AN3696

Current Sharing, Interleaved, Dual-Phase Application

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INTRODUCTION

The MCP19214/5 is a controller used in dual, high-efficiency DC/DC converters. This integrated circuit (IC) brings considerable aid to portable applications with the new concept of Current Sharing, Interleaved, Dual-Phase Application. Handheld terminals, electric bicycles, electric scooters, and notebook computers can benefit using this type of converter as it reduces electromagnetic interference (EMI), lowers input filtering requirements, and lowers power stress on components, which results in a board that generates less heat. Using this type of topology also has the advantage of halving the input current amplitude, reducing the peak current flowing towards the input capacitor. The losses from the input battery (12V) are also reduced as it draws less peak current for the board.

MCP19214/5 OVERVIEW

The MCP19214/5 devices are highly integrated, digitally enhanced PWM controllers used for battery chargers, bidirectional converters, LED lighting systems and other low-side switch PWM applications.

The MCP19214/5 devices feature two independent analog PWM controllers which can be interleaved to obtain a dual phase with current-sharing capability. The operating phase at 180°, lagged at the first phase, provides fast transient response, lowers input current and satisfies high-current Boost applications, while allowing for a reduction of the size of the external components.

Each PWM channel includes two error amplifiers with independent and adjustable reference voltage generators, current sense input with programmable leading-edge blanking, programmable slope compensation ramp generator, integrated internal programmable oscillator and MOSFET driver.

Like the other members of the digitally enhanced PWM controllers family, the MCP19214/5 devices include a fully programmable microcontroller core and a 10-bit analog-to-digital converter. Power trains supported by this architecture include, but are not limited to, Boost, Buck-Boost, Flyback, SEPIC and Ćuk. The MCP19215 device integrates an I^2C controller and an Addressable Universal Synchronous Asynchronous Receiver Transmitter (AUSART) module. The designer can develop specific communication protocols using the internal interfaces. A PMBus-compatible protocol, specific to power converters, can be implemented using the provided I^2C serial bus.

Complete customization of the device operating parameters, start-up or shutdown profiles, protection levels and fault-handling procedures are accomplished by firmware that can be developed using Microchip's MPBLAB® X Integrated Development Environment (IDE). The MCP19214/5 devices are programmed using PICkit™ 4 tool, which is one of Microchip's many in-circuit debuggers and device programmers.

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MCP19214/5 BOOST CONVERTER

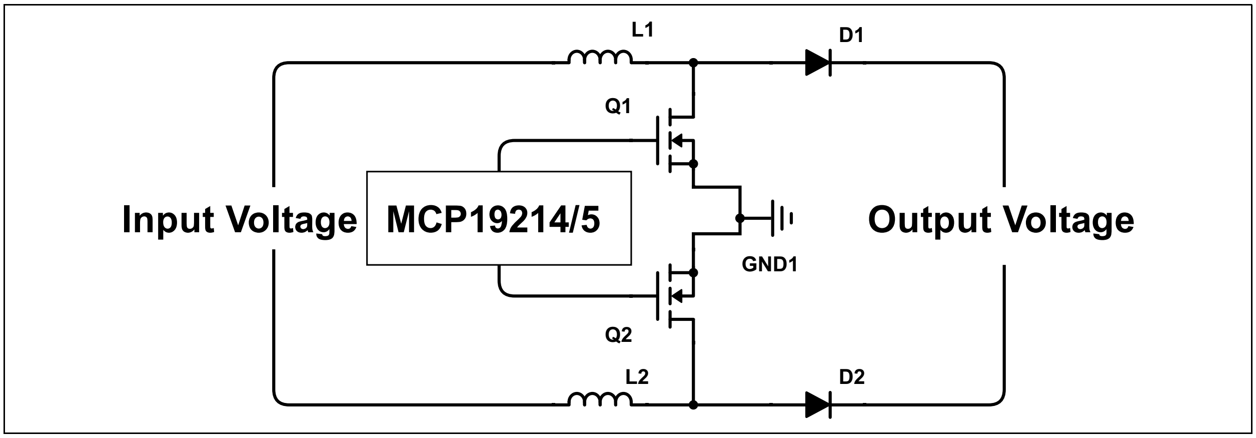

FIGURE 1: *MCP19214/5 – Dual-Phase Boost Converter.*

In Figure 1, the MCP19214/5 devices can control two independent power supplies, but in the presented application, the controller is used to drive the same output. Although the operation of the Boost DC/DC converter is asynchronous, the efficiency obtained in these high-power boards still exceeds 96%. This very high efficiency results in reduced cooling requirements and a smaller PCB.

