Linear Technology Chronicle

October 1998 — A Showcase of Linear Technology's Focus Products — Vol. 7 No. 10

Product of the Month

LTC1625: No R_{SENSE}™ DC/DC Controller Achieves 97% Efficiency

The **LTC®1625** is a synchronous step-down controller that drives external N-channel MOSFETs using few external components. Current mode control with MOSFET V_{DS} sensing eliminates the need for a sense resistor and improves control and efficiency (Figure 1).

No Sense Resistor

Many switching regulators require a sense resistor in order to limit output current under fault conditions. This resistor reduces the efficiency of the converter while adding both cost and complexity to the design.

The LTC1625 enlists "sense resistors" already in the system. The power MOSFET switches do double duty as current sense elements. By measuring the drain-to-source voltage of a MOSFET operating in the triode region, the $R_{DS(ON)}$ of the device can be used as a sense resistance. This is tricky to implement because inductor current information is only available when the MOSFET is turned on (see *Linear Technology* magazine, August 1998).

Because the new LTC1625 fully recovers the inductor current information, it behaves identically to traditional current mode controllers that use a sense resistor. Thus the circuit delivers the benefits of current mode control without the penalties of a sense resistor.

Additional Features

The LTC1625 is designed to drive two N-channel power MOSFETs in synchronous applications. The controller runs at a nominal 150kHz frequency that also may be set at 225kHz and can be locked to an external clock. Soft start capability has been built into the circuit to provide limited inrush current and a controlled delay for supply sequencing.

Providing gate charge to the power switches is a major source of efficiency loss.

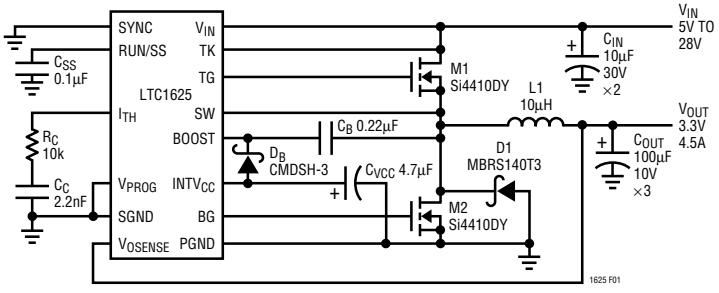

Figure 1. High Efficiency Step-Down Converter

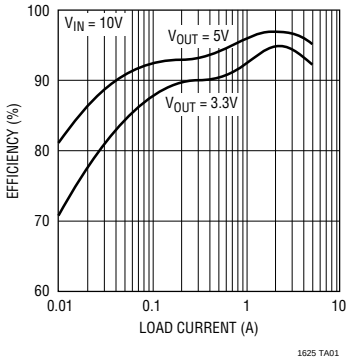

Figure 2. Efficiency vs Load Current

The LTC1625 reduces that loss. At low load current, the MOSFETs are turned off for a few cycles while the output capacitors support the load. This Burst Mode™ operation saves gate charge at the expense of fixed frequency operation. (Burst Mode operation may be overridden.) Also, the gate charge may be drawn from a more efficient second voltage source, if available, for further power savings.

The LTC1625 can be configured for a wide variety of output voltages. 3.3V and 5V outputs may be selected without an external resistive divider. With a divider, the LTC1625 is capable of regulating anywhere between the input voltage and the 1.19V internal reference. This is a significant improvement over prior current mode controllers that were constrained by the common mode range of the sense amplifier. The input voltage range is very wide, 3.7V to 36V, making the LTC1625 an extremely versatile circuit for efficiency- and control-sensitive products such as cellular phones, wireless modems and distributed power systems.

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Inside This Issue:

LT1610: Micropower Boost Converter Offers Smallest Footprint

The new **LT®1610** is a versatile, micropower DC/DC converter that provides the smallest solution for generating a regulated output voltage from a battery input as low as 1V.

