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How to Make Your Portable Game Console Play Longer

Introduction

Portable electronic game consoles present the challenge of delivering high graphics quality and a realistic gameplay experience within the constraints of the limited energy provided by battery-operated devices (Figure 1). The adoption of multi-core central processing units (CPUs) and powerful graphics processing units (GPUs), on the processing side, and multi-phase switching regulators, on the power supply side, go a long way toward achieving high levels of performance for sustained amounts of time. This article reviews the challenge of powering a portable game console and presents a configurable, high-current, high-efficiency, multi-phase switching regulator ideal for this application.

Figure 1. Portable Gaming in Action

Multi-Core CPUs for Portable Games

Multi-core CPUs for portable games enable complex, immersive, and realistic electronic gaming features—like real-time physics and real-time texture generation—within the limited energy available in portable applications. Multiple concurrent tasks can be executed faster when there are multiple cores available. The distribution of multiple complex tasks across different cores results in reduced power losses as each CPU runs at a lower frequency to complete its reduced task.

GPUs for Portable Gaming

GPUs for portable gaming handle ever-increasing pixel processing loads while remaining within mobile power budgets with the help of advanced power management techniques. System level and local clock speed management like Dynamic Voltage and Frequency Scaling (DVFS) help keep GPU power consumption to a minimum and deliver graphic performance approaching that of a desktop console.

On-the-Go Environment

When the docking station is not available, portable game consoles rely on a single-cell lithium battery to power the CPU, the GPU, and the DRAM module. Typically, a lithium battery of 4Ah capacity should sustain 5 hours of operation, adding up to an average current draw of 0.8A, and peak currents many times higher. Each of these smart loads (CPU, GPU, DRAM) must be powered by versatile switching regulators that can efficiently deliver current over a range spanning from a fraction of an amp to tens of amperes.

The Multi-Phase Buck Converter

Following a similar strategy, a multi-phase buck (step-down) converter is the best choice to power these smart loads. Dividing the current between four phases that are equally spaced in time across one clock period has several advantages compared to a single-phase architecture. First, the four interleaved phases assure output current ripple cancellation as shown in Figure 2. Notice how the total ripple current frequency is four times that of a single phase, while the amplitude is a quarter. Therefore, high-frequency, low-amplitude ripple current is obtained at a relatively low frequency operation of each phase. Lower ripple current means fewer capacitors are needed on the output, resulting in a smaller BOM.

Second, a multi-phase scheme is more efficient than a single-phase scheme. The latter, by running at four times the frequency of the quad phase, can also achieve low current ripple but at higher switching losses. In this case, the two schemes have an equal number of transitions within one period but the quad-phase converter transitions carry a quarter of the current of the single-phase converter.
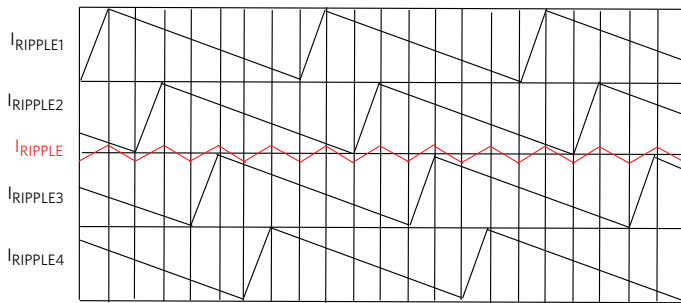
Figure 2. Quad-Phase Output Current Ripple Cancellation

Third, the multi-phase architecture results in the need for fewer input capacitors as the total input current, within one period, is the sum of four out-of-phase current pulses. Here, spreading the total input current over time reduces its RMS value, compared to single-phase operation, which allows for a smaller input current ripple filter.

MAX77812 Single-to-Quad-Phase, Single-to-Quad-Output, 20A Max, Configurable Buck Converter

The MAX77812 (Figure 3) is a configurable, quad-phase, high-current, buck (step-down) converter. High efficiency, a small PCB solution footprint, high output voltage accuracy, fast transient response, and a fast serial interface option make this device ideal for powering CPUs and GPUs in portable game consoles. The MAX77812's flexible architecture allows user-selectable phase configurations such as 4 (one four-phase output), 3 + 1 (two outputs, one tri-phase and one single-phase), 2 + 2 (two two-phase outputs, 2 + 1 + 1 (three outputs, one two-phase, two single-phase), and 1 + 1 + 1 + 1 (four single-phase outputs).

Single-Chip Processing System Power

By choosing the proper configuration, a single MAX77812 can power the processing block in portable game consoles. In Figure 3, a 2 + 1 + 1 configuration has been selected to power the GPU, CPU, and DDR memory.

