LINFINITY Application Note

AN-6

Power Solutions for Flexible Motherboards

LINFINITY MICROELECTRONICS

Rev. 2.1 07/98

Application Note

INTRODUCTION

As Intel, Cyrix, AMD, IBM and others introduce higher performance microprocessors, power requirements are continuously evolving. Power supplies are migrating to lower voltages, while currents increase. The move to lower voltages is not happening simultaneously, so while the processor manufacturer can dictate core voltages, the I/O section of the processor needs to communicate at the current standard voltage (3.3V). Split plane voltages, currently at 3.3V (I/O) and 2 - 2.8V (CPU core) will remain in a continuous state of change as Moore's Law predicts the rate of change of the processor. Supplying power to the processor, virtually an afterthought in previous times, now becomes a critical element in the design and manufacture of the motherboard.

Facing an increasingly competitive market, designers must create motherboards that are flexible enough to accept a number of processor variants at the lowest cost. Eliminating the need for board re-designs or production line changes to suit different processor power requirements reduces costs.

This application note presents a discussion of the power supply options facing designers, showing low cost flexible motherboard power supply designs, based on Linfinity's LX166x Advanced PWM Controller IC family.

POWER REQUIREMENTS

Most microprocessors require several power supplies:

- CPU core supply (V_{CORE}) – typically 1.8 – 3.3V at 5 - 15A. It is likely that the core supply will drop below 1.8V in the near future. Supplying V_{CORE} is the major challenge, due to the high power levels and stringent transient load change voltage specifications.
- I/O Buffer supply ($V_{I/O}$) – typically 3.3V. With demand for 3.3V power from other circuits such as memory, AGP controllers, chipsets, etc., total demand for current at 3.3V can be 8 – 10A or higher.
- GTL+ Bus supply (V_{TT}) – typically 1.5V at 3 – 5A in Pentium Pro and Pentium II processor systems.
- Clock supply (V_{CLOCK}) – typically 2.5V at 500mA or less in Pentium® II processor systems.

Available Power Sources

The silver box power supply on a typical motherboard supplies only 5V and 12V (at high power levels), although 3.3V is also available in ATX and NLX power supplies. The 5V (and 3.3V, if available) rail can be converted to the required voltage using either a linear regulator, such as Low Dropout (LDO) regulators or a switching regulator.

LINEAR REGULATORS

Three-terminal linear low dropout regulators, such as Linfinity's popular LX8384 series were commonly used for powering 3.3V processors, such as Pentium® processors below 200MHz, due to their ease of use, quality of performance and low system cost. However, there are several limitations of linear regulators as power levels increase.

- The heat generated in a linear regulator is always (V_{IN} - V_{OUT}) * I_{OUT} where V_{IN} is input voltage, V_{OUT} is output voltage and I_{OUT} is load current. As the current increases or the output voltage falls, heat dissipated by an LDO increases! This heat must be removed from the IC to avoid over-heating and circuit failure – heatsink requirements can become both expensive and bulky at high power levels.
- The minimum differential (dropout) voltage limits linear regulators. For most low dropout linear (LDO) regulators, this is around 1.3V. Therefore, standard LDO's cannot be used to convert 3.3 - 2.8V, where a dropout voltage under 0.5V is needed. For applications such as this, a BiCMOS LDO, such as the LX8610/30, can be used instead.

Linear regulators are still the optimal power source for low to medium current 5 – 3.3V or 3.3 – 1.5V conversion for applications such as V_{CLOCK} and GTL+ Bus supplies. They can be used on motherboard or accessory cards where point-of-use power distribution is required. Linfinity's family of low dropout regulators ranges from 500mA to 10A current capability, and is available in a range of surface mount and through-hole packages and in fixed and adjustable voltage versions.

The only external components required with LDO's are input and output capacitors; resistors (to set the output voltage in adjustable LDO's) and a heatsink (this can be PCB copper for surface mount packages at low power levels). For full datasheets, application notes and selection guides, see http://www.linfinity.com.

SWITCHING REGULATORS

Switching regulators usually have higher efficiency than linear regulators, reducing or eliminating the cost and size of heatsink. Switchers do, however, involve a higher de-

gree of complexity in design and layout. Some controllers are very susceptible to noise problems due to poor layout. Switchers are generally more expensive than linear regulators at lower currents, but the benefits of higher efficiency make switching regulators the solution of choice for higher power levels.

Many switching regulators have been specifically designed for microprocessor applications, and are optimized for fast transient response, performance and low cost.