The LT1610 addresses board space limitations in several ways. First, the switching frequency is 1.7MHz, allowing the use of tiny, inexpensive, minimum height inductors and capacitors. Second, the frequency compensation components have been integrated into the IC, eliminating an external RC in most cases. Finally, the device comes in LTC's 8-lead MSOP package, one-half the size of the 8-lead SO package.

The LT1610's input voltage range is from 1V up to 8V. Combined with its 30V, 300mA onboard switch, the circuit is useful for many regulator configurations, including boost, SEPIC and flyback. Output voltage can be up to 28V in the boost design. The device can generate 3V at 30mA from a single (1V) cell or 5V at 100mA from two cells (2V). As a Li-Ion cell to 3.3V SEPIC converter, the LT1610 can deliver 100mA. The circuit can also convert 3.3V to 5V at an output current of 200mA.

Operating quiescent current is only 50µA unloaded. The circuit includes a shutdown function that reduces the supply current to 0.5µA. The LT1610 features Burst Mode operation at light loads to provide high efficiency over a broad range of load current (Figure 2).

Single Cell to 3V Converter Example

A 1V to 3V boost converter is shown in Figure 1. The components take up very little space. The inductor measures 2.5mm by 3.2mm and is only 2mm tall. The tantalum capacitors measure 1.6mm by 3.2mm and are 1.6mm tall. Circuit efficiency, which reaches 77%, is detailed in Figure 2.

By simply changing the feedback resistor values (to 1MΩ and 322kΩ), the circuit can generate 5V from 2 cells or from a 3.3V input. The efficiency of that circuit reaches 83%.

The LT1610's 1.7MHz operating frequency, internal compensation and tiny MSOP package result in a low cost and minimal board space overall solution. For a data sheet and evaluation samples, contact your local Linear Technology sales office. Visit our web site at **www.linear-tech.com** for more information.

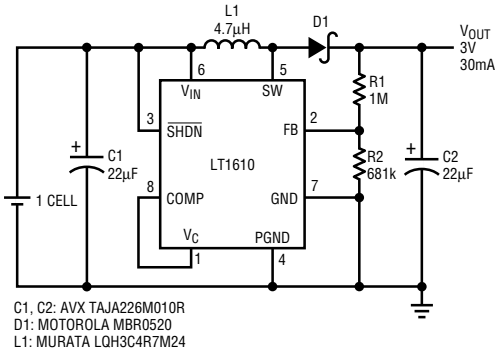

Figure 1. Single Cell to 3V Converter Delivers 30mA

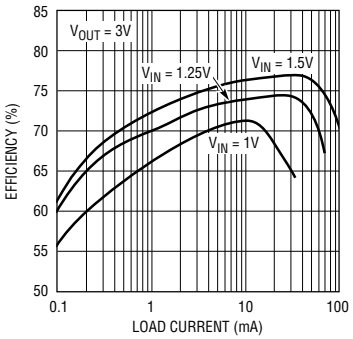

Figure 2. Single Cell to 3V Converter Efficiency Reaches 77%

LT1614: Tiny, Low Noise DC/DC Inverter Works to 1V Input

The **LT1614** is a fixed frequency, inverting mode switching regulator that provides a low noise negative output to –24V from as low as a 1V supply. It is designed for low power, noise-sensitive, space-limited portable products.

The inverting DC/DC converter function is traditionally realized with a capacitor-based charge pump. Although simple, the best charge pump solutions have output impedances in the 5Ω to 10Ω range which result in significant regulation problems when the load increases beyond a few tens of milliamperes. The LT1614 inductor-based inverting DC/DC converter uses closed-loop regulation to obtain an output impedance of 0.1Ω, eliminating output voltage droop under load.

The LT1614 utilizes a low noise topology and a fixed 600kHz operating frequency to ensure an output voltage free from low frequency switching harmonics, making it ideal for supplying low noise bias voltages for MR heads. The LT1614 can generate up to a 28V differential between input and output from a 1V to 5V input. The LT1614's tiny 8-lead MSOP package and small, minimal external components allow it to fit in tight places.

