



A Low Cost Dynamic VID Power Supply for Pentium® III Processors

INTRODUCTION

The latest Pentium® III mobile processors announced by Intel require a 2-level power supply voltage that must be dynamically switched. A power supply that satisfies these requirements can be constructed using a DC/DC controller containing an internal 5-bit DAC. However, substantial external circuitry is still required to switch between the two operating voltages. This paper presents a new solution that satisfies Intel's dynamic VID requirements, but with lower cost, smaller PCB area and better performance than competing solutions.

Many notebook computer manufacturers also prefer the VID feature because it provides flexibility to change output voltages to support future Intel processors, as well as processors from AMD and Cyrix. When using a DC/DC converter with a built-in 5-bit DAC, the output voltages must be changed by modifying jumpers or zero-ohm resistors on the motherboard. The alternative solution presented in this paper also provides complete voltage flexibility by simply changing the value of two resistors. In fact, even greater flexibility is available, since voltages are not limited to those specified in the 5-bit VID table.

DYNAMIC VID USING THE MAX1711

The MAX1711 data sheet (Rev. 0; 11/98) shows an example of a mobile VID power supply (see Figure 1). Most of the Figure has been taken directly from Maxim's data sheet (Figure 10, page 24); a 5-bit multiplexer and jumpers have been added since they are required for dynamic control of the output voltage.

This circuit is complex and expensive for the following reasons (quotations are taken directly from the MAX1711 data sheet):

1. POWER_GOOD Generation

The POWER_GOOD signal must go low during each change in output voltage. This is true whether changing from low to high or high-to-low. The POWER_GOOD

signal must stay low until the new output voltage has settled within specifications, but must not remain low for more than 100 μ s.

The MAX1711 data sheet states: "The internal PGOOD detector circuit monitors only output undervoltage; PGOOD will probably go low during upward transitions, but not downward." For this reason, a transition detector and timer circuit must be added.

2. Rapid Output Voltage Change

The CPU core power supply output voltage must adjust to the new programmed value in less than 100 μ s. In order to meet this requirement, the MAX1711 must be forced into PWM mode for a high-to-low voltage transition. The MAX1711 data sheet states: "If the minimum load is very light, it may be necessary to assert forced PWM mode (via SKIP) during the transition period to guarantee some output sink current capability. Otherwise, the output voltage won't ramp downwards until pulled down by external load current." External circuitry must be added to drive the SKIP pin high during voltage transitions.

3. Fast Transient Response

Powering a Pentium III processor demands extremely good transient response from the DC/DC converter. Linear Technology's OPTI-LOOP™ compensation technology allows use of fewer output capacitors, and without ESR limitations. Maxim explains the difficulty an engineer faces when trying to meet these requirements without OPTI-LOOP: "Selecting the output capacitors in dynamically adjusted VCORE applications can be tricky due to trade-offs between capacitor capacity and ESR...It may be necessary to mix capacitor types or use specialized capacitors such as those shown in Figure 7 in order to achieve the required ESR while staying within the min/max capacitance value window."



