LINEAR TECHNOLOGY

JUNE 1991 VOLUME I NUMBER 1

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Welcome to *Linear Technology*

by Bob Swanson, President & CEO

The founding theme of Linear Technology Corporation was to create a company capable of leading and directing linear circuit technology and design concepts of the future and thus become the market's preferred high performance linear specialist. Since our inception in late 1981, we have strived to provide high performance linear ICs with outstanding quality and reliability. It is important to everyone at LTC that the solutions we provide are delivered not just on time, but they continue to work properly and reliably.

Providing high performance ICs across wide analog product lines requires not only innovative design but excellent wafer processing and test. Our proprietary products are designed, wafer fabricated and tested by LTC. Although the Company is known as the home of many of the industry's design innovators; we are equally proud of our total manufacturing capabilities. In our own plant, we fabricate both N-Well and P-Well silicon gate CMOS, general purpose and high frequency bipolar devices, and we are now ramping up production on a full complementary bipolar process. Our ability to virtually tailor a process to the product and combine that with advanced wafer level trimming bring efficient solutions to high performance analog problems.

Looking back at our beginning in 1981, we recall that the conventional wisdom of the time suggested that only the large, "all product" companies would have the staying power to make it through the decade of the 80's. LTC's philosophy at the time was considered a maverick approach, i.e. we believed that the "focused" strategy was the only viable approach to delivering, to the customer, the best technology in each functional area. Today it's interesting to note that our approach has become the current conventional wisdom for companies big and small.

As we get ready to enter a second decade of operation and expanded analog product offerings, I am proud to introduce *Linear Technology* as a source of timely technical information on new products and applications. During the past five years we've found our product direction becoming more and more application specific. Our attempt to provide more complete solutions has lead to more complex products, the benefits of which are sometimes more difficult to understand by both our sales force as well as our customers.

In the 90's we hope to use this magazine to provide regular product introductions along with timely related circuit information, and applications ideas on all products. This will supplement our datasheet and application note effort which will continue unabated. *Linear Technology* is designed to help you, our customer. We are interested in your reactions, and hope you will share them with us.

Linear Technology from LTC Premiers to Analog World

by Walt Jung

LTC welcomes all readers to the premier issue of *Linear Technology*, a new publication from Linear Technology Corporation. *Linear Technology* will focus on the technical highlights of newly introduced LTC devices and emphasize how they are most usefully applied.

At times, this concept of application orientation may be extended to older devices as well, especially where newly developed ideas and techniques serve particular interests stimulated by customers. "Applications" is not necessarily restricted to just circuits, or pure hardware functions, they can and will encompass software in support of LTC devices.

We will try to balance the contents of each issue around an array of features and speciality items, all presenting fresh and useful approaches to linear technology topics. Our "Design Features" will be articles on recently introduced LTC ICs, and will serve as the mainstay of each issue. These articles emphasize what is new, unique or in what way different about each IC. We will steer this away from a dry tutorial approach and more towards what the particular IC makes happen in circuit. In the latter sense, yes, we hope there will be *lots* of interesting circuits showing how the new ICs are used.

Somewhat shorter in length will be a continuing series of brief "Design Idea" type applications, which can be new as well as old product related. The basic objective here is the crux of what it takes to usefully solve an application problem in a new or more efficient manner. We think the ideas for this first issue illustrate this criteria well, and it is expected that this section will be one of the more popular ones of *Linear Technology*.

Finally, we will round out each issue with an array of "New Device Cameos" which will cover recent LTC devices not otherwise featured in an issue.

As time goes on and the publication grows, we hope to stimulate reader involvement. Let us know your ideas on what "linear technology" topics will best serve your analog circuits.

Issue Highlights

Linear Technology leads off this issue with overview remarks by LTC president Bob Swanson. While these comments are much less technical than those surrounding it, they bear reading for the broader viewpoint they bring to these pages.

In this premier *Linear Technology* issue, we are fortunate to have a bounty of technical articles of the types mentioned above. In the main Design Feature articles, we have no less than 5 articles of note.

The piece by Bill Gross on his LT1223 discusses a new high speed complementary bipolar current feedback (transimpedance) amplifier, an important achievement for LTC in process capability.

Related by process is the article by George Feliz, on the LT1220 high speed op amp, also produced with LTC CB technology.

While it does not use an entirely new process, George Erdi's LT1122 fast settling JFET input op amp combines fast-settling and high speed with low input current, DC precision, and very low distortion.

Jim Williams' Design Feature on the LT1074 regulator highlights the most versatile power switching IC yet produced within the LTC proprietary family. The article highlights the functional characteristics of the device and shows some sample hookups.

Steve Pietkiewicz authors the final Design Feature, on his LT1073 single cell switching regulator. This IC represents some new achievements for size and power efficiency, and opens up new applications with relative supply voltage freedom.

In the Design Idea section we have interesting articles for circuit collectors. Walt Jung and Rich Markell lead off with a low distortion driver circuit, and Bob Reay discusses some RS485 interfacing issues in his Design Idea. Steve Pietkiewicz describes his LT1110 high speed single cell switching regulator as a laser pointer driver, followed by Sean Gold's piece on SCSI active termination. Jim Williams and Dennis O'Neill finish with an LT1123 regulator/driver used as a low dropout driver for a power PNP.

In the New Device Cameo section, LTC marketing introduces us to a several new device types. These are the LT1103 and LT1105 offline regulator ICs, the LT1240 series of high speed DC-DC converter ICs, the LTC1272 12 bit, 3µs, parallel A/D converter, and the LTC1289 low voltage single chip 12-bit DAS.

The LT1223, A New High Speed Current Feedback Amplifier

by Bill Gross

The LT1223 is the first current feedback amplifier (CFA) from LTC, and the second amplifier manufactured on the new complementary bipolar (CB) process. As such, it represents achievements for LTC in both process capability and an entirely new amplifier type. Current feedback amplifiers have distinct performance contrasts with familiar voltage feedback amplifiers (such as conventional op amps). Op amps are usually designed for excellent DC performance, often at the expense of AC parameters. Interestingly, current feedback amplifiers have intrinsic AC advantages over voltage feedback amplifiers, but their DC performance often suffers. Although current feedback amplifiers aren't new, they have only recently become popular, driven by complementary IC processes with fast PNP's.

Current Feedback Basics

The distinctions of how current feedback amplifiers differ from voltage feedback amplifiers are not obvious at first, because from the outside the differences can be subtle. Both amplifier types use a similar symbol, and can be applied on a first order basis using the same equations. However their behavior in terms of gain-bandwidth tradeoffs and large signal response is another story.

Unlike voltage feedback amplifiers, small signal bandwidth in a current feedback amplifier isn't a straight inverse function of closed loop gain, and large signal response is closer to ideal. Both benefits are because the feedback resistors determine the amount of current driving the amplifier's internal compensation capacitor. In fact, the amplifier feedback resistor (R_f) from output to inverting input works with internal junction capacitances of the LT1223 to set the closed loop bandwidth. Even though the gain set resistor (R_g) from inverting input to ground works with the R_f to set the voltage gain just like it does in a voltage feedback op amp, the closed loop bandwidth does not change.

The explanation behind this is fairly straightforward. The equivalent gain bandwidth product of the CFA is set by the Thevenin equivalent resistance seen at the inverting input and the internal compensation capacitor. If R_f is held constant and gain is changed via R_g, the Thevenin equivalent resistance changes by the same amount as the change in gain. From an overall loop standpoint, this change in feedback attenuation will in fact produce a change in noise gain, and a proportionate reduction of open loop bandwidth (as in a conventional op amp). With the CFA however, the key point is that changes in Thevenin resistance also produces a compensatory change in open loop bandwidth, unlike a fixed gain bandwidth amplifier (op amp). As a result, the net closed loop bandwidth of a CFA such as the LT1223 remains the same for various closed loop gains.

Figure 1 shows the LT1223 voltage gain vs. frequency, for five gain settings as noted, driving 100 ohms. Shown for comparison is a plot of the fixed 100MHz gain bandwidth limitation that a voltage feedback amplifier would have. It is obvious that for gains greater than one the LT1223 provides 3-20 times more bandwidth.

Because the feedback resistor determines the compensation of the LT1223, bandwidth and transient response can be optimized for almost every application. When operating on ±15V supplies, R_f should be 1k ohms or more for stability, but on ±5V the minimum value is 680 ohms, because the junction capacitors increase with lower voltage. For either case, larger feedback resistors can also be used, but will slow down the LT1223 (which may be desirable in some applications).