The circuit contains a low-battery detector with a 200mV reference and shuts down to less than 10µA current drain. No load quiescent current is 1mA and the internal 0.6Ω NPN power switch handles a 500mA current with only a voltage drop of 295mV.

Figure 1 shows the 5V to –5V application. The LT1614 operates by driving its NFB pin to a voltage of –1.24V, allowing direct regulation of the negative output. This converter topology, which consists of inductors in series with both input and output, results in low output noise and also in low reflected noise on the input supply. Output ripple is 40mV due to the ESR of the tantalum output capacitor C2. It may be substantially reduced further by use of a ceramic capacitor. Efficiency of the circuit is above 70% from 10mA to 200mA.

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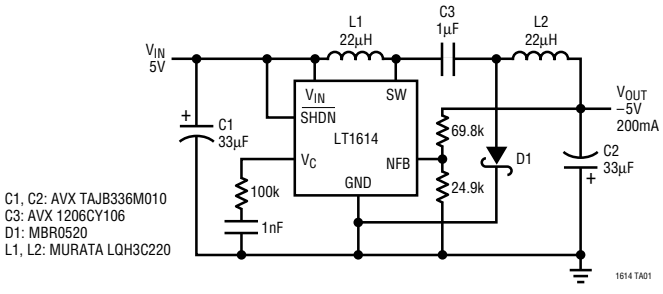

Figure 1. 5V to –5V Converter

Application of the Month

Ultralow Noise Power Supply

Low noise synthesizers need quiet power supplies for their VCOs and other critical circuitry. 3-terminal linear voltage regulators exhibit far too much noise for this application, calling instead for a regulator constructed from a voltage reference. A practical example is shown in Figure 1.

Current through the LT1021-5 reference is used to drive the base of a PNP pass device, resulting in an available output current of at least 1A. In this example, the current is intentionally limited to 200mA by the addition of emitter degeneration and base clamping. The low noise of the reference is preserved, giving a 100-fold improvement over the noise of an equivalent 5V, 3-terminal regulator, plus improved initial accuracy and long-term stability. Typical output noise is $7\mu V_{P-P}$ over a 10kHz bandwidth.

The LT1236-5 may also be used in this circuit. Other output voltages may be obtained with the wide selection of references available from Linear Technology. For more information, see data sheets and Application Note 42.

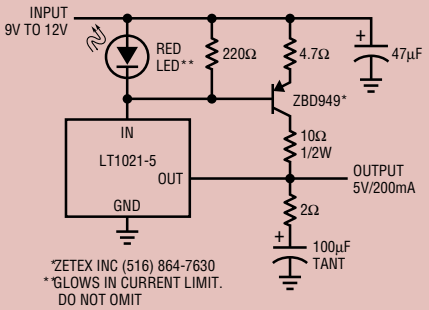

Figure 1. Ultralow Noise 5V, 200mA Supply Output Noise Is $7\mu V_{RMS}$ over a 10Hz to 10kHz Bandwidth. Reference Noise Is Guaranteed to Less Than $11\mu V_{RMS}$. Standard 3-Terminal Regulators Have One Hundred Times the Noise and No Guarantees

LTC1706-19 Adds Digital Voltage Control to an Entire Family of LTC Regulators

The relentless push of microprocessor development for higher speed and lower power dissipation, especially in laptop computers, is driving supply voltages to new low levels. Supply voltage has become so critical that different processors demand different yet precise levels to perform optimally.

The **LTC1706-19** takes a 4-bit digital word from a VID (Voltage Identification) microprocessor system and precisely controls the output voltage of a high performance DC/DC converter like the LTC1435A. The output of the regulator can be adjusted from 1.3V to 2V in 50mV increments. The LTC1706-19 is available right now and works with an entire family of LTC regulators (listed in Table 1) that have internal 1.19V references. Also, the LTC1706-19 is fully compliant with the Intel Mobile VID specification.

