*Application Brief*

# ***Establishing a Precise Current Limiter Over Wide Operation Voltages in Buck-Boost Converters***

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## Introduction

The LM5177 buck-boost controller uses two cascaded control loops to regulate the output voltage and current of the converter to the desired value. The outer loop is the voltage regulation loop, and the inner loop is the current regulation loop. Figure 1 illustrates the control loops for the buck-boost controller.

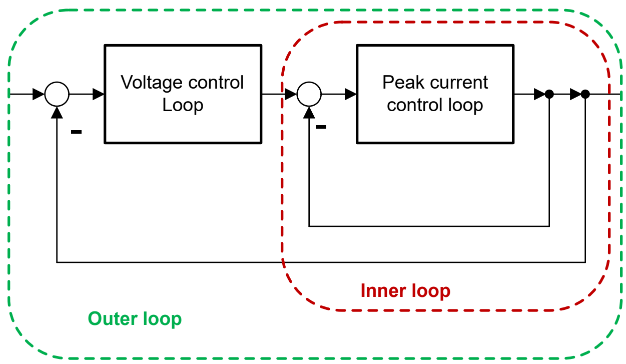


**Figure 1. Overview of Cascaded Control Loops**

The inductor current is an essential element in the voltage regulation loop to produce the required PWM for the power stage. Thus, to measure the inductor peak current, shunt resistance ($R_{CS}$) is used. The differential voltage across the $R_{CS}$ is fed to the differential amplifier to generate a corresponding voltage ramp ($V_{sense}$). There is a default maximum threshold for differential peak voltage for every buck-boost controller. In case, the differential peak voltage exceeds this voltage threshold the inductor current will limit to the corresponding peak current value. The peak current limit can be changed by selecting different values for the $R_{CS}$ resistance. The block diagram for the peak current limit is shown in Figure 2.