In this application note, a Boost converter is presented with 12V input, 48V output, and a power rating of 480W. Even at 96% obtained efficiency, the Boost converter requires a heat absorption element such as a heat sink (see Figure 2).

FIGURE 2: *MCP19214/5 – 480W, 12V Battery-Powered, 120 mm x 85 mm PCB Prototype.*

The final dimension obtained is 120 mm x 85 mm, a size which is competitive with similar products.

BOARD PERFORMANCE

As illustrated in Figure 3, the efficiency does not go lower than 96%, even in full load conditions at 480W. This level of efficiency reduces the thermal stress on every component, increasing lifetime and reliability.

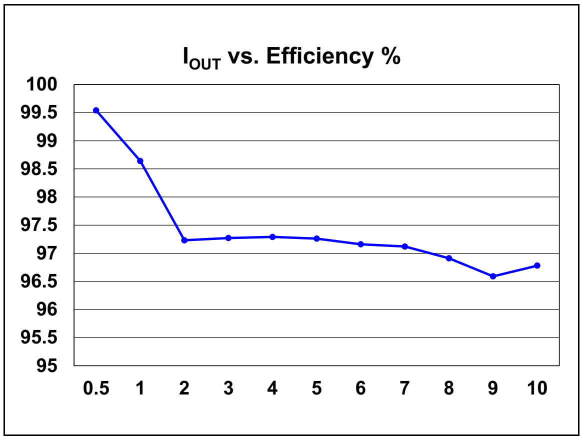

FIGURE 3: *Boost Performance.*

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CURRENT SHARING

Each channel senses the inductor/power MOSFET current through a shunt resistor. Information from each channel is read independently. The balance between interleaved dual-phase or current sharing is obtained by shorting the two outputs of the voltage error amplifiers wherein the transconductance amplifiers (OTAs) set the same peak current. See Figure 6, Figure 7, and Figure 8. The accuracy of the shared current depends on the precision of the sensed current flowing through the shunt resistor. Obtaining a perfect match between the phases can be acquired by selecting components with very low tolerance.

Figure 4 and Figure 5 depict representations of achieved current sharing. The mauve line represents the current from inductor L1, whereas the blue line represents the current from inductor L2.

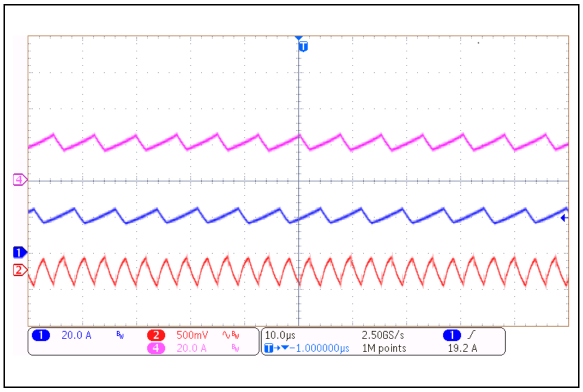

FIGURE 4: *Matching Of Currents in Inductors L1, L2 and Output Voltage Ripple.*

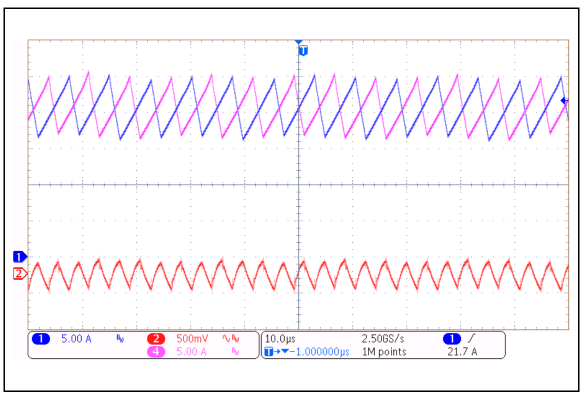

FIGURE 5: *Matching Of Currents in Inductors L1, L2 (Overlaid) and Output Voltage Ripple.*

The red signal represents the output voltage ripple which is a feature of the interleaved dual-phase board. The output voltage ripple frequency is double the switching frequency which results in a smaller output ripple and faster transient response.