SWITCHING REGULATOR SOLUTIONS

The LX166x family of Advanced PWM Controllers was designed by Linfinity to satisfy the power requirements of microprocessors with a low cost, high performance design requiring a minimum of external components. The controllers use voltage-mode, constant off-time control to achieve fast response and simplify loop compensation. In this technique, the off-time is modulated by the output voltage to provide a virtually fixed frequency of operation. Other key features include:

- Adaptive transient response – at low load, the DC set point is higher than the designated set point by about 40mV. At high loads, the output will be in the lower part of the allowable tolerance window. This technique results in added margin to handle transient load changes. See Figure 1.
- Flexible and accurate current sensing and current limiting to protect against over-current situations. The controllers detect a voltage drop across a resistive current sense element to trigger current limiting. The current sense element can be a sense resistor; a PCB trace resistance or the parasitic resistance of the main inductor. This method eliminates the errors caused by the variation of $R_{DS(ON)}$ and peak current levels, used in some alternative current sense methods. The LX1668 also offers the additional protection feature of hiccup-mode current limiting.
- Programmable output voltage for V_{CORE} by means of 5-bit Voltage Identification (VID) code. The output voltage can be adjusted from 1.30 to 2.05V in 50mV increments, and from 2.1 to 2.5V in 100mV increments. The VID codes correspond to Intel's specifications.
- Integral linear regulator and/or linear regulator driver in many devices. The LX1664/65 and LX1668 have a linear regulator output to drive a MOSFET as the pass element for a LDO, reducing costs by eliminating an LDO or shunt regulator. The LX1668 also has an internal 2.5V fixed LDO, suitable for powering V_{CLOCK}, in addition to the LDO driver.
- Available Power Good signal and Over Voltage Protection crowbar driver to protect against faults such as a short circuit in the upper MOSFET.
- Small package sizes (14-pin SOIC – LX1662; 16-pin – LX1663/64; 18-pin – LX1665 and 20 pin – LX1668). Lin-

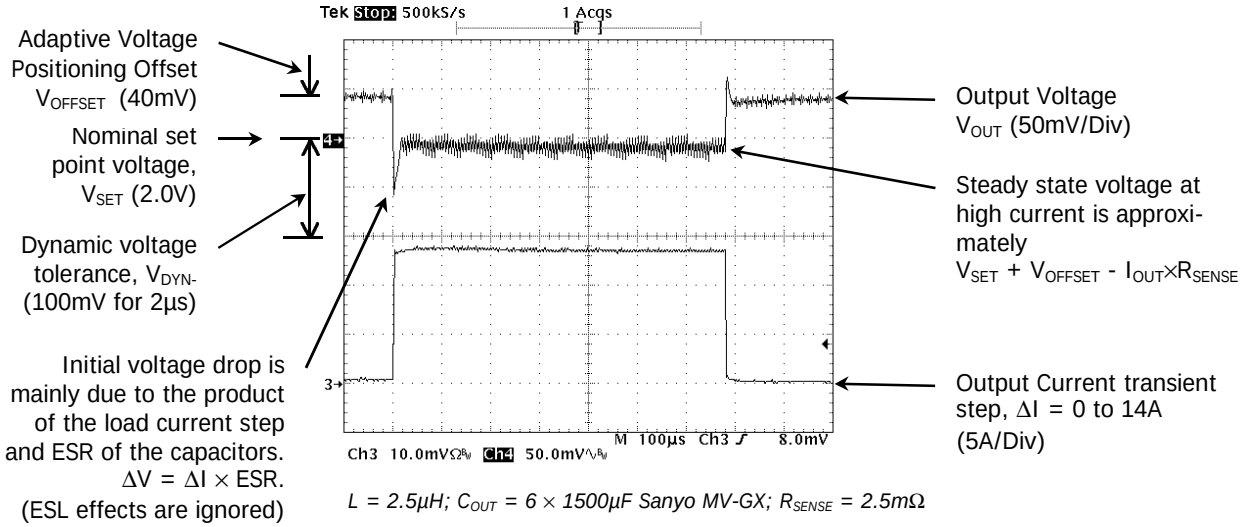

Figure 1: Adaptive Voltage Positioning

finity's controllers have the highest integration in the industry, leading to lower cost and more space efficient designs. The LX1668 is also available in a 20-pin TSSOP package for applications where small size is important.

Controllers for Microprocessor Applications

Linfinity offers controllers with single, dual and triple outputs to suit the requirements of different applications. The controller families are summarized in the table below.

CONCLUSION

It is clear that as processor core voltages continue to decrease and currents increase the heatsink requirements for linear regulators are getting tougher to meet, and linear solutions become more costly. Switching regulators, such as Linfinity's LX166x family, can provide the various voltages at higher efficiency and a lower total system cost. Their programmable outputs enable future processors to be powered with the same power supply.

The following application ideas present typical circuit configurations with key features and bills of material. Full datasheets and application notes can be downloaded from Linfinity's web site at http://www.linfinity.com. Evaluation boards and electronic (Gerber) layouts are available for most devices upon request.