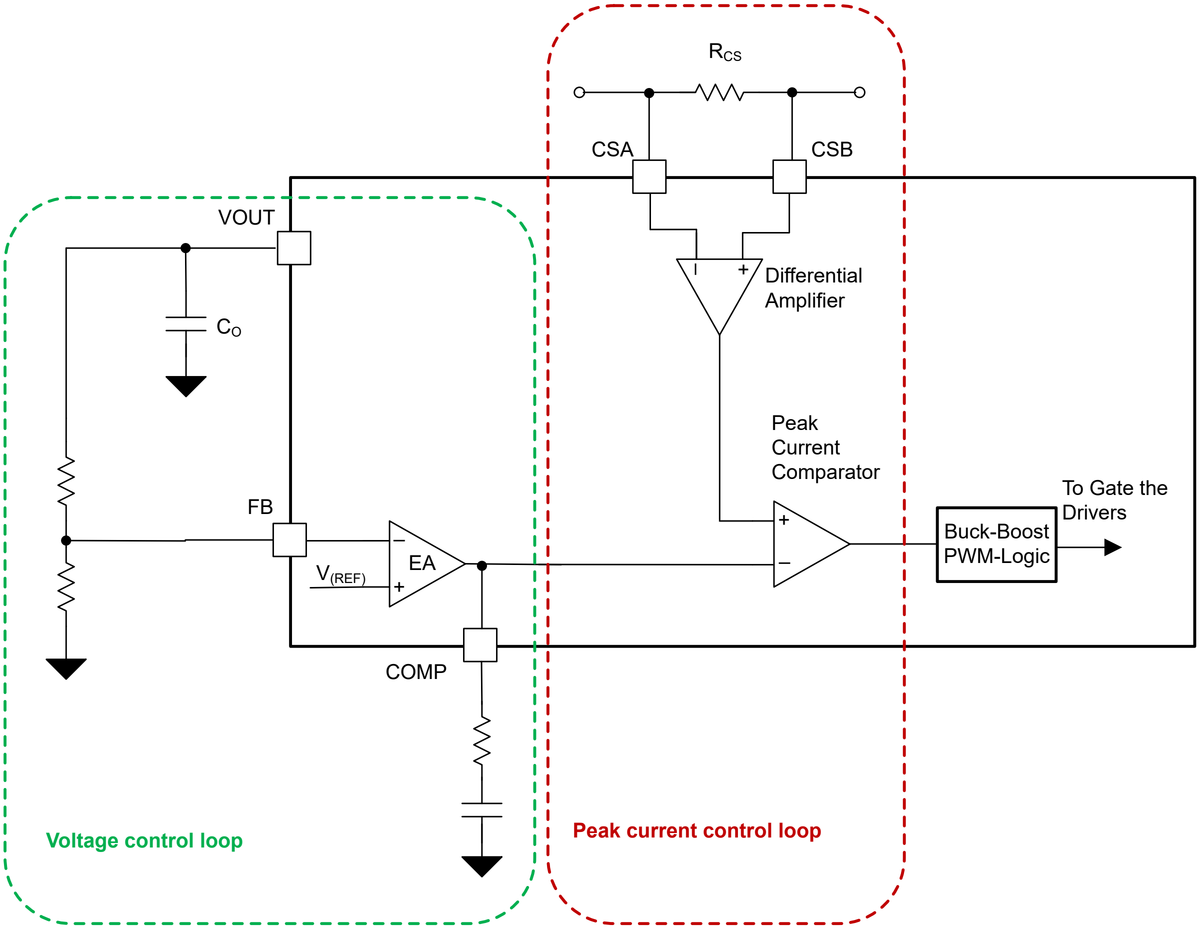


**Figure 2. Block Diagram for Inductor Peak Current Loop**

The peak current limit feature uses the inductor peak current to regulate the output load current for the power supply. Hence, it has numerous limitations in contrast to the average current limit feature. The bandwidth of the peak current limit comparator is the highest among other control loops in the controller, but due to the compensation limitations of the voltage loop, the overall bandwidth of the voltage regulation loop is less. Apart from this, it is a function of many applicative parameters such as switching frequency, inductor value, modes (buck, boost, and buck-boost), and so on. Thence, these dependencies restrict the operative range of the peak current limit and cause inaccuracy in its current protection threshold, thereby the average current limit feature will expand as a beneficial alternative to a sole peak current limit.

The average current limit has a control loop in the buck-boost controller, and it has a default priority over other control loops. If an average current limit loop is active, the current sense amplifier for the average current limit monitors the differential voltage across the sense resistor $R_{ISNS}$ and compares this value with an internal reference voltage. If the drop across the $R_{ISNS}$ is greater than the reference threshold, the average current limit loop will overwrite the output value of the $g_m$ stage in the voltage loop. This is done by regulating the peak current clamp value for the inductor peak current until the differential voltage is equal to the reference voltage. In such a way, the average current limit loop regulates and reduces the peak current capability of the DC/DC converter. The schematic of the average current limit loop is illustrated in Figure 3.

