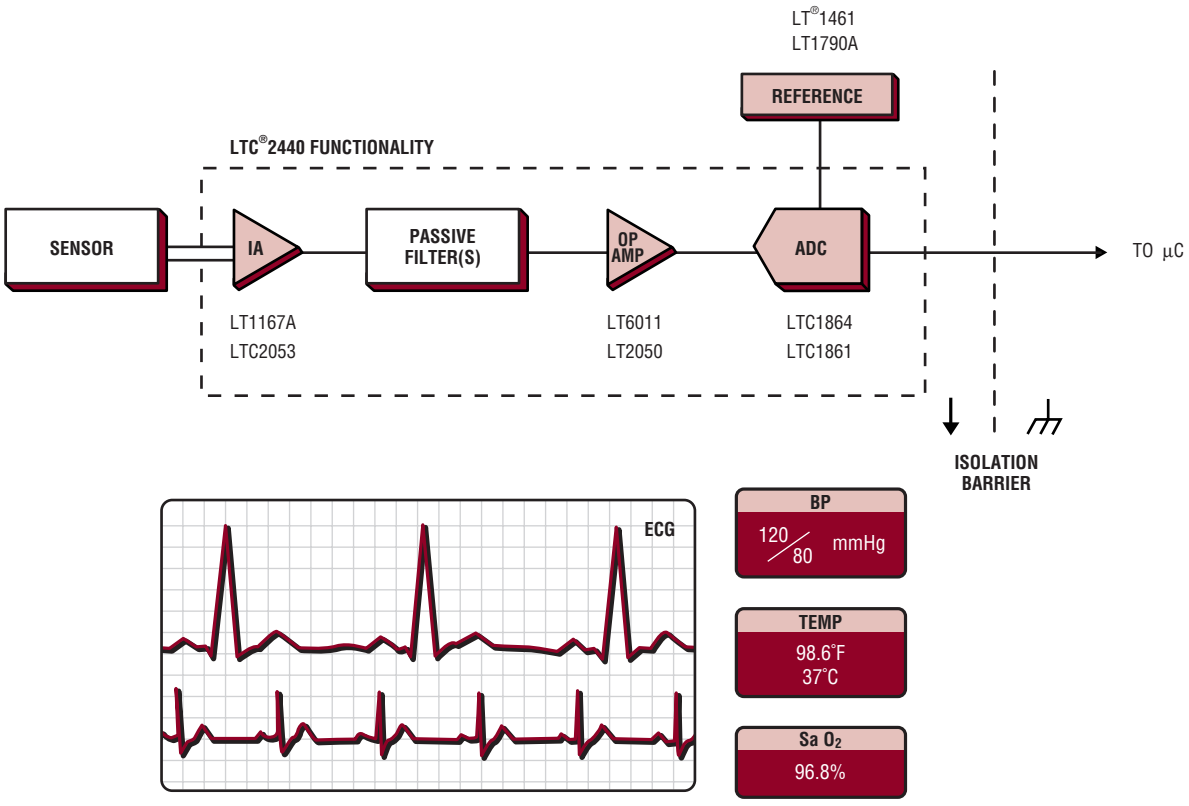
Linear Technology Chronicle

High Performance Analog Solutions from Linear Technology Vol. 12 No. 5

Focus...

Medical Diagnostics



Inside This Issue:

Advances in medicine and medical treatment bring the promise of more accurate diagnoses, new treatment methods and more patient-friendly medical care. From high resolution imaging systems to drug delivery systems and implantable electronics, analog and digital ICs are playing an expanding role in the medical field. These instruments increasingly require high performance, small size and low power—areas where Linear Technology excels.

In addition, rising medical costs are driving the need for portable equipment capable of monitoring the patient beyond the confines of a hospital. Medical data stored in the device is downloaded to a PC or transmitted electronically back to the hospital. Portable solutions demand very accurate low power front-end ICs.

The following pages provide a sample of Linear Technology's ICs that are well-suited for various medical monitoring applications such as electro-encephalograph (EEG) and electro-cardiograph (ECG) machines, pulse oximetry measurements, infusion/insulin pumps, dialysis machines, vital signs monitors and medical imaging.

