LDO Linear Regulators Rival Switchers for Efficiency

by Tom Gross

Introduction

Switching power supplies owe much of their popularity to their efficiency, even when the distinction is not necessarily deserved. For instance, when low voltage input supplies are available, and currents are around an amp or so, a less complex low dropout linear regulator can match the efficiency of a switcher. Furthermore, if the design is limited to all surface mount applications, with heat sinking provided by the board, a linear regulator can provide switcher-like efficiency over a fairly wide range of input voltages.

For example, a linear regulator provides excellent efficiency in a 1.8V-to-1.2V application. Even at 2A of output current, only 1.2W of power is dissipated. This is sufficiently low enough for a multi-layer board to provide adequate heat sinking.

Thermal Limitations

While efficiency is always quoted as a benchmark for switching regulators, power loss is often more important. Power loss sets the size of the heat sink, and the size of the heat sink is—more than any other component—directly related to the size of the board.

Linear regulators are about simplicity, so their advantages are clearest in designs where no more than the multi-layer circuit board is needed to provide heat sinking. To a first approximation, a multi layer board can dissipate power at 40°C per watt. If we want to limit the regulator maximum temperature to 125°C, 1W of dissipation allows an ambient temperature of 85°C. An ambient temperature of 85°C is a conservative design number that satisfies the requirements of most industrial applications.

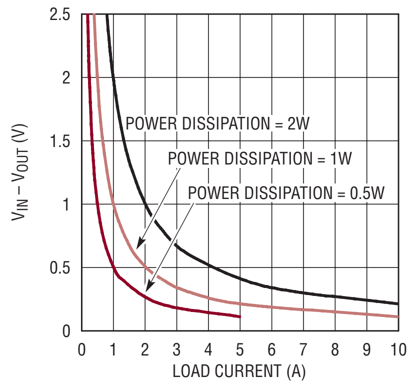


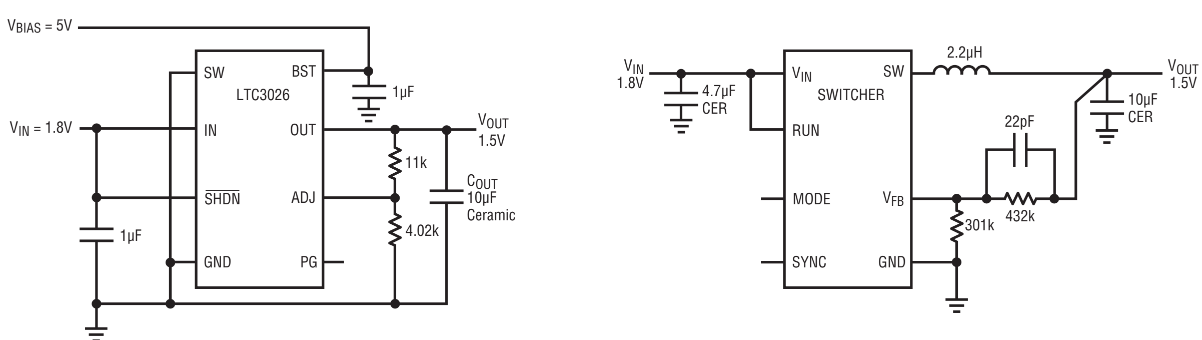
Figure 1. Various power dissipation limits shown as a function of load current and input-to-output differential voltage.

At low input and output voltages, linear regulators offer excellent regulation, and in many cases, deliver efficiency rivaling that of switching regulators. In all cases a linear regulator circuit is simpler and less costly.

The amount of output current that the linear regulator can deliver depends on the input-to-output differential voltage and the power loss limitations. For instance, in a 2.5V-to-1.5V design, the 1V differential voltage allows for 1A of load current to meet the 1W dissipation requirement (see Figure 1). If the differential voltage is only 0.7V, as in a 2.5V-to-1.8V regulator, the maximum load current increases to over 1.4A.