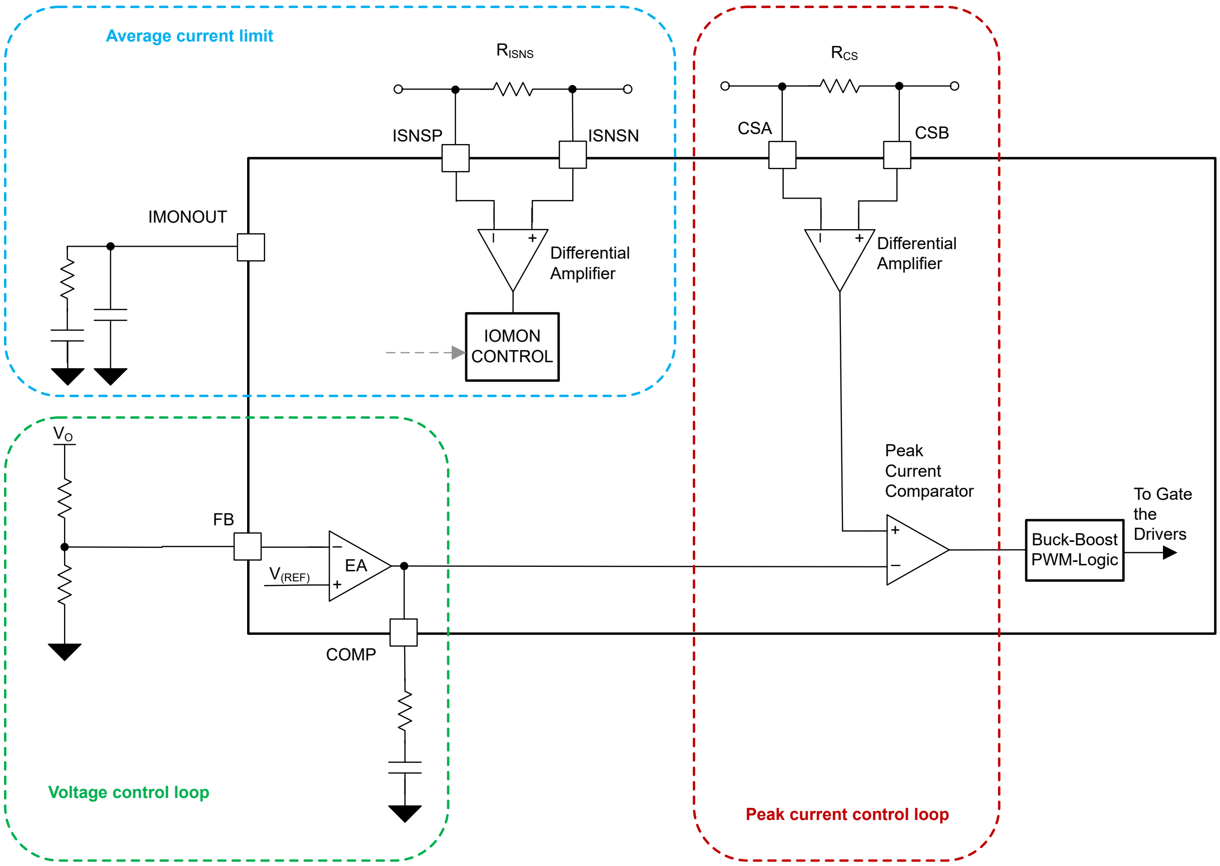


**Figure 3. Block Diagram for Average Current Limit Loop**

To enable the wide range of the average current limit of the power supply, an external shunt resistance $R_{ISNS}$ is used for the average current limit loop. In addition to this, compensation is added at the IMONOUT- pin to enhance the stability of the average current limit loop with optimal performance for a wide range of applications or operating points. For most applications, a compensation bandwidth with a factor of 3 to 5 times faster than the compensation of the output voltage loop has given good results.

### Application Demonstration

To validate the operation of the average current limit, a hardware test is conducted on the *LM5177 Buck-Boost Controller Evaluation Module*. For this test, the buck-boost controller is set to operate the converter in boost mode with an output voltage of 12 V, and the applied input supply voltage is 6 V. To set a desired output voltage value, the voltage divider ratio at the feedback pin of the LM5177 Buck-Boost Controller needs to be changed accordingly. The first test is run without the average current limit, and this is the normal operation of the controller. The result in Figure 4 shows that the inductor peak current increases with the load current, but the output voltage regulates around 12 V.

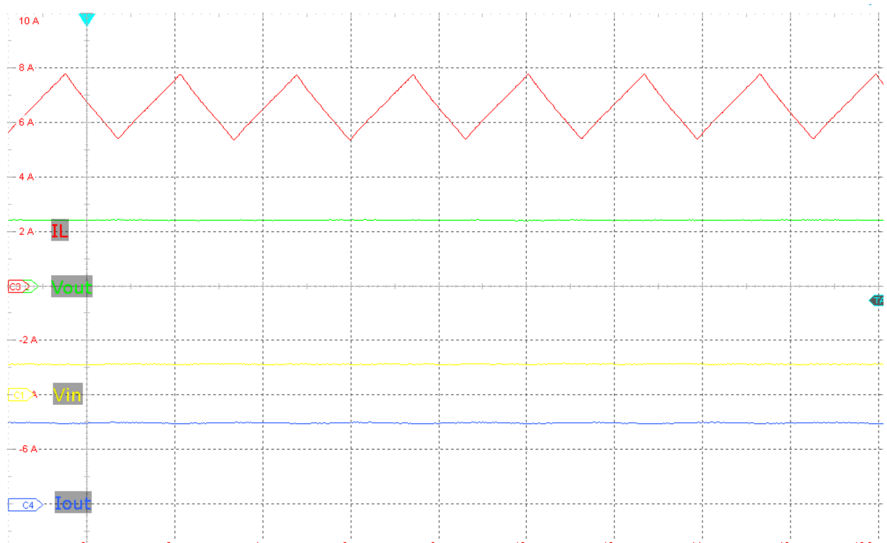


**Figure 4. Boost Mode Without ILIM Operation**

On the contrary, the test results shown in Figure 5 depict the average current limit operation. The value set for the average current limiter is 3 A. Hence, the result confirms that the inductor peak current is clamped around 3 A, and the supply has a constant output current of 3 A. To regulate the supply output current, the supply output voltage can decreases down to 0 V with a further increase in the load current.

