Application Report
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Performing Accurate PFM Mode Efficiency Measurements

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ABSTRACT

When performing measurements on DC-DC converters using pulse frequency modulation (PFM), proper care must be taken to ensure that the measurements are accurate. Due to the nature of a converter operating in PFM mode, the test setup required to obtain correct measurements differs from the test setup that is normally used to acquire measurements of the device operating in PWM mode. An improper test setup can result in incorrect efficiency measurement data that varies considerably from the data-sheet specifications provided by Texas Instruments.

This application report contains guidelines that can assist the user in acquiring accurate efficiency measurements. An example of measurements taken on the TPS61020 is provided.

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1 Introduction

Pulse frequency modulation (PFM) is a switching method commonly used in many DC-DC voltage converters to improve efficiency at light loads. PFM mode is also referred to as *power save* mode in TI data sheets. A converter operating in power save mode uses PFM at light load currents and pulse width modulation (PWM) at heavier load currents. This type of operation allows the converter to maintain high efficiency over a wide range of output current. Figure 1 and Figure 2 display two graphs comparing the efficiency of the TPS61020 in PWM and PFM/power save mode.

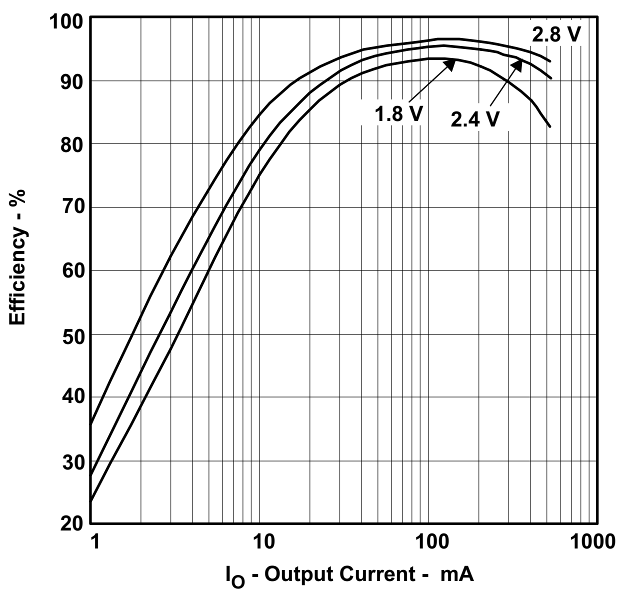

Figure 1. PWM Efficiency

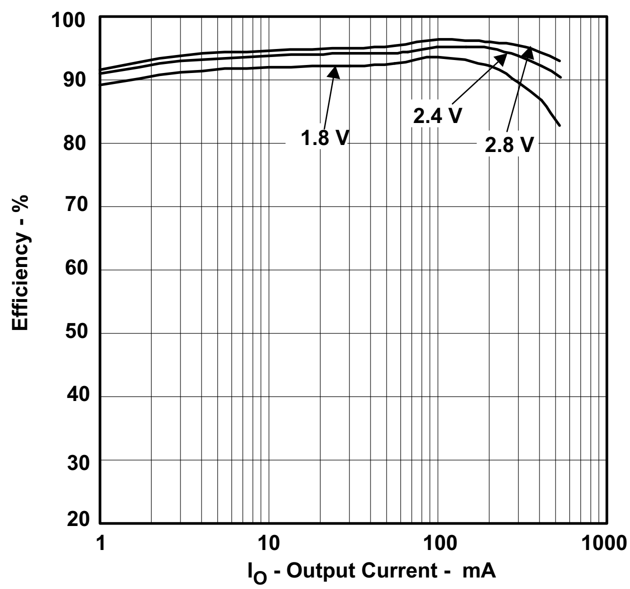

Figure 2. Power Save Mode Efficiency

While in PFM mode, the converter only operates when the output voltage is below the nominal output voltage. When this happens, the converter begins switching until the output voltage is regulated to a typical value between the nominal output voltage and 0.8% above the nominal output voltage. During the period where the converter is powered down, all unnecessary internal circuitry is turned off to reduce the IC's quiescent current. This control method significantly reduces the quiescent current to a typical value of 20 µA, which results in a higher efficiency at light loads.

