Power for Pentium® Processors; Meeting VRE Requirements

Craig Varga

Introduction

Providing power for the Pentium® microprocessor family is not a trivial task by any means. In an effort to simplify this task we have developed a new switching regulator control circuit and a new linear regulator to address the needs of these processors. Considerable time has been spent developing an optimized decoupling network. Here are several circuits using the new LTC®1266 synchronous buck regulator control chip and the LT®1584 linear regulator to provide power for Pentium processors and Pentium VRE processors. The Pentium processor has a supply requirement of 3.3V ±5%. The Pentium VRE processor requires 3.500V ±100mV.

The circuits shown here are designed to supply worst-case specification voltages to the Pentium VRE processor over line, load, transient and temperature. At first glance it may seem that simpler circuits, such as 3-terminal regulators, can provide this function. Worst-case analysis shows the margin to be too small (or negative) to ensure adequate operation over a wide production range. The combination of tight tolerance, tight transient response and large production volumes requires designs with adequate margin to ensure proper operation over the product's life. Failure of this circuit to provide proper power supply voltages can result in intermittent machine lock-up, freezes or erratic operation. There are no self-test software routines which can exercise the power supply over the entire expected combination of load, line and temperature conditions.

LTC1266 Drives N-Channel MOSFETs

The LTC1266 controller offers several advantages over its predecessors. It will drive all N-channel MOSFETs instead of requiring P-FETs for the high side switches. This lowers cost and improves efficiency. It also has a higher gain error amplifier which results in improved load regulation when compared to the LTC1148 family. There is also an undedicated comparator which may be used for a power good monitor, an overvoltage detector or an undervoltage lockout in these applications. There is a shutdown pin and a new burst inhibit function. Burst Mode™ operation is inhibited on all the designs shown here, however for the Pentium processor supplies (non VRE parts) Burst Mode operation may be enabled if desired. This is done by tying Pin 4 low. The reference tolerance available on the LTC1266 (or any other PWM controller for that matter) is not accurate enough to meet the Pentium VRE processor specification. The LT1431 however, does have a sufficiently accurate reference for these applications and permits very effective remote sensing capability (see Figure 2). Do not enable Burst Mode operation on Pentium VRE processor supplies as the circuits shown will not operate correctly at no load.

Handling the Load Transients

The Pentium processor has several habits which require careful attention if the circuit is to be reliable. The main problem is the load transients which the processor generates. The load can go from a low power (200mA) state to nearly 4A in two clock cycles or 20ns. While this is going on, the supply voltage must be held within the specification limits. The Pentium VRE processor specification is ±2.9% tolerance. This specification includes line, load, temperature regulation and initial set point tolerances as well as transient response. As may be imagined, meeting these requirements is not easy. With only 2.9% total deviation from the ideal voltage allowed, the static specifications (line, load, temperature and initial set point) must be held to approximately ±1% if any amount of transient response is to be permitted at all. Realistically, approximately 60mV peak transient response is obtainable. To achieve this, a large amount of low ESR tantalum capacitor must be installed as close to the processor as possible. The microprocessor socket cavity is the best place. As an absolute

minimum, use four pieces of a 100µF, 10V AVX type TPS tantalum. If more height is available, such as with a ZIF socket, it is preferred to use four each, 220µF, 10V parts instead. With the 100µF parts there is very little margin in the design. Also, do not reduce the quantity of the capacitors if going to a larger value. The ESR specifications are the same for the 100µF, 220µF and 330µF capacitors. The reason for paralleling four capacitors is to reduce the ESR as well as providing bulk capacitance. In the case of standard Pentium processor (non VRE) applications, if the above capacitor recommendations are followed, the circuits without the LT1431 (Figures 1 and 3) may be used successfully. In all cases there should be a minimum of 24 pieces of a 1µF ceramic capacitor to decouple the high frequency components of the transient. (Intel recommends 24 each, 1µF X7R ceramic capacitors for high frequency bypass.)

Circuit Board Layout Considerations

All the capacitors in the decoupling network should be installed on power and ground plane areas on the topside of the board. An absolute minimum of one feedthrough per end for each capacitor into the internal power and ground plane should be used. It is preferred to use two feedthroughs per capacitor end (112 total). Any more than 64 proves to be of no benefit for transient improvement, but will still help attenuate very high frequency noise. At 30 feedthroughs total, expect about a 2mV increase in transient droop. This is about a 5% degradation in performance. Decoupling capacitors should be connected with planes rather than traces. The traces will be far too inductive. The total network ESR must be less than 0.0065Ω and ESL less than 0.07nH for the Pentium VRE processor.

