Testing Power Electronic Systems Efficiently

With today's increased incorporation of power electronics and switching devices in overall system design, there is a growing need for accurate measurement of both the power behavior of the applied power electronics and other inter-related electrical and physical parameters. **Clive Davis, Marketing Manager, Test and Measurement, Yokogawa Europe & Africa**

It may be surprising to learn that there is no accredited traceability for power measurement calibration anywhere in the world above 200 kHz. Indeed there are only five calibration laboratories which can perform ISO 17025 accredited power calibrations at 100 kHz. This naturally affects the validity of power measurements, particularly in switching applications where higher frequencies are present. There are a variety of products available to measure power, the selection of which will depend on a number of factors, including the stage of the development of the power electronics product and the desired accuracy of the measurement.

Architecture and design

At the architecture and design stage, we are considering the development of individual parts, and measurements include characteristics such as fast inverter switching, high-frequency dynamic behavior, overshoot on pulses, and the need to trigger on individual waveforms. A mixed-signal oscilloscope with up to eight input channels to view input and output signals in three-phase systems can be used to make these measurements (Figure 1). With a waveform-displaying product, such as an oscilloscope, it can seem easier to understand power measurement as even standard measuring features can be used to derive the value of active power. However, consideration must be given to both the accuracy and the stability of the measurement. Accuracy specifications of oscilloscopes do not include those for power measurement and generally do not even include any for AC voltage measurements.

So, although IGBT and SiC MOSFET switching losses, for example, can be measured using dedicated oscilloscope features, the absolute accuracy is not specified, and it is difficult to estimate the errors. Possible sources of error include the inaccuracy of the scope, the inaccuracies of the probes and the phase differences between them. In power measurement, phase differences can be a major source of error. The error from phase differences can be reduced, however, by using the automatic probe anti-skew feature if available. Thus, by paying attention to the measurement and perhaps using a reference circuit, an oscilloscope can indeed be used to judge if a circuit modification has increased or reduced the losses.

Verification and prototyping

The next stage is verification and prototyping, at which the individual parts

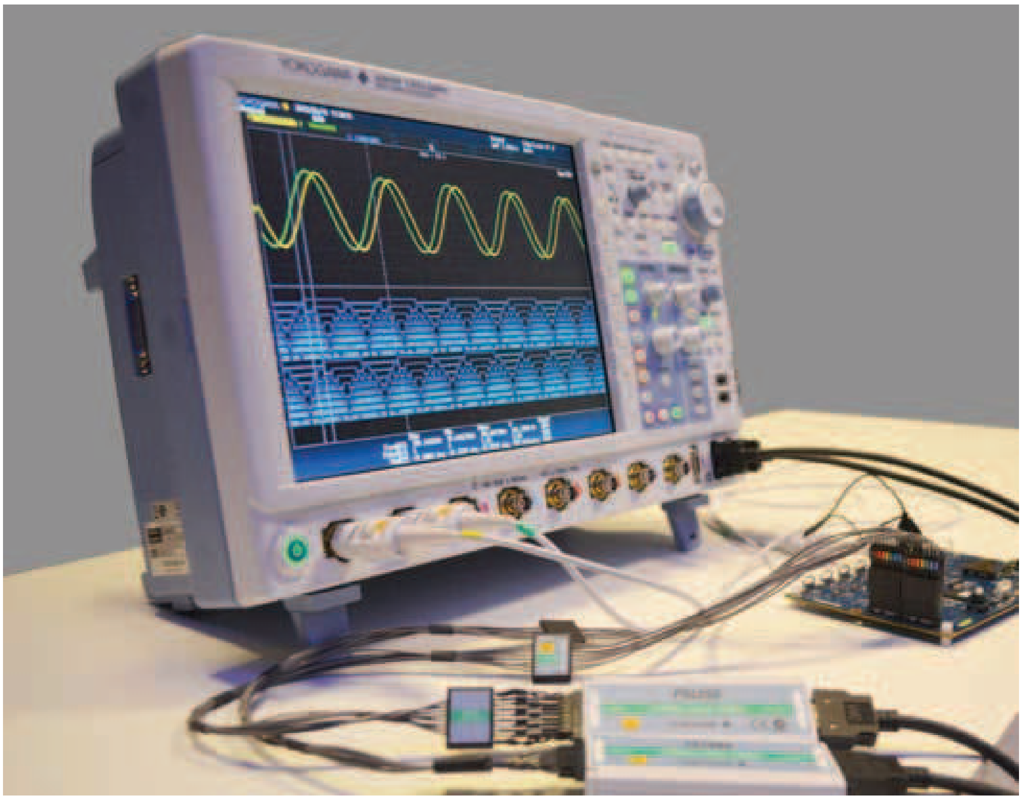

Figure 1: The DLM4000 mixed-signal oscilloscope offers up to eight input channels to view input and output signals in three-phase systems