In contrast to PWM mode, in which the converter is continuously switching, PFM mode allows the converter to switch in short bursts. Figure 3 and Figure 4 show the switch node waveforms when the converter is operating in PWM and PFM mode, respectively

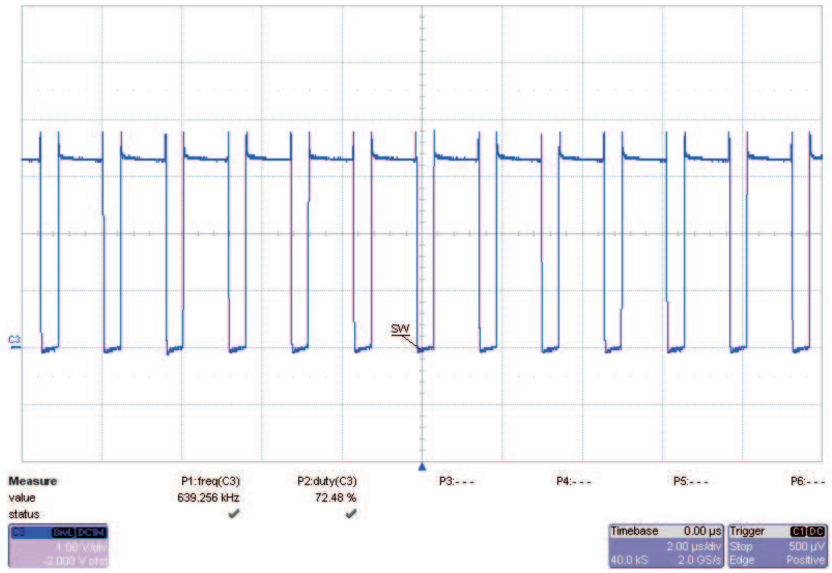

Figure 3. PWM Switching Node Waveform

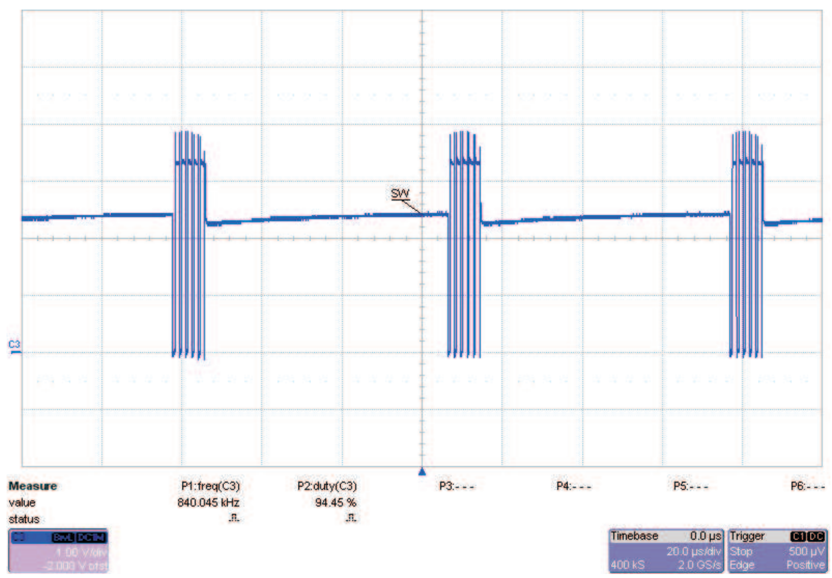

Figure 4. PFM Switching Node Waveform

Note: The time scale in Figure 3 is 2 µs/div, whereas the time scale in Figure 4 is 20 µs/div

2 Efficiency Measurements

2.1 PWM Efficiency Measurements

When measuring the efficiency of DC-DC converters, it is important that the voltage and current meters are sensing their values at the proper locations. For example, the setup shown in Figure 5 can be used to perform efficiency measurements of a boost converter operating in PWM mode.