Input Capacitance

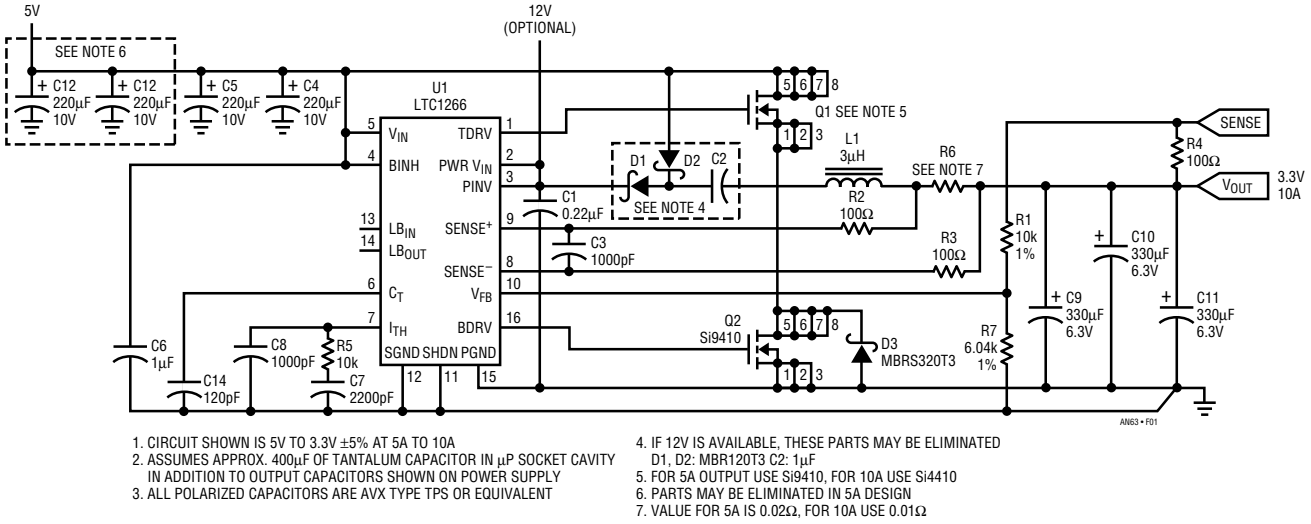
Another important consideration is the amount of capacitance on the power supply input. For switchers, the ripple current rating must be high enough to handle the regulator input ripple. In addition, this capacitance will decouple the load transients from the 5V supply. If insufficient capacitance is used, the disturbance on the 5V supply will exceed the ±5% specification for the TTL logic powered by this voltage. Since the magnitude of this disturbance is quite dependent upon the nature of the 5V power supply, and the performance of these supplies varies widely, it is difficult to say just how much capacitance is needed. In general however, if enough capacitance is present to handle the ripple current, the disturbance on the 5V supply will be acceptable. Good transient response on the 5V supply translates to a need for less input capacitance. If sufficient bulk capacitance is present on the motherboard for the 5V supply, less additional capacitance will be required on the processor supply input. As a minimum there should be at least one low ESR capacitor within an inch of the regulator. Be careful to look at the level of disturbance on the 5V supply to make sure the 5V remains within specifications.

Powering the Pentium Processor

The same basic circuit is used for both the 5A and 10A switcher designs. The necessary substitutions are shown on the schematic, Figure 1. If 12V is available to power the LTC1266, the bootstrap capacitor and diodes may be eliminated. The 12V solution is preferred as it is simpler and somewhat more efficient. If no 12V is available, use the bootstrap circuit. Note also that different MOSFETs are specified for the 5A and 10A circuits. The Si4410 offers less than 1/2 the ON resistance of the Si9410 shown for the 5A circuit.

