

Easily Test DC-DC Converters Using the Keysight DC Power Analyzer

Introduction

Power system technology used in modern electronic equipment faces extreme challenges due to the need for increased system power efficiency, especially in battery powered devices. The main system block involved in power conversion and delivery is the DC-DC converter, which converts DC power from an unregulated to a regulated voltage. Many designers want to verify or characterize the performance of the DC-DC converter in terms of efficiency, load and line regulation, power supply rejection ratio (PSRR) analysis, transient response, ripple, and turn-on time. Performing these tests on DC-DC converters in a benchtop environment; however, requires different test instruments such as a digital multimeter (DMM), oscilloscope, power supply, and electronics load. The main challenge here is in being able to properly synchronize the instruments to execute the various needed measurements.

This application note explains how to easily carry out DC-DC converter testing using a Keysight Technologies, Inc. N6705C DC Power Analyzer and MSOX2/3/4000 Series oscilloscope. Keysight's BenchVue software provides the framework for developing simple automated tests to completely characterize the DC-DC converter without having to write any code, substantially saving time.

Using a N6705C DC Power Analyzer and BenchVue Software for DC-DC Converter Parameter Testing

In general, the test setup is dependent on the type of test being performed. To characterize the DC-DC converter, for example, you first have to connect it between the power source and the electronic load in order to sink the converter's current (Figure 1). Then, you must measure the voltage and current across the input (V_{in} and I_{in} , respectively) and output (V_{out} and I_{out} , respectively). These values constitute the input power (P_{in}) and the output power (P_{out}).

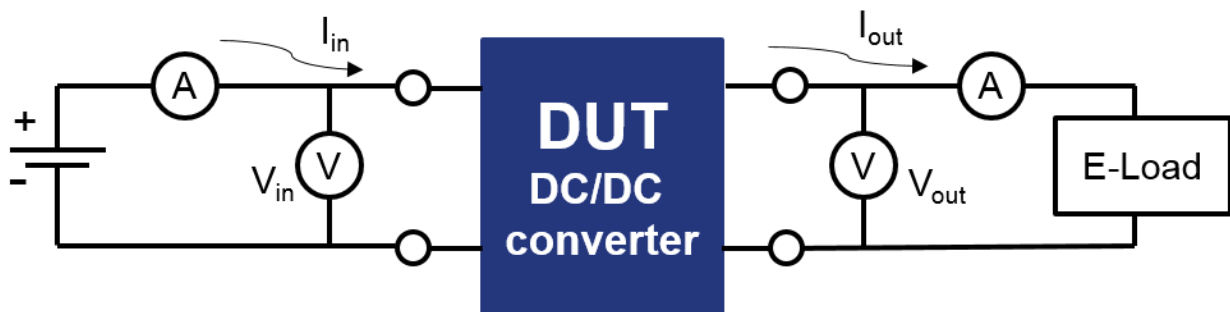


Figure 1. DC-DC converter connection

The DC characterization can be simplified by replacing the power supply, DMM and electronic load with the N6705C DC Power Analyzer. A built-in feature offering highly accurate, flexible measurement capabilities helps designers perform the necessary tests.

The N6705C combines one to four programmable DC power and measurement units (i.e., a 2- or 4-quadrant source and measurement unit, aka SMU), a DMM for each channel; an oscilloscope that shows voltage, current and power versus time, which allows designers to view the signal in real time; and a data logger—all in one integrated package (Figure 2A).

Each of the four output characteristics are determined by the plug-in power module used for that output. There are 34 different power modules available for N6705C; their key specifications make them a good match for wide DC-DC validation with different power values. BenchVue software allows designers to build a simple test flow for the DC-DC converter with the N6705C power analyzer, without any of the programming hassles. This software's intuitive user interface makes it easy to connect and synchronize the different Keysight instruments to run custom validation test, and enables quick capture and viewing of any data coming from those instruments (Figure 2B).



Figure 2. A) Keysight DC power analyzer, B) Keysight BenchVue interface

Efficiency Test

Typically, the most important DC test for the DC-DC converter is efficiency. This is especially true for battery-powered devices, because efficiency has a direct impact on the life of a device.

The efficiency of the converter is the ratio between the output power and the input power. To run the test, use one channel of the N6705C as input voltage and monitor the converter input current, and use another channel, configured as a load by setting it to sink current, and measure the voltage on the output of the converter. Use BenchVue to draw the flow of the test.

In this particular example, the DC-DC converter was configured to output a constant voltage of 15 V. The efficiency was measured at three different input voltage values: 6 V, 9 V and 12 V. The load channel was configured to sweep a load current from 0 to 10 mA and measure the output voltage. Figure 3A shows the flow diagram representing the test described in BenchVue, while Figure 3B shows the results.