The LT1223 delivers excellent slew rate and bandwidth with better DC performance than previous CFA's. On ±15V supplies with a 1k feedback resistor, the small signal bandwidth is 100MHz into a 400 ohm load, and 75MHz into 100 ohms. The input will follow slew rates of 250V/µs with the output generating over 500V/µs, and output slew rate is over 1000V/µs, for large input overdrive. Input offset voltage is 3mV (max), and input bias current is 3µA (max). An 10k pot can be used for (optional) offset null, connected to pins 1 and 5 with wiper to V^+

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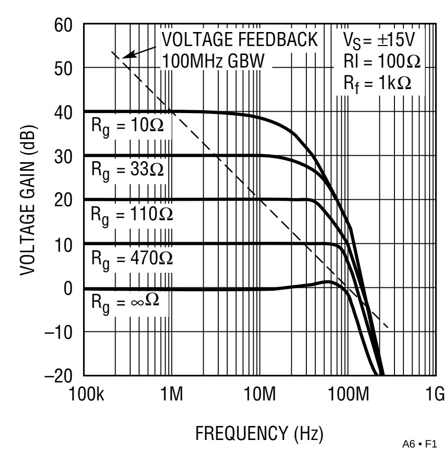

Figure 1. LT1223 Voltage Gain vs. Frequency, Compared to 100MHz Op Amp

LT1220 High Speed CB Process Op Amp

By George Feliz

The LT1220 is the first in a family of new, high performance amplifiers employing LTC's advanced complementary bipolar (CB) process. To the user this means that practical high speed ICs are now available, with consistent AC performance between PNP/NPN transistors, and without supply voltage sacrifices or other application limitations.

Unity-gain stable, the LT1220 op amp features a 45MHz gain bandwidth and a 250V/µs slew rate, but doesn't sacrifice DC accuracy. The LT1220 has high open-loop gain of 20V/mV(min), input bias/offset currents of 300nA(max), and an input offset voltage less than 1mV. These DC specifications lend themselves to data acquisition systems up to 12 bits. Large signal settling time is 90ns to 0.1%, or 165ns to 0.01%, both figures for 10V steps. For ease of application, the amplifier is tolerant of capacitive loading, and can drive 500 ohm loads to ±12V.

Some interesting design features enhance the performance of the LT1220. Although it has only one gain stage, high voltage gain is achieved with a proprietary circuit. Due to the balanced nature this scheme boosts voltage gain without contributing to drift. In addition, a triple emitter-follower output buffer maintains this high gain, even when driving 500 ohms. Low input currents are achieved by bias cancellation circuitry, meaning that the compensation resistor typically used on the amplifier's (+) input isn't needed. Finally, the amplifier's ability to remain stable with increasing capacitive loads is accomplished by sensing the load induced output pole, and adding compensation to the amplifier gain node.

The LT1220 is well suited to virtually any general purpose application needing extended bandwidth. Examples are active filters, cable drivers and buffers, data acquisition, and video applications. It can be used to upgrade the performance of other amplifiers such as the HA2505/15/25, HA2541, AD841, AD847, and the LM6361.

For higher closed-loop gain, the LT1220 family has two other members. The LT1221 is stable in gains of +4V/V or greater, and has the same 250V/µs slew rate of the LT1220, but with higher open-loop gain, 50V/mV(min). The LT1222 is stable in gains of +10V/V or more, with no compensation cap. For greater application flexibility, the LT1222 also has the compensation node available on pin 5 (an example would be compensation of 30pF for a stable gain of –1). The LT1222 has an open-loop gain of 100V/mV(min), and a slew rate of 200V/µs (with no external capacitor).

High Speed I/V Converter

An important application class for the LT1220 is an I/V converter at the output of a fast settling current mode DAC. An example of such a DAC buffer with 12 bits resolution is shown in Figure 1. Here, the LT1220 is configured with an AD565, a fast 12 bit DAC which sinks 2mA of current for full scale and settles in 250ns(max). A 5k ohm resistor internal to the DAC is used as the feedback resistor around the LT1220. To null the 25pF output capacitance of the DAC and for optimum settling, a 5pF capacitor is used across the feedback resistor.

Figures 2a and 2b show ± step settling waveforms at the opamp output as measured at a false sum node between the output and a -10V reference, as per Figure 1. The net settling time is less than 350ns, including the dominant delay of the DAC plus a few nsec of delay in the FET buffer. The key specifications needed for the op amp are high gain, low input bias current, and fast settling. For additional DC accuracy, an optional nulling amplifier can be used to drive the LT1220 offset adjust pins to reduce offset voltage change over temperature.

A SPICE macromodel for the LT1220 is included in the LTC op amp library.

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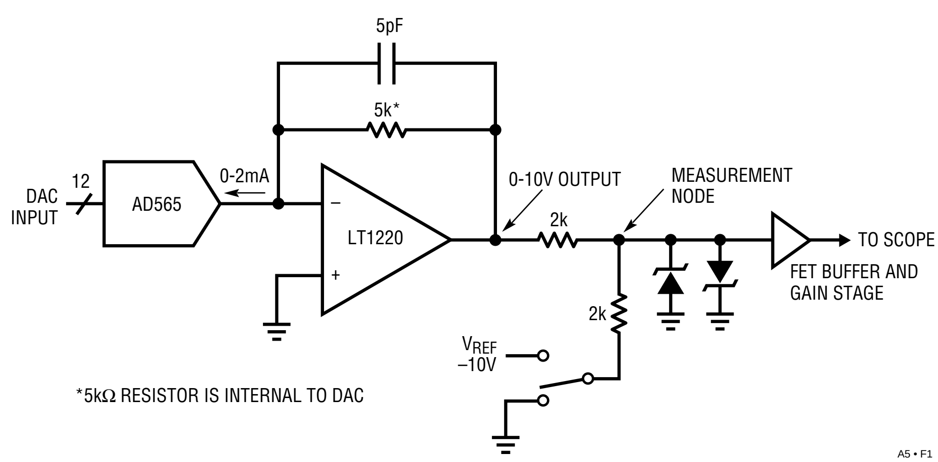

Figure 1. LT1220 High Speed I/V Converter

LT1220 continued from page 3

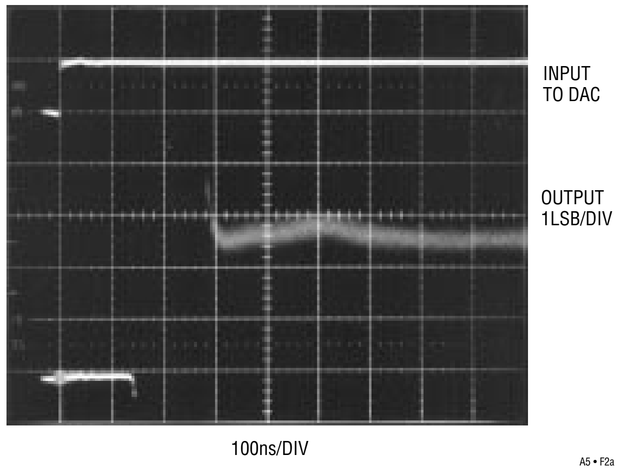

Figure 2a. Positive Step

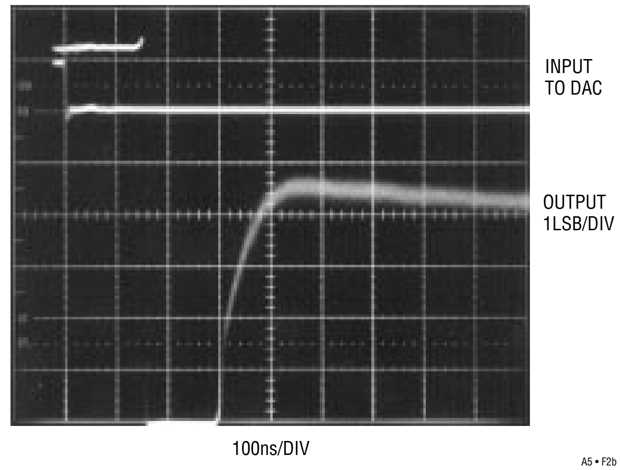

Figure 2b. Negative Step

LT1223 continued from page 3

(like the LT1056 scheme). This trim shifts inverting input current about ±10µA, effectively producing input voltage offset.