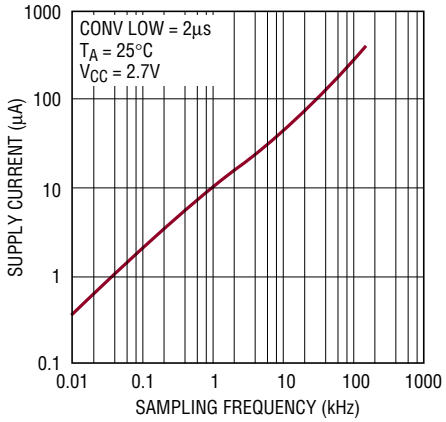
SAR ADCs for Medical Applications

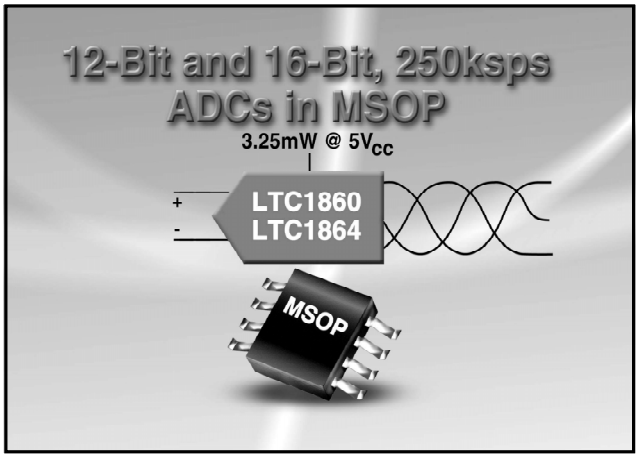
Medical monitoring such as ECG/EEG and pulse oximetry requires precision analog-to-digital conversion with sample rates up to 100ksps. Depending on the system architecture, 12-bit to 16-bit SAR type ADCs are good choices. System requirements for portability in these monitors are driving the need for low power solutions and small footprint devices. Linear Technology has developed a family of devices targeted at handling these requirements.

The LTC1864 16-bit, 250ksps ADC and its family of devices offer an excellent combination of speed, resolution and power in a small footprint. The device automatically powers down between conversions, effectively reducing the power dissipation as the sampling frequency decreases. This family allows the designer a pin-for-pin upgrade path from a 12-bit design directly to a 16-bit solution and the choice of single-ended or differential inputs. Features of these parts include:

- **Up to 250ksps sample rate**
- **Supply voltages down to 3V**
- **Supply current as low as 20µA**
- **True conversion start allows for precise control of sample timing**
- **Conversion rate independent of system clock**
- **Tiny MSOP packages**

Supply Current vs Sampling Frequency





Successive Approximation Register ADCs for Medical Monitoring

Part Number	Supply Voltage (V)	Resolution (Bits)	Sample Rate (sps)	INL Error (LSB)	DNL Error (LSB)	Interface	Package	Input Range (V)
LTC1864	5	16	250k	6	2	Serial	MSOP-8	V_{REF}
LTC1864L	3	16	150k	6	2	Serial	MSOP-8	V_{REF}
LTC1865	5	16	250k	6	2	Serial	MSOP-10	V_{REF}
LTC1865L	3	16	150k	6	2	Serial	MSOP-10	V_{REF}
LTC1603	5	16	250k	3	1	Parallel	SSOP-36	±2.5
LTC1609	5	16	200k	2	1	Serial	SSOP-28	5,10,±10
LTC1417	5, ±5	14	400k	1.25	1	Serial	SSOP-16	4 or ±2
LTC1418	5, ±5	14	200k	1.25	1	Serial/Parallel	SSOP-28	4 or ±2
LTC1860	5	12	250k	1	1	Serial	MSOP-8	V_{REF}
LTC1860L	3	12	150k	1	1	Serial	MSOP-8	V_{REF}
LTC1861	5	12	250k	1	1	Serial	MSOP-10	V_{REF}
LTC1861L	3	12	150k	1	1	Serial	MSOP-10	V_{REF}

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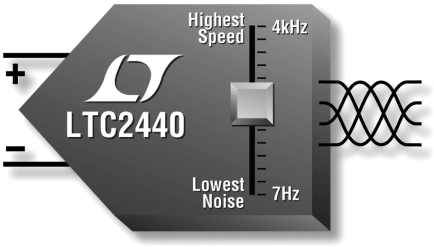
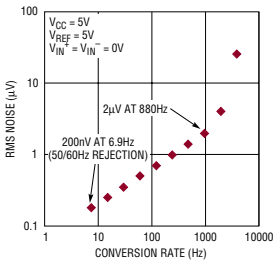
24-Bit Delta Sigma ADC for Direct Sensor Conversion

