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Multiphase Converter ICs Solve Powering Requirements for Microprocessors

Although they are more complicated than their single-phase cousins, multiphase controller IC-based circuits provide better capability for powering the new generation of microprocessors.

THE TREND toward higher-current, lower-voltage microprocessors has created a need to supply up to 100 A and even more at about 1 V. The multiphase converter answers this need. Multiphase converters employ two or more identical, interleaved converters that are connected so that their output is a summation of the outputs of the cells. Fig. 1 shows a three-phase multiphase converter.

To understand the advantages of the multiphase converter, we must first look at the characteristics of single-phase converters used to supply high current and low voltage. With a conventional single-phase converter, the output ripple and dynamic response improve with increased operating frequency. In addition, the physical size and value of the output inductor and capacitor go down at higher frequencies. Unfortunately, after the frequency reaches its upper limit, converter switching losses increase and lower the converter's efficiency, forcing a design tradeoff between operating frequency and efficiency.

To overcome these single-phase frequency limitations, multiphase cells operate at a common frequency, but are phase-shifted so that conversion switching occurs at regular intervals controlled by a common control chip. The control chip staggers each converter's switching time, so that the phase angle between each converter switching is 360°/n, where n is the number of converter phases. The outputs of the converters are paralleled, so that the effective output-ripple frequency is n × f, where f is the operating frequency of each converter. This provides better dynamic performance and less decoupling capacitance than a single-phase system.

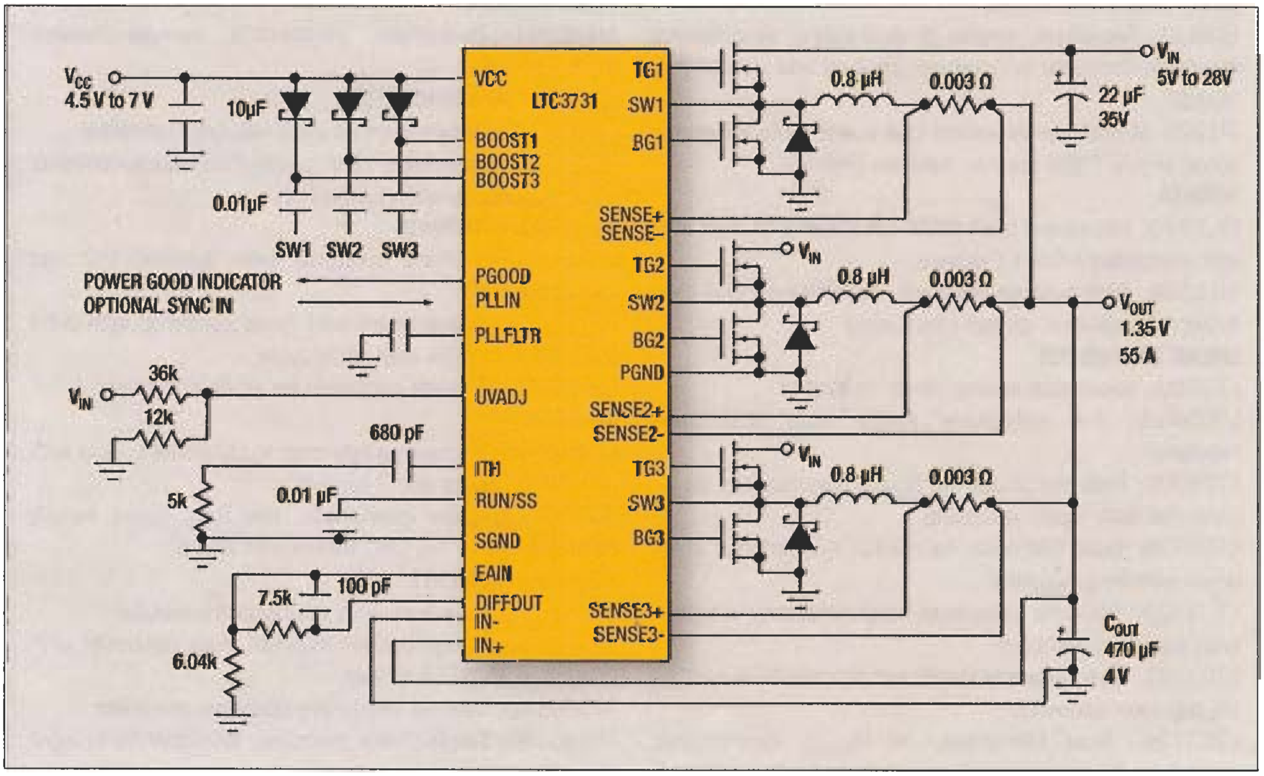

Fig. 1. Linear Technology's LTC3731 is a PolyPhase synchronous step-down switching regulator controller that drives all N-channel external power MOSFET stages in a phase-lockable fixed frequency architecture.

Current sharing among the multiphase cells is necessary so that one does not take too much current. Ideally, each multiphase cell should consume the same amount of current. To achieve equal current sharing, the output current for each cell must be monitored and controlled.

The multiphase approach also offers packaging advantages. Each converter delivers 1/n of the total output power, reducing the physical size and value of the magnetics employed in each phase. Also, the power semiconductors in each phase only need to handle 1/n of the total power. This spreads the internal power dissipation over multiple power devices, eliminating the concentrated heat sources and possibly the need for a heat sink. Even though this uses more components, its cost tradeoffs can be favorable.