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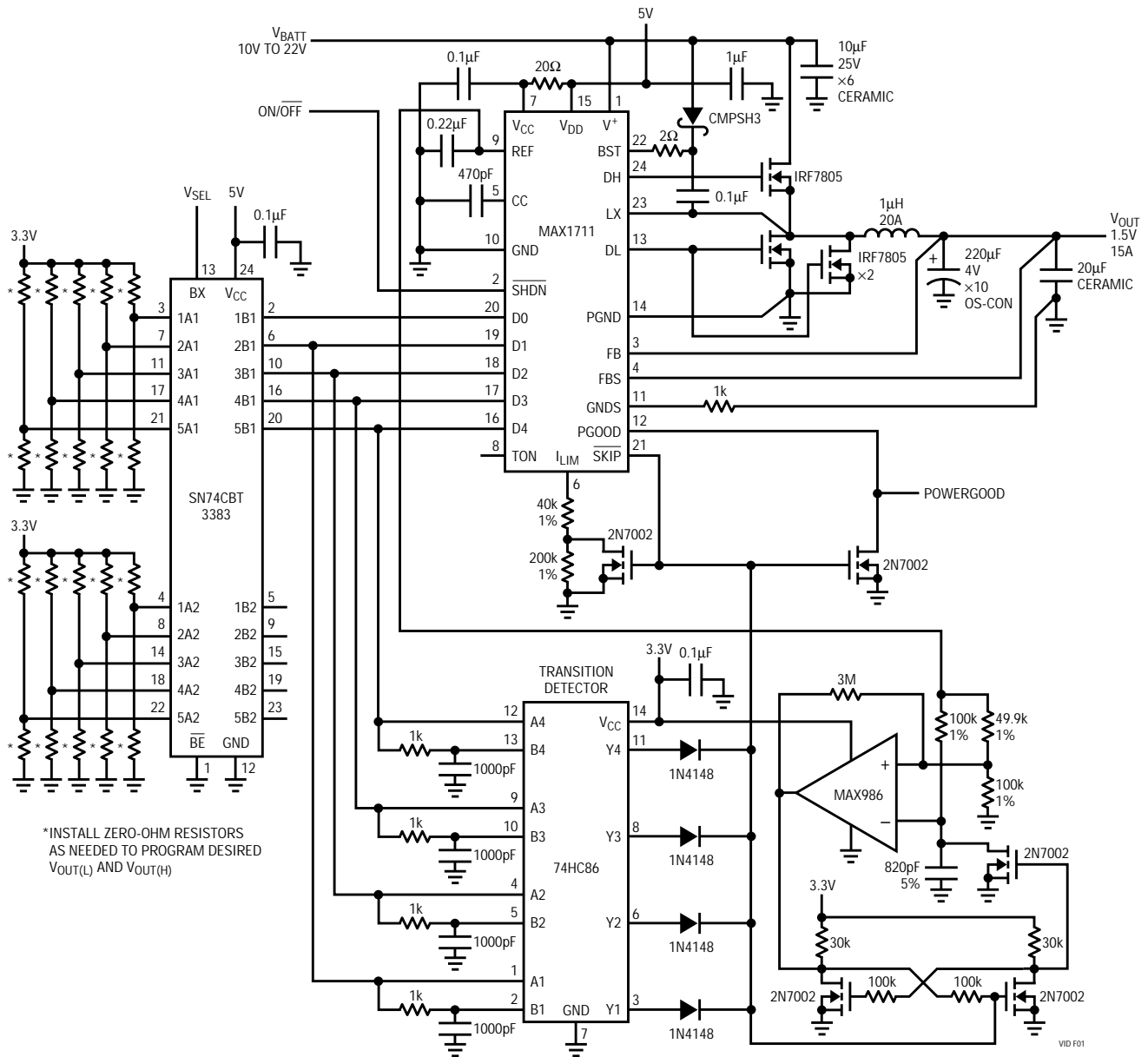


Figure 1. MAX1711 Dynamic VID Implementation Requires Additional Circuitry for Operation

Figure 7 in the MAX1711 data sheet shows $6 \times 47\mu\text{F}$ ceramic output capacitors in parallel. However, because the ESR of these capacitors is too low for feedback loop stability, the user must also insert at least $5\text{m}\Omega$ of PCB trace resistance in series with the high current path. This PCB trace resistor consumes PCB area and also *reduces the DC/DC converter efficiency by 3.5% with a 10A load!*

The dynamic VID circuit shown in the MAX1711 data sheet (Figure 10, page 24) uses $10 \times 220\mu\text{F}$ OS-CON capacitors plus a $20\mu\text{F}$ ceramic capacitor on

the output. This is expensive and consumes considerable PCB area.

4. Inrush Current Limiting

Using large amounts of output capacitance has another side-effect: very large current pulses are required to change the output voltage. The MAX1711 data sheet states: "attempting to slew the output upward quickly causes large current surges at the battery as the IC goes into output current limiting during the transition."

