

Keysight Technologies

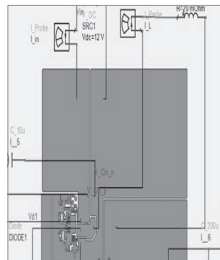
Increasing Reliability and Efficiency in Next Generation Power Converter Designs (Part 3)

Hardware Design and Debug

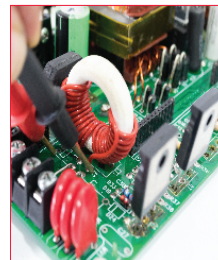
Application Note



Power Device
and Component
Evaluation



Electronic
Design
Automation



Hardware
Design and
Debug



Design
Validation/
Certification

Introduction

The need to reduce energy consumption as well as CO2 emissions is driving the growth of power electronics and power converters. These needs are driven by growth in the vehicle electrification and home energy management systems where renewable energy usage is becoming more prevalent. Two of the main power converter design drivers are increased conversion efficiency and better reliability. In green energy applications such as solar power, Levelized Cost of Energy (LCOE) is the main decider for what solar inverter a customer chooses for their solar installation. Both efficiency and reliability are two of the main variables in the LCOE algorithm that determines whether your inverter company gets the sale or not. In hybrid electric (HEV) and electric vehicles (EV) reliability is tied to an automotive manufacturer's reputation and is also linked to safety and the preservation of human life. Hence comprehensive EV test for the various vehicle electrical subsystems at the design and test stages is vital.

The ceiling or limits of these design drivers was getting close for many power converter applications that used power devices based on silicon. The emergence of wide band gap (WBG) power devices based on silicon carbide (SiC) and gallium nitride (GaN) hold promises of raising the ceiling of these design drivers. With the ability to switch faster, handle higher voltages, and larger temperature ranges WBG devices can increase efficiency and reliability as well as reduce form factor in next generation power converter designs. But before power converter designs based on WBG power devices can become main stream there are design and test challenges that must be understood and overcome to utilize them to their full potential.

This is part three in a four part series that takes a look at each stage of the power converter design cycle. At each stage we will look at design and test challenges of next generation power converters and discuss hardware and software tools to help you overcome them. We will put an emphasis on improving the design drivers previously mentioned: increasing efficiency, improving reliability, and reducing form factor. We also consider the design and test challenges that WBG devices introduce into the power converter design cycle. Each of the four parts of this series will cover one of the following design cycles:

1. Power device and component evaluation
2. Design software simulation
3. **Hardware design and debugging**
4. Design validation and certification

Hardware Design and Debug

Once you have fully optimized your design in software simulation, it is time to build hardware prototypes of the design and begin testing them ensure they match the expected results of the simulation and the overall requirements of the project. If something is not right, for instance you are not getting the output stability you expected, you need the right tools to get the insight into your design to track down the root cause of the of the issue so you can correct it. Also as the design is coming together EMC levels need to be checked to avoid time consuming and costly design rework. Keysight's large benchtop hardware and software portfolio, spanning from DC to RF, can help you do just that with differentiated capabilities targeted at power electronic designers to help them get the most efficient and reliable product to market fast. In the following sections we will discuss some common test challenges power electronics engineers face and how Keysight's hardware and software can help you overcome them.

Optimizing your design and speeding up the design process:

When integrating and testing the prototype hardware of your power converter design, you need an instrument that gives you quick and easy insight into each stage of your power converter design so that you can spot problems right away to ensure optimization of the design. Depending on the stage of the power converter you are developing and testing, you may need to verify the harmonic content of your output current or the switching losses of your H-Bridge or even the overall efficiency of the design. Keysight's InfiniiVision X-Series Oscilloscopes with the power measurements option gives you an easy-to-use and highly versatile all-in-one power circuit simulator tool that delivers measurement insight into every stage of your power converter design.