OTHER APPLICATION NOTES

AN Number	Title	Applicable Devices
AN-7	A Simple Current-Sense Technique Eliminating a Sense Resistor	LX166x
AN-8	Hiccup Mode Current Limiting	LX1668 LX1669
AN-9	Modulated Constant Off-Time Control Mechanism	LX166x
AN-10	Design Procedure for Microprocessor Buck Regulators	LX166x

Download from http://www.linfinity.com

SWITCHING REGULATOR SELECTION GUIDE

Device	Package	5-bit VID	Power Good	OVP Driver	Adaptive Voltage Positioning	Hiccup Mode Current Limit	Synchronous Rectification	External LDO	Internal LDO	Current Sense Threshold (mV)	Production
LX1660	SO-16					•	•			100	Now
LX1661	SO-16				•	•	•			100	Now
LX1662	SO-14	•			•		•			100	Now
LX1662A	SO-14	•			•		•			60	Now
LX1663	SO-16	•	•	•	•		•			100	Now
LX1663A	SO-16	•	•	•	•		•			60	Now
LX1664	SO-16	•			•		•	•		100	Now
LX1664A	SO-16	•			•		•	•		60	Now
LX1665	SO-18	•	•	•	•		•	•		100	Now
LX1665A	SO-18	•	•	•	•		•	•		60	Now
LX1668	SO-20 TSSOP	•(TTL)	•	•	•	•	•	•	•	60	8/98
LX1669	SO-16	•(TTL)	•	•	•	•	•			60	8/98

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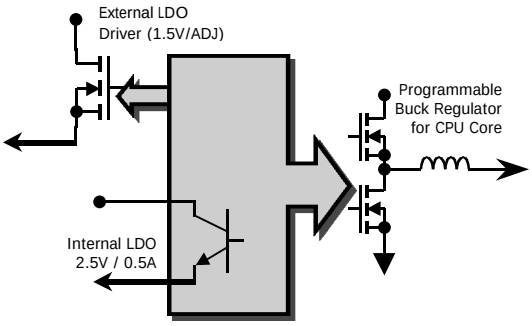
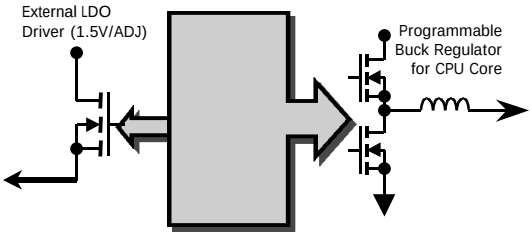
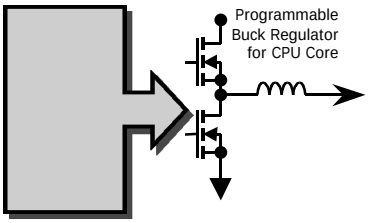
Controller Options for Microprocessor Power

The table below shows the major options and topology of Linfinity's regulator controllers for microprocessor power.

Topology	Devices	Block Diagram
Triple Output Combination of programmable switching regulator with two linear regulators (one internal, one external).	LX1668	
Dual Output Combination of programmable switching regulator with a single external linear regulator driver.	LX1664 LX1665	
Single Output Programmable or adjustable switching regulator.	LX1662/63 LX1669 (programmable) LX1660/61 (adjustable)	

Application Idea 1: LX1668 Triple Output Regulator

DESCRIPTION

The LX1668 provides a programmable synchronous buck regulator controller, together with a linear regulator driver (external MOSFET) and an internal 2.5V (fixed) low dropout regulator. The main output is programmable between 1.3 and 3.5V using a 5-bit, TTL-compatible voltage identification (VID) code.

The LX1668 is compatible with Energy Star (Green PC) specifications – the CPU core output can be disabled while keeping the internal LDO active.

Advanced fault protection features include internal over-voltage protection (OVP) and hiccup-mode over-current protection. An OVP pin can be used to drive an SCR to clamp the output to ground, or to turn off an ATX power supply in case of an over-voltage condition.

The modulated constant off-time architecture results in simple system design with no external compensation network required. Transient response is enhanced by 40mV adaptive voltage positioning.

