Accurate power measurement: the key to energy efficiency

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In response to pressures to optimise energy efficiency throughout industry, a number of trends are emerging across the power landscape:

- In the automotive sector, we are seeing increased electrification of the power train and the growing adoption of hybrid, electric, plug-in and fuel-cell based transportation technologies.
- In modern power electronics, fast switching speeds have enabled greater efficiencies and component miniaturisation, resulting in developments like the Internet of Things as well as new mobile technologies.
- In manufacturing, the increased adoption of energy-efficient automation and control, motors and drives, IT infrastructures and heat recovery are bringing significant cost savings.

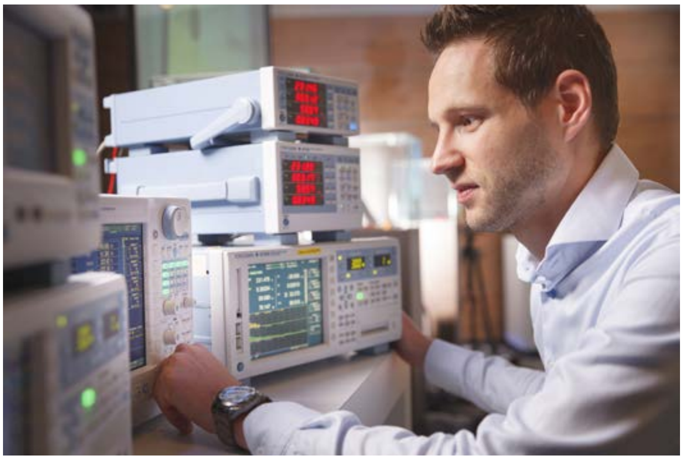
This drive for more efficiency has resulted in an increased effort by governments and regulatory bodies to develop new standards for energy consumption of various classes of equipment. Manufacturing companies have to comply with these standards and show that their products meet these requirements.

These standards have significant implications on production processes and product usage. Standards such as IEC 62301 for standby power consumption, IEC 61000-3-2 for harmonics and IEC 61000-3-3 for flicker define limits for different classes of electrical and electronic equipment that affect both market validation (fitness for use) and product differentiation.

Inaccuracies in power measurements

Given this changing landscape, accurate power measurement plays an important role in modern industry. However, accuracy in power measurement is about more than just voltage and current uncertainties. For accurate analysis of power consumption, measurements must go beyond just voltage or current uncertainty and take power uncertainty as a whole into consideration. For example, many instrument specifications quote “typical values” on their data sheets. Apart from the fact that the accuracy of a power measurement depends on the measurement range, these values cannot be 100% guaranteed without full calibration. Hence any specified accuracy value should be accompanied by the range over which it is valid.

For accurate power measurement, it is also necessary for the power analyser to accurately detect the zero crossing of the current or voltage waveform. Similarly, for measurements using current sensors, it is important to choose a sensor whose amplitude and phase uncertainty match those of the power analyser.



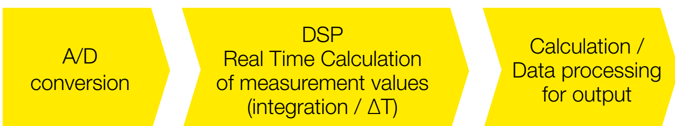
Power measurements across the development cycle

An engineer’s power measurement needs can vary or evolve across the development cycle. For example, isolated tests of individual components in early development stages may only need waveform analysis at limited accuracy but when a multi-component system needs to be tested the system has to be looked at as a whole, calling for sophisticated multichannel, multi-parameter measurements. In addition, the closer testing gets to the production line, the stricter the requirements become for accuracy and compliance with standards.

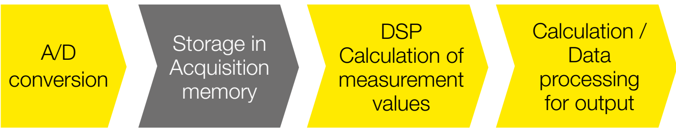
The underlying principle behind any power measuring instrument involves sampling the voltage and current waveforms simultaneously, multiplying them together after acquisition, integrating the resultant instantaneous power readings over a whole number of fundamental waveform cycles, and then dividing by the time.

There are two broad classes of power measurement instruments.

1. **Streaming or averaging type instruments** (Fig 1a), including the traditional power meters and power analysers. Streaming instruments use high resolution at the analogue/digital conversion stage and instantaneously compute or integrate the voltage, current and power values in order to achieve continuous measurements and high accuracies.



2. **Digital storage type instruments** (Fig. 1b): A digital storage instrument such as an oscilloscope, ScopeCorder or Precision Power Scope acquires data at high sampling rate, stores it in acquisition memory and then processes it for output. During processing of the sampled data, there is “dead time” when the instrument is not reading the input waveform, thus missing the data points for continuous measurements.



The high sampling rates in digital storage type instruments allow for a better representation of the input waveform, making them ideal for analysing single-shot events. However, oscilloscopes are not designed for stability and do not specify AC uncertainty. Therefore, when high accuracy is needed, a streaming or averaging type power analyser is usually the better choice. Hybrid instruments like the Precision Power Scope combine waveform analysis with high accuracy measurements.

