

# DESIGN NOTES

## High Efficiency Power Sources for Pentium™ Processors

Design Note 90

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In many applications, particularly portable computers, the efficiency of power conversion is critical both from the standpoint of battery life and thermal management. Desktop machines may also benefit from higher efficiency, particularly a "green PC." While linear regulators can offer low cost and high performance solutions, they can only offer 67% efficiency in 5V to 3.3V applications. Switching regulators are more efficient and minimize or even eliminate the need for heat sinks at a higher cost for the components. Efficiencies around 90% are routinely obtained with Linear Technology's best regulator designs (see Figure 2). The LTC1148 based circuit (Figure 1) meets the requirements of the P54-VR specification for output voltage transient response with the indicated decoupling network.

### Selection of Input Source

Several options exist as to where to derive raw power for the regulator input. In most desktop systems a large amount of 5V power is available. Also, there is usually a reasonable source of 12V at hand. The 5V supply will most likely have the highest power output capability since it is called upon to power the bulk of the system logic. This logic can be sensitive to voltage changes outside of  $\pm 5\%$ .

When the processor draws large transient currents, the 5V supply will be perturbed. In all "buck" type switching regulators there is an inductor in the path between the raw input supply and the load. This has the effect of limiting the rise time of the input currents and minimizing the disturbance to the 5V supply. However, the typical cheap off-line "brick" supply has terrible transient response, and the 5V

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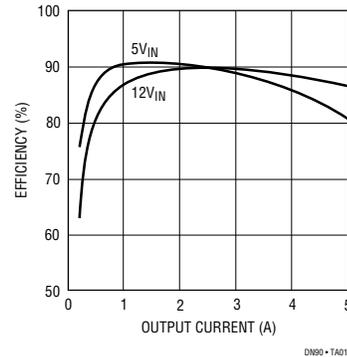


Figure 2. Efficiency vs Load

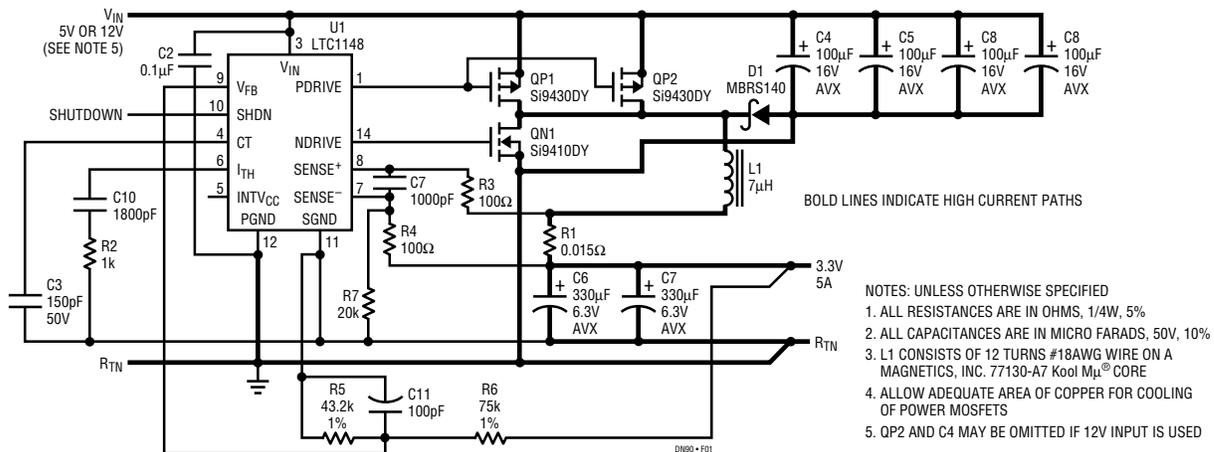


Figure 1.

supply may still be disturbed enough to cause logic problems. This is especially true as the load currents rise to the levels expected in multiprocessor systems.