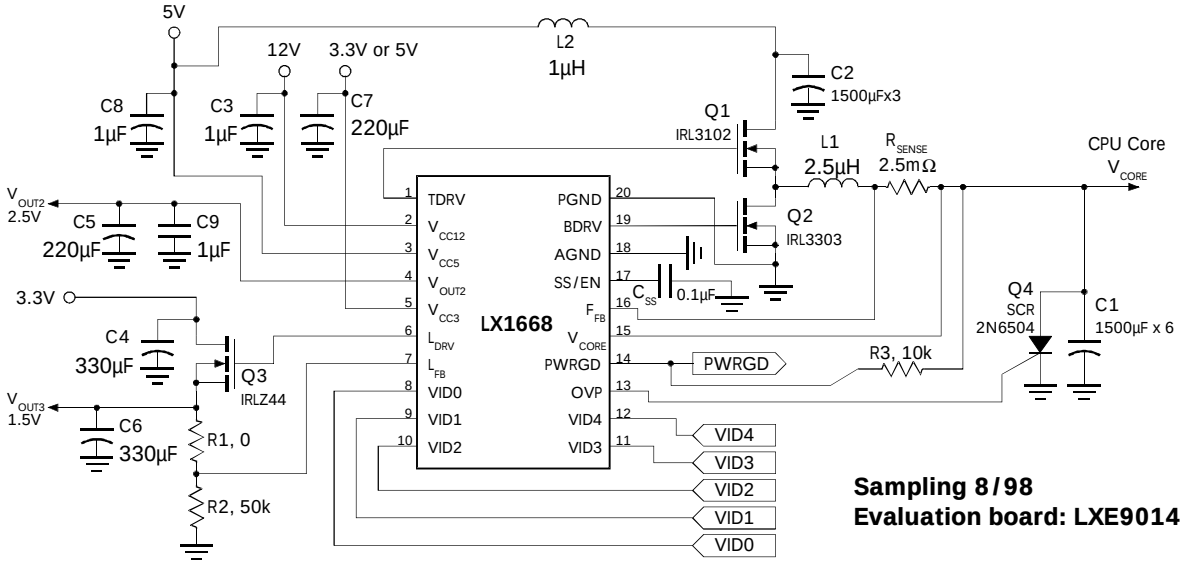
KEY FEATURES

- PWM Output Programmable By 5-Bit TTL-Compatible Voltage Identification (VID) Code
- External Adjustable Linear Regulator Driver (Requires No Resistors For Setting 1.5V Output)
- Internal 2.5V Fixed Low Dropout Regulator (500ma)
- Hiccup Mode Current-Limiting For Fault Protection
- "Green PC" Shutdown Mode
- Soft-Start
- 20-Pin SOIC or TSSOP Package
- Accurate Current Sensing By PCB Trace Resistor; Loss-Less Inductor Resistance Or SMD Sense Resistor Methods
- Lowest Total Cost Of Any Pentium II Processor Power Supply Solution

APPLICATIONS

- Pentium® II processor supplies
- AMD-K6™ and Cyrix M II™, MediaGX™ supplies

TYPICAL APPLICATION



Sampling 8/98
Evaluation board: LXE9014

BILL OF MATERIALS

Item	Description	Quantity
U1	LX1668 Controller IC	1
C1, C2	Capacitor, 1500µF, 6.3V, 44mΩ ESR	9
C4, C6	Capacitor, 330µF	2
C5, C7	Capacitor, 220µF	2
C3, C8, C9	Capacitor, 1µF	3
C_{SS}	Capacitor, 0.1µF	1
Q1, Q2	FET (low $R_{DS(ON)}$)	2
Q3	FET (IRLZ44 or similar - $R_{DS(ON)}$ need not be low)	1
R_{SENSE}	Sense resistor, 2.5mΩ (PCB trace)	1
R1, R2	Resistor (R1 = 0Ω; R2 = 50kΩ for V_{OUT2} = 1.5V)	1
L1	Inductor, 2 – 3µH	1
L2	Inductor, 1µH	1
Total Component Count		**25**

Application Idea 2: LX1669 Single Output Regulator

DESCRIPTION

The LX1669 provides a programmable synchronous buck regulator controller, programmable between 1.3 and 3.5V using a 5-bit, TTL-compatible voltage identification (VID) code.

Advanced fault protection features include internal over-voltage protection (OVP) and hiccup-mode over-current protection. An OVP pin can be used to drive an SCR to clamp the output to ground, or to turn off an ATX power supply in case of an over-voltage condition.

The modulated constant off-time architecture results in simple system design with no external compensation network required. Transient response is enhanced by 40mV adaptive voltage positioning.