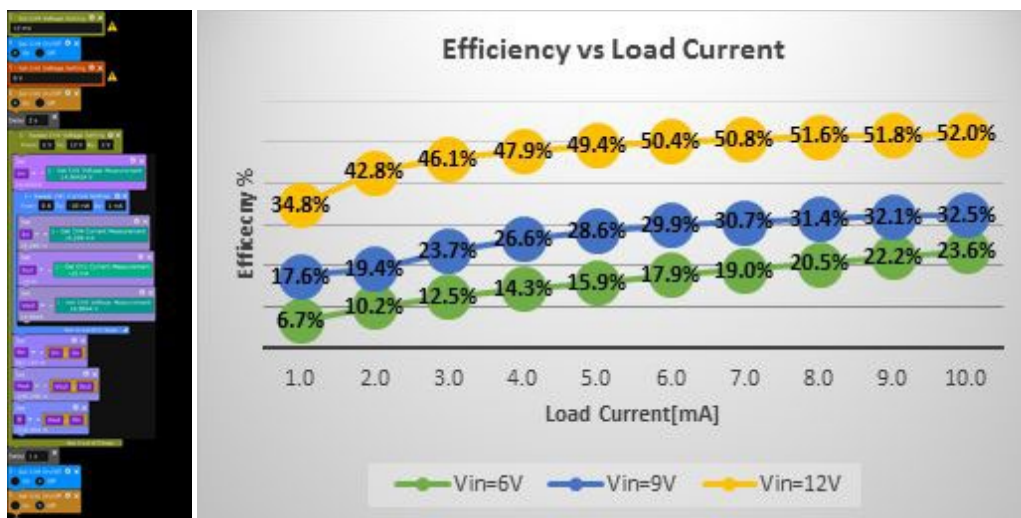


Figure 3. A) BenchVue efficiency test flow, B) Efficiency test results

Load Regulation Test

The load regulation test measures the ability of the DC-DC converter to sustain the specified voltage output when the load current (I_{load}) varies at constant input voltage. To execute this test, after powering up the product, slowly vary the output load between the specified minimum and maximum current values. The measured output voltage changes should be within the range specified in the product's technical specification. For the test setup, use the same connection employed for the efficiency test.

Figure 4A shows a test flow on BenchVue that can be used to run a load regulation test. Figure 4B shows a typical result of this test when the constant input voltage is applied at 9 V and the channel of the N6705C is configured to sweep the current from 0 to 50 mA.

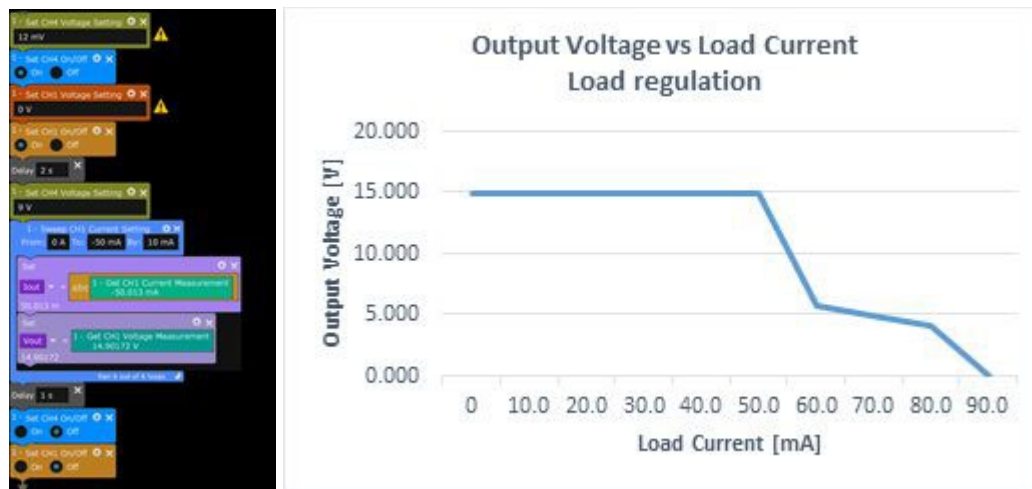


Figure 4. A) BenchVue load regulation test flow, B) load regulation test results

Line Regulation Test

The line regulation test represents the ability of the DC-DC converter to sustain the specified output voltage while the input voltage is varied between a specified range of voltages. To carry out this test, set the input power source to a value within the input range of the product and power up the product. While monitoring the product output voltage, slowly vary the input voltage between the specified minimum and maximum values. The measured output voltage changes should be within the range specified in the product's technical specification.