High-resolution delta sigma converters such as the LTC2440 24-bit ADC give designers an alternative to traditional signal chain solutions. To obtain the resolution needed, traditional signal chains use a discrete amplifier followed by a SAR type ADC. For low frequency DC signals as small as ±50mV, a designer can achieve better than 18 bits of resolution by connecting the sensor directly to the high resolution LTC2440. This eliminates the need for precision amplifiers or programmable gain amplifiers. The LTC2440 also allows the designer to trade off conversion rate with overall accuracy. A flexible conversion rate from 7.5Hz at 200nV of noise to 3.5kHz at 10mV of noise allows the designers to "dial in" the speed and resolution needed for their applications.

- **24-bit no latency conversion, data is valid for every conversion**
- **Low noise : 200nV at 7.5Hz**
- **Software adjustable conversion rate**
- **Differential input**
- **Low power**
- **Small 16-pin SSOP package**



Speed vs RMS Noise



Delta Sigma ADCs

Part Number	Bits	MUX	Output Rate (Hz)	Noise (μV_{RMS})	Power (mW)	Differential Input	Package
LTC2440	24		3500	0.2	55	YES	SSOP-16
LTC2410	24		7.5	0.8	1	YES	SSOP-16
LTC2413	24		7.5	0.8	1	YES	SSOP-16
LTC2412	24	2	7.5	0.8	1	YES	SSOP-16
LTC2418	24	16/8	7.5	1	1	YES	SSOP-28
LTC2414	24	8/4	7.5	1	1	YES	SSOP-28
LTC2415	24		15	1.1	1	YES	SSOP-16
LTC2411	24		7.5	1.45	1	YES	MSOP-10
LTC2408	24	8	7.5	1.5	1		SSOP-28
LTC2404	24	4	7.5	1.5	1		SSOP-28
LTC2402	24	2	7.5	3	1		MSOP-10
LTC2401	24		7.5	3	1		MSOP-10
LTC2435	20		15	4	1	YES	SSOP-16
LTC2431	20		7.5	2.8	1	YES	MSOP-10
LTC2430	20		7.5	2.8	1	YES	SSOP-16
LTC2428	20	8	7.5	6	1		SSOP-28
LTC2424	20	4	7.5	6	1		SSOP-28
LTC2422	20	2	7.5	6	1		MSOP-10
LTC2421	20		7.5	6	1		MSOP-10
LTC2420	20		7.5	6	1		SO-8
LTC2433-1	16		6.8	1.45	1	YES	MSOP-10
LTC2436-1	16	2	6.8	0.8	1	YES	SSOP-16
LTC2439-1	16	8	6.8	1	1	YES	SSOP-28

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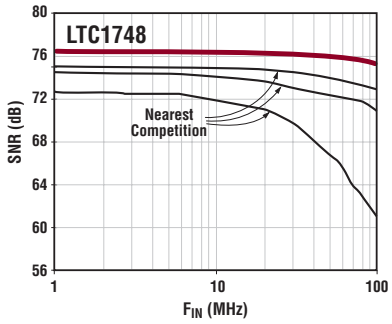
High Speed ADCs for Medical Imaging

Medical imaging applications use a wide range of high performance data converters. Ultrasound, MRI and x-ray imaging all use multichannel sampling systems to gather image data. These applications require a very wide dynamic range, making the dynamic performance of the ADC critical. High signal-to-noise-and-distortion (SINAD) and spurious free dynamic range (SFDR) are needed for optimal performance. Additionally, in applications such as MRI where undersampling techniques are used, wide bandwidth track and hold performance is critical.

Linear Technology has developed a line of high performance 12- and 14-bit high speed ADCs for imaging applications. The LTC1748 is a flagship part offering the designer 80Msps conversion rate with industry leading 76dB of dynamic performance. Key features include:

- **Up to 80Msps conversion rate**
- **240MHz bandwidth track and hold**
- **Excellent SFDR and SINAD specifications**
- **Pin compatible 12-bit and 14-bit family**
- **Digital outputs compatible with 5V, 3V, 1.8V and LVDS logic levels**

SNR vs Input Frequency



High Speed 14-Bit and 12-Bit ADCs

Part Number	T/H Bandwidth (MHz)	Resolution (Bits)	Speed (Msps)	SINAD (dB)	SFDR (dB)
LTC1748	240	14	80	76	90
LTC1742	240	14	65	76	90
LTC1744	150	14	50	77	87
LTC1746	240	14	25	77.5	96
LTC1747	240	12	80	72	87
LTC1741	240	12	65	72	87
LTC1743	150	12	50	72.2	85
LTC1745	240	12	25	72.5	96

High Speed Amplifiers for Imaging

Signal paths in imaging applications require high performance amplifiers to condition the image signal. These amplifiers need to combine high gain bandwidth, fast slew rate and low distortion to preserve the image.