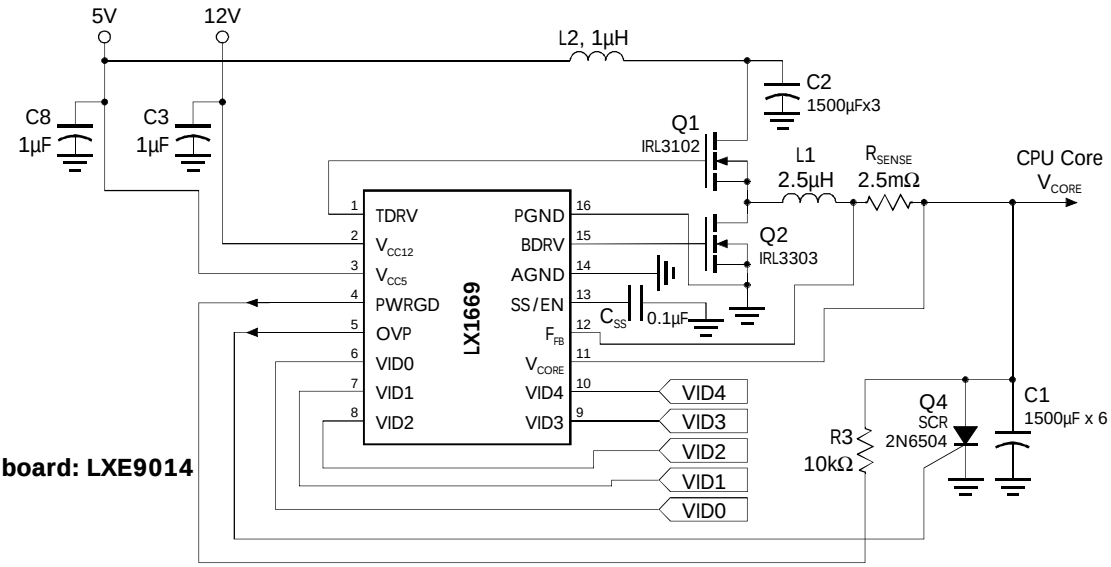
KEY FEATURES

- PWM Output Programmable By 5-Bit TTL-Compatible Voltage Identification (VID) Code
- Hiccup Mode Current-Limiting For Fault Protection
- Disable Function
- Soft-Start
- 16-Pin Narrow Body SOIC
- Accurate Current Sensing By PCB Trace Resistor; Loss-Less Inductor Resistance Or SMD Sense Resistor Methods

APPLICATIONS

- Pentium® II processor supplies
- AMD-K6™ and Cyrix M II™, MediaGX™ supplies

TYPICAL APPLICATION



Sampling 8/98
Use evaluation board: LXE9014

BILL OF MATERIALS

Item	Description	Quantity
U1	LX1669 Controller IC	1
C1, C2	Capacitor, 1500µF, 6.3V, 44mΩ ESR	9
C3, C8	Capacitor, 1µF	2
C_{SS}	Capacitor, 0.1µF	1
Q1, Q2	FET (low $R_{DS(ON)}$)	2
R_{SENSE}	Sense resistor, 2.5mΩ (PCB trace)	1
L1	Inductor, 2 – 3µH	1
L2	Inductor, 1µH	1
Total Component Count		**18**

Application Idea 3: LX1664/65 Dual Output Regulator

DESCRIPTION

The LX1664/65 provides a programmable synchronous buck regulator controller together with a linear regulator driver (external MOSFET). The main output is programmable between 1.3 and 3.5V using a 5-bit, TTL-compatible voltage identification (VID) code.

Advanced fault protection features include internal over-voltage protection (OVP) and pulse-by-pulse current limiting. An OVP pin (LX1665 only) can be used to drive an SCR to clamp the output to ground, or to turn off an ATX power supply in case of an over-voltage condition. The LX1665 also has a Power Good pin.

The modulated constant off-time architecture results in simple system design with no external compensation network required. Transient response is enhanced by 40mV adaptive voltage positioning.