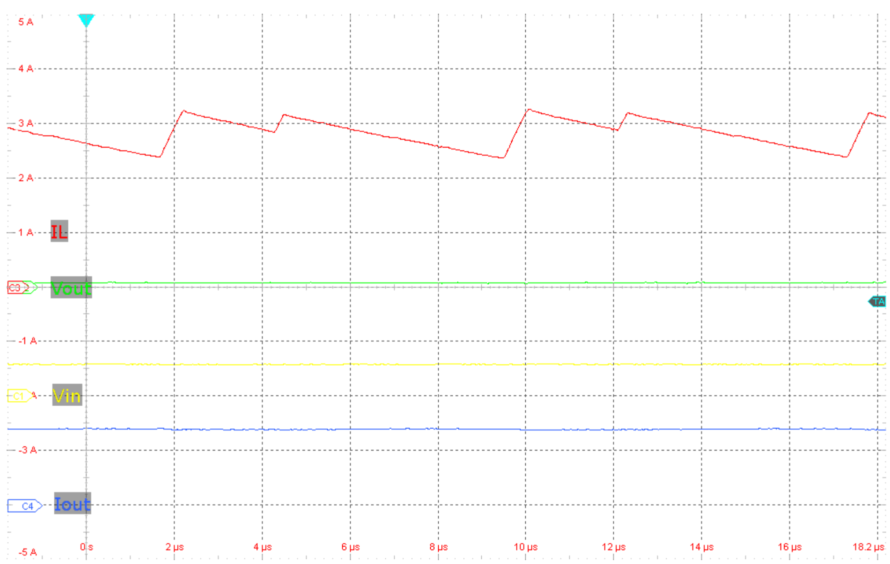


**Figure 5. Boost Mode with ILIM Operation**

The tests for peak and average current limiters were conducted for different topologies (buck, boost, and buck-boost) of the converter. The current regulation limit set for the average and peak current limiter is 3 A and 9 A, respectively. Figure 6, Figure 7, and fontoxml-text-placeholder text="Type the link text" demonstrate the results collected from these tests. It is evident from the results that the average current limit precisely and accurately regulates the output supply current at 3 A in the buck and buck-boost modes, but gives a slight inaccuracy in the value for the boost mode. On the contrary, a considerable deviation from the desired current regulation limit is observed for the peak current limit, in all three topologies. These deviations and inaccuracies in the peak current limit regulation is because of its dependency on many control parameters of the buck-boost controller (such as input voltage, switching frequency, and so on).

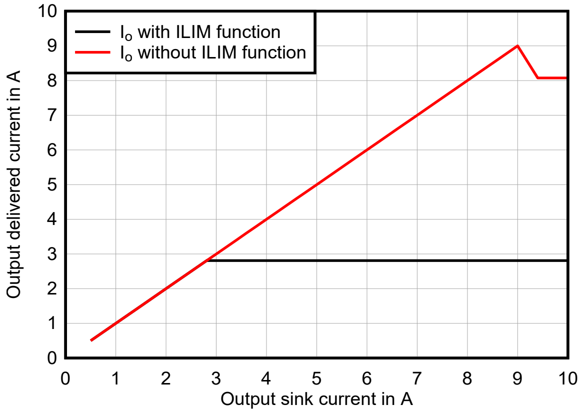


**Figure 6. ILIM Boost Mode $V_{IN}$ 6 V**

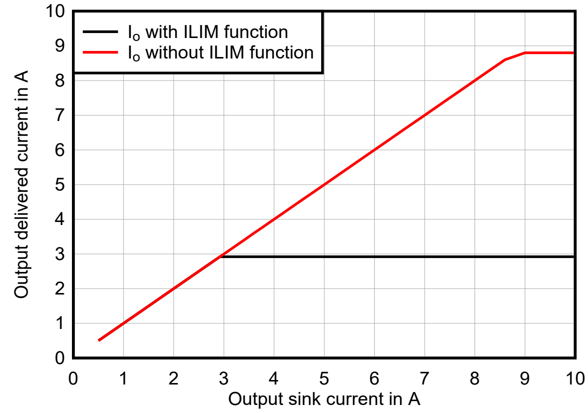


**Figure 7. ILIM Buck Mode $V_{IN}$ 24 V**

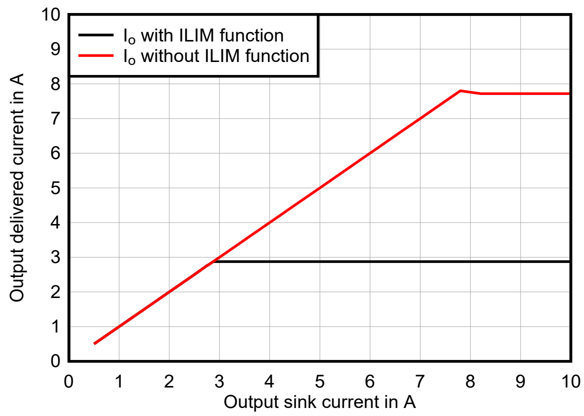


**Figure 8. ILIM Buck Boost Mode $V_{IN}$ 12 V**

## Summary

It is evident from the results that the average current limit feature of the buck-boost controller has a high response, accuracy, and precision compared to the peak current limit. Therefore, it is recommended to use this feature for systems that are critical to over-currents and short circuits. Further, the operational independence of the average current limiter from the control parameters of the buck-boost controller makes this feature a reliant constant current source for numerous applications.

## References

- Texas Instruments, *LM5177 80-V Wide VIN Bidirectional 4-Switch Buck-Boost Controller*, data sheet
- Texas Instruments, *LM5177 Buck-Boost Controller Evaluation Module*, user's guide.

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