High Configurability for Reuse

The MAX77812's flexible architecture makes the device easy to reuse. As an example, designers may initially choose a 2 + 1 + 1 phase configuration: 2 phases for GPU, 1 for CPU, and 1 for DRAM. Later on, they may realize that the GPU needs more current. With the MAX77812, they have the option to switch to a 3 + 1 configuration: 3 rails for the GPU and 1 rail for the CPU. This is done by simple pin-strapping without part number changes. The addition of a single-phase buck converter for the DRAM is still necessary but it is much less painful than redesigning the GPU multi-phase buck converter. The MAX77812 flexibility speeds up design and qualification, reducing time to market.
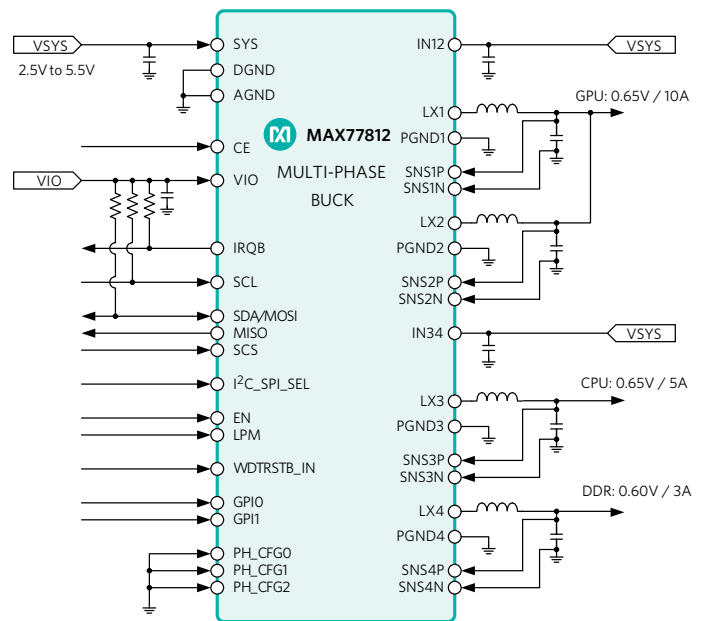

Figure 3. MAX77812 2 + 1 + 1 Application Diagram

High-Speed Serial Interface

The MAX77812 can be configured as a 30MHz SPI high-speed serial interface to provide flexible enable (EN) control of each regulator. DVS operation and output-voltage ramp rate control enable rapid output voltage adjustment to optimize performance in all system operating states. The device also features an I^2C-compatible, 2-wire serial interface.

DVFS Operation

During DVFS operation, the buck converter responds to a command to quickly change the output voltages to new target values. The high peak-current limit, coupled with low inductance and small output capacitance allow the buck regulator to operate with high slew rates. DVFS operation can cause very high current peaks of short duration. For example, an output loaded by a 100µF capacitor will require a current of 6A to raise its value by 60mV in 1µs (60mV/µs slew rate). This, together with the high variability of the CPU and GPU current profiles, explains the necessity for the voltage regulator to have a maximum current rating as high as 20A.

High Accuracy Saves Power

As power goes with V^2/R, a 1% loss in accuracy results in 2% wasted power. That is the same as taking the efficiency curve and lowering it by two percentage points. The MAX77812's high initial setpoint accuracy (±0.5%) and phase differential remote-sense feedback enable very tight DC and AC accuracy at the point of load.

Power-Saving Modes

To save power, the MAX77812 operates in skip mode (SKIP) at light loads and automatically transitions to PWM at heavy loads (auto-mode). The trade-off is slow transient response which results in high output-voltage transient spikes. A low power skip mode (LP SKIP) is also available for even lower power consumption in light load operation.

Enhanced Transient Response

The output of a slow voltage regulator will dip under a positive transient load and will need to be positioned higher to assure that the load receives the minimum voltage necessary to operate. This results in wasted power and greater heat generation, ultimately ending in less battery life. Maxim's Enhanced Transient Response (ETR) assures best-in-class performance by monitoring the output voltage and forcing the output stage appropriately in presence of high slew rate.

If the system can predict the application of a heavy load, the best strategy is to force PWM mode (FPWM = 1) just ahead of a load step change. This way the allowance made for the output voltage droop can be reduced to a minimum and the output voltage can be set as low as possible, improving efficiency.

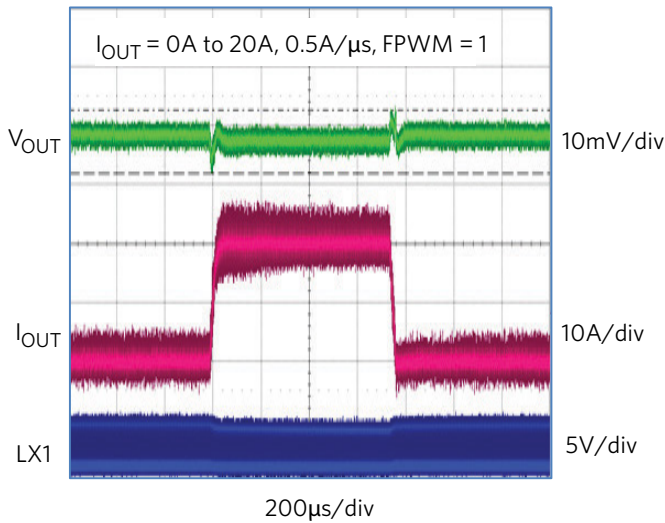The excellent transient response of the MAX77812 in forced PWM mode is demonstrated in Figure 4.