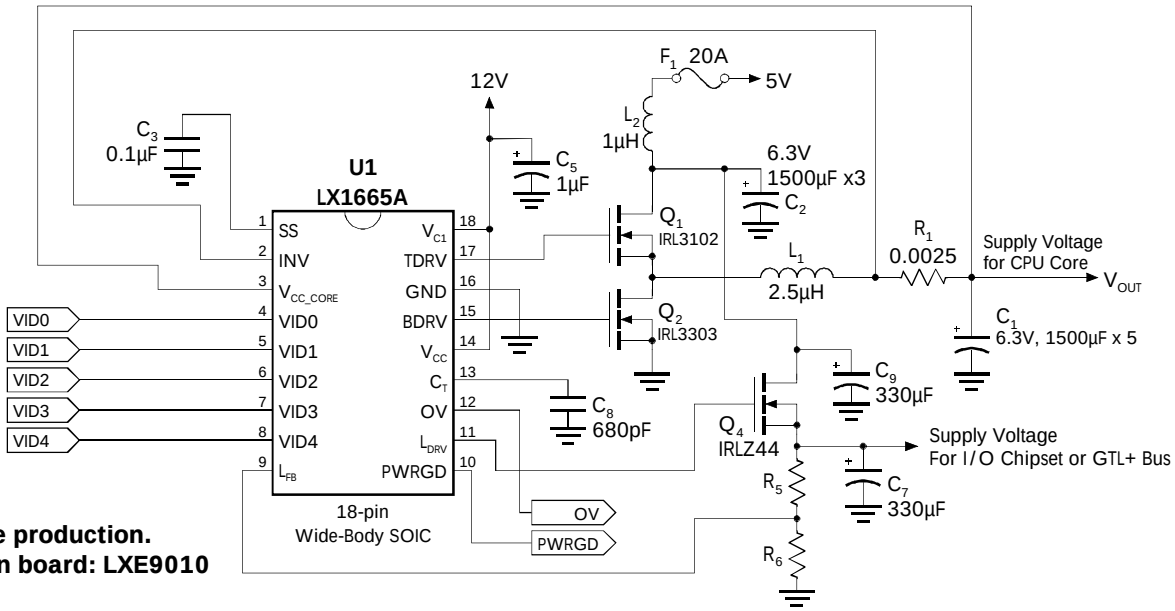
KEY FEATURES

- PWM Output Programmable By 5-Bit VID Code
- External Adjustable Linear Regulator Driver (Requires No Resistors For Setting 1.5V Output)
- Soft-Start And Pulse-By-Pulse Current Limiting
- 16-Pin Narrow Body SOIC (LX1664) Or 18-Pin Wide Body SOIC (LX1665) Packages
- OVP Driver And Power Good Flag (LX1665 Only)
- Accurate Current Sensing By PCB Trace Resistor; Loss-Less Inductor Resistance Or SMD Sense Resistor Methods

APPLICATIONS

- Pentium II Supplies
- Socket 7 Processor Supplies
- PowerPC™ And DEC Alpha™ Supplies

TYPICAL APPLICATION



In volume production.
Evaluation board: LXE9010

BILL OF MATERIALS

Item	Description	Quantity
U1	LX1665 Controller IC	1
C1, C2	Capacitor, 1500µF, 6.3V, 44mΩ ESR	6
C7, C9	Capacitor, 330µF	2
C5	Capacitor, 1µF	1
C3	Capacitor, 0.1µF	1
C8	Capacitor, 680pF	1
Q1, Q2	FET (low $R_{DS(ON)}$)	3
Q4	Linear regulator FET (IRLZ44 or similar – $R_{DS(ON)}$ need not be low)	1
R1	Sense resistor, 2.5mΩ (PCB trace)	1
L1	Inductor, 2 – 3µH	1
L2	Inductor, 1µH (5V-input filter)	1
Total Component Count		**19**

Application Idea 4: LX1662/63 Programmable Regulator...

DESCRIPTION

The LX1662/63 provides a programmable synchronous buck regulator controller suitable for powering the CPU core of advanced microprocessors. The output is programmable between 1.3 and 3.5V using a 5-bit, TTL-compatible voltage identification (VID) code. The LX1662 is the smallest available programmable controller for Pentium II processor power supplies, in a 14-pin narrow body SOIC package.

Advanced fault protection features include internal over-voltage protection (OVP) and pulse-by-pulse current limiting. An OVP pin (LX1663 only) can be used to drive an SCR to clamp the output to ground, or to turn off an ATX power supply in case of an over-voltage condition. The LX1663 also has a Power Good pin.

The modulated constant off-time architecture results in simple system design with no external compensation network required. Transient response is enhanced by 40mV adaptive voltage positioning.

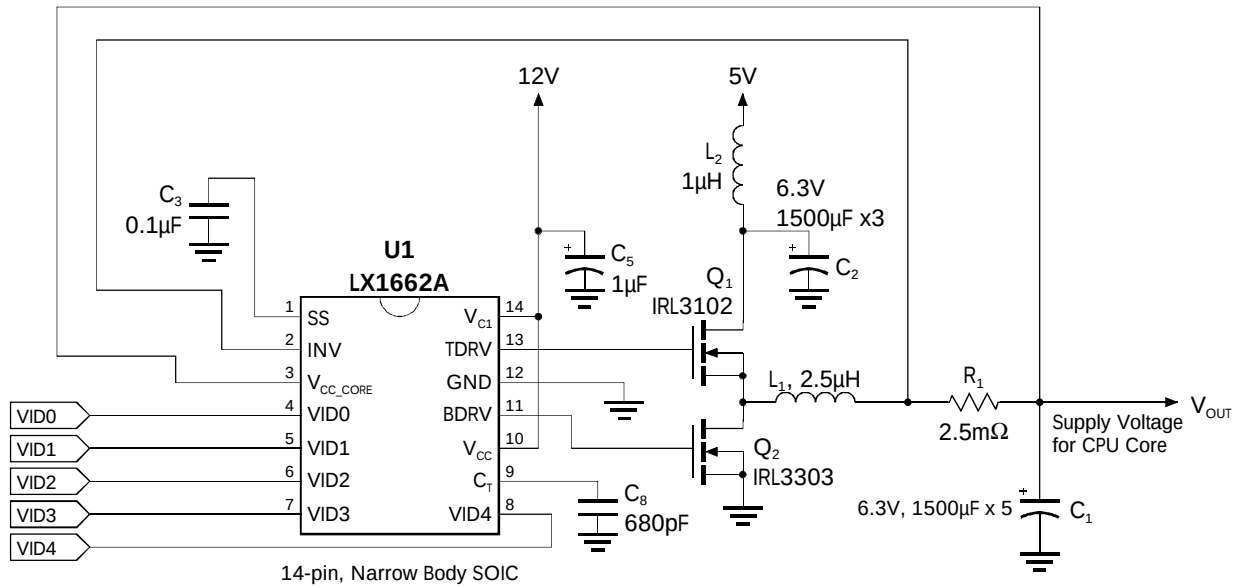
KEY FEATURES

- PWM Output Programmable By 5-Bit VID Code
- Soft-Start And Pulse-By-Pulse Current Limiting
- 14-Pin Narrow Body SOIC (LX1662) Or 16-Pin Narrow Body SOIC (LX1663) Packages
- OVP Driver And Power Good Flag (LX1663 Only)
- Accurate Current Sensing By PCB Trace Resistor; Loss-Less Inductor Resistance Or SMD Sense Resistor Methods.
- Adaptive Voltage Positioning Enhances Transient Response With Fewer Capacitors