The LT1223 also has shutdown control, optionally available at pin 8. Pulling more than 200µA from pin 8 drops the supply current to less than 3mA, and puts the output into a high impedance state. The easy way to force shutdown is to ground pin 8, using an open collector (drain) logic stage. An internal resistor limits current, allowing direct interfacing with no additional parts. When pin 8 is open, the LT1223 operates normally.

The table summarizes the LT1223 specifications, along with those of the EL2020, a popular industry type.

Applications

Figure 2 shows the LT1223 in a typical video cable driver application. With $R_f = R_g$, the LT1223 has a gain of two to recover the 6dB loss in driving the double terminated 75 ohm cable. It is very important to terminate both ends of the cable or the frequency response (and time domain response) will be set by the length of the cable. Even a 4-5 foot cable terminated on only one end will have significant errors at 10MHz.

For this video application, as often used in studios, the LT1223 CFA topology performs quite well. For standard NTSC composite video at 1Vpp input, the differential gain and phase are 0.02% and 0.12 degrees, respectively. Other uses for the LT1223 are wideband cable drivers and buffers, fast settling I/V converters, fiber optic LED drivers, photo-diode amplifiers, R_f and IF amplifiers, radar IF processing, and high gain preamps which must retain maximum bandwidth per stage.

Table 1. Current Feedback Amplifier Comparison

Parameter	LT1223	EL2020
BW (MHz)	100	50
SR (V/µs)	1000	500
I_O (mA, Min)	50	30
V_{OS} (mV, Max)	3	10
$-I_B$ (µA, Max)	3	40
$+I_B$ (µA, Max)	3	15
R_{OL} (MΩ, Min)	1.5	0.3

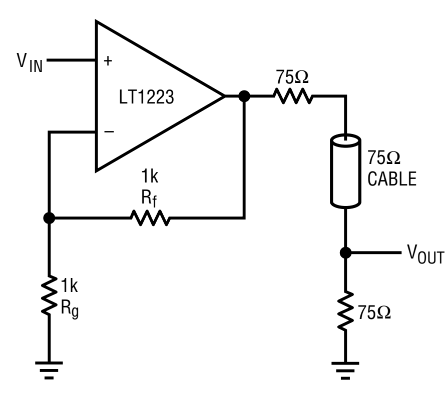

Figure 2. LT1223 Video Cable Driver

The LT1122 Fast Settling JFET Op Amp

By George Erdi and Walt Jung

The LT1122 is a new, high performance JFET input op amp. Optimized around high speed and fast settling performance, the LT1122 uses a modified bipolar-FET process. The performance resulting is a combination of not just excellent AC parameters, but low input currents and DC precision, achieved within a junction-isolated process.

Unity-gain stable, the LT1122 features a 14MHz gain bandwidth and a typical 80V/µs slew rate (SR) with controlled symmetry. For a 10V step, it settles to 1mV at the sum node in 340ns(typ), or 540ns max. The LT1122's excellent DC accuracy specifications include an open-loop gain of 500V/mV(typ) into a 2k load, (250V/mV into 600 ohms), input bias/offset currents of 75 and 40pA(max) respectively, and an input offset voltage of 0.6mV(max). For driving difficult loads, the LT1222 has a 40mA current limit, and can drive 600 ohm loads to ±12V(min).

The LT1122 achieves these combined parameters with a unique polygate JFET. In conventional FET technology, the gate contact is tens of micrometers away from the actual channel of the FET, creating a response pole due to the gate implant series resistance and capacitance, thereby limiting bandwidth. In the LT1122 JFET design, a polysilicon layer provides a gate contact directly over the channel, eliminating this pole. In addition, the circular structure and small drain diffusion used minimizes gate-drain capacitance.

Atop these and other speed related circuit improvements, the LT1122 has very low audio range distortion. For example, THD at an inverting gain of 10 is 0.001% or less to 20kHz, with non-inverting performance only slightly worse. For IM distortion via the CCIF method, the LT1122 has performance as much as 2 orders of magnitude better than typical industry JFET amplifiers such as 156/356 types. The low total distortion is largely due to two design factors. One is the LT1122 SR which is not only high at 80V/µs, but which also is intrinsically symmetrical. This factor eliminates the even order distortion effects present in a topology with asymmetric transconductance. Another factor is the linear all NPN output stage, which features high output current and very high speed.

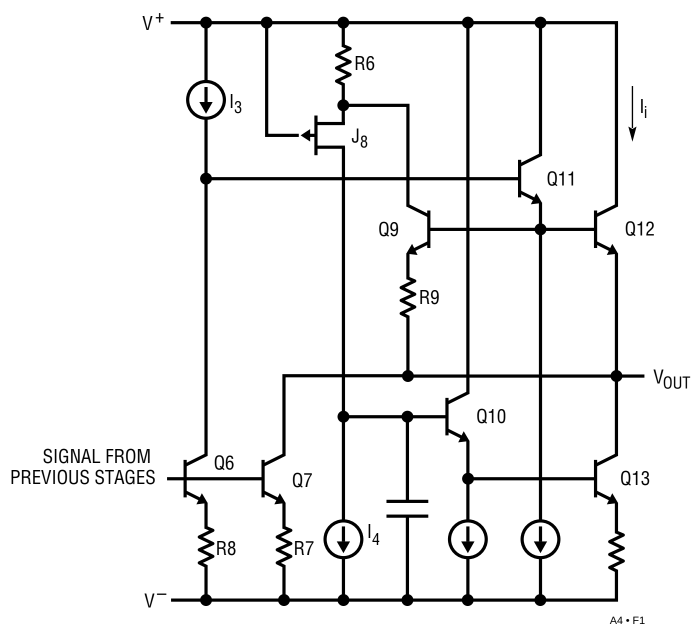

Figure 1. LT1122 Output Stage

This LT1122 output stage is shown in Figure 1 in simplified form, and has several features which contribute to high linearity. One is the local loop which controls the idle current in Q12 (I_i). This loop is comprised of Q12, R9, Q9, R6, J6, Q10 and Q13, and it causes the output follower Q12 to always conduct the idle current or more, so providing a low output impedance. Without precautions however, this type of stage can also distort for some conditions. If for example, Q12 sources load current greater than I_i, the control loop turns off, and Q13 can then no longer return to sinking load current immediately. If unchecked, this would lead to crossover glitches, when the output must quickly change from sourcing to sinking load current. Here however, the problem is solved by Q7, an additional main loop drive input which can provide the short term sink current required. This allows Q13 to turn back on more slowly, but without adding distortion.

Fast settling is the main feature of the LT1122, and is 100% tested in a settling time test fixture described on the data sheet. The LT1122 is available in 4 electrical grades, 2 premium (A & B) and 2 standard (C & D). Of these, the A & C parts are 100% tested for settling, with the others (B & D) sample tested.

The LT1074 Family of Step Down Switching Regulators

by Jim Williams

A substantial percentage of DC regulator requirements involve reduction or step down of a primary voltage. Linear regulators do this, but they don't achieve the efficiency of switchers. The theory supporting step down or "buck" switching regulation is well established, and has been exploited for some time. However, conveniently applied ICs allowing practical implementations haven't been available. A new power IC device, the LT1074, permits broad application of step down regulators with minimal complexity and low cost. Further, more complex step down regulator functions are possible with it also.

The LT1074 is a 5A bipolar switching regulator requiring minimal external parts for operation. While the block diagram of Figure 1. reveals a complex device, basic operation is still fairly straightforward. A description of the main circuit elements and their pin functions is as follows.

