

Performing Accurate Power Save Mode Efficiency Measurements

Jatan Naik

PPM - Portable Power

ABSTRACT

When performing measurements on DC-DC converters using pulse frequency modulation (PFM) or any power save mode, proper care must be taken to ensure that the measurements are accurate. An accurate PFM mode efficiency measurement is critical for systems which require high efficiency at low loads, such as in smart home systems, tablets, wearables, and metering. 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.

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.

Contents

1	Introduction	2
2	Efficiency Measurements	4
3	Conclusion	7
4	References	7

List of Figures

1	PWM Efficiency	2
2	Power Save Mode Efficiency	2
3	PWM Switching Node Waveform	3
4	PFM Switching Node Waveform	3
5	PWM Measurements	4
6	PFM Measurements	5
7	Input Current Waveform	6
8	Efficiency Comparison	7

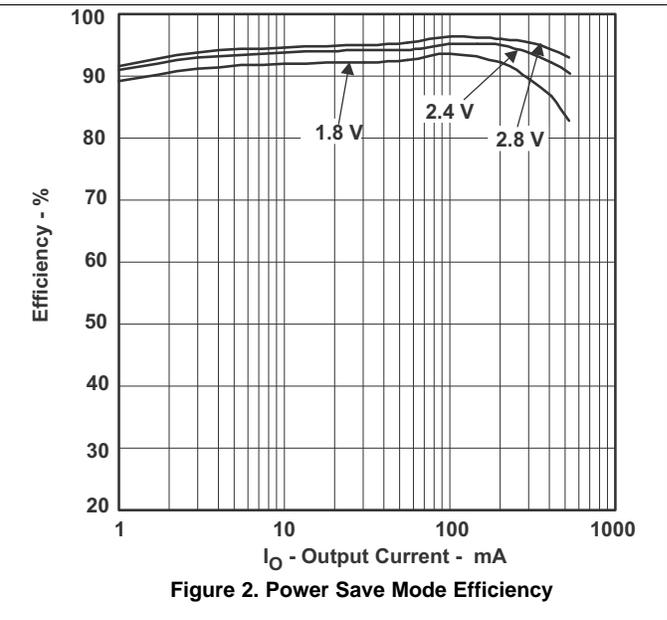
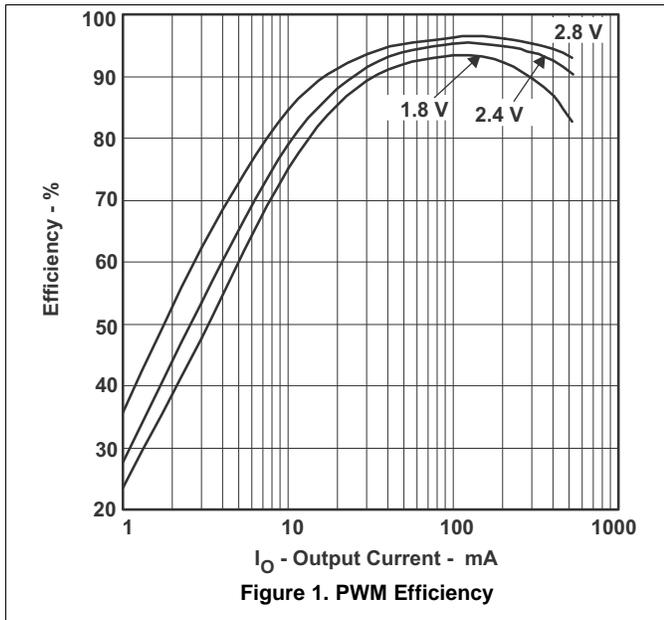
List of Tables

Trademarks

E2E is a trademark of Texas Instruments.
 All other trademarks are the property of their respective owners.

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.



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 μ A, which results in 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.