Linear Technology produces a wide variety of amplifiers for these demanding applications. For example, the LT1810 is a 180MHz GBW amplifier with 350V/µs slew rate and very low distortion of –90dBc.

This dual amplifier is an excellent choice for high-speed data acquisition.

High Speed Op Amps

Single	Dual	GBW Typ (MHz)	SR Min (V/µs)	THD Typ (dBc)	Noise Typ (nV/√Hz)	I_{SUPPLY} Max (mA/Amp)	Package
LT1360	LT1361	50	800	–72	9	5	SO-8
LT1363	LT1364	70	1000	–72	8.5	7.5	SO-8
LT1803	LT1804	85	100	–75	21	3	SO-8, ThinSOT™, DFN-8
LT1806	LT1807	325	140	–80	3	14	SO-8, ThinSOT
LT1809	LT1810	180	350	–90	16	13	SO-8, ThinSOT
LT1812	LT1813	100	750	–76	8	3.6	SO-8, ThinSOT, DFN-8
LT1818	LT1819	400	2500	–85	6	10	SO-8, ThinSOT

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Instrumentation Amplifiers

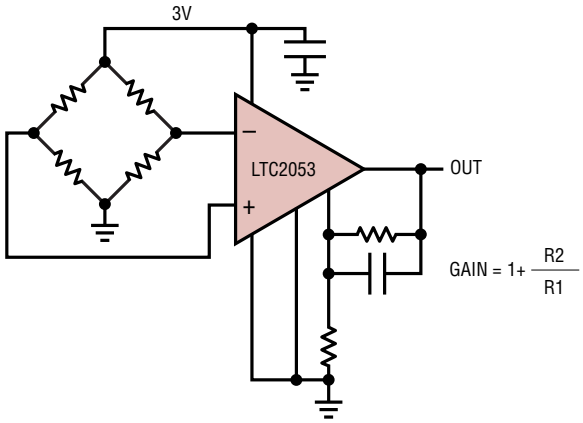
For applications such as bridge type transducers that require high-impedance differential inputs, instrumentation amplifiers are the solution of choice for boosting low level signals. Linear Technology offers a family of instrumentation amplifiers suitable for many applications.

With 10µV maximum offset voltage and 50nV/°C of drift, the LTC2053 offers the highest level of DC precision available on the market today. For applications not requiring the high level of DC accuracy provided by the LTC2053, the LTC6800 offers a pin-compatible solution with 100µV of offset and 250nV°C of drift. These parts feature:

- **Very low offset voltage and offset drift**
- **116dB typical CMRR with any programmed gain including unity**
- **Rail-to-rail input and output**
- **Supply voltages from 2.7V to ±5V**

For applications requiring the measurement of dynamic signals, the LT1167 and LT1168 offer higher bandwidth and low wideband noise for accurate measurements of signals in the kilohertz range. For low power applications such as handheld diagnostic equipment or implanted devices, the LT1789 offers high performance while consuming only 95µA of supply current.