When we discussed dynamic measurements of power devices in part one, we introduced the InfiniiVision X-Series oscilloscope. Here we want to discuss in more detail its power measurements option and how it can give you quick insight into the performance of your power converter designs. The power measurements option is a turn-key embedded application available on any InfiniiVision 3000, 4000, or 6000 X-Series oscilloscope. This licensed option essentially turns the oscilloscope into a complete power analysis tool by providing:

- 14 power-related measurements
- Connections diagrams
- Automatic de-skew
- Automatic setups

Figure 1 is a screen capture from an InfiniiVision oscilloscope that provides an overview of the 14 power-related measurements that the option delivers.

Figure 2 shows an example of a switching device power and energy loss measurement of a step-down Buck switch mode power supply (SMPS). With the power measurements option, the scope automatically optimizes vertically scaling of the voltage and current waveforms, turns on the power waveform ($V \times I$), and then continuously measures the power and energy loss across one switching cycle. The scope also provides a precision offset calibration so that losses during the conduction phase (when voltage is very low) can be performed in the presence of large switching voltages with maximum accuracy. Oscilloscope and/or probe offset error, even if it's within the scope's specifications; can contribute to significant measurement errors during the conduction phase of switching.

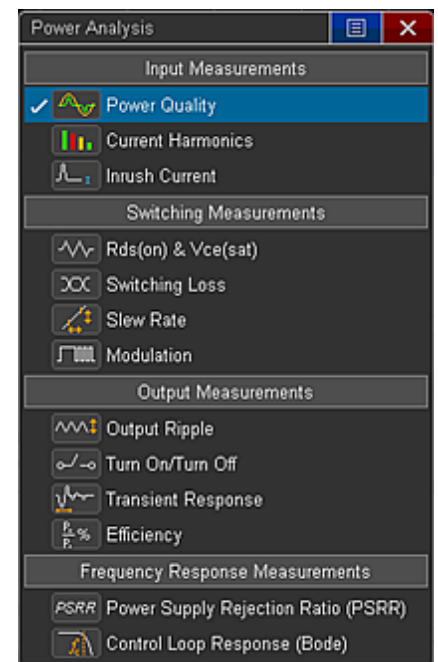


Figure 1. 14 power related measurements that the option provides

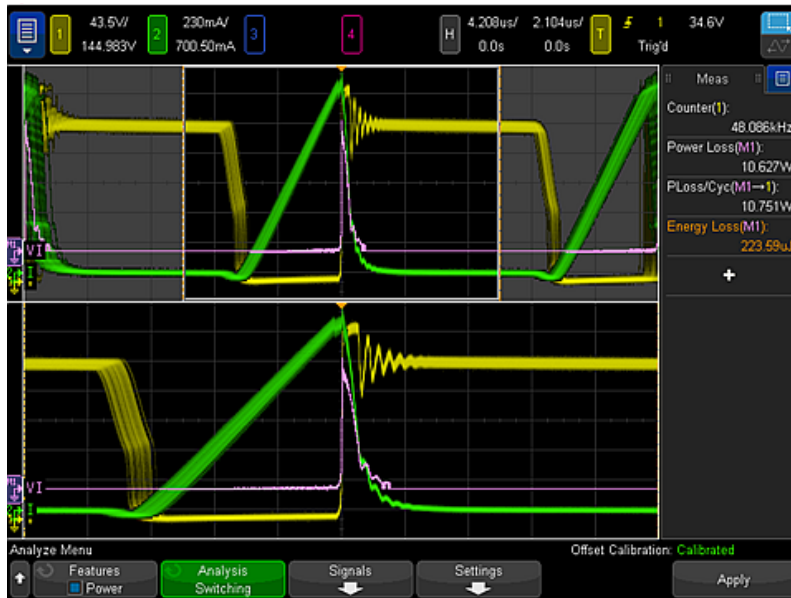


Figure 2. Switching device power and energy loss measurement

Figure 3 shows some of the AC power measurements that the power measurement option delivers. An oscilloscope cannot deliver the accuracy or resolution that a power analyzer can deliver for these kind of measurements. What it offers though is an all in one instrument to verify and check these type of measurements during the design and debug process. The goal being to reduce the time you spend switching between different test equipment to get the measurement answer you are looking for.