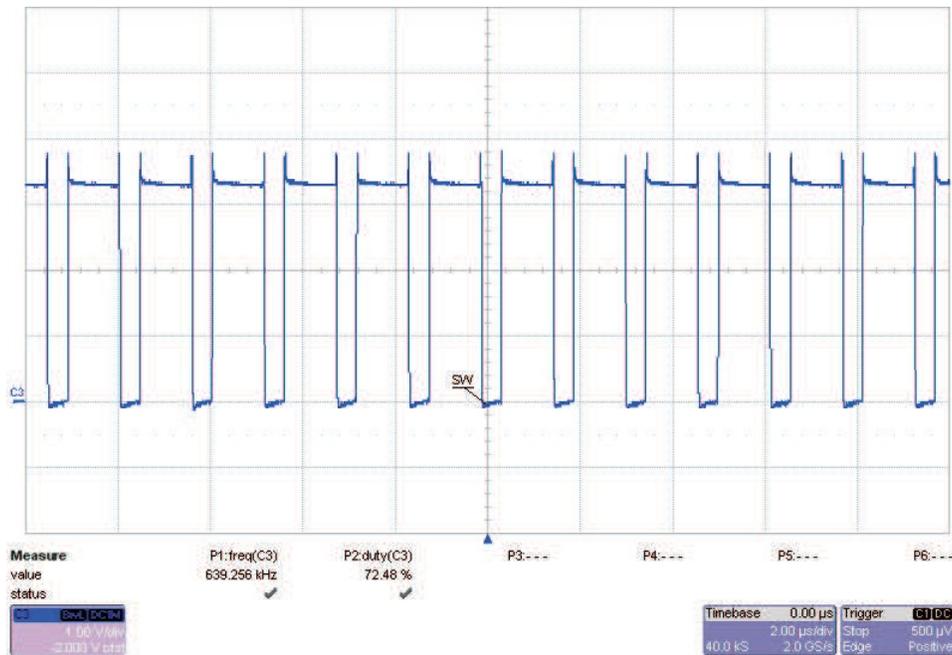


Figure 3. PWM Switching Node Waveform

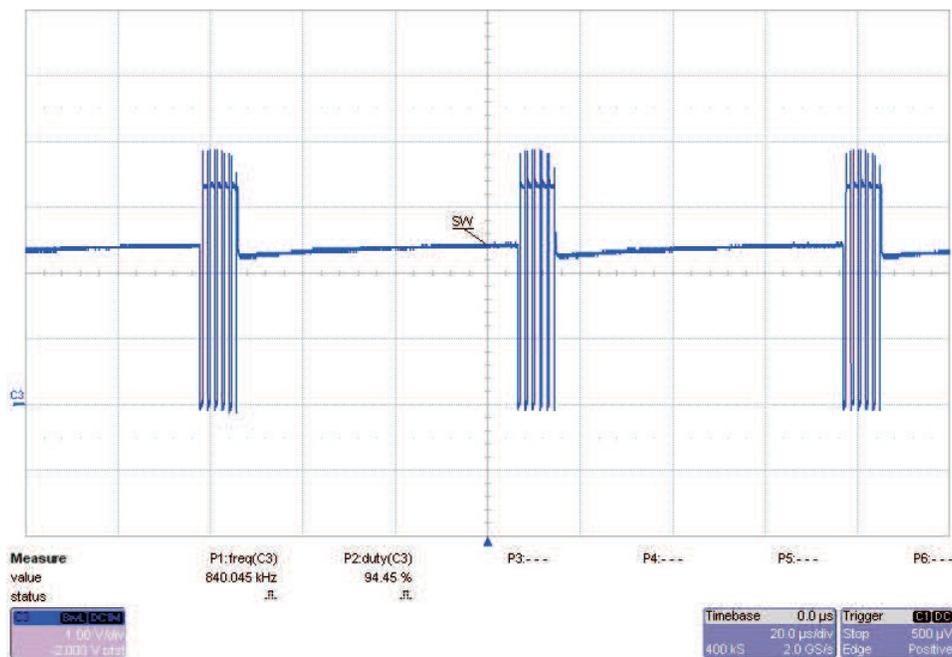


Figure 4. PFM Switching Node Waveform

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.