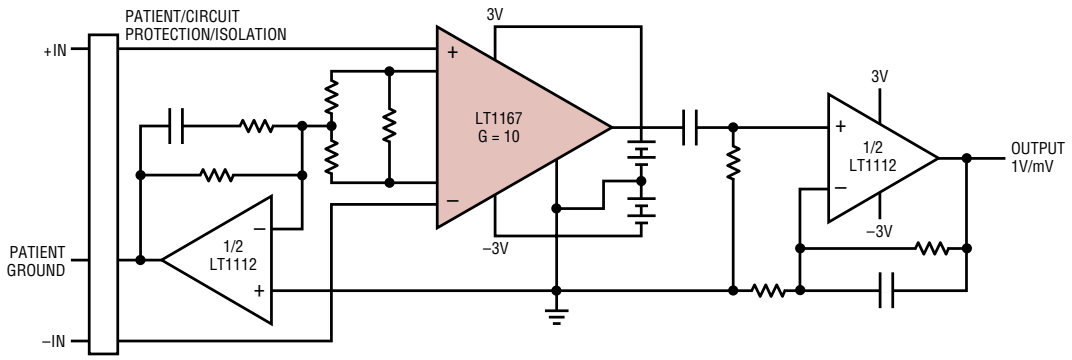
LTC2053 Differential Bridge Amplifier



Instrumentation Amplifiers

Part Number	V_{OS} Max (µV)	V_{OS} Drift Max (µV/°C)	CMRR Min (dB)	GBW Typ (kHz)	I_{SUPPLY} Max (mA)	Package
LT1167	40	0.3	120	800	1.5	SO-8
LT1168	40	0.3	120	400	0.53	SO-8
LT1789	40	0.3	100	30	0.1	SO-8
LTC2053	10	0.05	105	200	1.3	MSOP-8
LTC6800	100	0.25	95	200	1.9	MSOP-8

Nerve Impulse Amplifier Using the LT1167



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Precision Amplifiers for Medical

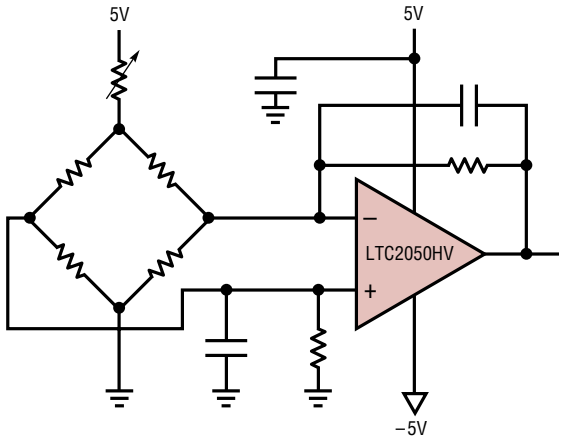
Low-level sensor signals require precision op amps to amplify the signal without adding significant sources of error through offsets, bias currents and noise. For low bandwidth applications like blood gas analysis, zero drift amplifiers provide the low offset and drift required for ultraprecise measurements.

The LTC2050 zero-drift amplifier in the ThinSOT package features unmatched DC accuracy. Performance specifications include:

- **3µV maximum offset voltage and 0.03µV/°C offset drift**
- **CMRR 120dB min**
- **Rail-to-rail output**
- **Supply voltages from 2.7V to ±5.5V**

For higher bandwidth applications such as vital signs monitoring, ECG/EEG and other diagnostics, sensor output frequencies can range up to several kilohertz. Here precision amplifiers with reasonable bandwidth, low noise and excellent precision are required.

LTC2050 Differential Bridge Amplifier



Zero Drift Amplifiers

Part Number	V_{OS} Max (µV)	Drift Max (µV/C)	CMRR Min (dB)	E_{NOISE} Typ (μV_{P-P})	I_{SUPPLY} Max (µA/Amp)	V_{SUPPLY} (V)	Rail-to-Rail	Package
LTC1050/1	5	0.05	120	0.6	1.5	4.75 to 18	–	SO-8, SSOP-16
LTC2050/1/2	3	0.03	120	1.5	1.1	2.7 to 12	Out	ThinSOT, DFN-8 MSOP-8 SSOP-16

Precision Op Amps for Medical Applications

Part Number	GBW Typ (MHz)	I_{BIAS} Max (nA)	V_{OS} Max (µV)	E_{NOISE} Typ ($nV/\sqrt{Hz}$)	Rail-to-Rail	I_{SUPPLY} Max (mA)	Package	Comment
LT1001	0.8	4	60	9.8	_	2.7	SO-8	Low Noise and Precision
LT1007	5	35	60	2.5	–	4.7	SO-8	Low Noise
LT1013A (Dual)	0.5	20	150	22	–	0.5	SO-8	Precision
LT1028A	0.035	90	40	0.85	–	10	SO-8	Lowest Voltage Noise
LT1112A (Dual)	0.75	0.25	60	14		0.45	SO-8	Precision
LT1677	4.5	20	60	4.5	In/Out	4	SO-8	Combines Low Noise, Speed and Precision
LT1800 (Dual)	80	250	350	8.5	In/Out	2	SO-8	Combines Speed and Precision
LT1881A (Dual)	1	0.2	50	14	Out	0.9	SO-8	Low Bias Current and Current Noise
LT6011 (Dual)	0.33	0.3	60	14	Out	0.15	DFN-8, SO-8	Combines Precision and Low Power

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Micropower Devices for Portable Medical Instrumentation

As medical instrumentation moves out of the lab and into portable handheld devices, the need for analog components combining high performance with low power and small size is growing. Linear Technology offers a wide range of low power amplifiers, comparators and references ideal for high performance portable medical applications.