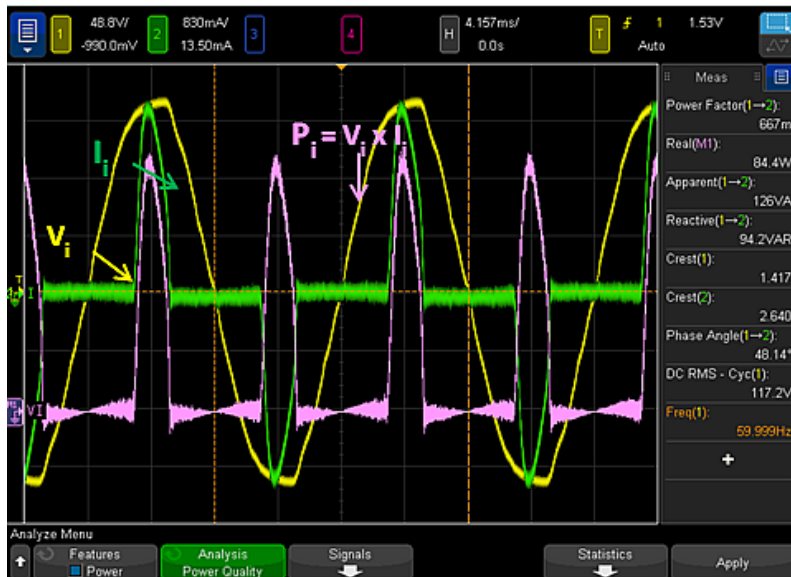


Figure 3. AC power measurements

For more information on the infiniivision scope family and its power measurements option, including a series of videos show casing each of the 14 Power-related measurements go to www.keysight.com/find/scopes-power

Reduce costly design delays and rework with EMC pre-compliance testing:

With next generation power converter design's moving towards higher switching frequencies and smaller form factors, meeting EMC standards will become more challenging. This requires more thorough pre-compliance to avoid costly design reworks and delays that result from failed EMC testing in design validation stages. Keysight's EMI measurement application on X-Series signal analyzers allows you to perform pre-compliance measurements and diagnostic evaluation of your designs. Find and fix problems before they enter the test chamber with the N6141A measurement application on the N9030A PXA, N9020A MXA, or N9010A EXA, or W6141A on the N9000A CXA for a low-cost pre-compliance test solution. EMC pre-compliance capabilities include:

- Built-in CISPR and MIL-STD compliant bandwidths, detectors and band presets
- Automated testing to regulatory Limit Lines with user-selected margins
- Amplitude correction for antennas, LISNs, cables, preamps
- Built-in report generation