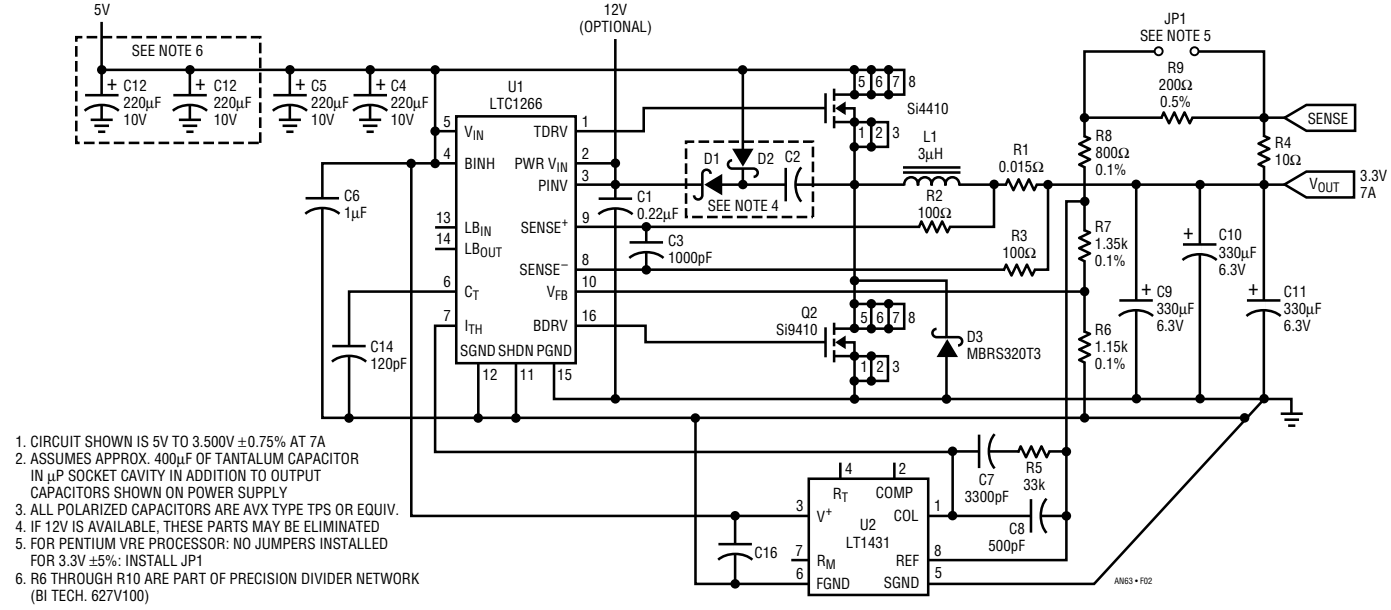
High Accuracy Switcher Solution—Basics of Operation

The solution for the Pentium VRE processor relies on the accuracy of the LT1431 (see Figure 2). The internal reference is specified at 2.5V ±0.4% worst-case at 25°C. The bulk of the parts produced is closer to ±0.2%. This device consists of a precision reference and a wide bandwidth amplifier with an open-collector output. The feedback divider is set to place the Reference Input pin at 2.5V with the desired output present. The 2.5V is further divided to 1.15V to drive the LTC1266 V_{FB} pin. This pin will normally want to sit at 1.25V. As such, the LTC1266 sees the output as being too low and tries to force its internal error amplifier to the positive rail, which is 2.0V. This output shows up as a current out of the I_{TH} pin. The open-collector of the LT1431 pulls enough current from this pin to set the output of the supply at the desired voltage. Since this constitutes a high gain servo loop, the output is regulated very accurately. Loop compensation is accomplished by R5, C7 and C8. The internal error amplifier of the LTC1266 will function as an overvoltage protection loop should the LT1431 ever fail.



1. CIRCUIT SHOWN IS 5V TO 3.3V ±5% AT 5A TO 10A
2. ASSUMES APPROX. 400µF OF TANTALUM CAPACITOR IN µP SOCKET CAVITY IN ADDITION TO OUTPUT CAPACITORS SHOWN ON POWER SUPPLY
3. ALL POLARIZED CAPACITORS ARE AVX TYPE TPS OR EQUIVALENT
4. IF 12V IS AVAILABLE, THESE PARTS MAY BE ELIMINATED D1, D2: MBR120T3 C2: 1µF
5. FOR 5A OUTPUT USE Si9410, FOR 10A USE Si4410
6. PARTS MAY BE ELIMINATED IN 5A DESIGN
7. VALUE FOR 5A IS 0.02Ω, FOR 10A USE 0.01Ω

Figure 1. High Current Supply for Standard 3.3V CPUs



1. CIRCUIT SHOWN IS 5V TO 3.500V ±0.75% AT 7A
2. ASSUMES APPROX. 400µF OF TANTALUM CAPACITOR IN µP SOCKET CAVITY IN ADDITION TO OUTPUT CAPACITORS SHOWN ON POWER SUPPLY
3. ALL POLARIZED CAPACITORS ARE AVX TYPE TPS OR EQUIV.
4. IF 12V IS AVAILABLE, THESE PARTS MAY BE ELIMINATED
5. FOR PENTIUM VRE PROCESSOR: NO JUMPERS INSTALLED FOR 3.3V ±5%: INSTALL JP1
6. R6 THROUGH R10 ARE PART OF PRECISION DIVIDER NETWORK (BI TECH. 627V100)

Figure 2. High Precision Microprocessor Supply

Linear Regulators Provide Simple, Low Cost Solution

For the standard Pentium processor, the LT1584 linear regulator will provide very good performance for 5V to 3.3V regulation. The transient response of this regulator is extremely fast as compared to previous 3-terminal regulators and allows the bulk decoupling capacitance for the processor to be minimized.