If this is the case, using the 12V supply may prove advantageous. Since the 12V supply is not directly regulated, nothing that is terribly sensitive to voltage level is normally powered off the 12V bus. Moreover, with switching regulators, as a first order approximation, as the supply voltage rises the input current drops. As such, even though the input power is nominally the same whether running from a 5V or 12V supply, the current requirement is much lower if 12V is utilized for the input source.

The downside of 12V operation is lower light load efficiency than 5V operation. The efficiency with a 5V input powering a 3.3V switcher is likely to be several percentage points better than at 12V due to a reduction in switching losses. Every situation is somewhat different and a thorough analysis of the trade-offs must be undertaken to optimize the design. The schematic shown in Figure 1 offers the option to run from several supply choices. Each circuit was optimized for the specified input voltage, but will function well over a fairly wide range of supply voltages.

### Transient Response Considerations

As with a linear regulator, the first several microseconds of a transient are out of the hands of the regulator and dropped squarely in the lap of the decoupling capacitor network. In the case of the switcher, the ultimate response of the regulator will be quite slow compared to a linear regulator. In the circuits shown, the approximate time required to ramp the regulator current to equal the high load condition is 11 $\mu$ s, about 2.4 times that of an LT1585 high speed linear regulator in the same application. This means in layman's terms, that the LT1585 linear regulator requires less bulk capacitance than the LTC1148 switcher solution.

### Circuit Operation

Figure 1 is a schematic of the two regulators. For the 12V input, omit QP2 and C4. The design is a standard synchronous buck regulator that is discussed in detail in several Linear Technology Application Notes as well as the LTC1148 data sheet. Since the required output voltage is not the standard 3.3V, which is available factory set, an adjustable regulator is used. R5 and R6 set the output voltage to the desired level, in this case 3.38V. R7 is used to inhibit Burst Mode™ operation at light loads. If the system were permitted to operate in Burst Mode, the

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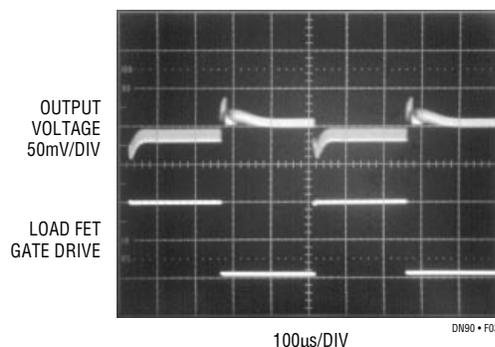
output voltage would rise by about 50mV at low load currents. If added low load efficiency is desired and the slightly higher low load output voltage can be tolerated, this resistor can be omitted.

To meet the transient requirements of the P54-VR, a fairly large amount of capacitance is needed beyond what is required to make the regulator function correctly. A viable decoupling scheme is to use 10 each, 1 $\mu$ F surface mount ceramics and 7 each, 220 $\mu$ F, 10V surface mount tantalums at the processor socket. In addition to the socket decoupling, two pieces of a 330 $\mu$ F, 6.3V surface mount tantalums are required at the power supply.

The input capacitors were selected for their ability to handle the input ripple current. At a 5A load current this is a little over 4A with a 5V input and 2.6A for a 12V input. The capacitors are rated at slightly over 1A each at 85°C. If the input can be switched on very rapidly, the input capacitor voltage rating should be at least two times the supply voltage to prevent dV/dt failures.

By running the operating frequency at 150kHz, the small inductor used is sufficient. Also, since the design is synchronous, the ripple current may be permitted to get quite high without causing any problems for the regulator control loop. This would not be true in a non-synchronous design. A major advantage of high ripple current is the regulator's ability to ramp output current rapidly. The rate of rise of output current is directly proportional to input/output differential and inversely proportional to the inductor value. Using a small inductor aids in achieving fast response to transients.

5V Input, 0.2A to 4A Load Step



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