APPLICATION CIRCUIT

Using the Current mode control technique has the advantage of being stable and reliable, balancing the amount of current shared which is essential to this converter type. In theory, the current sourced by Channel 2 is equal to the current sourced by Channel 1.

In the example for PWM Channel 1 (see Figure 6), the current flowing through resistor R10 is the current in inductor L1. Such small voltage values on resistor R10 (1 mΩ) can be difficult to sense. At a current of 20A, the resulting voltage would be 20 mV. In order to compensate this disadvantage, an operational amplifier can be used (such as the MCP6021 device). To improve current sharing, another correction ramp can be added through R9, C12 and into the positive input of U2. This way, a summing amplifier is obtained in which one of the inputs for the positive pin is the current flowing in the inductor. To compensate for the mismatch of the shunt resistors, inductors and traces, an artificial ramp can be added to the positive pin.

The output of the MCP6021 device (U2) is then fed back into MCP19214/5, directly into IP1, which is the negative input of the PWM Comparator 1.

Next, the positive input of the PWM comparator must be taken into consideration. The voltage divider with R27 and R33 senses the output voltage and feeds the voltage to the V_{FB} pin, which is the negative input of voltage error amplifier. The reference voltage (V_{REF1} and V_{REF2}) is digitally controlled by setting the same value in VREFCON1 and VREFCON2 registers. The error amplifiers on both channels are both OTAs, therefore the outputs V_{COMP1} and V_{COMP2} can be tied together. The output of the error amplifier controls the current which flow through R17, C14 and C17, obtaining a compensated voltage for the positive input of the PWM Comparator 1. Slope compensation can also be applied by using the SLPCRCON1 and SLPCRCON2 registers. The second driver is 180° out of phase from PWM 1. The voltage present on the V_{COMP} pin through compensation network is compared to the voltage already obtained and outputs the same amount of peak current to inductor L2. Programming the same peak current results in the mean value of the current through inductors being the same. The mean value of current from PWM Channel 1 in inductor L1 is obtained by low-pass filtering the peak current signal in R48 and C31. Channel 2 should be similar to Channel 1, using the mean value of current signal, which lowers the error between the two signals. In Figure 4 and Figure 5, the practical results confirm the theoretical matching between the two currents through inductors L1 and L2.

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Powering the board without a soft start extension circuit may be harmful in any given situation. For high-power applications, boosting from 12V to 48V at 10A would require approximatively 40A at the input. Transient voltages during start-up could damage the components and therefore soft start is required for this type of application. Additionally, the output voltage and the duty cycle are limited during start-up.