This is particularly troublesome in the case of the MAX1711 for two reasons: 1) large output capacitance means more charge must be transferred to change the output voltage, and 2) output current limiting is very inaccurate. This second problem is a result of using the lower MOSFET $R_{DS(ON)}$ for current limiting. The resultant wide current limit tolerance means that current drawn from the battery during a low-to-high transition may be much more than the maximum load current. In order to prevent very large surge currents, Maxim's dynamic VID implementation must include extra circuitry to reduce the current limit threshold during voltage changes.

5. Multiplexing VID Values

The MAX1711 accepts a 5-bit VID digital programming word to set the output voltage. However, because this 5-bit input must be switched between two different values, a multiplexer and two sets of jumpers must be connected to the MAX1711's VID input (see Figure 1). Two sets of resistors/jumpers and the 24-pin multiplexer require considerable additional PCB area.

6. Output Overvoltage Protection

The MAX1711 uses a fixed output overvoltage threshold of 2.25V nominal (2.29V maximum). This may be high enough to cause damage to low voltage processors. In addition, if the overvoltage protection ever does activate, a *negative* voltage can be delivered to the processor as the output capacitor discharges and "rings"

below ground. The MAX1711 data sheet states: "If the load can't tolerate being forced to a negative voltage, it may be desirable to place a power Schottky diode across the output to act as a reverse-polarity clamp."

DYNAMIC VID USING THE LTC1735-1

A simple dynamic VID power supply may also be constructed using the LTC1735-1 (see Figure 2). This solution has several important advantages:

- Lower DC/DC converter cost
- Significantly less PCB area is required
- OPTI-LOOP compensation provides better transient response
- Complete output voltage programming flexibility down to $V_{OUT} = 0.8V$
- "Soft-Latch" output overvoltage protection

VID Resistor Selection

Instead of a 5-bit VID DAC, the LTC1735-1 relies on an external 2-range voltage feedback divider. A voltage select signal changes the feedback divider ratio, and, therefore, the programmed output voltage. Any two output voltages may be selected, with V_{OUT} as low as 0.8V. Selecting different output voltages simply requires changing the values of two external resistors. Programming resistors can be modified according to the following simple formulas:

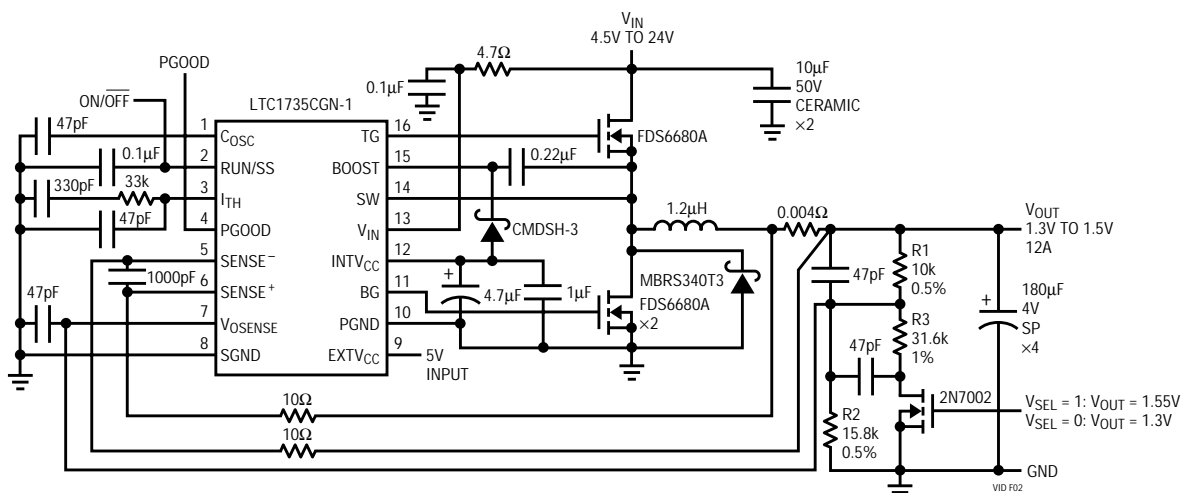


Figure 2. LTC1735-1 Dynamic VID Implementation is Very Simple

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$$R2 = \frac{8k}{V_{OUT(L)} - 0.8V}$$

$$R3 = \frac{8k}{V_{OUT(H)} - V_{OUT(L)}}$$

For a typical case of $V_{OUT(L)} = 1.3V$ and $V_{OUT(H)} = 1.55V$, $R2 = 15.8k$ and $R3 = 31.6k$ as shown in Figure 2. Resistors $R1$ and $R2$ should be 0.5% tolerance, but resistor $R3$ may be 1% tolerance.