APPLICATIONS

- Pentium II supplies
- Socket 7 processor supplies
- PowerPC™ and DEC Alpha™ supplies
- DC:DC converters

TYPICAL APPLICATION



14-pin, Narrow Body SOIC

In volume production.
Evaluation board: LXE9009

BILL OF MATERIALS

Item	Description	Quantity
U1	LX1663 controller IC	1
C1, C2	Capacitor, 1500µF, 6.3V, 44mΩ ESR	6
C5	Capacitor, 1µF	1
C3	Capacitor, 0.1µF	1
C8	Capacitor, 680pF	1
Q1, Q2	FET	2
R1	Sense resistor, 2.5mΩ (PCB trace)	1
L1	Inductor, 2 – 3µH	1
L2	Inductor, 1µH (5V-input filter)	1
Total Component Count		**15**

Application Idea 5: LX1660/61 PWM Controller

DESCRIPTION

The LX1660/61 is an adjustable synchronous buck regulator controller suitable for powering microprocessors or other low voltage loads. Advanced fault protection features include internal over-voltage protection (OVP) and hiccup-mode over-current protection. The modulated constant off-time architecture results in simple system design with no external compensation network required. The LX1660/61 can be used in synchronous or non-synchronous rectifier configurations.

Transient response is enhanced (in the LX1661 only) by 40mV adaptive voltage positioning. The LX1660 does not have adaptive voltage positioning and is ideal for use in applications requiring an accurate DC setpoint, at the expense of transient response voltage tolerance.

The LX1660/61 can also be used with the LX1670 Programmable Reference and Voltage Monitor for a complete Pentium II processor power supply.

KEY FEATURES

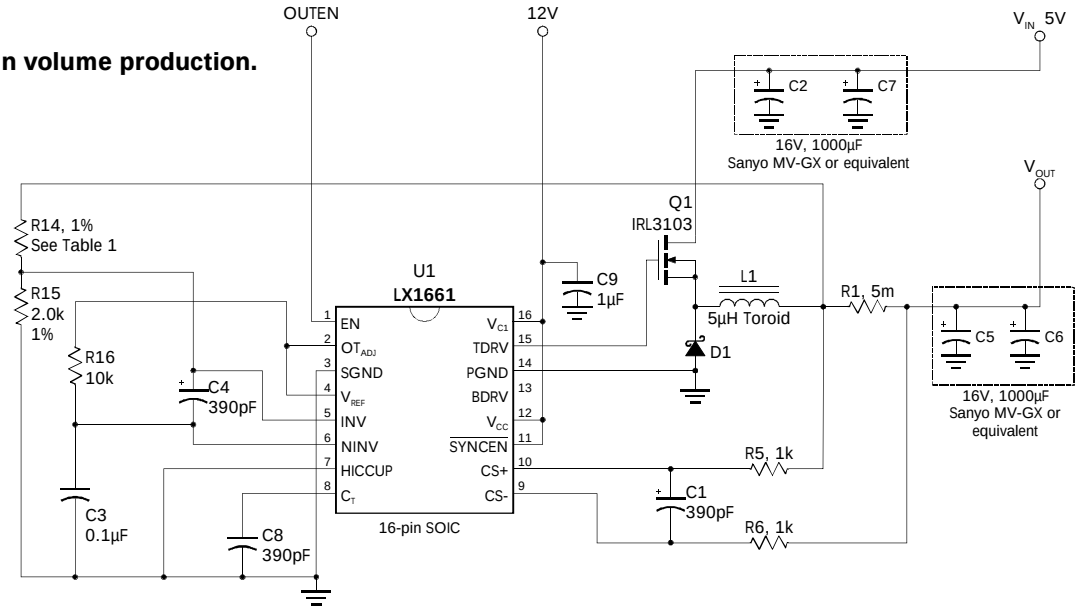
- Hiccup Mode Current-Limiting For Fault Protection
- Soft-Start
- 16-Pin Narrow Body SOIC Package
- Output Voltage Adjustable By Resistor Divider
- Soft-Start And Pulse-By-Pulse Current Limiting
- Accurate Current Sensing By PCB Trace Resistor, Loss-Less Inductor Resistance Or SMD Sense Resistor Methods.
- Adaptive Voltage Positioning Enhances Transient Response With Fewer Capacitors

APPLICATIONS

- Graphics and Media Processor Power
- Socket 7 Processors

TYPICAL APPLICATION

In volume production.



