LINEAR TECHNOLOGY

DESIGN NOTES

Fast Regulator Paces High Performance Processors

Design Note 87

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New high performance microprocessors require a fresh look at power supply transient response. Pentium™ processors, for example, have current demands that go from a low idle mode of 200mA to a full load current of 4A in 20ns. A transition of the same magnitude occurs as the processor reenters its power saving mode. In addition, the overall supply tolerances have been narrowed significantly from the traditional ±5% for 5V supplies and include transient conditions. When all possible DC error terms are accounted for, the transient response of the power supply when subject to the load step mentioned above must be within ±46mV!

To address this problem Linear Technology has developed the LT1585 linear regulator. It features 1% initial accuracy, excellent temperature drift and load regulation, and virtually perfect line regulation. Complementing superb DC characteristics, the LT1585 exhibits extremely fast response to transients. The regulator is offered as an adjustable regulator requiring two resistors to set the operating point, as well as fixed versions which have been trimmed and optimized for 3.3V, 3.38V, 3.45V, and 3.6V outputs. Fixed versions are fully specified for worst-case DC error bounds; in adjustable designs the effects of the external voltage-setting resistors must be taken into account.

Transient response is affected by more than the regulator itself. Stray inductances in the layout and bypass capacitors, as well as capacitor ESR dominate the response during the first 400ns of transient. Figure 1 shows a bypassing scheme developed to meet all of the requirements for the Intel P54C-VR microprocessor. Multiple capacitors are required to reduce the total ESR and ESL, which affect the transient response.

Input capacitors C1 and C2 function primarily to decouple load transients from the 5V logic supply. The values used here are optimized for a typical 5V desktop computer "silver box" power supply input. C5 to C10 provide bulk capacitance at low ESR and ESL, and C11 to C20 keep the ESR and ESL low at high (>100kHz) frequencies. C4 is a damper and it minimizes ringing during settling.

A good place to locate the surface mount decoupling components is in the center of the Pentium socket cavity on the top side of the circuit board. Consider using concentric rings of power and ground plane on the top layer of the board within the socket center for bussing the

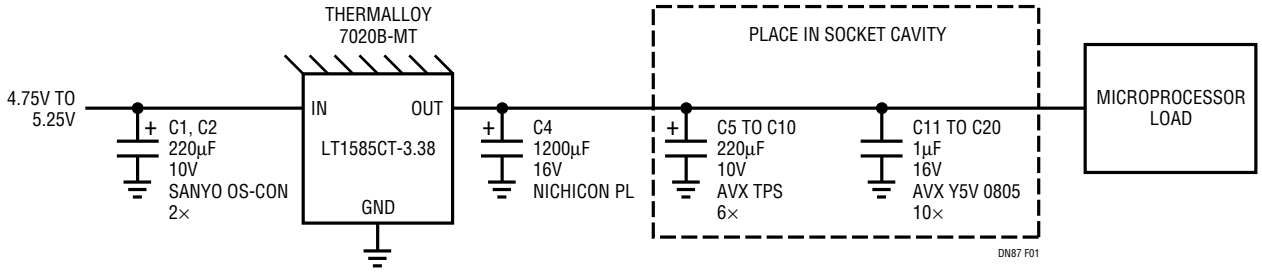

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Figure 1. Recommended Bypassing Scheme for Correct Transient Response

capacitors together. Tie the main power and ground planes to these cavity planes with a minimum of two vias per capacitor. This will minimize parasitic inductance. The regulator and damper capacitor should be located close to (<1") the microprocessor socket to minimize circuit trace inductance.

Verifying the regulator and microprocessor layout can be accomplished with a controlled load such as the Power Validator™ manufactured by Intel. This device plugs directly into the microprocessor socket and simulates worst-case load transients conditions.

An oscilloscope photograph of the LT1585's response to a worst-case 200mA to 4A load step is shown in Figure 2. Trace C is the load current step, which is essentially flat at 4A with a 20ns rise time. Trace A is the output settling response at 20mV per division. Cursor trace B marks –46mV relative to the initial output voltage. At the onset of load current, the microprocessor socket voltage dips to –38mV as a result of inductive effects in the board and capacitors, and the ESR of the capacitors. The inductive effects persist for approximately 400ns. For the next 3µs the output droops as load current drains the bypass capacitors. The trend then reverses as the LT1585 catches up with the load demand, and the output settles after approximately 50µs.

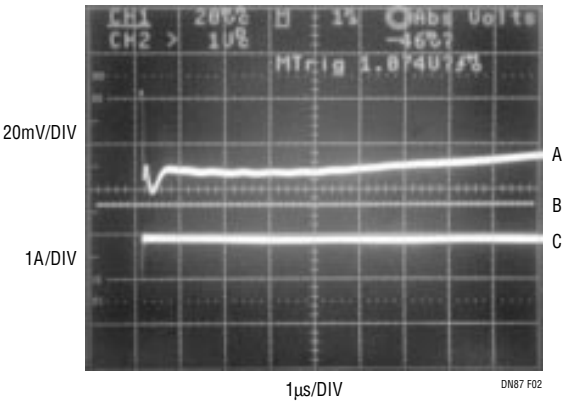

Figure 2. Transient Response at Onset of 4A Load Current Step

Running 4A with a 1.7V drop, the regulator dissipates 6.8W. The heat sink shown in Figure 1, with 100ft/min air flow is adequate for worst-case operating conditions.

The adjustable version of the LT1585 makes it relatively easy to accommodate multiple mircoprocessor power supply voltage specifications (see Figure 3). To retain the tight tolerance of the LT1585 internal reference, 0.5% adjustment resistors are recommended. R1 is sized to carry approximately 10mA idling current (≤124Ω), and R2 is calculated from:

$$R2 = \frac{V_O - V_{REF}}{\frac{V_{REF}}{R1} + I_{ADJ}}$$

where:

I_{ADJ} = 60µA and V_{REF} = 1.250V

Figure 3 shows the connections for R1 and R2. Note that C5 to C10 are reduced in value from Figure 1 without compromising the transient response. The addition of C3 makes this possible and also eliminates the need for C4.

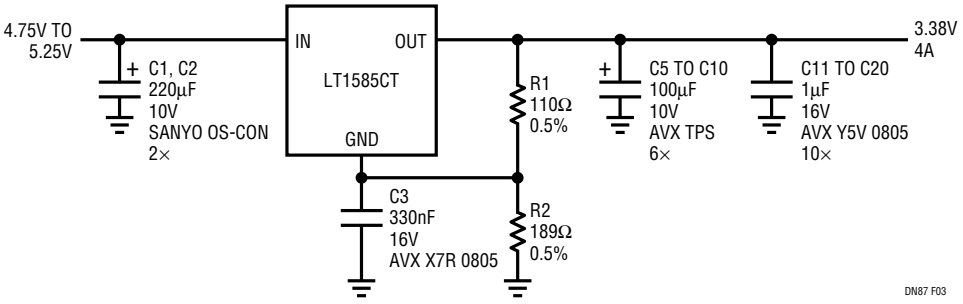

Figure 3. Recommended Adjustable Circuit

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