The LT1074 uses a special controlled saturation Darlington NPN output switch, with the emitter out-

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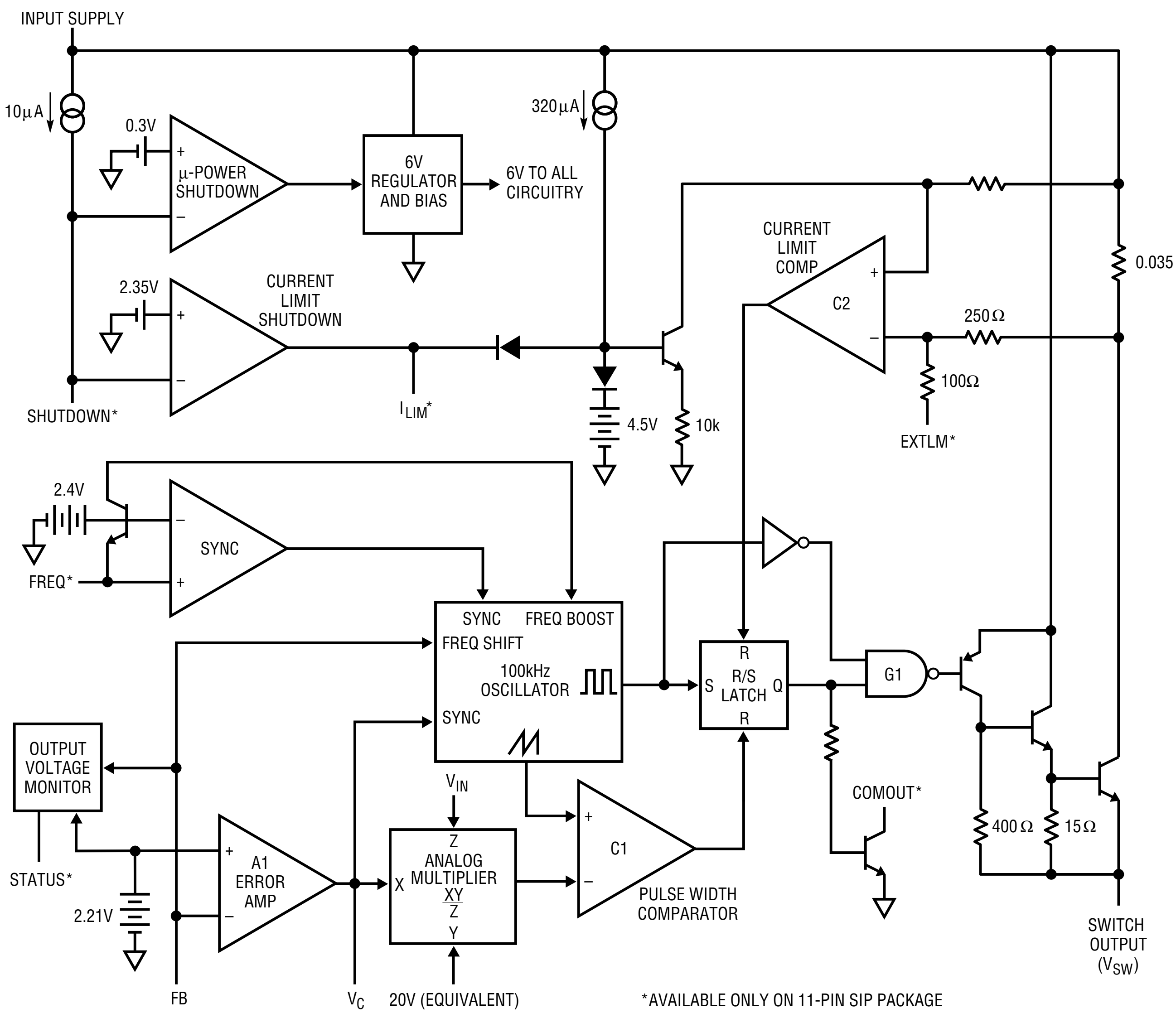

Figure 1. LT1074/LT1076 Block Diagram

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put at pin VSW. This switch uses an isolated design, allowing voltage swings up to 40V below the ground pin. In addition, the switch also has a continuous current monitor. The oscillator of the LT1074 operates at 100kHz, driving the switch through a control latch. Duty cycle control comes from a pulse width comparator, which in turn is driven by the main error amplifier through the analog multiplier. This multiplier allows a loop gain independent of input voltage, optimizing transient response. The error amp of the LT1074 compares a sample of the output presented to the FB pin to an internal 2.21V (±2.5%) reference. Loop compensation is accomplished by a simple RC network at the amplifier output (VC pin), to ground.

While the above describes the basic operational loop of the LT1074 design, accessory internal functions also exist. These are I_{LIM}, FREQ, STATUS, COMOUT, SHUTDOWN and EXTLIM pins (available only in the 11 pin package). As alluded, there are multiple power packages used with the LT1074., a 4 lead TO-3 (K), a 5 lead TO-220 (T), and the 11 lead SIP package (V), which permits the optional clock synchronization, micropower shutdown, current limit programming and other features. The LT1074 is available in two basic voltage grades, the LT1074 for 45V(max) inputs, and the LT1074HV, usable to 64V. There is also a 2.5A rated device, the LT1076.

Applications

Figure 2 is a practical LT1074 voltage step down or "buck" circuit, using minimum componentry. It closely follows a voltage step down conceptual model, described as follows.

When the LT1074 (internal) switch closes, input voltage appears at the inductor, and current flowing through the inductor-capacitor combination builds over time. When the switch opens, current flow ceases and the magnetic field around the inductor collapses. Faraday teaches that the voltage induced by the collapsing magnetic field is opposite to the originally applied voltage. As such, the voltage at the inductor's left end heads negative, and is clamped by the diode. The charge accumulated on the capacitor has no discharge path, leaving an output DC potential. This potential is lower than the input, because the inductor limits current during the switch on-time.

Ideally, there are no dissipative elements in this voltage step down conversion. Although the output voltage is lower than the input, there is no energy lost in this conversion. In practice, the circuit elements do have losses, but step down efficiency is still higher than with inherently dissipative (e.g. voltage divider) approaches. In this circuit, feedback

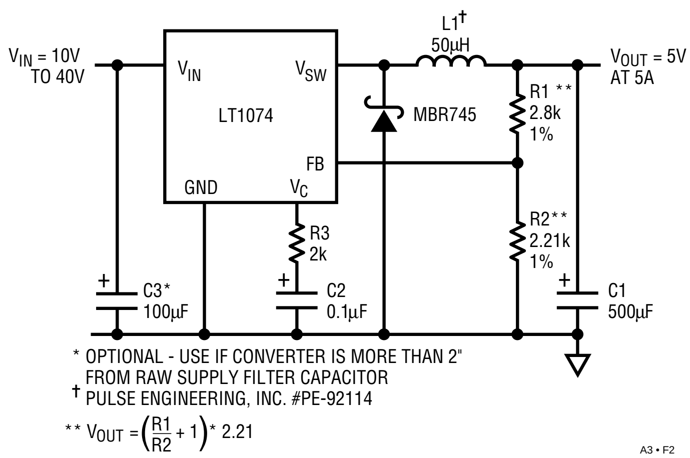

Figure 2. LT1074 Step Down Regulator (5V output)

controls the switch, to regulate output voltage. The switch on-time (e.g. inductor charge time) is varied to maintain the output against changes in either input or loading.

With respect to a practical circuit using the LT1074 regulator, some additional new elements appear. The RC components at the LT1074 VC pin provide frequency compensation, stabilizing the feedback loop. Output sensing resistors R1/R2 are selected to scale the output to the desired voltage V_{OUT}, generally as noted in the figure, with values shown in this case for 5V.

Performance wise, the circuit operates over an input range of 10-40V, and has a maximum output of 5A. Efficiency is about 80% at a current of 1A, while output ripple is about 25mV with the filtering as shown. With these and other switching regulators, power components are critical to performance, and should be rated for switching use at the currents anticipated.

Regulated negative outputs with the LT1074 are easily obtained also, using a simple two terminal inductor. The basic positive to negative converter of Figure 3 demonstrates this, essentially grounding the inductor, steering diode current to what is now a negative output. This design accomplishes the plus-to-minus DC level shift by connecting the LT1074 GND pin direct to the negative output, requiring an isolated heat sink.

Feedback is sensed from the grounded positive output terminal, and the regulator again forces its feedback pin 2.21V above its GND pin. Output voltage scaling is numerically as in Figure 2, with a negative sign. Circuit ground is common to input and output, making system use easy.

Overall performance is as noted, and is similar to the positive buck converter of Figure 2, but with some unique distinctions. On the plus side, note that the input/output voltages of this configuration are seen in se-

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ries by the LT1074, as V_{IN}. This has the effect of allowing a very low absolute level for the positive input, down to as low as 5V, making the circuit an efficient 5V to -5V power converter. On the down side, note in this instance the LT1074 control pins are floating off ground, presenting some potential problems with control interfacing (when necessary).

Figure 4, another variant, is used when it is desirable to operate the case (GND) pin of the regulator at common. This option uses an op amp as a precision feedback level shifter. A1 facilitates loop closure, providing a scaled inversion of the negative output to the LT1074 FB pin. Precision resistors R1/R2 set negative output voltage as noted (values shown for a -5V output). The VC pin of the LT1074 is left open, and the RC network around A1 gives frequency compensation.