OUTPUT VOLTAGE	
V_{OUT}	R14
2.8	806Ω
3.3	1.30kΩ

$V_{OUT} = 2 \times (1 + R14/R15)$

Set R15 = 2kΩ

BILL OF MATERIALS

Item	Description	Quantity
U1	LX1661 controller IC	1
C2, C5, C6, C7	Capacitor, 1500µF, 6.3V, 44mΩ ESR	4
C9	Capacitor, 1µF	1
C3	Capacitor, 0.1µF	1
C1, C4, C8	Capacitor, 390pF	3
Q1	FET	1
D1	Schottky diode	1
R1	Sense resistor, 5mΩ (PCB trace)	1
R5, R6	Resistor, 1kΩ	2
R14, R15	Resistors – see table	2
L1	Inductor, 2 – 3µH	1
Total Component Count		**18**

Application Idea 6: High Current, Low Cost 5V to 3.3V DC:DC Converter

DESCRIPTION

The LX1553 is a current-mode PWM controller, and can be used for a 5V – 3.3V regulator at 10A or more for I/O, chipset and memory supplies where an ATX power supply is not available, and the current levels are too high for a low dropout regulator. The LX1553 is designed for low cost, not optimal transient response, making it ideal for this application.

The output voltage is adjusted by means of the resistors R1 and R2 according to the following equation:

$$V_{OUT} = V_{REF} * (1 + R2/R1)$$

where $V_{REF} = 2.5V$

KEY FEATURES

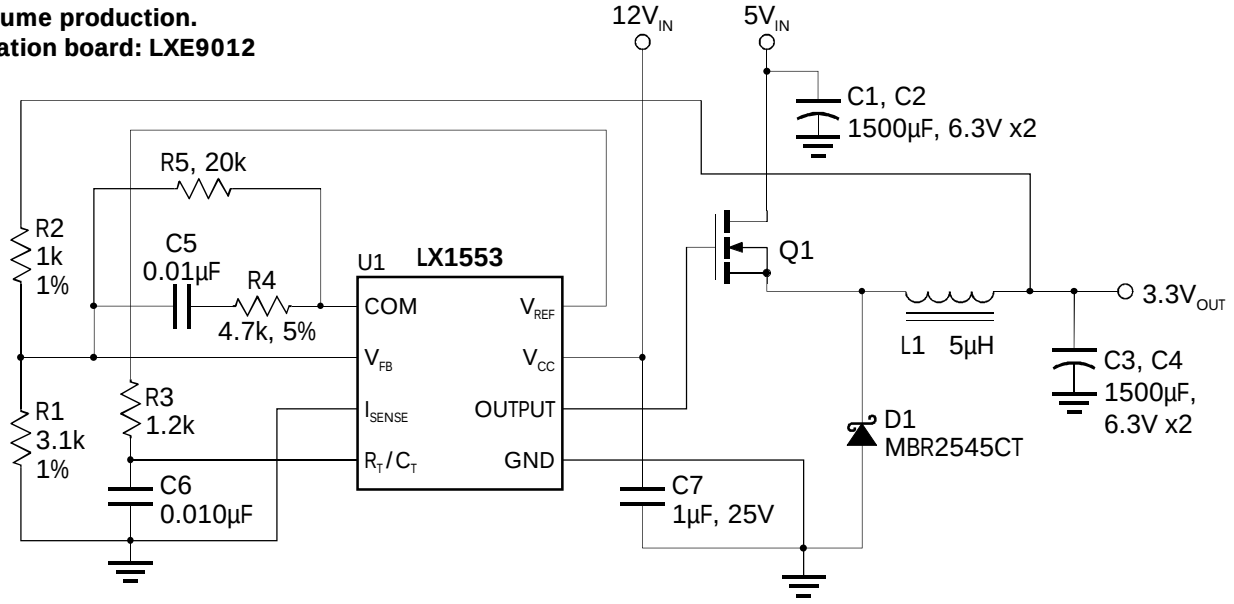
- Low cost, high current 5V – 3.3V regulator solution
- SO-8 package

APPLICATIONS

- Graphics and media processor power
- 5V – 3.3V conversion for chipsets, I/O and memory on motherboards

TYPICAL APPLICATION

In volume production.
Evaluation board: LXE9012



BILL OF MATERIALS

Item	Description	Quantity
U1	PWM Controller IC, LX1553, Linfinity	1
C1 – C4	Capacitor, 1500µF, 6.3V	4
C7	Capacitor, 1µF	1
C5, C6	Capacitor, 0.1µF	2
Q1	FET	1
D1	Schottky diode	1
R5	Resistor, 20kΩ	1
R3	Resistor, 1.2kΩ	1
R1, R2	See table for details	2
L1	Inductor, 5µH	1
Total Component Count		**15**