High Accuracy, Versatile, Small Package

The digitally programmed resistive divider in the LTC1706-19 is better than ±0.25% accurate across the 1.3V to 2V range and is unaffected by temperature. This results in an overall accuracy of ±1.25% when coupled with the LTC1435A in the Intel Mobile Pentium® II processor VID power converter shown in Figure 1. The four, 40k, pull-up resistors on the VID digital inputs are built in, and the LTC1706-19 is housed in a space efficient SO-8 package.

The LTC1706-19 can also be used to program the output voltages of regulators with different onboard references. Used with the LT1575, an UltraFast™ transient response, low dropout linear regulator controller with a 1.21V reference, the output will range from 1.27V to 2.03V in steps of 50.8mV. Using only one N-channel power MOSFET, the two circuits make an extremely flexible, efficient, compact power supply.

The LTC1706-19 is the ideal companion chip to provide precise, programmable low voltage outputs for DC/DC converters. Its compact size, compatibility and high accuracy are just the right features for today's portable equipment.

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Table 1. Compatible LTC Processor Power Supply Products

LTC Switcher	Potential Application
LTC1433/LTC1434	Low Power Supplies for DSPs or Palm Computer CPUs
LTC1435A LTC1436A	Mobile Pentium II CPU Power
LTC1436A-PLL LTC1437A	Cellular Telephones and Noise-Sensitive Equipment
LTC1438/LTC1439 LTC1538/LTC1539	Multiple Voltage Systems
LTC1624	High Performance DSP Power
LTC1625	Industrial and Single Board Computer CPU Power

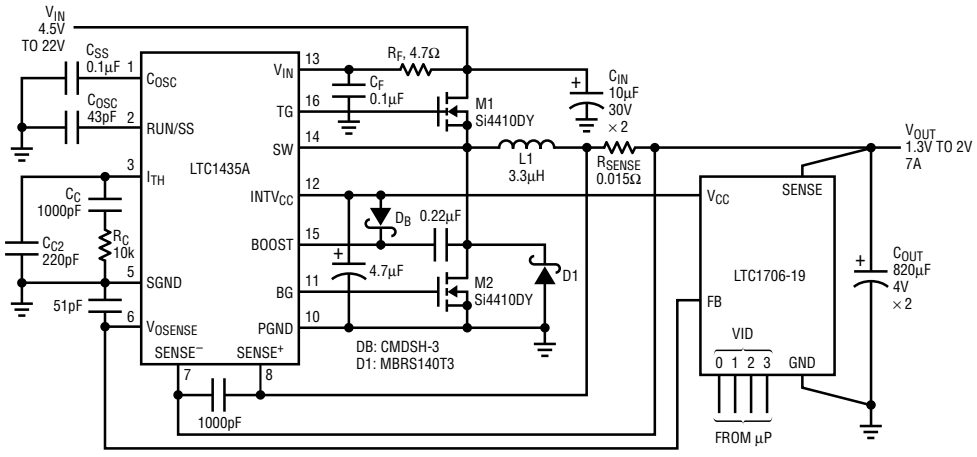

Figure 1. Intel Mobile Pentium II Processor Power Converter

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Rugged LT1636 Micropower Op Amp: Rail-to-Rail, Over-The-Top, 44V Breakdown

The **LT1636** is a 55µA rail-to-rail input/output op amp capable of handling supply voltages from 2.7V to 44V. It features a high level of fault protection and an output shutdown function. The LT1636 is a single op amp in a tiny MSOP-8 package (SO-8 and DIP also available).

Tough Op Amp

An Over-The-Top amplifier, the LT1636's unique input stage can handle up to 44V common mode voltage while operating on a supply as low as 2.7V. It offers protection against reverse supply voltages up to 27V and includes built-in resistors that protect inputs for fault voltages as great as 22V below the negative supply. This broad voltage range capability eliminates the need for protection circuitry, allowing designers to increase circuit versatility and to reduce the size and expense of products.