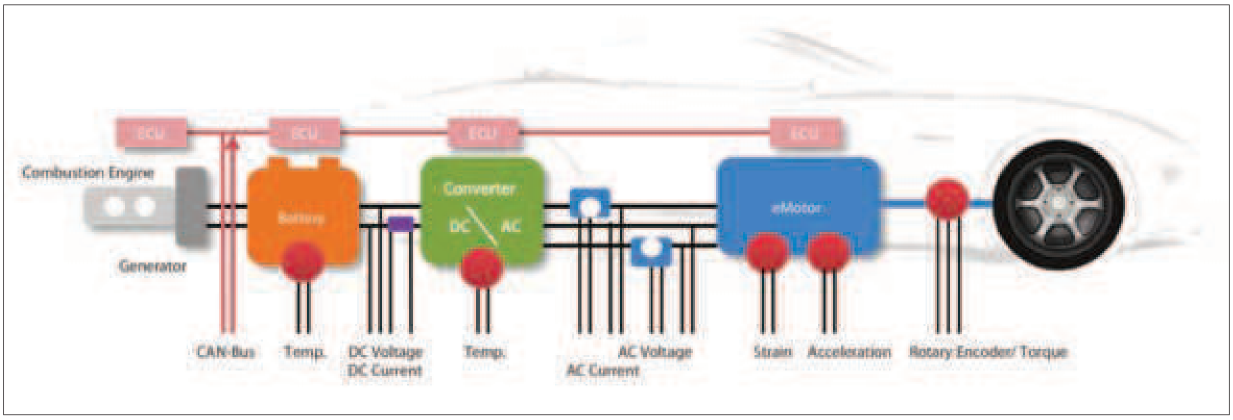

Figure 2: Schematic of an electric car drive train, illustrating the various signals that need to be measured at the verification and prototyping stage

are combined and form the system under test. To understand the dynamics of the application requires the measurement and analysis of a combination of electrical, mechanical and physical signals and, in automotive applications, signals from buses such as CAN and LIN (Figure 2). For this type of measurement, ScopeCorders are used. As a portable data acquisition recorder, a ScopeCorder can capture and analyze both transient events and trends for long periods. Using flexible modular inputs, it can combine measurements of electrical signals, physical parameters from sensors and CAN and LIN serial buses, and can trigger on electrical power related and other calculations in real time.

Efficiency validation

In the efficiency validation stage, the key factors that need to be tested are power analysis, conversion efficiency, harmonics and, for instance, the battery charge and discharge process. For tests of this type, the instrument of choice is the power analyzer, offering high precision, high accuracy, high stability, and the ability to carry out calibrated measurements. A key difference therefore between an oscilloscope type product and a power analyzer is that a power analyzer is fully specified for power measurement and voltages and currents are connected directly.

At this point, in order to select an appropriate instrument, the user also needs to consider what absolute accuracy is required for the power measurements, the frequencies in the signal and how this accuracy is proven. Where small improvements in input/output efficiency are being sought, for example for PV inverters, where efficiencies are typically 95 to 98 %, small improvements can only be recognized if the accuracy of the measuring instrument is at the highest level. With an ISO 17025 accredited calibration at frequencies up to 100 kHz, it is possible to not only prove the specified accuracy but also achieve much better performance than the specification (Figure 3).

Hybrid instruments

In addition to the dedicated instruments described above, engineers and R&D professionals are also looking for hybrid instruments that can be used at all stages of the development cycle. When the power consumed by the load varies – for example during the start-up of a motor – it may be necessary to measure power at much shorter intervals. A specific requirement is to provide the time-based measurement functionality of an oscilloscope combined with the accuracy of a power analyzer (Figure 4). Instruments such as precision power scopes provide users with flexibility, accuracy and wide bandwidth, allowing them to draw together the range of power readings needed to optimize the efficiency of boost circuits and inverters – two key elements in overall electric vehicle