For example, the low power LT6011 dual precision amplifier provides impressive DC specifications while drawing only 135µA per amplifier. Ideal for portable applications, the LT6011 is available in the small 3mm x 3mm DFN package. Key features of the part include:

- **60µV maximum offset voltage with only 0.8µV/°C drift**
- **0.3nA maximum bias current**
- **Rail-to-rail outputs**
- **Only 135µA (max) supply current per amplifier**
- **Small 3mm x 3mm DFN package**

Dual Micropower Op Amps for Medical Instrumentation

Part Number	GBW Typ (MHz)	V_{OS} Max (µV)	E_{NOISE} Typ (nV/√Hz)	Rail-to-Rail	I_{SUPPLY} Max (mA)	Package	Comment
LT1490	0.1	500	50	In/Out	0.05	MSOP-8, DFN-8	Low power, low cost
LT1638	1.1	350	27	In/Out	0.25	MSOP-8, DFN-8	High speed
LT1673	0.013	375	185	In/Out	0.0015	SO-8	Low power
LT1782	0.19	800	50	In/Out	0.06	ThinSOT	Over-The-Top® inputs
LT1801	80	350	8.5	In/Out	2	MSOP-8, DFN-8	High speed
LT1881A	1	50	14	Out	0.9	SO-8	Precision
LT2178A	0.06	70	49		0.018	SO-8	Low power, precision
LT6011	0.33	60	14	Out	0.15	SO-8, DFN-8	Precision
LTC1047	0.2	10	0.8μV_{P-P}		0.15	SSOP-16	Zero Drift

Micropower Comparators

Part Number	Description	Prop Delay Typ (µs)	I_{SUPPLY} Max (µA)	Package
LTC1540	Comparator, reference	50	0.7	MSOP-8, DFN-8
LTC1541	Comparator, reference, op amp	8	7.5	MSOP-8, SO-8, DFW-8
LTC1842	Dual comparator, reference	4	5.7	SO-8
LTC1444	Quad comparator, reference	4	8.5	SSOP-16
LT6700	Dual comparator, reference	18	10	ThinSOT

Micropower Reference

Part Number	Output Voltage (V)	Accuracy	I_{SUPPLY} Max (µA)	Package	Description
LTC1540	1.182	2.0%	0.7	MSOP-8, DFN-8	Comparator and reference, lowest power reference available
LT1389A	1.25, 2.5, 4.096, 5	0.05%, 10ppm	0.6	SO-8	Lowest power shunt reference
LT1634A	1.25, 2.5, 4.096, 5	0.05%, 10ppm	7	SO-8	Precision shunt reference
LT1790A	1.25, 2.5, 3, 3.3, 4.096, 5	0.05%, 10ppm	60	ThinSOT	Low power and precision series reference
LT1461	2.5, 3, 3.3, 4.096, 5	0.04%, 3ppm	50	SO-8	Low TC, low dropout, shutdown

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Thermoelectric Cooler Controller

Medical instruments like blood analyzers and DNA sequencers require tight temperature control in order to obtain precise results. Typically a Peltier device (TEC) is used to control the temperature. The TEC can heat or cool depending in the direction of the current flowing through the device.

The LTC1923 TEC controller provides an efficient means of bidirectional current flow control to a TEC. The part maintains temperature stability to an astounding 0.01°C, meeting the needs of even the most demanding application. The LTC1923 includes independent adjustable heating and cooling current limit, soft-start for controlled start-up, output slew rate control to reduce system noise and a host of auxiliary circuits to protect the laser and provide redundant system monitoring. Available in the space saving 5mm x 5mm QFN package, an LTC1923 solution occupies only 0.6in x 0.8in of board space (doublesided). Features include:

- **Temperature stability to 0.01°C**
- **High efficiency, low noise topology**
- **Solution footprint in less than 0.6in x 0.8in**
- **Available in 5mm x 5mm QFN and 28-pin SSOP packages**

Laser Temperature Control Loop Achieving Setpoint Stability of 0.01°C