Figure 1 shows that there is a wide range of power combinations that can be filled under these circumstances. In surface mount designs, power loss correlates directly to board area as power is usually dissipated through the metal layers. With this in mind, Figure 1 covers a range of linear regulator applications that compare well with switching regulators—which are very efficient at high input-to-output differential voltages, but rarely have better than 75%–80% efficiency at low input-to-output differential voltages.

For instance, consider a low dropout regulator regulating 1.8V-to-1.2V at one amp. With an input-to-output differential of 0.6V, the maximum amount of output current available increases to over 1.5A, at one watt of power dissipation (see Figure 1).



a. b.

Figure 2. Two 1.5V output DC/DC converters. The first (a) is a typical linear regulator using the LTC3026 with an external bias supply. The second (b) is a typical 1.5V switching regulator application. In circuit (a), if an external bias supply is not present, the LTC3026 can generate its own bias with an internal boost converter and an external inductor (10 µH, 150mA).

Increasing the maximum power dissipation to 2W, allows well over 3A of output current. The efficiency of a switching regulator operating under these conditions is typically 75%. The added complexity and cost of a switching regulator makes a linear regulator look even better.

Comparison of a Switcher and Linear Regulator in the Same Application

Compare the two different topologies in a 1.8-to-1.5 volt application. In this design, the power dissipation is low enough that even three amps of output current do not exceed our 1W power limitation. Figure 2a shows a 1.5A application using the LTC3026 CMOS linear regulator. A comparable step-down switching regulator circuit is shown in Figure 2b. Figure 3 compares the efficiencies and power losses of both circuits. As shown, the switching converter is more efficient at low load currents, but the linear regulator efficiency matches, then surpasses, the switcher efficiency as the load current increases. The same is true for the power losses. The linear regulator fares better as load current increases.

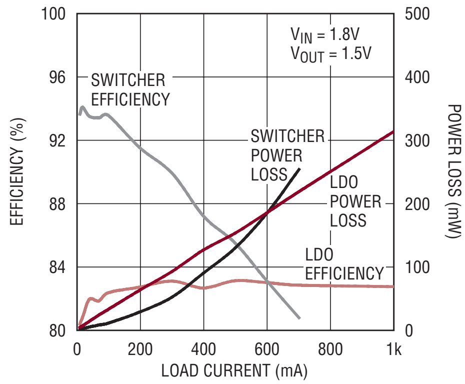


Figure 3. Efficiency and power loss of the LTC3026 linear regulator compare favorably to that of a switching regulator. The LDO maintains good efficiency to 1.5A.

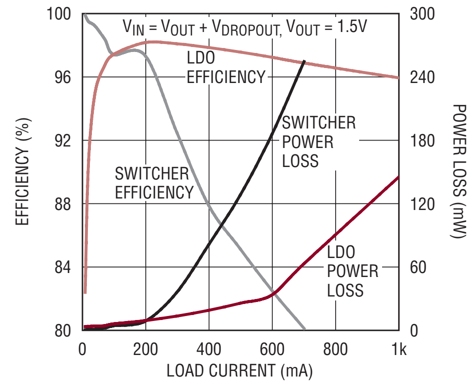


Figure 4. At the lowest input-to-output differential voltage, $V_{IN} = V_{OUT} + V_{DROPOUT}$ and V_{OUT} = 1.5V, the efficiency and power losses of the linear regulator fare even better compared to those of the switching regulator.

As the input-to-output differential voltages decrease, such as occurs in battery-powered applications, the linear regulator efficiency compares even more favorably to the switcher (see Figure 4). For instance, at 500mA of load current, where the dropout voltage of the LTC3026 is only 60mV, the linear regulator is over 97% efficient, whereas the switcher efficiency is around 85%. In this case, the linear regulator beats the switcher in all aspects—efficiency, power loss, size, simplicity and cost.

Conclusion

At low input and output voltages, linear regulators offer excellent regulation, and in many cases, deliver efficiency rivaling that of switching regulators. In all cases a linear regulator circuit is simpler and less costly. In applications where the board can adequately dissipate the power, linear regulators can handle a reasonable range of inputs and output voltages.