Advantages of this circuit compared to Fig. 3 is that the LT1074 package can directly contact a grounded heat sink. Additionally, this circuit permits ground referred addressing of the regulator's control pins. Disadvantages are that it requires a higher minimum input voltage, plus an additional active device..

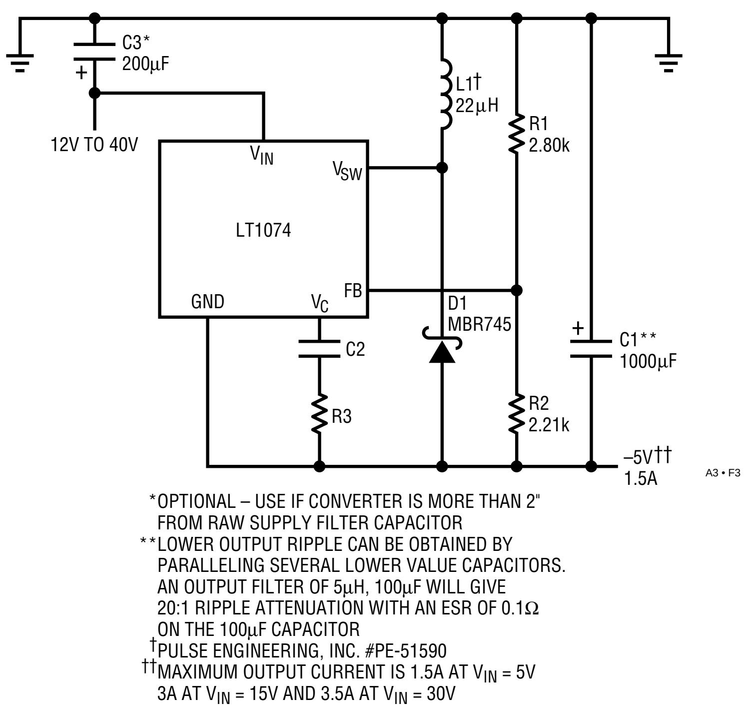

Figure 3. Positive to Negative Converter

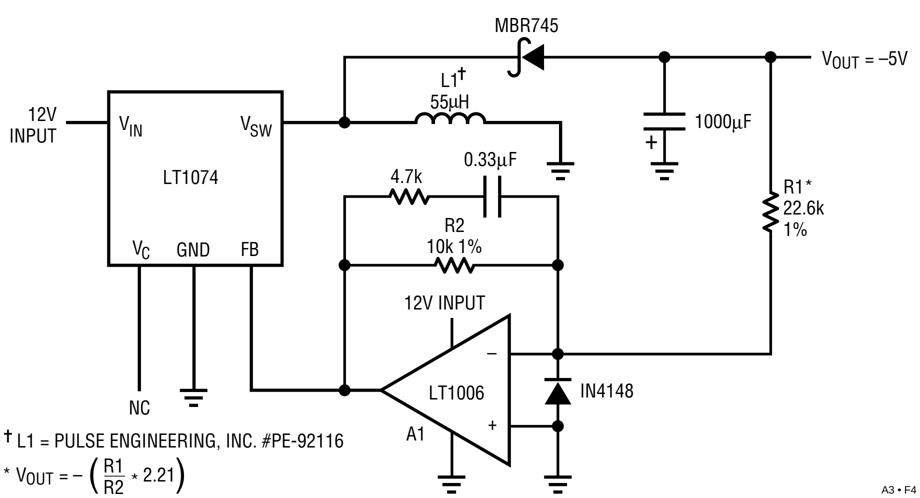

Figure 4. Positive to Negative Converter with Op Amp Level Shift

Higher Output Currents with Tapped Inductors

Buck (step-down) convertors have a switch current at least as high as regulator output current. This limits LT1074 output current to 5A in the simple buck convertor topology. A slightly modified version (shown on the data sheet) can double available output current to 10A when input voltage is a minimum of 20V. The modified version uses a 3 to 1 tapped inductor which generates current gain in the inductor.

During switch "on" time current flows through the entire inductor to the output and can have a maximum value of 5A. When the switch turns off, the voltage at the tap flies negative and current flows to the output through just 1/4 of the inductor. Energy conservation requires that this current be four times the current which was flowing in the entire inductor. Average current delivered to the output is between 5A and 20A, as determined by operating switch duty cycle. For low input voltages, switch duty cycle is very high, and maximum output current is only slightly above 5A. For input voltage above 20V, duty cycle is low enough to deliver 10A output current.

The voltage on the LT1074 switch pin flies negative to about 17V during switch "off" time due to the transformer action of the inductor. Leakage inductance, however, would cause, at switch turn-off, the switch voltage to briefly fly negative without limit. Clamps are needed to protect the LT1074.

The LT1073 Single Cell Switching Regulator

by Steve Pietkiewicz

Battery-powered electronic equipment continues to become more popular. Miniaturization levels have increased, due largely to trends toward surface mount devices and increased IC functionality. Component sizes have now been reduced to a point where the battery can become a significant percentage of system volume, forcing size reduction efforts in this area. The LT1073, a new micropower switching regulator circuit, generates a wide range of output voltages from inputs as low as 1.5V (single cell). This enables attendant reductions in both battery volume and net power consumption.

The LT1073 consists of the elements shown in the functional block diagram of Figure 1. In operation, it acts as a gated oscillator switcher, enabling the oscillator as needed to maintain a given output voltage. The regulation loop of the device consists of a 212mV reference, a comparator, an oscillator, a driver, and a controlled saturation NPN output switch. The uncommitted amplifier A2 is an "Auxiliary Gain Block" with an open collector NPN output (AO) for various ancillary uses. The I_{LIM} pin is used to control current limit, from a maximum internal limit of 1A downward.

The LT1073 is most notable for its ability to operate efficiently at low input voltages, from as low as 1.0V up to 12V, while consuming less than 100µA. A related device, the LT1173 works over a 2-36V range. Operable in either boost or buck modes, LT1073 family devices come in 8 pin plastic DIP or surface mount packages, and in 3 electrical versions. These are the LT1073 and LT1173, general purpose voltage programmable parts, and the LT1073-5 and LT1073-12, fixed voltage versions. The latter come preconfigured with internal resistors for output voltages of 5 and 12V with 5% guaranteed accuracy. In the circuit examples below are shown the two basic LT1073 operating modes.

Applications

The LT1073-5 functions nicely as a 1.5V single-cell to 5V boost converter, shown in Figure 2a. Just three more components beyond the LT1073-5 itself are required for this practical step-up converter. In this straightforward circuit, the LT1073-5's SENSE pin monitors the output voltage. When the voltage drops below 5V, the oscillator switches on, causing current to alternately build in L1, then dump into C1, raising output voltage. A built-in small hysteresis precludes need for frequency stabilization.

The circuit delivers 5V at 40mA for a cell voltage as low as 1.25V, and at 1V it still delivers 10mA. Conversion efficiency is 65% as shown, with still higher efficiency possible using a larger inductor (at some expense of maximum output current). Note that for these circuit types, the diode, inductor and capacitor specified are performance-critical "power" components, so here substitutions aren't advised. The same general performance advantages of this circuit can be extended to other voltages with the use of the LT1073, and two external resistors for voltage setting.