For this test, the channel of the N6705C on the input voltage of the DC-DC converter sweeps over the specified voltage range, while the channel on the output of the DC-DC converter measures the output voltage. Figure 5A shows a test flow on BenchVue to run a line regulation test. Figure 5B shows a typical result of this test when the sweep of the input voltage from 2 to 12 V is applied and the other channel measures the output voltage of the DC-DC converter.

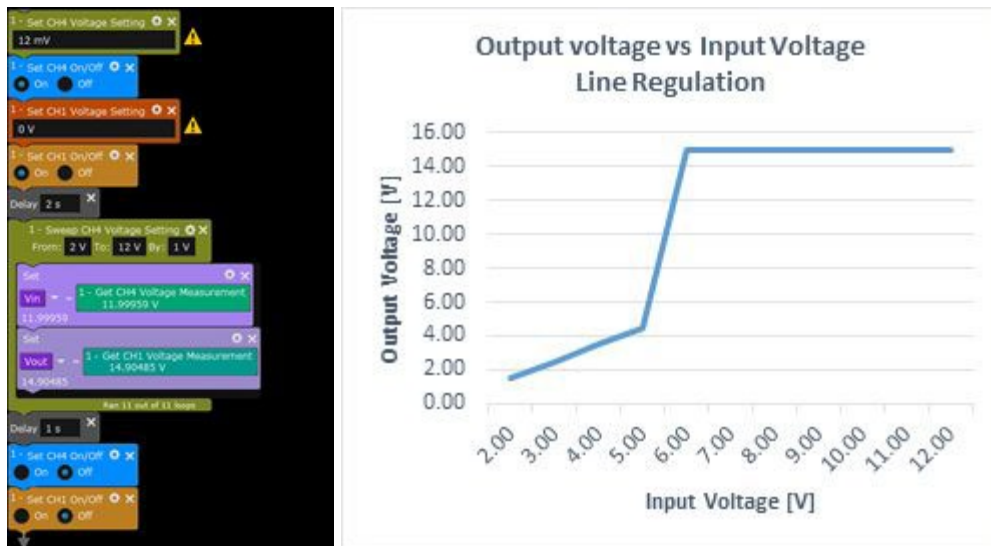


Figure 5. A) BenchVue line regulation test flow, B) Line regulation test results

In addition to the DC parameter testing performed by the SMU, some tests require the use of an oscilloscope to characterize the AC parameters of the DC-DC converter. These tests include ripple test, start-up time and transient response. In order to perform these tests, Keysight's DC-DC converter test solution includes the MSOX4000 Series oscilloscope, as shown in Figure 6.

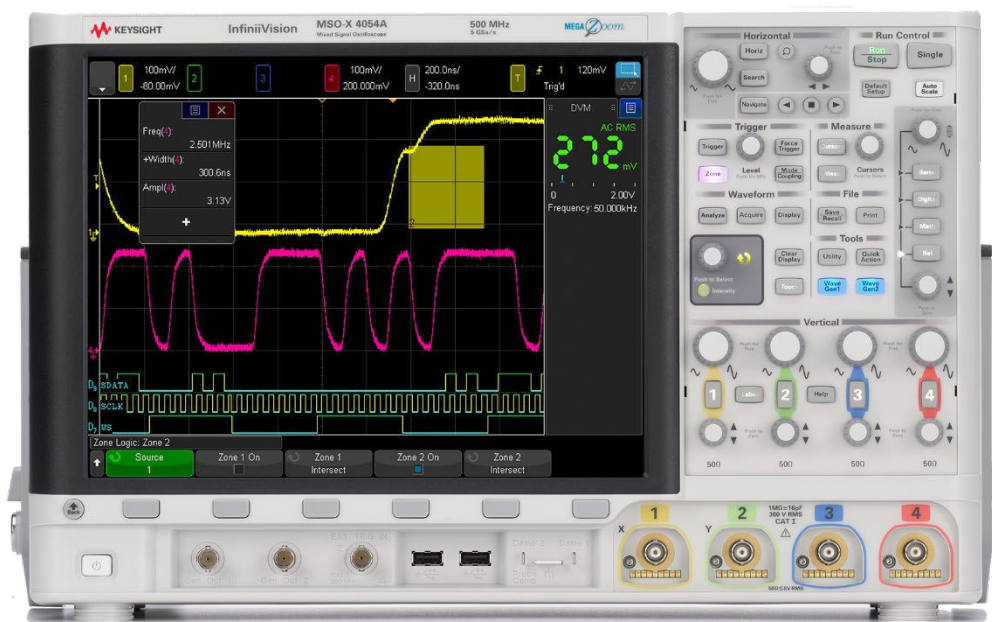


Figure 6. Keysight's MSOX4000 series oscilloscope

Start-Up Time Test

The start-up time test measures the time delay between when the input voltage is applied to the DC-DC converter and the time it takes to reach to the steady output voltage. For this test, one SMU channel of the N6705C is applied to the input voltage and one channel of the oscilloscope is connected across the input of the DC-DC converter. Another oscilloscope channel is connected on the output of the DC-DC converter. Using BenchVue, the start-up time is automatically calculated. Additional measurements on the signal (e.g., rise-up time, fall-down time and peak-to-peak voltage) can also be extracted. Figure 7A shows a test flow on BenchVue to run a start-up time test. Figure 7B shows a typical result of this test.