Multiphase converters have important advantages, including:

- Reduced rms current in the input-filter capacitor allows use of a smaller and less expensive types
- Distributed heat dissipation, reduces the hot-spot temperature, increasing reliability
- Higher total power capability
- Increased equivalent frequency without increased switching losses, which allows use of smaller equivalent inductances that shorten load transient time
- Reduced ripple current in the output capacitor reduces the output-ripple voltage and allows use of smaller and less expensive output capacitors.

When choosing the number of phases, consider some of the disadvantages of multiphase converters, which include:

- The need for more switches and output inductors than in a single-phase design, which leads to a higher system cost than a single-phase solution, at least below a certain power level
- More complex control
- Possible uneven current sharing among the phases
- Added circuit layout complexity.

As current requirements increase, so does the need for increasing the number of phases in the converter. ICs providing just two phases may not be adequate because of their limited output-current range. An optimum design requires

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ANALOG DEVICES

ADP3182: Adjustable output single-/two-/three-phase synchronous buck controller

INTERNATIONAL RECTIFIER

IR3622: Two-phase, single- or dual-output synchronous stepdown controller with output tracking and sequencing (RoHS)

iP1206: Multiphase optimized LGA power block integrates power semis, PWM control, passives (RoHS)

INTERSIL

ISL6310: Two-phase buck PWM controller with high current integrated MOSFET drivers

ISL6558: Multipurpose precision, multiphase PWM controller with optional voltage positioning

LINEAR TECHNOLOGY

LT3782: Two-phase stepup dc-dc controller

LTC3415: 7-A polyphase synchronous step-down regulator

LTC3709: Fast two-phase, no R_{SENSE} synchronous dc-dc controller with tracking/sensing

LTC3728: Dual 550-kHz, two-phase synchronous stepdown switching regulator

LTC3729: 550-kHz polyphase, high-efficiency synchronous stepdown switcher

LTC3731: Three-phase 600-kHz synchronous buck switching regulator controller

LTC3736: Dual two-phase, no R_{SENSE} synchronous controller with spread spectrum

LTC3828: Dual two-phase stepdown controller with tracking

MAXIM

MAX5038: Dual-phase, parallelable, average current-mode controller

MAX5041: Dual-phase, parallelable, average current-mode controller

NATIONAL SEMICONDUCTOR

LM2647: Dual synchronous buck regulator controller

LM5642: High-voltage, dual synchronous buck converter with oscillator synchronization

STMICROELECTRONICS

L6711: Three-phase controller with dynamic VID and selectable DACs

L6712: Two-phase interleaved dc-dc controller with 3-bit DAC, 85% to 90% max. duty cycle

L6722: Three-phase controller for dc-dc converters

SEMTECH

SC457: Single-phase, single-chip V_{CORE} power supply with integrated drivers and 7-bit DAC

SC458: Complete dual-phase, low V_{OUT} power supply controller with 7-bit DAC (RoHS and WEEE)

TEXAS INSTRUMENTS

TPS40090: High-frequency multiphase controller

TPS40130: Two-phase synchronous buck controller with integrated MOSFET drivers

TPS40140: Dual- or two-phase stackable controller

TPS40180: Single-phase controller, stackable up to eight phases tradeoffs between the number of phases, current per phase, switching frequency, cost, size and efficiency. Higher output current and lower voltage also require tighter output-voltage regulation.

To evaluate multiphase design decisions, review the approaches employed by available ICs. One approach is to use a PWM controller IC with integrated MOSFET drivers. Characteristics of this technique include:

- Heating and noise generated by the on-chip gate drivers may affect controller performance.
- For most of these chips, it is impractical to cascade them for additional phases.
- Accurate current sharing is difficult with this configuration.
- Three phases appears to be the limit.

Another approach is to employ a separate controller and separate gate drivers. Characteristics of this approach include:

- PWM controller is isolated from the heat and noise of the gate drivers.
- Because the current sense signal is routed to the controller, current sharing is more complex.
- There are additional controller-to-driver delays because of the separated ICs.

Yet another approach is to use a dual-phase controller with integrated gate drivers and built-in synchronization and current sharing. Its characteristics include:

- It allows only an even number of phases.
- Although it simplifies the design, it may result in unused or redundant silicon, pins and external components.
- Driver heat and noise generated on-chip can degrade controller performance.

Therefore, existing topologies may not provide the freedom required in selecting the number of phases. The ideal solution is a scalable topology that allows the easy addition or removal of any multiphase cell without sacrificing performance. This scalable approach must be able to share current equally among the distributed phase cells. Such a technique minimizes parasitics and eases board layout.

International Rectifier recently introduced the XPhase IR3513 control IC that provides overall control of a scalable number of phases along with an internal gate driver, current sense and sharing, and PWM to provide a stand-alone single-phase regulator or interface with additional phase ICs enabling a power solution with any number of phases. With this arrangement, the final solution requires only a single IC per phase to deploy one to X phases. Alternative approaches require a control IC plus 1 to X driver ICs or scalable "all-in-one" ICs that do not use all IC pins or circuitry leading to increased solution cost and size. ⏻