continued with "LT1073" on page 11

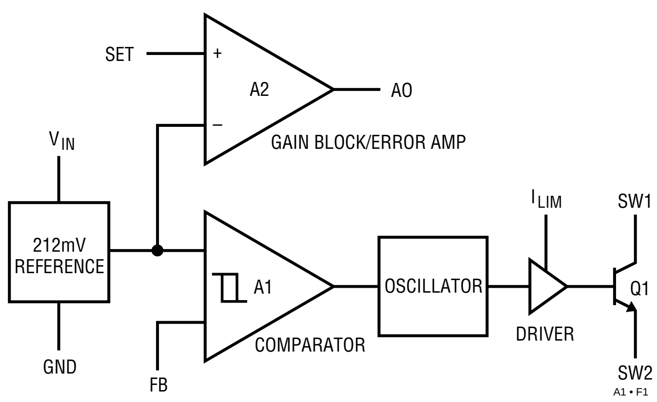

Figure 1. LT1073 Block Diagram

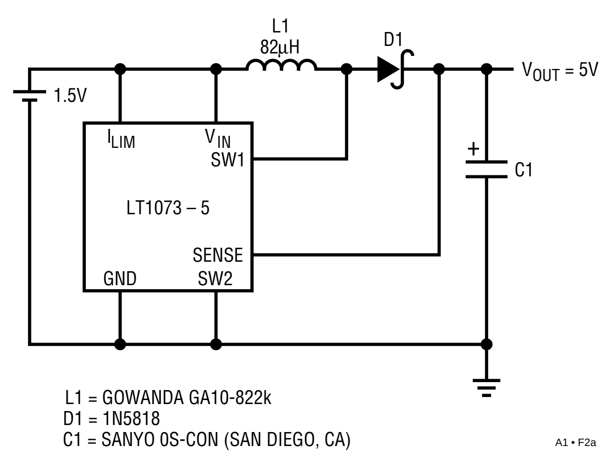

Figure 2a. Single Cell to 5V Step Up Converter

LTC485 Line Termination

by Bob Reay

The termination of the data line connecting LTC485 transceivers is very important because an improperly terminated line can cause data errors. The data line is usually a 120Ω shielded twisted pair of wires which is terminated at each end with a 120Ω resistor (Figure 1). For some applications a problem occurs when the output of the drivers are forced into a high impedance state because the termination resistors short the inputs to the receivers. Since the receivers are differential comparators with built in hysteresis, their output will remain in the last logic state.

For the applications which must force the outputs of the receivers to a known state, but still maintain low power consumption, the cable can be terminated as in figure 2. A capacitor (typically 0.1μF) has been connected in series with the 120Ω termination resistor R2, and two bias resistors (R1 and R3) have been added. When data is being transmitted, the capacitor looks basically like a short circuit and a differential signal is developed across the termination resistor. When the drivers are forced into a high impedance state, the bias resistors force the receiver into a logic 1 state. The receiver inputs can be reversed when the output must be a logic 0.

Because the capacitor is in series with the bias string, no DC current flows when data is not being transmitted. Care must be taken to transmit data at a high enough data rate to prevent the bias resistors from charging the capacitor to the wrong state before the next data bit arrives. Also note that differences in the V^+ supplies or grounds will cause DC current to flow in the cable, but this can be kept to a minimum by using high value bias resistors.

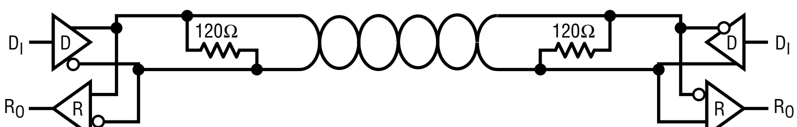

Figure 1. DC Coupled Termination

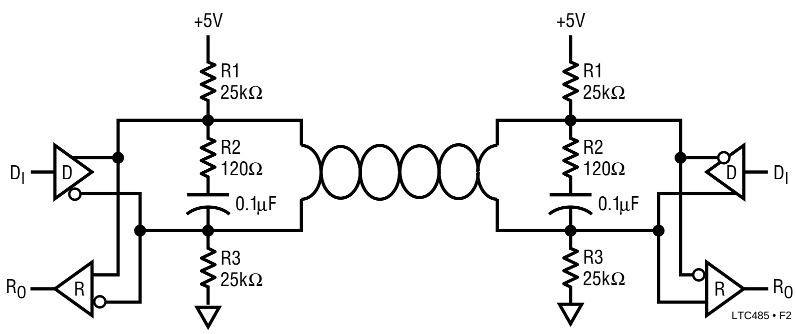

Figure 2. AC Coupled Termination

LT1073 continued from page 10

The LT1073 shows off its buck mode versatility in Figure 2b, configured here as a 9V to 5V step down converter. This circuit deploys the current limit feature of the LT1073, used here to let the converter work with wide input ranges. With most gated-oscillator switchers, the switch stays on for a fixed time period. With input voltages too high, currents can build to levels of inductor saturation. Or, under worst-case conditions, the device can destruct.

In this circuit, current limiting in the LT1073 monitors switch current and turns it off when current reaches a predetermined level. R3, the 220 ohm resistor between the I_{LIM} and V_{IN} pins sets this current limit to about 400mA. For a minimum of output ripple, the LT1073's gain block is used as a pre-amplifier in front of the comparator input pin, FB. This measure reduces output ripple to 100mV p-p. The output voltage of this buck type LT1073 converter is programmed by resistors R2 and R1. As noted in the diagram, these two resistors scale the 212mV reference up to the final output voltage, or 5V. The circuit delivers 5V at 90mA, working from a 6.5 to 12.6V input.

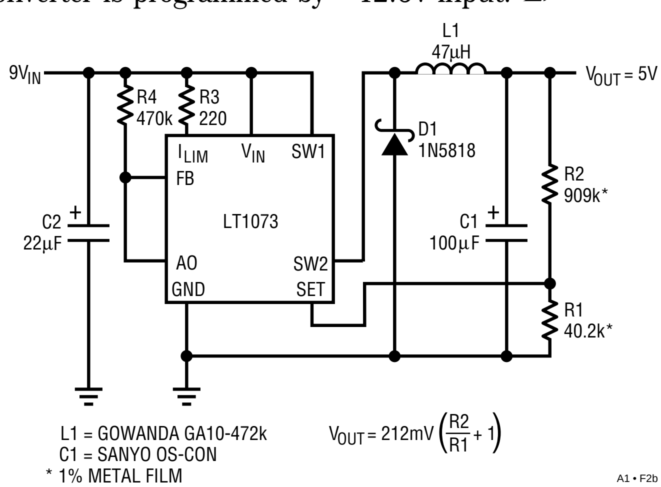

Figure 2b. 9V to 5V Step Down Converter

A Fast, Linear, High Current Line Driver

Walt Jung and Rich Markell

Among linear applications not usually seen are those which require high speed combined with either very low DC error, or high load current. Such applications can be solved by combining the best attributes of two ICs, either one of which may not be capable by itself of the entire requirement.

A case in point is the line driver of Figure 1, which uses an LT1122 JFET input op amp as the gain element combined with an LT1010 buffer. This provides the output current of the LT1010 (typically 150mA) but with the basic DC and low level AC characteristics of the LT1122. The circuit is capable of driving loads as low as 100 ohms with very low distortion. The input referred DC error is the low DC offset of the LT1122, typically 0.5mV or less. Large signal characteristics are also very good, due to the 80V/µs symmetrical SR of the LT1122.

The circuit as shown is configured as a precise gain of 5 non-inverting amplifier by gain set resistors R2 and R1, with the LT1010 unity gain voltage follower inside the overall feedback loop. This provides current buffering to the op amp, allowing it to operate most linearly. Small signal bandwidth is set by the time constant of R2 and C1, and is 1MHz as shown, with a corresponding risetime of about 400ns.

Performance with ±18V supplies is shown in Figures 2a and 2b, with output generally 5Vrms or equivalent, driving 100 ohms directly. THD is shown in Figure 2a, with input level swept up output clipping level, at a fixed 10kHz frequency. The distortion is generally well below 0.01%, and improves substantially for lower frequencies.

CCIF IM distortion performance of the circuit for similar loading is shown in Figure 2b, driving a load of 100 ohms at a swept level, again up to output clipping. The LT1122 amplifier is represented by the lower of the two curves, with distortion around the 0.0001% level. Also shown for comparison in this plot is the distortion of a type 156 JFET op amp (also driving the LT1010 buffer with other conditions the same). The 156 op amp uses a design topology with an intrinsically *asymmetric* SR. This manifests itself as rising even order distortion for methods such as this CCIF test. For this example, the distortion is more than an order of magnitude higher than that of the faster and symmetric slewing LT1122 for the same conditions.

Applications of this circuit include low offset linear buffers such as for A/D inputs, line drivers for instrumentation use, and audio frequency range buffers such as very high quality headphone use.