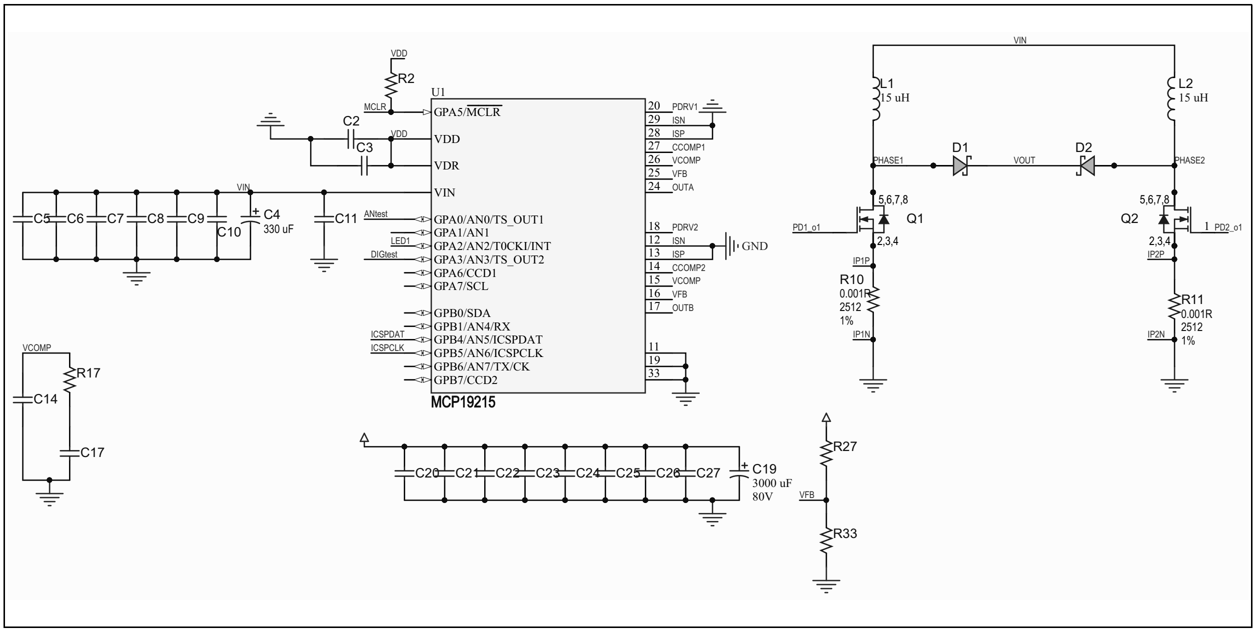

FIGURE 6: *Design Application Circuit (Detailed View) – Power Stage.*

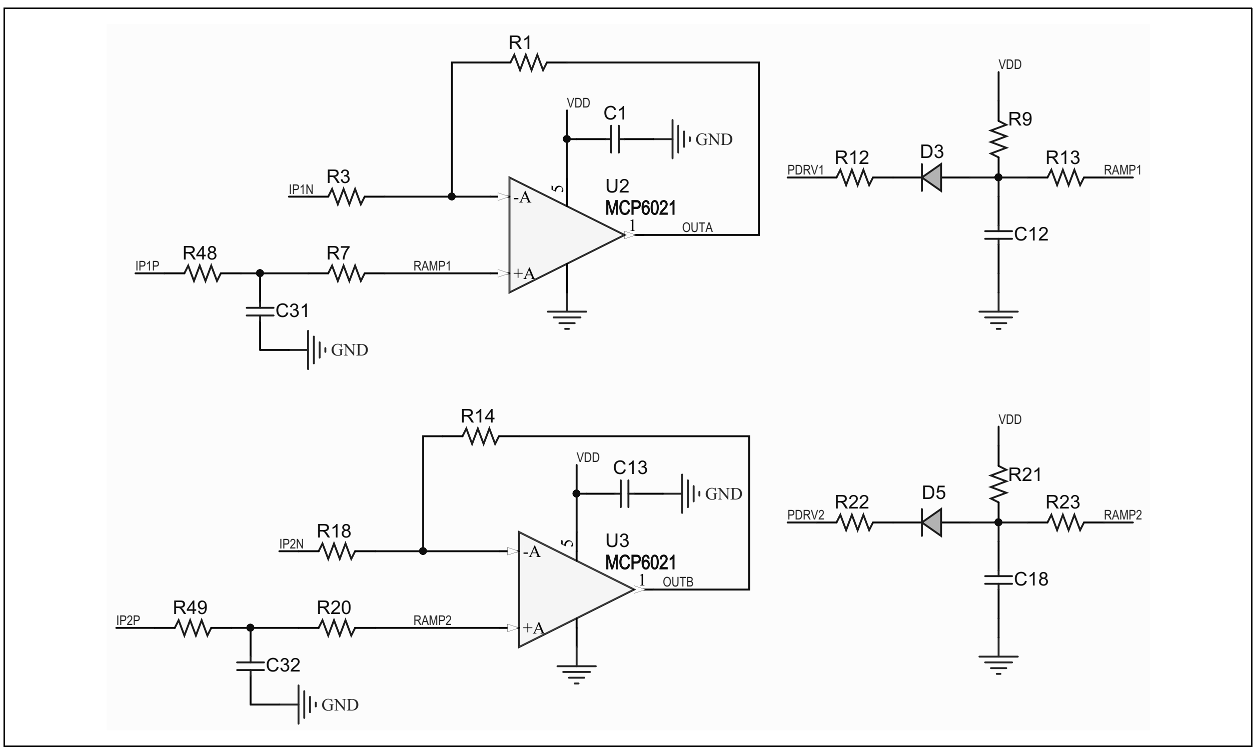

FIGURE 7: *Design Application Circuit (Detailed View) – Current Measurement.*

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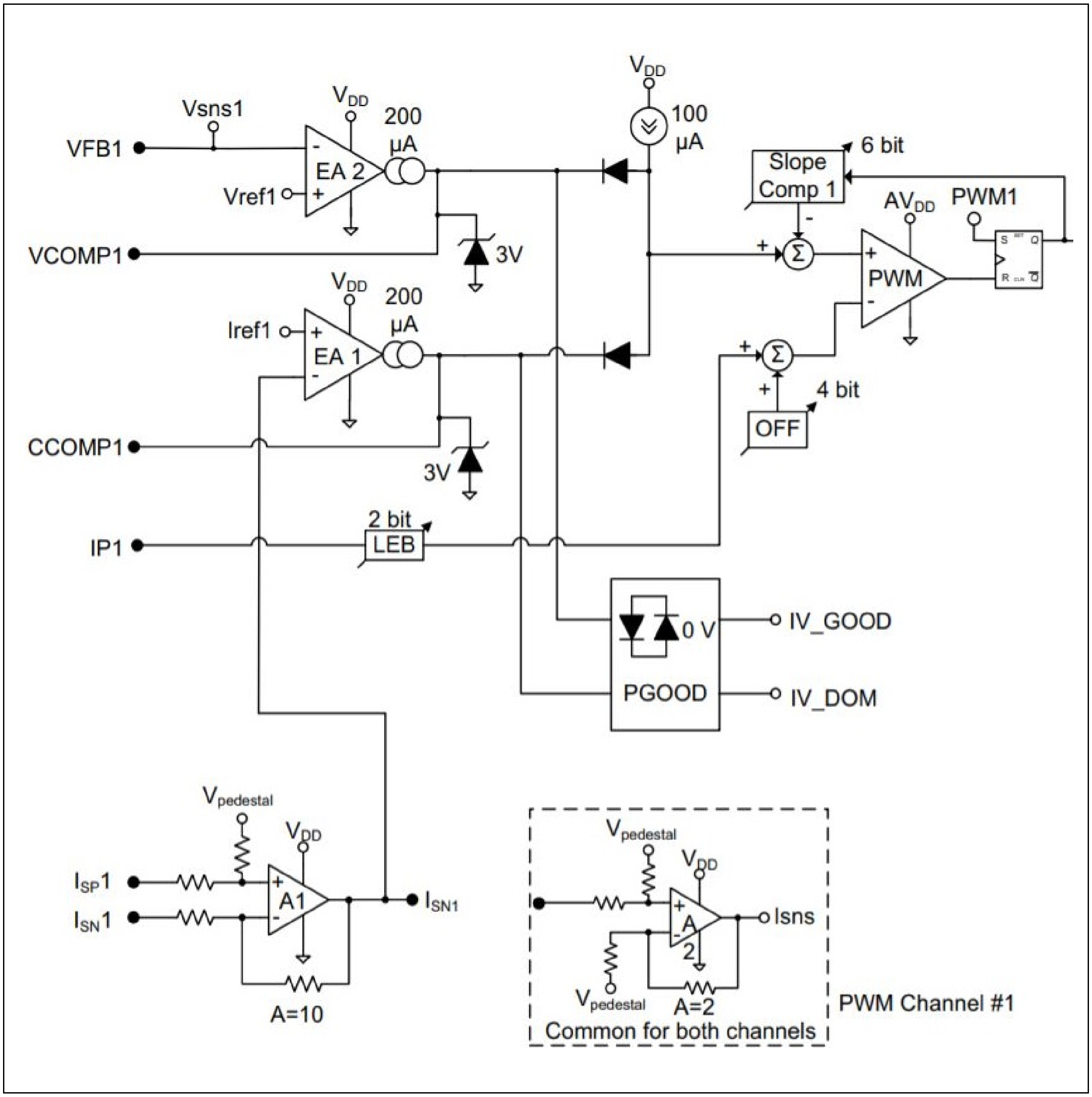

FIGURE 8: *MCP19214/5 Simplified Internal Block Diagram.*

CONCLUSION

Therefore, by using the new concept of interleaved dual-phase, the performance of boost converters can be increased. This performance increase allows for designers to select smaller and more efficient components during development. An efficient board generates less heat, which represents the main advantage of this new topology. This type of converter has the benefit of reducing the thermal stress on the switching MOSFET. Likewise, the inductor selection is flexible in this design.

REFERENCES

1. MCP19214/5 Data Sheet, *"Digitally Enhanced Power Analog, Dual Channel, Low-Side PWM Controller"* (DS20005681), Microchip Technology Inc.
2. MCP6021/2/3/4 Data Sheet, *"Rail-to-Rail Input/Output, 10 MHz Op Amps"* (DS20001685), Microchip Technology Inc.

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