POWER_GOOD Operation

The PGOOD signal generated by the LTC1735-1 automatically goes low every time V_{OUT} is changed by the voltage select signal. Because the LTC1735-1's internal power good comparator operates on both low-to-high and high-to-low transitions, no additional circuitry is required. Figures 3 and 4 show the LTC1735-1 making both low-to-high and high-to-low transitions. Figure 3 shows the response with a 100mA load current, while Figure 4 uses a 9A load current. Regardless of the load current, the output voltage completes the voltage transition in less than $30\mu s$, easily meeting the $100\mu s$ specification requirement.

Transient Response

Linear Technology's OPTI-LOOP compensation allows optimization of transient response, without limitations on output capacitor ESR. Figure 5 compares the transient response of the LTC1735-1 with OPTI-LOOP versus the MAX1711. The MAX1711 transient response scope photograph was taken from the MAX1711 data sheet, and uses 3 x $470\mu F$ Kemet T510 tantalum output capacitors.

Output Overvoltage Protection

The LTC1735-1 contains internal overvoltage protection (OVP) circuitry that activates when the output rises to 7.5% above the programmed voltage. The OVP threshold is not a fixed value, but moves as the output voltage is changed. For example, if the output voltage is programmed to 1.55V, the OVP will limit the output to 1.67V.

Linear Technology's exclusive "soft-latch" circuitry provides robust OVP protection, but does not result in negative output voltages as with the MAX1711. Consequently, no power Schottky diode is needed across the output.

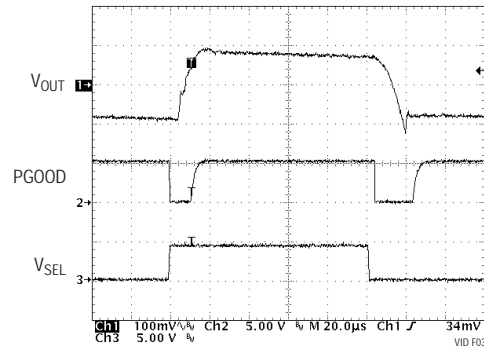


Figure 3. LTC1735-1 Voltage Programming Response at $I_{OUT} = 100mA$

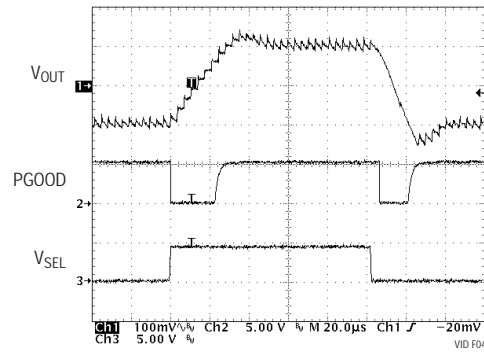


Figure 4. LTC1735-1 Voltage Programming Response at $I_{OUT} = 9A$

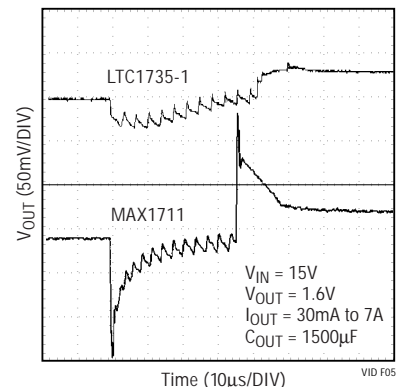


Figure 5. LTC1735-1 vs MAX1711 Transient Response

Demo Board

The LTC1735-1 circuit shown in Figure 2 is available as a demo board (part number DC267). Contact your LTC representative to obtain a sample demo board for evaluation in your own laboratory.