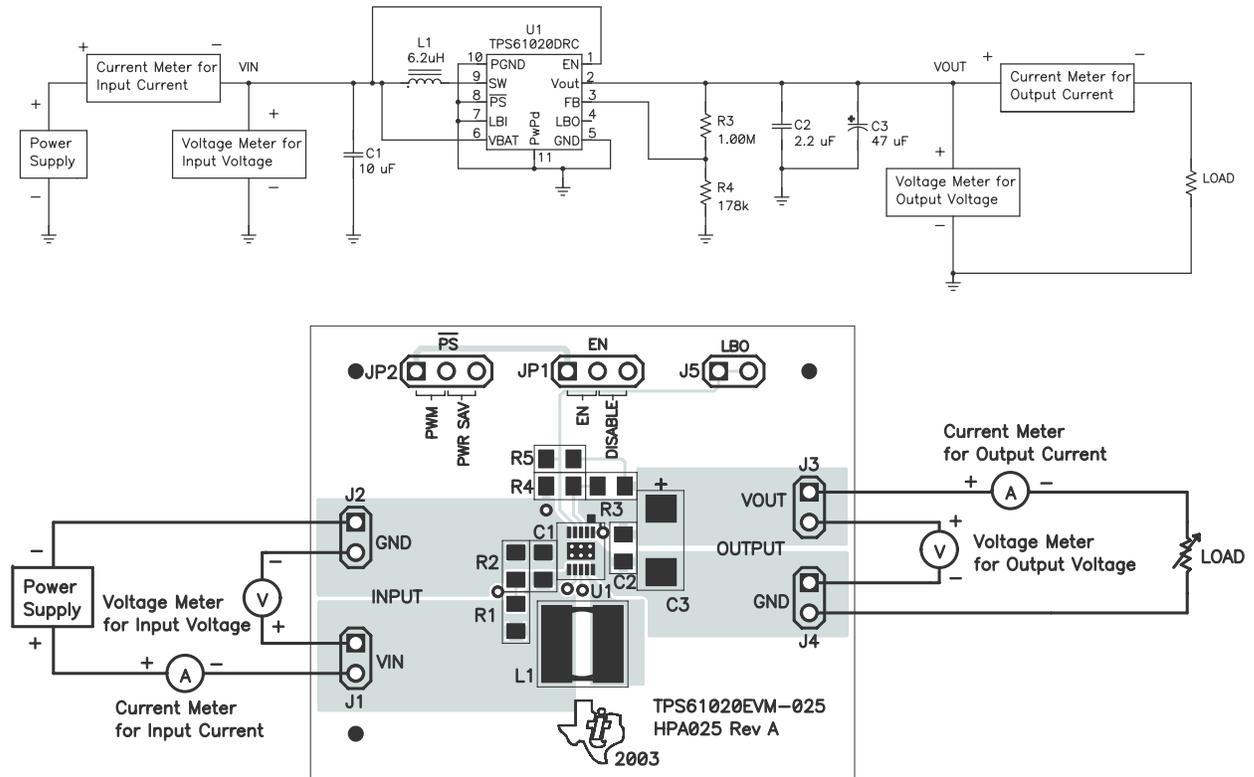


Figure 5. PWM Measurements

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.