The circuit in Figure 3 will provide up to 7A at 3.3V. For 5% tolerance systems, use standard 1% resistors for the feedback divider. If however the application is for a Pentium VRE processor-based system, the DC accuracy of the regulator is not guaranteed to meet the specification requirements under all combinations of line, load and temperature. If typical specifications are used, the regulator will meet requirements, but worst-case calculations reveal larger tolerances than needed to ensure 100% specification compliance. To address this issue, the circuit shown in Figure 4 can be used. With the addition of the LT1431, the reference tolerance is less than half that specified for the LT1584. Temperature effects are nearly eliminated since the LT1431 stays at box ambient rather than the elevated

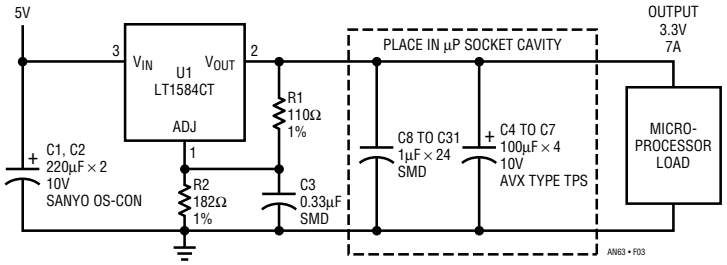


Figure 3. Low Parts Count Linear Supply

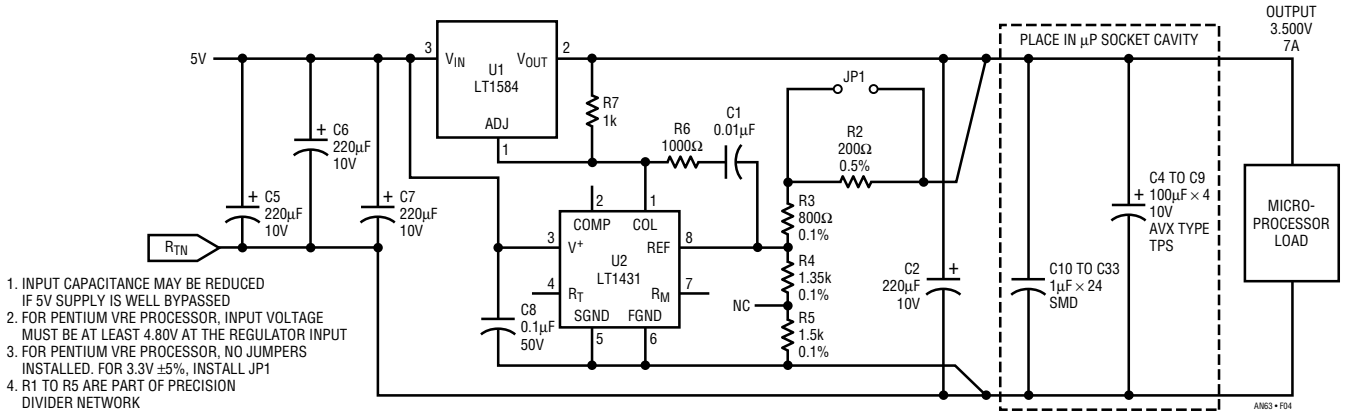


Figure 4. High Precision Linear Regulator

temperature experienced by the internal reference of the LT1584. Also, remote sense is now possible, so any static distribution losses are corrected. This also eliminates problems which may be caused by connector pin contact resistance increasing with time. This circuit also exhibits improved transient response compared to the LT1584 by itself. As a caveat, the minimum input voltage required to meet the Pentium VRE processor output specifications from 25°C and up is 4.80V measured at the regulator input.

The circuit operates by forcing the LT1584 ADJ pin voltage to whatever voltage is required to obtain the desired output voltage. Since R7 is across the 1.25V ADJ to V_{OUT} reference of the LT1584, it acts like a current source. Pin 1 of the LT1431 has an open-collector output which can sink this current to ground and therefore control the ADJ pin to ground voltage. A feedback divider from output to the LT1431 REF pin sets this pin at 2.500V. The internal amplifier in the LT1431 has a very high gain in this configuration, hence static errors are nearly nonexistent. Moreover, since this amplifier is also quite fast, the ADJ pin can be moved further than the actual disturbance caused by a load transient. Thus, a significant response time improvement may be realized with this scheme over an LT1584 by itself.

Conclusion

The Pentium microprocessor offers some interesting challenges to the power system designer. In an attempt to run at higher clock speeds the power supply voltage specifications have gotten tighter and stop clock power saving modes have introduced severe load transients not present in previous generations of processors. However, with careful attention to detail, both in component selection and mechanical layout, the performance required may be obtained. Also, with properly designed switchers, the need for high efficiency can be met while providing the required dynamic performance.

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487
(408) 432-1900 • FAX: (408) 434-0507 • TELEX: 499-3977
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