Figure 4. MAX77812 Transient Response in FPWM

MAX77812 Efficiency Advantage

The enhanced features of the MAX77812's integrated power MOSFETs result in superior efficiency compared to competitive quad-phase solutions. The efficiency comparison in Figure 5 (2520 size inductors) shows that the MAX77812 has an advantage of up to 7% (15A) versus a competing device.
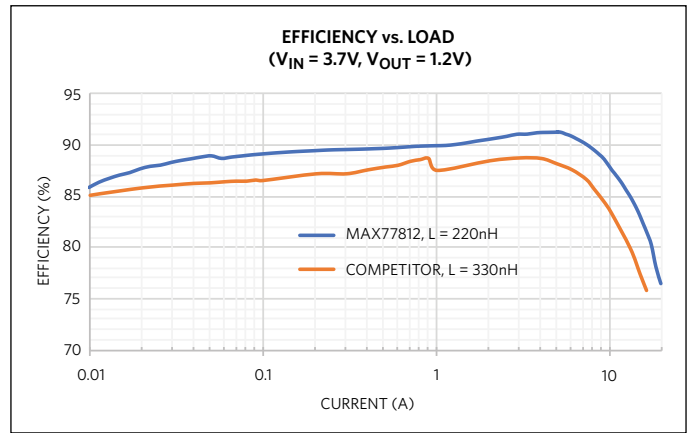

Figure 5. MAX77812 Efficiency Advantage

Small Size

The MAX77812 achieves world-class performance with a miniature PCB footprint that has small inductors and output capacitors. A programmable current limit minimizes the inductor sizes based on the system's actual requirements. Figure 6 shows the MAX77812 PCB footprint which occupies only 78.75mm^2.

The MAX77812 is available in a 64-bump, 0.4mm-pitch WLP package with a height of 0.64mm (typical).
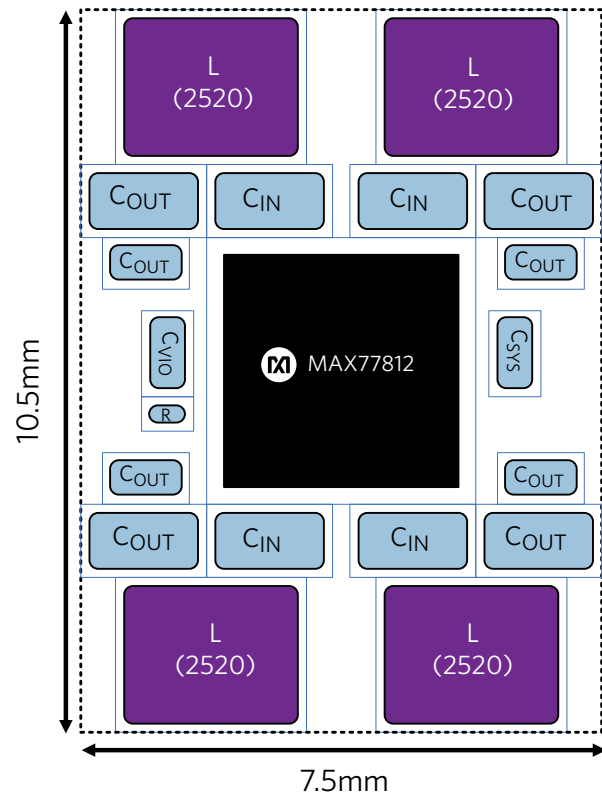

Figure 6. MAX77812 Small-Size PCB

Conclusion

We have discussed the portable game console's challenge of delivering high graphics quality and a realistic gameplay experience within the constraints of small space and limited energy provided by a battery-operated device. The MAX77812 single-to-quad-phase, single-to-quad-channel high-current buck regulator, thanks to its high efficiency, small PCB size, high output voltage accuracy, fast transient response, and fast serial interface, is ideal for powering multi-core CPUs and GPUs in portable game consoles. The buck regulator's flexible architecture allows user-selectable phase configurations, making the device easy to adapt to specification changes, thereby speeding up design, qualification, and time to market.

Glossary

ASSP: Application Specific Standard Product

DVFS: Dynamic Voltage and Frequency Scaling. System level

DVS: Dynamic Voltage Scaling. IC level

BOM: Bill of materials

PCB: Printed circuit board

RMS: Root mean square

SPI: Serial peripheral interface

Learn more:

MAX77812 Quad-Phase, 20A Max, Configurable Buck Regulator

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