LINEAR TECHNOLOGY

DESIGN NOTES

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A Simple Ultra-Low Dropout Regulator

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Linear voltage regulators with low dropout characteristics are a frequent requirement, particularly in battery powered applications. It is desirable to maintain regulation until the battery is almost entirely depleted. Regulator dropout limits significantly impact useful battery life, and as such should be minimized. Figure 1 shows dropout characteristics for a monolithic regulator, the LT1085. The <1.5V dropout performance is about twice as good as standard monolithic regulators. In many cases this device will serve nicely, but applications requiring lower dropout mandate a different approach.

Figure 2's simple regulator has only 85mV dropout at 2.5A — a 13x improvement. At lower currents dropout decreases to vanishingly small values. This circuit is particularly applicable in battery driven lap top computers, where multi-output power supplies are used. In operation, the LT1431 shunt regulator adjusts its output ("collector") to whatever value is required to force circuit output to 5V. The LT1431's internal trimming eliminates the usual feedback resistors and trimpots. Q1, the pass element, runs as a voltage overdriven source follower. This configuration offers the lowest possible dropout voltage,* although it does require a +12V bias source for Q1's gate. This +12V source is commonly present in lap top computers and similar devices because of disc drive and peripheral power requirements. Power drain on the +12V supply is a few milliamperes.

*A detailed discussion of various methods for achieving low dropout appears as Appendix A ("Achieving Low Dropout") in LTC Application Note 32, "High Efficiency Linear Regulators."

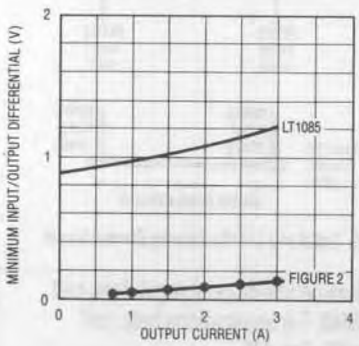

Figure 1. Dropout Performance for a Low Dropout Monolithic Regulator vs Figure 2

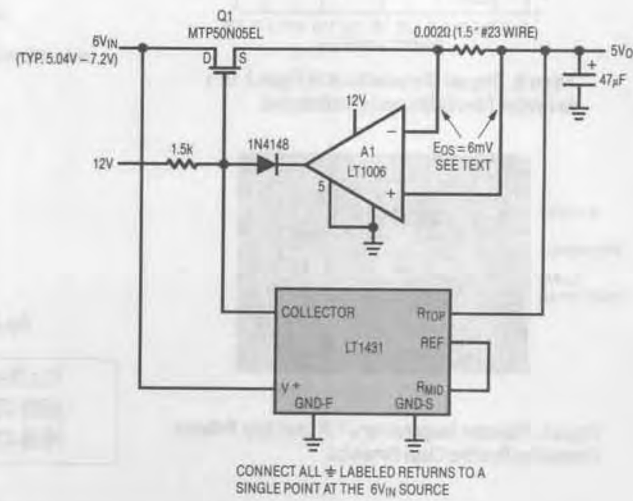

Figure 2. Ultra-Low Dropout Regulator

Providing short circuit protection without introducing significant loss requires care. A1 achieves this by sensing across a 0.002Ω shunt (1.5″ of #23 wire). This introduces only 6mV of drop at the circuits 3A current limit threshold. A 6mV current limit trip point is derived by grounding A1's offset pin 5. The 6mV input offset generated at A1 by doing this is stable over time, temperature and unit-unit variation, and substitutions for A1 are not advisable. Currents beyond 3A cause A1 to pull low, stealing Q1's gate drive and shutting off the regulators output. Under overload conditions A1 and Q1 form a well controlled linear current control loop with smooth limiting. Figure 3 details dropout characteristics. Results for the MTP50N05EL MOSFET specified for Q1 show only 85mV dropout, decreasing to just 8mV at 0.25A. For comparison, data for some higher resistance transistors also appears.

Q1's source follower connection makes regulator dynamics quite good compared to common source/emitter approaches. Figure 4 shows no load (Trace A low) to full load (Trace A high) response. Regulator output (Trace B) dips only 200mV and recovers quickly with clean damping. The positive slew recovery time is due to the 1.5kΩ bias resistor acting against Q1's input capacitance (Trace C is Q1's gate). Quicker response is possible by a reduction in this value, although current drain from the +12V supply will increase. The value used represents a good compromise. Transient recovery for load removal is also well controlled.

This regulator offers a simple solution to applications requiring extremely low dropout over a range of output currents. The performance, low parts count and lack of trimming make it an attractive alternative to other approaches. For reference, pertinent information on construction of wire shunts appears in Figures 5 and 6.

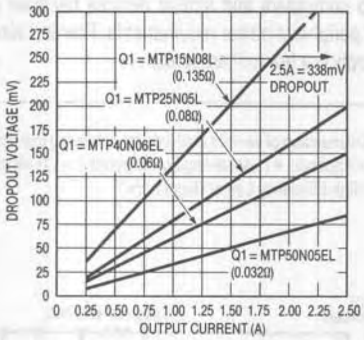

Figure 3. Dropout Characteristics for Figure 2. Q1's Saturation Directly Influences Performance.

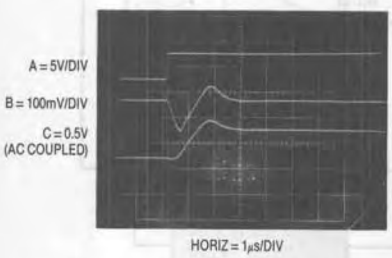

Figure 4. Transient Response for a Full Load Step. Follower Connection Provides Clean Dynamics.

WIRE GAUGE	μΩ/INCH
10	83
11	100
12	130
13	160
14	210
15	265
16	335
17	421
18	530
19	670
20	890
21	1000
22	1300
23	1700
24	2100
25	2700

Figure 5. Resistance vs Size for Various Copper Wire Types

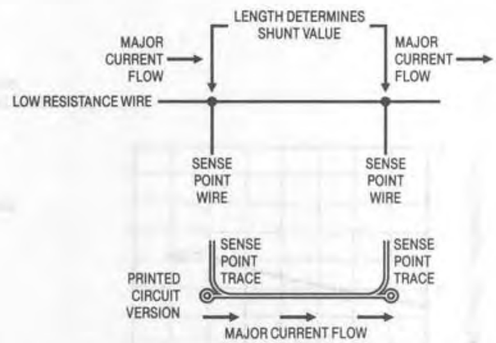

Figure 6. Detail of a Low Resistance Current Shunt

For literature on low dropout regulators, call **(800) 637-5545**. For applications help, call (408) 432-1900, Ext. 445.