Figure 3: The WT3000 precision power analyzer

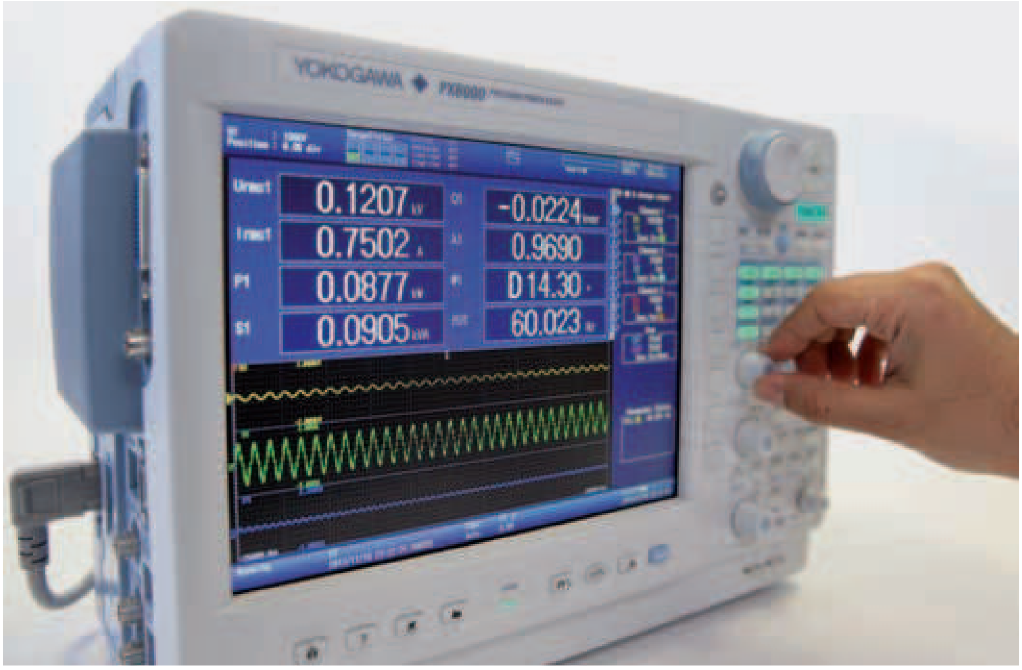

Figure 4: The PX8000 Precision Power Scope

performance.

Like a power analyzer, a precision power scope is capable of accurately measuring steady-state power and related variables, since they share the same input techniques and measurement principles. However, as it also shares characteristics of oscilloscopes and ScopeCorders, it is capable of capturing and measuring the power arbitrarily over any part of the power waveform using start and stop cursors. This is particularly useful for examining transient phenomena and in the design of periodically controlled equipment. The trigger functionality helps to set various trigger conditions based on the analysis of the transient phenomena to understand the behavior of the system under test. During the start-up phase of an inverter and motor in an electric or hybrid car, for example, current increases can be analyzed in each cycle (Figure 5). And, when the load changes rapidly, the engineers can gain insights that will enable them to improve the control of the inverter.

The need for calibration

As more and more innovation focuses on energy efficiency and the use of renewable energy resources, engineers are increasingly demanding accuracy and precision from their power measurements. At the same time, new standards such as IEC62301 Ed2.0 and EN50564:2011, covering standby power consumption, and the SPEC guidelines, covering power consumption in data centers, demand more precise and accurate testing to ensure compliance.

To meet these challenges, R&D teams are coming to terms with the need for new levels of precision in power measurement, but these levels of precision can only be achieved if the measuring instruments are properly calibrated with reference to national and international standards.

Regular calibration by a laboratory, which can provide very low measurement uncertainties at the specific measurement points applicable to individual users, should enable instrument makers and their customers to have confidence in their test results.

Laboratories that are accredited to ISO 17025 (General requirements for the competence of testing and calibration laboratories), however, have demonstrated that they are technically competent and able to produce precise and accurate calibration measurements. Yokogawa's European Calibration Laboratory is the only industrial (i.e. non-government or national) organization to offer traceability up to 100 kHz, and makes it the only power meter manufacturer which can directly prove the performance of its own instruments.

Literature

Clive Davis, Erik Kroon, "The Need for High-Frequency High-Accuracy Power Measurement", Power Electronics Europe 6/2015, pages 29 - 31

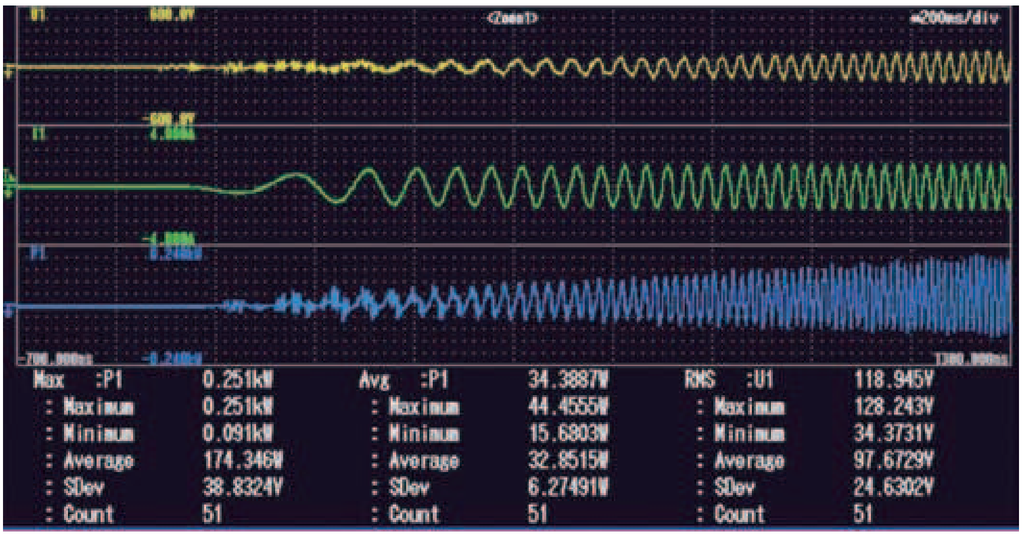

Figure 5: During the start-up phase of an inverter and motor in an electric or hybrid car, for example, the Precision Power Scope allows current increases to be analysed in each cycle