Figure 7. BenchVue start-up test flow, B) Results of a start-up test, time-based measurement

Ripple Test

The DC-DC converter has different internal topologies used at different internal switching frequencies that are reflected in the output ripple frequency. The ripple on the output voltage is measured as rejected input noise on the output voltage using an oscilloscope, with one channel on the input and one channel on the output of the converter. The N6705C DC Power Analyzer creates the arbitrary waveform required in this application as a mixed signal comprising a DC signal with a ripple, which is used to power the DC-DC converter.

To perform a ripple test of the DC-DC converter, one channel of the N6705C was configured as an arbitrary waveform generator to reproduce a DC signal with a small sine wave added, and one channel of the oscilloscope was connected to the input of the DC-DC converter. Another oscilloscope channel was connected to the output of the DC-DC converter. The voltage peak for the sine wave was 250 mV (v0), the DC voltage was 9 V (v1), and the frequency was 250 Hz (f). Figure 8A shows the arbitrary waveform setup screen of the output voltage used as input voltage to power the DC-DC converter. Figure 8B shows the screenshot of the time-based measurement of the ripple test.

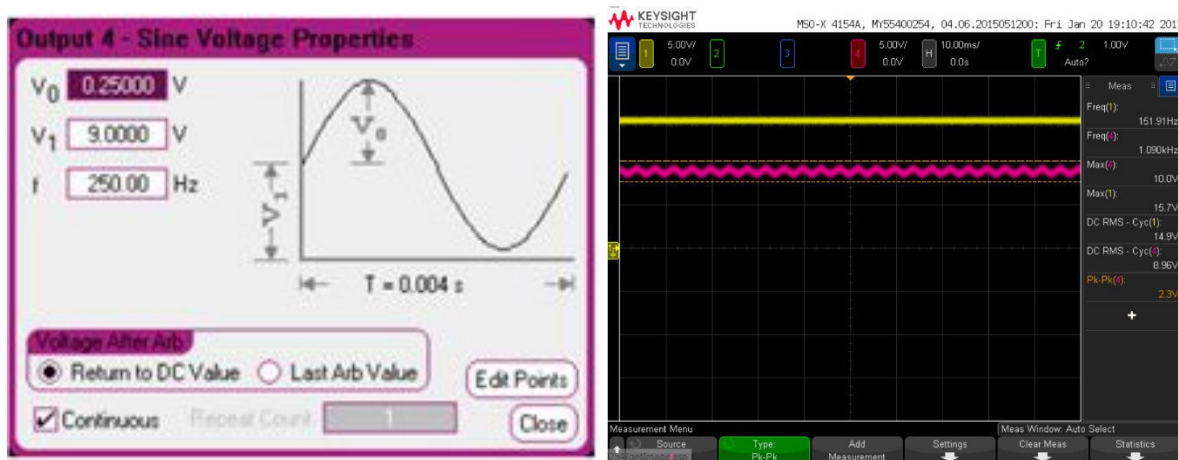


Figure 8. A) Power analyzer screenshot arbitrary waveform setup, B) Screenshot of the scope view results

Other Workable Tests on the DC-DC Converter and Scaling-Up of Keysight's Solution

Another built-in test function of the N6705C is spectral analysis, which enables designers to analyze the AC components of the output voltage and measure the frequency domain. To cover more power applications such as hybrid electric vehicles (HEVs), uninterruptable power supplies (UPS), and many other bidirectional energy systems and devices that operate at multi-kilowatt power levels, it's possible to replace the N6705C with a Keysight APS N6900/N7900 DC Power Supply. The APS DC Power Supply covers DC power levels up to 2 kW using the same methodologies presented in this application note.

Summary

Testing the DC-DC converter is a process that usually requires several different instruments, with additional effort needed to synchronize the instruments together. The Keysight solution presented here is flexible, with a built-in capability to produce a complete setup to power and test DC-DC converters in a wide variety of test conditions without the hassle of programming. Other related applications that can benefit from this flexible solution are IC regulator testing, power supply testing and several different charging-system tests.

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