Power Electronics Measurement

In a world that loves pictures, why does real-time sampling and computation remain the best technique?

Introduction

Most people reading this document will be directly or indirectly interested in the analysis of electrical power conversion and ultimately, in quantifying the power efficiency associated with a product or system.

Given the largely digital nature of modern measurement instrumentation, it is common for an engineer tasked with selection of a measurement instrument, to focus their efforts on the easily defined and commonly understood digital criteria of ‘sample rate’ or ‘bit count’ defined for a product of interest.

This focus is encouraged by many instrumentation manufacturers who benefit from such a simplistic approach, overlooking more complex and demanding considerations that usually make the specification of an A/D a largely meaningless criteria on which to select a precision power measurement instrument.

The primary challenge for precision measurement in power electronics is always the analogue hardware, including signal conditioning, data handling and ultimately calibration since it is these factors not the specification of an A/D device, that absolutely dominate measurement accuracy.

In this document, we consider misconceptions related to digital instrumentation and the functional elements of good design that dictate the total performance of all high-performance power measurement instruments.

Misconceptions - What’s in a picture?

On the leading page of this document, the main picture shows a PPA5500 series power analyzer in front of a dual motor test system to which is it is connected.

The PPA is set in SCOPE mode as shown here, where a PWM voltage on one phase is visible, above the associated phase current.

We know from experience that:

A. Users like to look at a picture and
B. They assume that the same data points are used to derive quantitative measurements

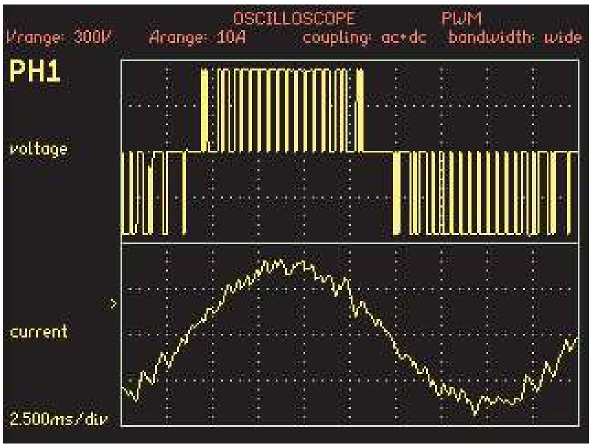


Fig 1

True real time computation architecture

For important reasons that we will explain in this document, the sampling and computation technique used in a PPA when in power analyzer (measurement) mode is completely different to that of the scope mode or indeed any conventional sampling design.

This results in an accuracy of measured values presented in the PPA Power Analyzer mode that is not achieved with a digital oscilloscope, DAQ or typical power analyzer.

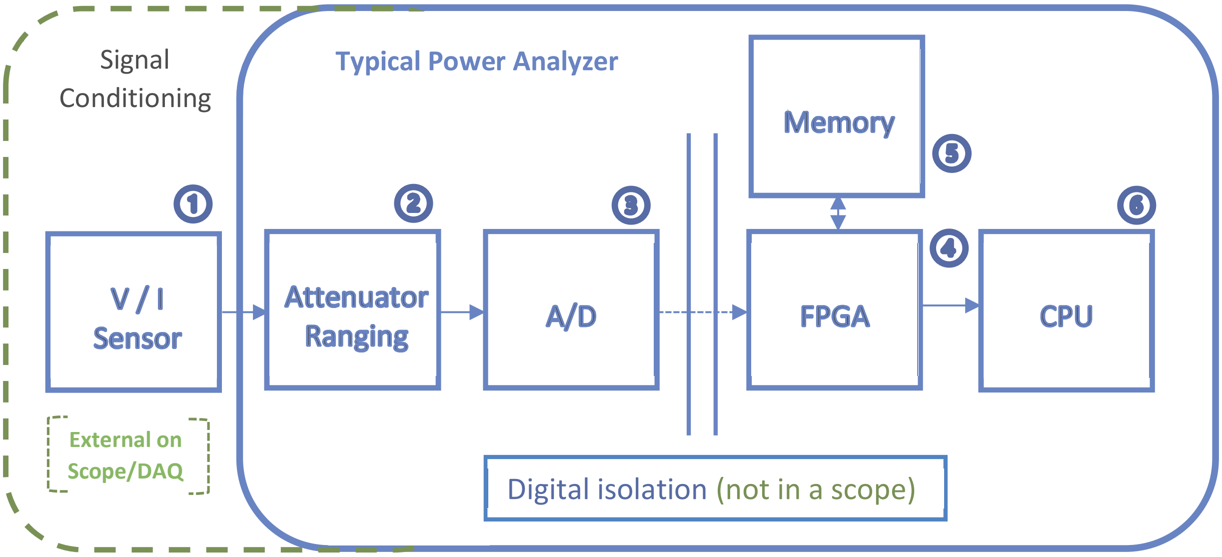
In the following pages, we explain why.

Fig 2

Conventional digitising techniques

Oscilloscope and DAQ designs are primarily focused on a sampling speed and resolution that will suit a wide range of measurement applications and combine this variable sampling with memory, into which the derived samples can be stored or buffered.