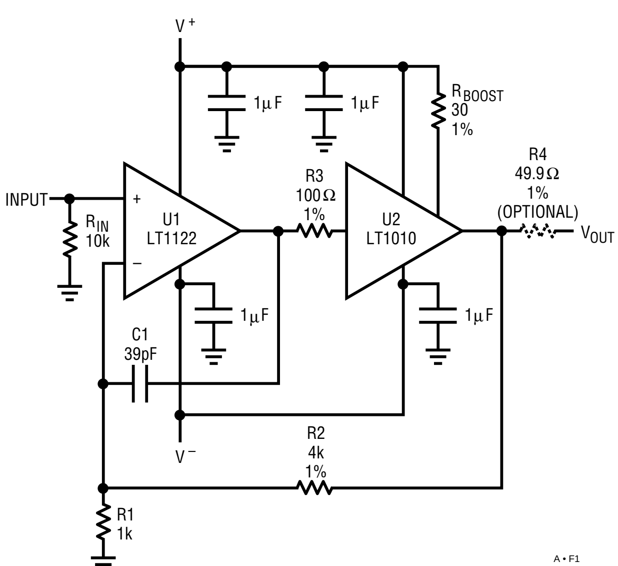

Figure 1. Line Driver

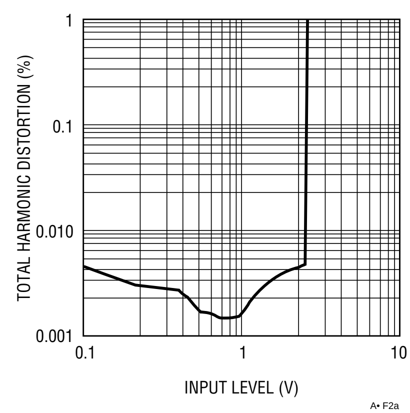

Figure 2a. THD vs. Input Level

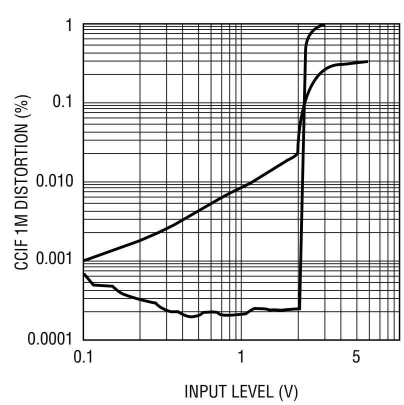

Figure 2b. CCIF IM Distortion vs. Input Level

A Single Cell Laser Diode Driver Using The LT1110

Steve Pietkiewicz

Recently available visible lasers can be operated from 1.5V supplies, given appropriate drive cirtcuits. Because these lasers are exceptionally sensitive to overdrive, power to the laser must be carefully controlled lest it be damaged. Over-currents as brief as 2 microseconds can cause damage.

In the circuit of Figure 1, an LT1110 switching regulator serves as the controller within the single-cell powered laser diode driver. The LT1110 regulator is a high speed LT1073 (see "The LT1073.." this issue). It is available in an 8 pin miniature SOIC.

The LT1110 is used here as an FM controller, driving a PNP power switch Q2, with a typical "ON" time of 1.5 microseconds. Current in L1 reaches a peak value of about1.0A. The output capacitor C2 has been specified for low ESR, and should not be substituted (damage to the laser diode may result).

The Gain Block output of the LT1110 functions with Q1 as an error amplifier. The differential inputs compare the photodiode current developed as a voltage across R2 to the 212mV reference. The amplifier drives Q1, which modulates current into the I_{LIM} pin. This varies oscillator frequency to control average current.

Overall frequency compensation is provided by R1 and C1, values carefully chosen to eliminate power-up overshoot. The value of current sense resistor R2 determines the laser diode power, as shown the 1000 ohms results in about a 0.8 milliwatt output.

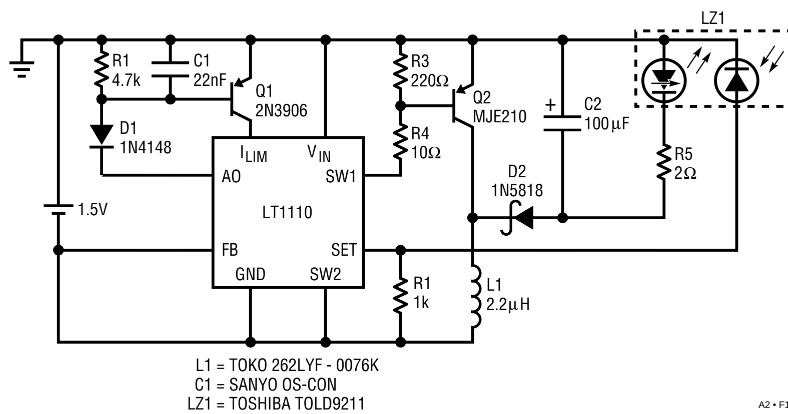

Figure 1. LT1110 Laser Diode Driver Operating from a Single Cell

Low Dropout Regulator Simplifies Active SCSI Terminators

Sean Gold

The active terminator shown in Figure 1 uses an LT1117 low dropout three terminal regulator to control a logic supply. The LT1117's line regulation makes the output immune to variations in TERMPWR. After accounting for resistor tolerances and variations in the LT1117's reference voltage, the absolute variation in the 2.85V output is only 4% over temperature. When the regulator drops out at TERMPWR-2.85, or 1.25V, the output linearly tracks the input with a 1V/V slope. The regulator provides effective signal termination because the 110 ohm series resistor closely matches the transmission line's characteristic impedance, and the regulator provides a good AC ground.

In contrast to a passive terminator, 2 LT1117s require half as many termination resistors, and operate at 1/15 the quiescent current or 20mA. At these power levels, PC traces provide adequate heat sinking for the LT1117's SOT-223 package. Beyond solving basic signal conditioning problems, this LT1117 terminator handles fault conditions with short circuit current limiting, thermal shutdown, and on chip ESD protection.

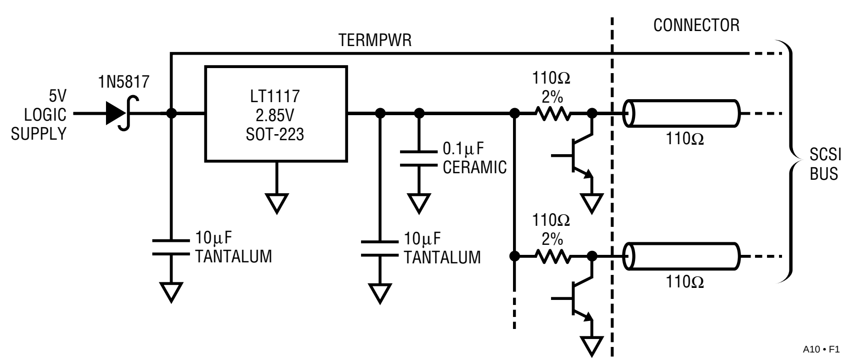

Figure 1. SCSI Active Termination

An LT1123 Ultra Low Dropout 5V Regulator

Jim Williams and Dennis O'Neill

Switching regulator post regulation, battery powered apparatus, and other applications often require low V_{IN}-V_{OUT}, or dropout, linear regulators. For post regulators this is needed for high efficiency. In battery circuits lifetime is significantly effected by regulator dropout. The LT1123, a new low cost reference/control IC, is designed specifically for cost-effective duty in such applications. Used in conjunction with a discrete PNP power transistor, the 3 lead TO-92 unit allows very high performance positive leg regulator designs. The IC contains a 5V bandgap reference, error amplifier, NPN darlington driver, and circuitry for current and thermal limiting.

A low dropout example is the simple 5V circuit of Fig. 1, using the LT1123 and an MJE1123 silicon PNP. In operation, the LT1123 sinks Q1 base current through the DRIVE pin, to servo control the FB (feedback) pin to 5V. R1 provides pull-up current to turn Q1 off, and R2 is a drive limiter. The 10µF output capacitor (Cout) provides frequency compensation. The LT1123 is designed to tolerate a wide range of capacitor ESR so that low cost aluminum electrolytics can be used for C_{OUT}. If the circuit is located more than 6 inches from the input source, the optional 10µF input capacitor (C_{IN}) should be added.

Normally, such configurations require external protection circuitry. Here, the MJE1123 has been cooperatively designed by Motorola and LTC for use with the LT1123. The device is specified for saturation voltage for currents up to 4 amperes, with base drive equal to the minimum LT1123 drive current specification. In addition, the MJE1123 is specified for min/max beta at high current. Because of this factor and the defined LT1123 drive, simple current limiting is practical. In limit, excessive output current causes the LT1123 to drive Q1 hard until the LT1123 current limits. Maximum circuit output current is then a product the LT1123 current and the beta of Q1. The foldback characteristic of the LT1123's drive current combined with the MJE1123 beta and safe area characteristics provide reliable short circuit limiting. Thermal limiting can also be accomplished, by mounting the active devices with good thermal coupling.