Micropower and Precision

The LT1636's inputs draw virtually no current in battery charging applications when the wall adapter or the charge source is removed. Unlike most micropower op amps the LT1636 can drive heavy loads; its rail-to-rail output drives 18mA and is unity-gain stable. The maximum supply current of 55µA is reduced to 4µA in shutdown mode. The circuit is specified on 3V, 5V and ±15V supplies.

The LT1636 is a precision amplifier with less than 225µV input offset voltage and less than 8nA of input bias current (see Table 1). The LT1636's combination of features makes it useful in a wide range of products including battery charging and current monitoring, high side current sensing and charge control in portables and high speed modems, bias voltage tracking in passive LCD displays and battery buffering in high voltage industrial control systems and electric vehicles.

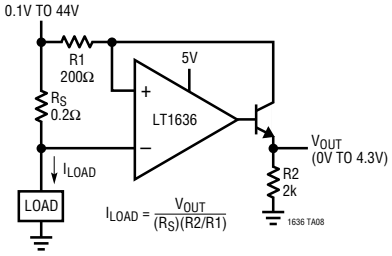
Dual and quad op amps with similar features and specifications are the LT1490/LT1491 and the faster LT1638/LT1639.

For a data sheet and evaluation samples, contact your local Linear Technology sales office. For more information, visit our web site at **www.linear-tech.com**.

Table 1. LT1636 Overview

Supply Voltage Range	2.7V to 44V
Supply Current (Max)	55µA
Shutdown Current (Max)	12µA
Offset Voltage (Max)	225µV
Input Offset Voltage Drift (Max)	10µV/°C
Input Bias Current (Max)	8nA
Gain Bandwidth (Typ)	220kHz
CMRR (Typ)	110dB

Over-The-Top Current Sense



LT1671 Fast and Low Power Comparator

The **LT1671** is a low power (450µA), fast (60ns) comparator designed to operate on either single 5V or ±5V supplies. It has maximum offset voltage of 2.5mV, complementary TTL compatible outputs and output latch capability. The wide input voltage range extends from the bottom supply rail to within 1.5V of the top rail. The LT1671 is made with Linear Technology's new 6GHz complementary bipolar technology, which results in a dramatically improved speed/power product compared to industry-standard comparators developed in slower NPN-only technologies.

Propagation delay (Figure 1) is less than 80ns (maximum) with 20mV overdrive (100ns maximum, with 5mV overdrive). These speeds are great for low power analog signal processing and data acquisition circuits. The LT1671's supply current is only 800µA (maximum).

The LT1671 includes a Latch Enable function that is useful for sampling signals. The latch allows the most recent output state to be retained as long as the latch pin is held high. The complementary outputs allow for differential signaling and improved noise performance.

These features combine to make the LT1671 well-suited for applications such as high performance micropower crystal oscillators (Figure 2), single supply voltage-to-frequency converters and high speed, high accuracy level detectors. The LT1671 is offered in SO-8 and is pin compatible with the industry-standard LT1016 and LT1116 comparators. Contact your local Linear Technology sale office for a data sheet and evaluation samples.Visit our web site at **www.linear-tech.com** for more information.

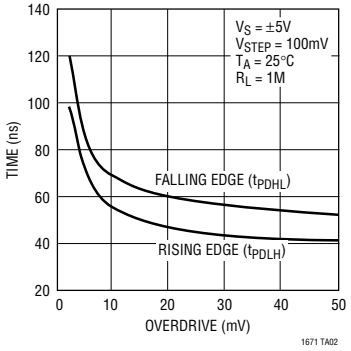


Figure 1. Propagation Delay vs Overdrive

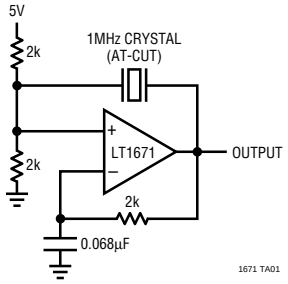


Figure 2. 1MHz Crystal Oscillator

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