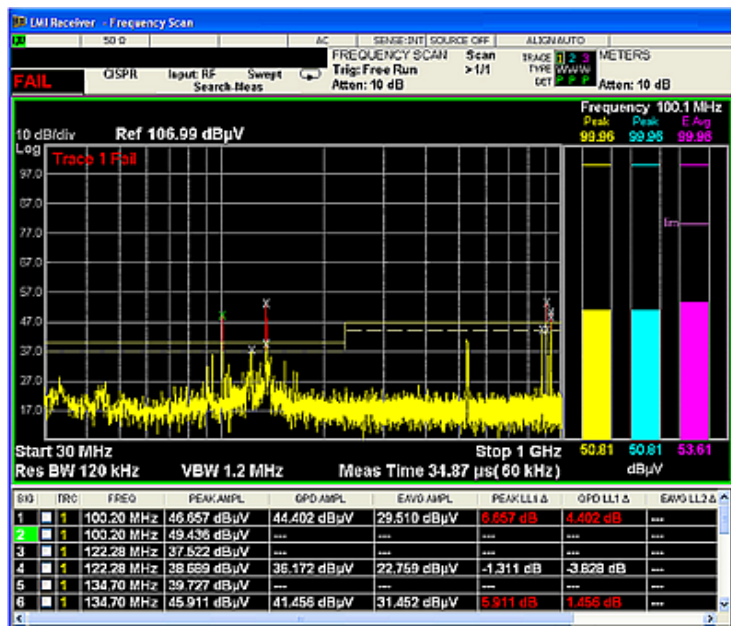


Figure 4. Pre-compliance measurement being made with N6141A measurement application

Simulating precise and complex control signals:

For simulating precision and complex control signals for testing and verifying your design through its whole operating range, Keysight Technologies, Inc. offers a wide range of function/arbitrary/pulse generators. For instance Keysight's 33500 and 33600 series of TrueForm function /arbitrary waveform generators offers the ability to accurately go below 1% duty cycle on a pulse width modulated (PWM) signal. They also give you high resolution control of the duty cycle setting for precision PWM signals. Finally the Trueform family of function generators offer the ability to create complex sequences of multiple signals. For instance you could have signal 1 execute two times, then have signal 2 execute in a loop until a trigger event causes it to switch to signal 3 seamlessly. This is great for simulating complex control signals or stepping a design through various ranges automatically. Keysight also offers the 81150A and 81160A family of pulse function arbitrary noise generators that provide high accuracy and resolution signals as well as versatile waveform and noise generation for advanced needs. When testing the ability of your power electronics circuits to withstand noise both the Trueform family and the 811x0A family offer various modulation and arbitrary waveform capabilities to simulate any real world signal that you may find in your design.

Reducing test complexity with flexible power dc sources:

Often power electronics R&D labs support a large power range of designs. For example, to test a wide range (2kW – 200kW) of inverter or DC to DC converter designs, requires various instrumentation grade DC power sources of different power, voltage, and current ranges. This can lead to test complexity and higher support costs, not to mention loss of square footage in the lab. Keysight's N8900 Autoranging System DC Power Supply family comes in a wide range of voltage and current combinations at 5kW, 10kW, and 15kW power ranges. The autoranging output allows them to support a large voltage range and current range in a single unit. For instance the N8900 Series offers a maximum voltage of 1500V and maximum current of 510A all in a 15kW form factor. In Figure 5 you can see an example of the V and I power curve of the N8957A .

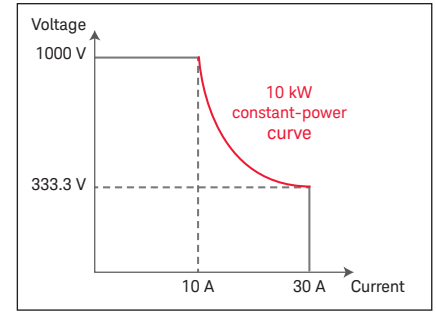


Figure 5. Voltage and current power curve of the N8957A

The autoranging capability allows it to take the place of multiple power supplies, from a 1500V/10A supply to a 500V/30A supply. Also the N8900A family comes in a 3U form factor so it will not take up too much of your lab space. For higher power needs, N8900 supplies can be paralleled together up to and beyond 150kW for maximum power range flexibility.

The growth of battery power or storage based applications has led to the growth of bi-directional inverters and DC to DC converters where power can flow in both directions. The N6900 and N7900 Advanced Power System (APS) family of high performance DC power sources can source power and optionally sink power using the N7909A power dissipater unit. The dissipater unit isn't simply an electronic load combined with a power supply. The APS family uses synchronous rectification to give it full two quadrant operation so it can operate continuously through 0A. The optional dissipater unit is only needed for quadrant II operation, providing the ability to dissipate the current flowing into the power supply. Figure 6 provides a high level overview of the APS's patented architecture. The ADP stands for "automatic downprogrammer" and it monitors current flowing into the supply and controls the optional dissipater unit shown on the bottom. The APS family offers this unique flexibility for testing bi-directional power converters.