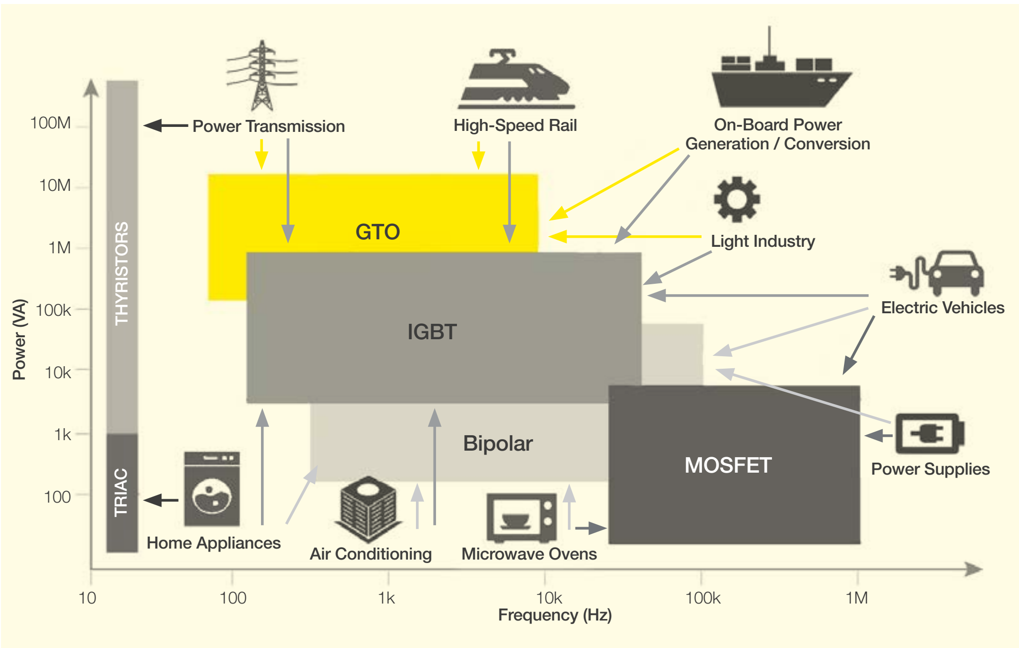
It is unlikely that a single instrument can provide the answer to all the measurement needs across a product’s development lifecycle. However, most development and test benches feature an oscilloscope as a general-purpose measurement instrument. Waveform analysis aside, an oscilloscope can double as an intuitive low-cost solution for power measurement, but oscilloscopes cannot offer the traceable accuracies needed for confidence in compliance testing. Neither do they offer the versatility and flexible data-acquisition capabilities needed for system testing.

The high accuracy needs of compliance and efficiency testing are instead better served by power analysers that specify their uncertainties across different operating conditions. Unlike oscilloscopes, they feature direct inputs for current and isolated voltages, thus eliminating errors from probes, transducers and internal phase effects. Also, errors due to common-mode effects are specified: not just stated as a common-mode rejection ratio (CMRR).
For measuring interrelationships between components to assess system behaviour, the flexible data acquisition capabilities of a ScopeCorder are far more suitable.

Choosing the right instrument

The measurement instrument needs to match the application’s needs in terms of operating bandwidth, voltage, current, accuracy and number of inputs. In addition, depending on the application, one or more of the following requirements may also need to be satisfied:

- Fast and automatic updates of measurement range or update rate to measure input signals fluctuating in amplitude or frequency
- Specifications at power factors other than unity
- Harmonic and flicker analysis capabilities based on IEC standards
- Measurement ranges with high crest factors to capture distorted signals or large, unexpected peaks
- Computation of electrical parameters in star, delta and other wiring configurations
- Functionality and sampling rates for analysing PWM and other complex waveforms
- Measurement of physical parameters such as torque, mechanical power, slip, rotation speed, temperature, pressure, strain etc.
- Time-domain measurements for analysing cycle-by-cycle or sub-cycle power transients.



(Source: modified from the figure 1 http://www.appliedmaterials.com/ja/nanochip/nanochip-fab-solutions/december-2013/power-struggle)

Trusting the measurement accuracy

With instruments belonging to different accuracy classes and different manufacturers specifying accuracy differently, it is important to understand the sources of measurement inaccuracies and their effect on the measurement results. In this context, an ISO 17025 accredited calibration goes a long way in instilling confidence.

Conclusion

The accurate measurement of power is an important consideration for engineers looking to extract product efficiency by optimising power consumption and reducing losses. Adopting the right strategy can make all the difference, and it is therefore vital to adopt a measurement strategy that takes steps to:

- Understand the measurement objectives across each stage of the development cycle.
- Assess the technology existing on test benches and identify gaps in capabilities
- Empower development and testing teams with the technologies that address these gaps in insights, functionality and accuracy to ensure data-driven manufacturing decisions.

Measurement technologies need to be reliable over the long term and offer healthy support in hardware, software and services in order to help manufacturers take their products from concept through production with greater quality in shorter time frames.