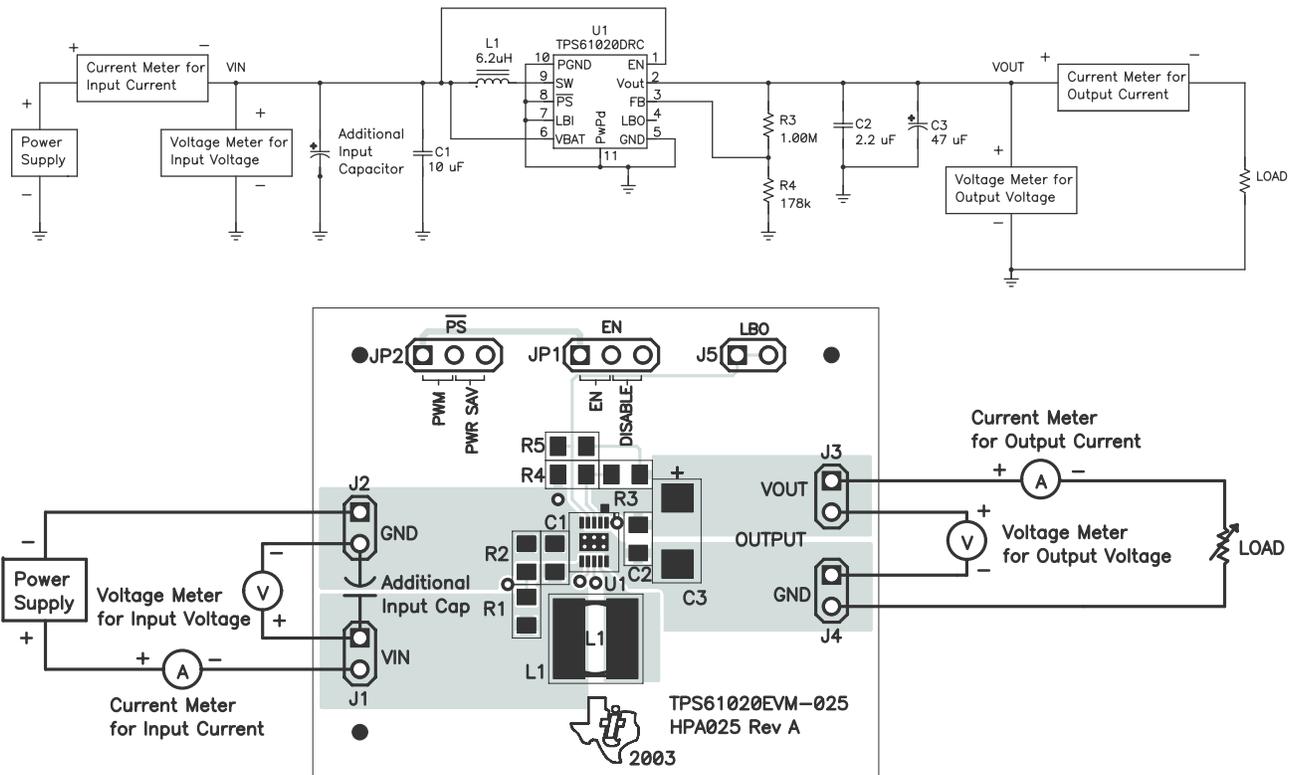


Figure 6. PFM Measurements

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.

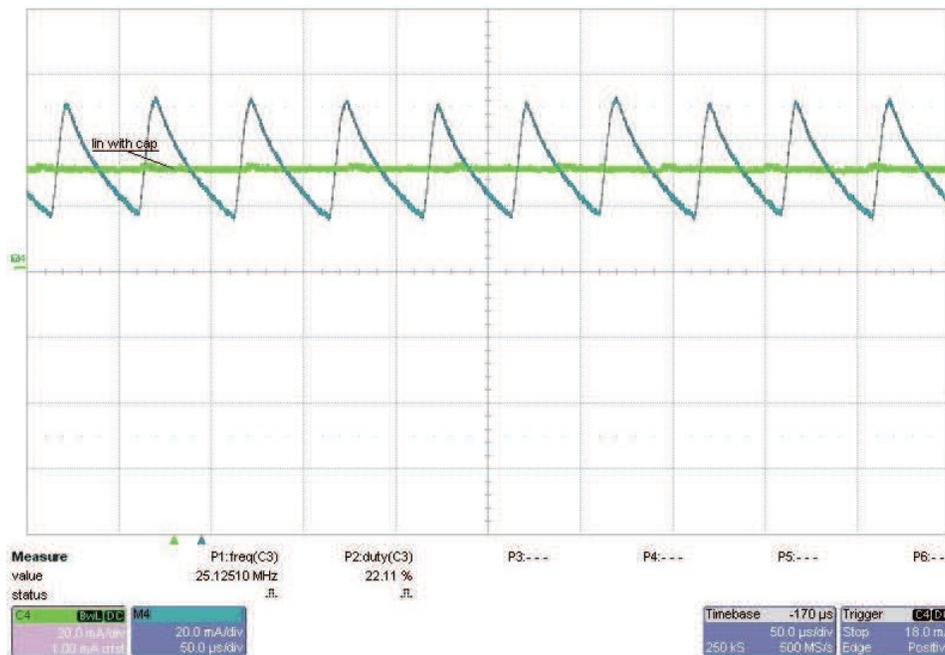


Figure 7. Input Current Waveform

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.

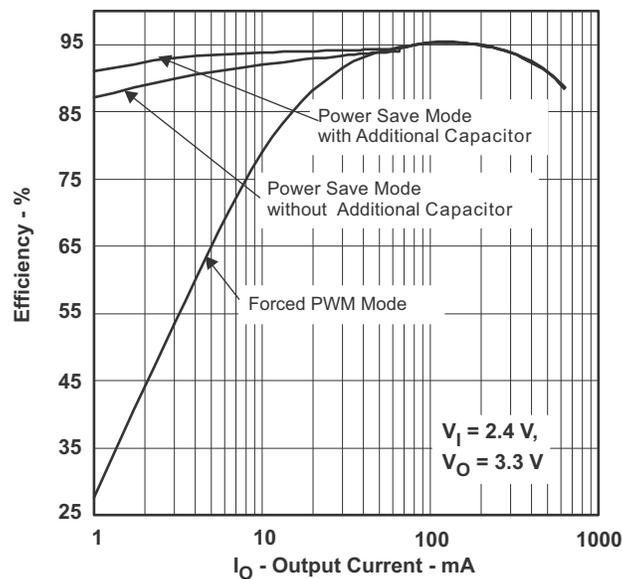


Figure 8. Efficiency Comparison

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.

4 References

- [Accurately measuring efficiency of ultralow-IQ devices](#), 1Q 2014, Analog Applications Journal
- [What is that giant tantalum cap on the input of the EVM?](#), May 20, 2015, Fully Charged Blog, TI E2E™ Community

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (April 2006) to A Revision	Page
• Changed the title From: Performing Accurate PFM Mode Efficiency Measurements To: Performing Accurate Power Save Mode Efficiency Measurements	1
• Changed the abstract section	1
• Added the <i>References</i> section	7

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2018, Texas Instruments Incorporated