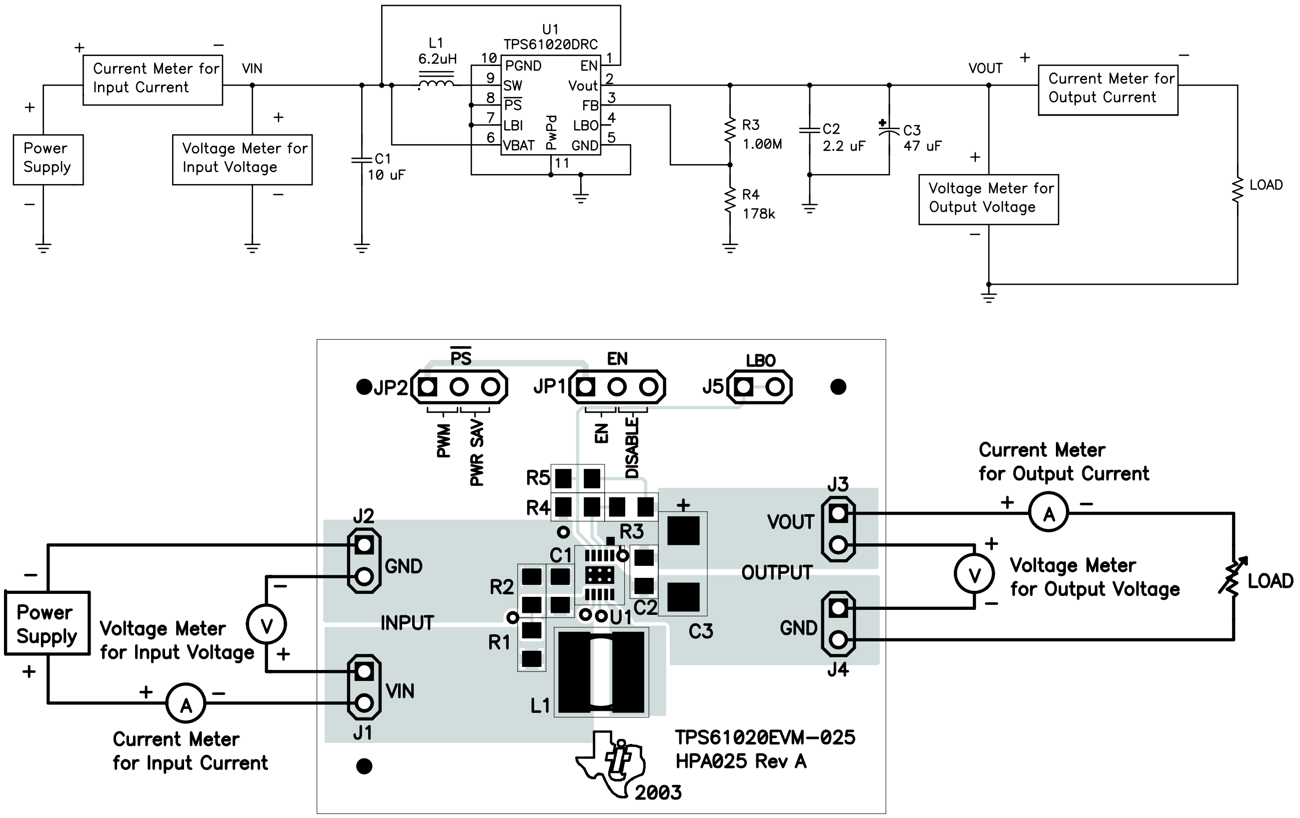

Figure 5. PWM Measurements

Most laboratory power supplies display their voltage output setting, but it is important that the voltage displayed on the power supply is not used in efficiency calculations. Instead, a separate voltmeter should be connected directly across the input of the converter, as shown in Figure 5. This ensures that the measured voltage is the true voltage at the input of the converter and does not include additional voltage drops across the current meter or any cabling. Similarly, a separate voltmeter should be connected directly across the output of the converter to acquire the output voltage values.

2.2 PFM Efficiency Measurements

In order to accurately measure the efficiency of a converter operating in PFM mode, the test setup shown in Figure 5 must be slightly modified to the setup shown in Figure 6.