Performance of the circuit is notable, as it has lower dropout than any monolithic regulator. Line and load regulation are typically within 5 millivolts, and initial accuracy is typically inside 1%. Additionally, the regulator is fully short circuit protected, with a no load quiescent current of 1.3mA.

Figure 2 shows typical circuit dropout characteristics, in comparison with other IC regulators. Even at 5A the LT1123/MJE1123 circuit dropout is less than 0.5V, decreasing to only 50mV at 1A. Totally monolithic regulators cannot approach these figures, primarily because their power transistors do not offer the MJE1123 combination of high beta and excellent saturation. For example, dropout is ten times lower than in 138 types, and significantly better than all the other IC types. Because of Q1's high beta, base drive loss is only 1-2% of output current even at high output currents. This maintains high efficiency under the low V_{IN}-V_{OUT} conditions the circuit will typically see. As an exercise, the MJE1123 was replaced with a 2N4276 germanium device. This provided even lower dropout performance, but limiting couldn't be production guaranteed without screening.

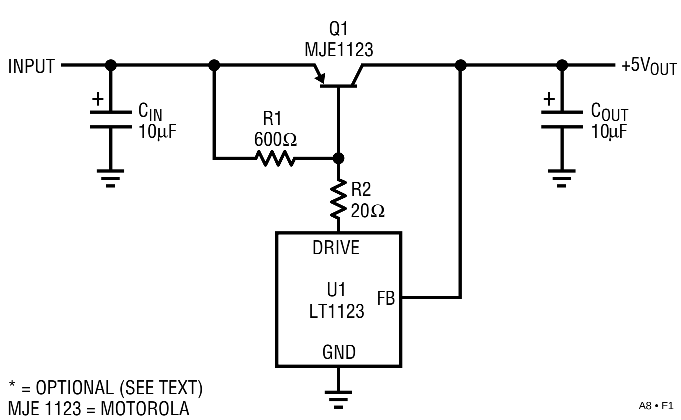

Figure 1. The LT1123 5V regulator features ultra-low dropout.

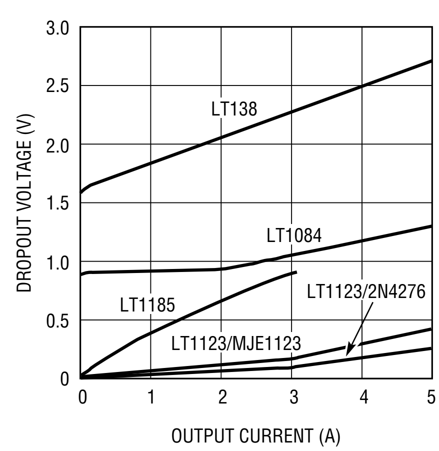

Figure 2. LT1123 regulator dropout voltage vs. output current

New Device Cameos

By LTC Marketing

LT1103 and LT1105: Offline Switching Regulator Control ICs Need No Opto Feedback

The LT1103 and LT1105 are switching regulators designed for 15-200W offline applications. Using an external source-driven FET switch, the LT1103 is optimized for 15-100 watt applications. A unique feedback technique not requiring opto isolation allows 1% line/load regulation with the LT1103. Current mode operation provides easy frequency compensation, and the device is well suited for both transformer isolated flyback and forward converter topologies. The IC contains the oscillator, control, and protection circuitry, and it needs only a few external components for a fully functional, efficient offline converter. Internal bootstrap circuitry requires only 200µA startup current.

Related to the LT1103 is the companion LT1105, used in FET gate driven designs. The LT1105 allows for up to 200W offline converters using an external sense resistor, with other features similar to the LT1103. Both devices come in 11 pin plastic SIP packages, and the data sheet includes several offline circuits.

LT1240 Series: High Speed DC-DC Converter Control ICs

The LT1240 series devices are 8-pin, current mode, pulse width modulation switching controllers. LT1240 devices are manufactured using LTC's high speed process, and are pin compatible upgrades to industry standard 1842/3842 products. LT1240 series units have improvements over the older counterparts in such areas as speed, lower quiescent and start-up currents, and new operational features. Current spikes in the totem pole output have been eliminated and internal delay times reduced, making 500kHz operation practical.

Several new features contained in the LT1240 series make use easier than with previous ICs. These include leading-edge blanking of the current sense comparator to prevent premature tripping, eliminating the input filter and allowing minimum delays, trims in the oscillator for both frequency and sink current (with these parameters tightly specified), an output stage which is clamped to a voltage maximum. The drive and reference outputs are actively pulled low during under voltage lockout.

LTC1272: 12-Bit, 3µs, 250kHz Sampling A/D Converter

The LTC1272 A/D is a substantially improved pin compatible upgrade to the industry standard 12-bit AD7572. The LTC1272 offers true single supply operation, improved conversion time (3µs vs. 5µs), and an on-chip S/H (transparent to those not needing it). The device, LTC's first parallel out 12-bit A/D, is easily interfaced due to the ability of data transfer in either two 8-bit bytes or a single 12-bit word. On chip clock circuitry supports timing with either an external crystal or from a TTL/CMOS clock source up to 4MHz. While the LTC1272 is faster, it runs on a single 5V supply with typical power consumption of only 75mW (including S/H, reference, and quick conversion functions). The LTC1272 replaces AD7572 and PM7572 units in demanding new (or old) designs where the designer has speed and/or power issues with the older AD7572.

LTC1289: Low Voltage Single Chip 12-bit Data Acquisition System

The LTC1289 is a complete data acquisition system IC that includes an A/D, sample and hold, 8-channel MUX, serial I/O port, all operating on a single +3V supply. This new product features all of the system functions of the LTC1290, but is implemented with a low voltage CMOS process, with guaranteed operation down to +2.7V.

Key accuracy specifications of the LTC1289 include ±1/2 LSB linearity/gain errors, and ±1.5LSB offset error for the "B" electrical part. In addition to the above functional features, the device's strength is a 26µs conversion time, achieved with only 1mA of supply current. This combination makes the LTC1289 a versatile yet high performance front end for portable low voltage equipment, such as 3.3V battery-powered systems. The LTC1289 currently stands alone as a data acquisition system operational on 3V.

For further information on the above, or any other devices mentioned in this issue of Linear Technology, use the reader service card supplied. Or, call the LTC literature service number, (800) 637-5545. Ask for pertinent data sheets and app notes. LT

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

DESIGN TOOLS

Applications on Disk

NOISE DISK

This IBM-PC (or compatible) progam allows the user to calculate circuit noise using LTC op amps, determine the best LTC op amp for a low noise application, display the noise data for LTC op amps, calculate resistor noise, and calculate noise using specs for any op amp.

SPICE MACROMODEL DISK

This IBM-PC (or compatible) high density diskette contains the library of LTC op amp SPICE macromodels. The models can be used with any version of SPICE for general analog circuit simulations. The diskette also contains working circuit examples using the models, and a demonstration copy of PSPICE™ by MicroSim.

FILTERCAD DISK

FilterCAD is a menu-driven filter design aid program which runs on IBM-PCs (or compatibles). This collection of design tools will assist in the selection, design, and implementation of the right switched capacitor filter circuit for the application at hand. Standard classical filter responses (Butterworth, Cauer, Chebyshev, etc.) are available, along with a CUSTOM mode for more esoteric filter responses. SAVE and LOAD utilities are used to allow quick performance comparisons of competing design solutions. GRAPH mode, with a ZOOM function, shows overall or fine detail filter response. Optimization routines adapt filter designs for best noise performances or lowest distortion. A design time clock even helps keep track of on-line hours.

Technical Books

Linear Databook — This 1,600 page collection of data sheets covers op amps, voltage regulators, references, comparators, filters, PWMs, data conversion and interface products (bipolar and CMOS), in both commercial and military grades. The catalog features well over 300 devices. $10.00

Linear Applications Handbook — 928 pages chock full of application ideas covered in-depth through 40 Application Notes and 33 Design Notes. This catalog covers a broad range of "real world" linear circuitry. In addition to detailed, systems-oriented circuits, this handbook contains broad tutorial content together with liberal use of schematics and scope photography. A special feature in this edition includes a 22-page section on SPICE macromodels. $20.00

Monolithic Filter Handbook — This 232 page book comes with a disk which runs on PCs. Together, the book and disk assist in the selection, design and implementation of the right switched capacitor filter circuit. The disk contains standard filter responses as well as a custom mode. The handbook contains over 20 data sheets, Design Notes and Application Notes. $40.00

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