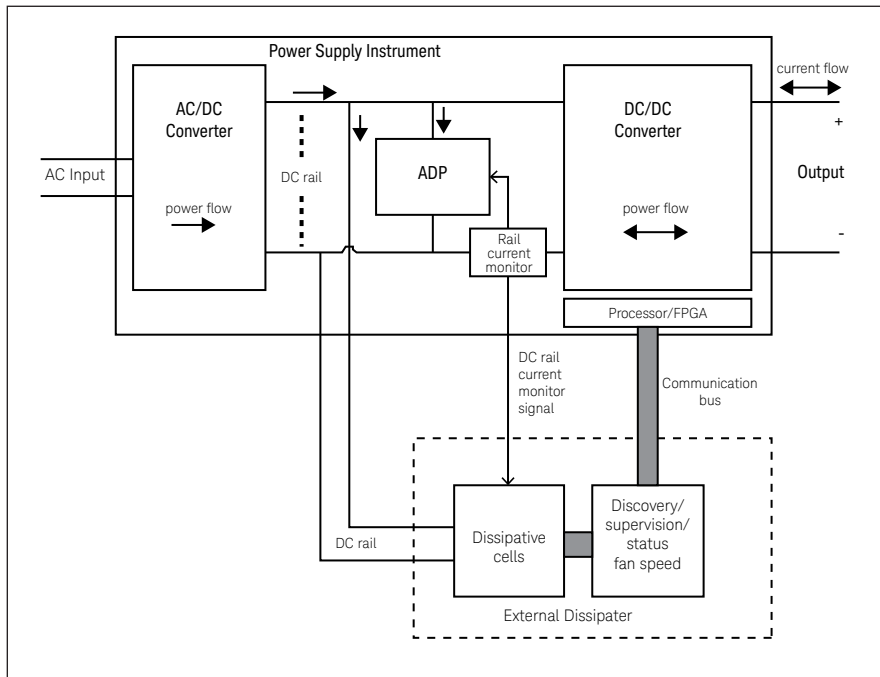


Figure 6. APS Architecture

The APS family comes in 1kW and 2kW power levels at various voltage and current combinations. APS units can be paralleled up to 10 kW for higher power needs. Besides the optional 2 quadrant capability, the APS family has an extensive list of other advanced features including:

- High accuracy and simultaneous voltage and current measurements
- Built-in digitizer for capturing dynamic voltage or current transients
- Capability to generate voltage or current arbitrary waveforms
- Optional “black box recorder” to log measurements and events in case something goes wrong

For more information on the Advance Power System N6900 and N7900 DC source families go to www.keysight.com/find/aps. To see Keysight's full selection of DC sources go to www.keysight.com/find/power.

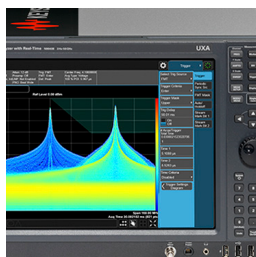
Summary

In this application note we looked at the challenges power electronics engineers face when debugging and optimizing their design prototype. We discuss how Keysight provides a number of different hardware and software power circuit simulator tools to help you overcome these challenges. For instance Keysight's InfiniiVision X-Series Oscilloscopes with the power measurements option gives you an easy-to-use and highly versatile all-in-one tool that delivers measurement insight into every stage of your power converter design. For new EMI challenges that WBG devices present Keysight offers the N6141A EMI pre-compliance measurement application for our signal/spectrum analyzer families that allow you to spot early EMI issues before you get too far down the design process.

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Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology.

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