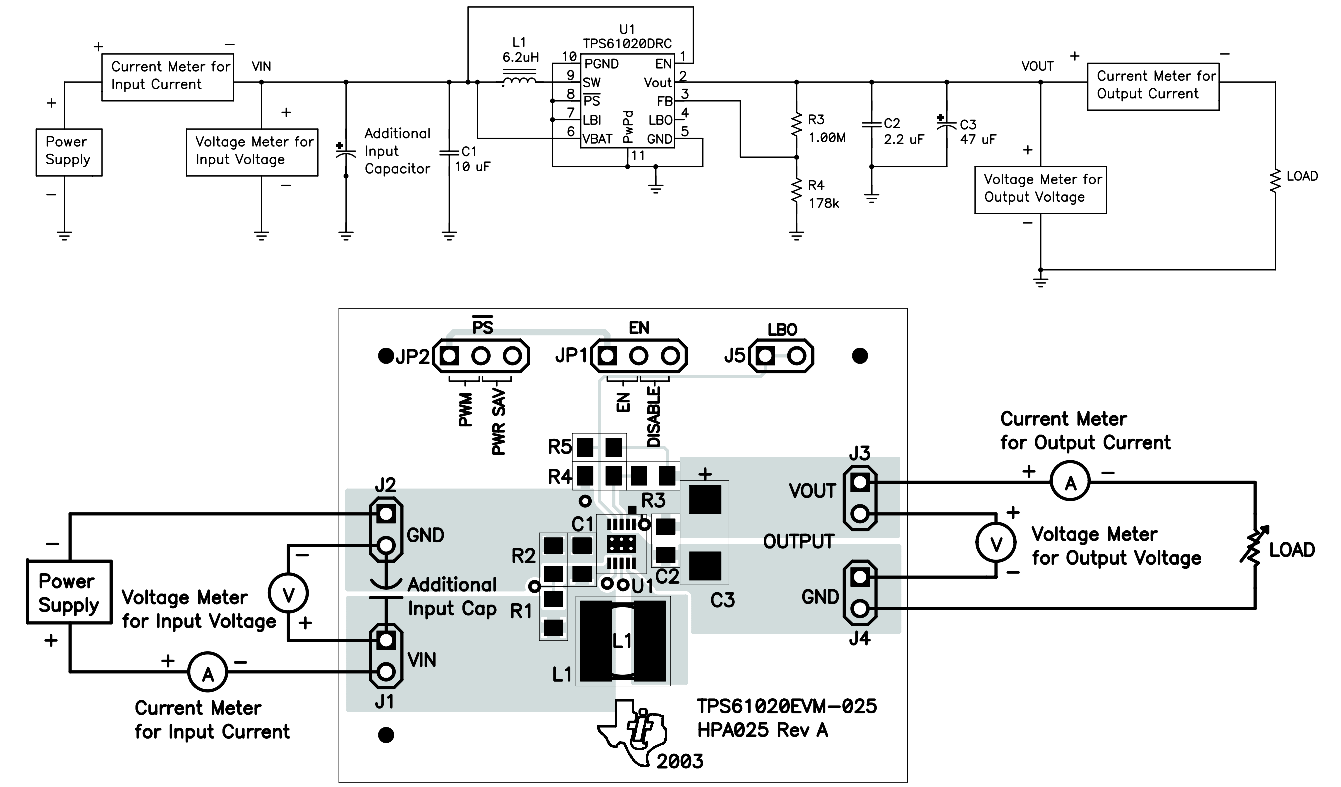

Figure 6. PFM Measurements

Figure 6 is exactly the same as Figure 5, with the exception of a capacitor added across the input. This capacitor must be added to ensure that the efficiency measurements are correct. Typically, the capacitance of the added input capacitor should be much larger than the capacitance of C1. To understand why an additional capacitor is needed, consider the waveforms shown in Figure 7.

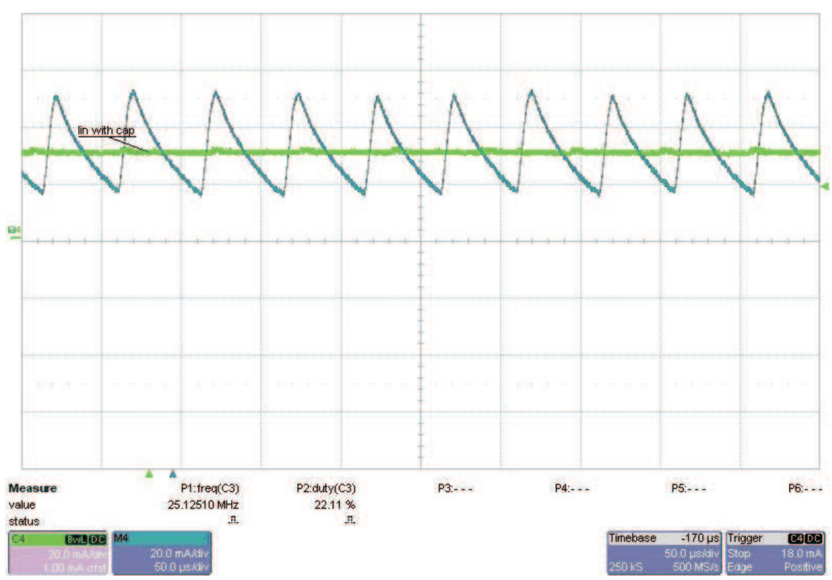

Figure 7. Input Current Waveform

In Figure 7, the triangular waveform represents the input current of a converter operating in PFM mode without the additional input capacitor (i.e., when the test setup is as shown in Figure 5). The straight waveform represents the input current when a capacitor is added across the input (i.e., when the test setup is as shown in Figure 6). If no capacitor is added, then the input current meter cannot accurately determine the amperage of the input current, because the input current has a large sinusoidal component. In contrast, adding a large capacitance across the input produces a steady current waveform, allowing the input current meter to accurately sense the amperage of the input current. Although the current sensed by the meter is purely DC, the current provided by the added capacitor will be similar to the saw tooth waveform in Figure 7, except it will not have a DC offset. Thus, the role of the capacitor can be viewed as separating the input current into DC and AC. A current meter monitoring the current provided by the added capacitor would sense a saw tooth waveform with no DC offset.

Using the test setup shown in Figure 5 to measure PFM efficiency may result in incorrect data that varies by as much as 15% from the actual efficiency. This disparity is most evident at low input voltage and current load. Figure 8 displays efficiency measurements taken with and without an additional input capacitor for various input voltages. At approximately 65-mA output current, all three curves converge. This is because the converter switches from PFM to PWM mode at 65-mA output current. Furthermore, adding the additional input capacitor has no effect on PWM measurements; the efficiency measured is the same whether the capacitor is added or not.

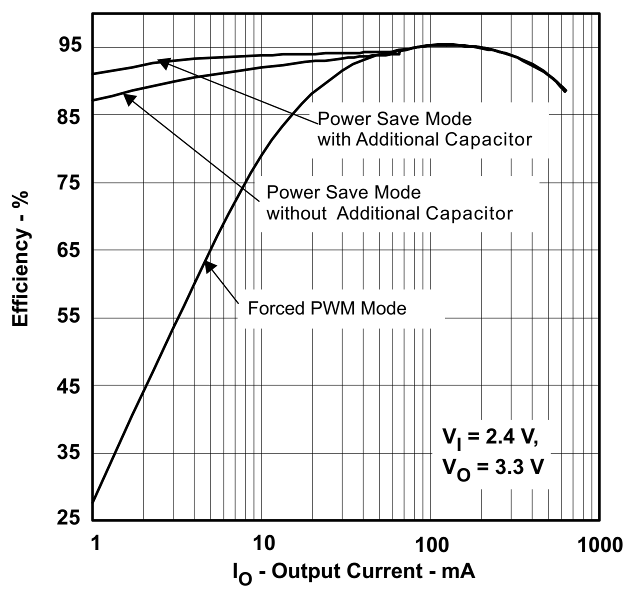

Figure 8. Efficiency Comparison

3 Conclusion

Care must be taken when measuring the efficiency of DC-DC voltage converters. The voltmeters being used should be connected directly across the input and output of the converter, regardless of whether it is operating in PFM or PWM mode. Additionally, a large capacitor should be added across the input of the converter to ensure that PFM mode efficiency measurements are properly taken.

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