Fig 3



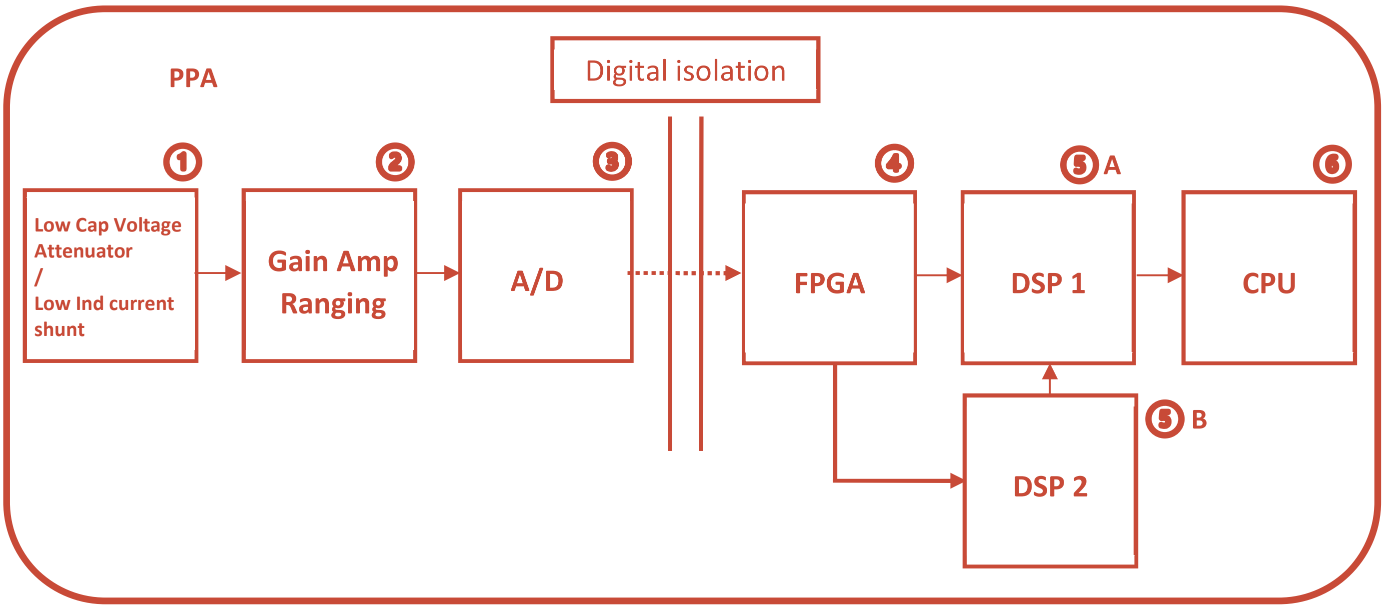
Key points relating to power analysis:

- Signal conditioning is often external, with measurement accuracy uncertainty that dominates total error
- Finite memory inevitably dictates the sample rate available as the time base is reduced
- Graphical presentation and measurements derived from time-based sample windows are asynchronous with primary power components and therefore require averaging to achieve stability

Power analysis with Real Time sampling and computation

The PPA series incorporates signal conditioning specifically designed for the challenges of modern power applications and will therefore not suffer the measurement uncertainties associated with external devices. Additionally, and unique to the PPA analyzers, is an isolation and digital processing technique that removes the obstacle of digital memory size or speed.

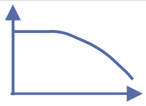
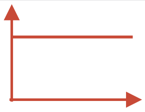
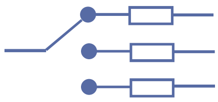
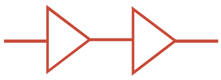
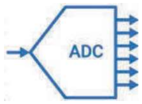
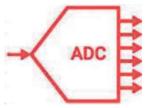
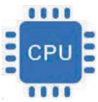
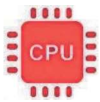
Fig 4



Key points relating to power analysis:

- Proprietary voltage and current signal conditioning provide exceptionally flat response
- High frequency digital isolation eliminates signal uncertainty associated with conventional isolation
- Proprietary FPGA/DSP structure computes power real time at full sample rate irrespective of time base because there is no memory limitation
- Unique end to end calibration over the complete operating range provides market leading accuracy

Analogue and processing differentiators

	Conventional		PPA	Comment
1	 Reactive components of Voltage and Current sensing devices dictate the analogue frequency response	1	 Proprietary analogue design with low capacitance voltage attenuators and low inductance current shunts	The 'front end' of any measurement instrument dictates what follows. Optimum design always considers the combination of analogue and digital techniques
2	 Hardware ranging manages sensitivity but adds switching and linearity issues	2	 Precision solid state gain amplifier ranging design overcomes switching and linearity problems	Full range voltage voltage and current inputs followed by a gain amplifier ensure constaint frequency response, minimum range delay and maximum reliability
3	 Analog to digital conversion	3	 Analog to digital conversion	BIT count is commonly and wrongly quoted as an accuracy differentiator See white paper D000123 Headline sample rate rarely applies in practice due to memory contraints See stage 5
4	 High speed sample processing	4	 High speed sample processing	Processing principle dictated by memory or processing structure defined in stage 5
5	 Digital samples stored in memory and processed as window blocks. This is ideal for oscilloscopes or DAQ's but is an obstacle in power electronic applications, where finite memory limits the low time base sample rate and measurement precision is compromised by asynchronous measurement windows	5 A	 Full speed sampling irrespective of timebase elimates memory contraints	Real time DSP computation allows full sample rate at any timebase. Measurement windows set set by independent frequency detection.
		5 B	 Dedicated processor derives correct measurement window and triggers DSP1 at precise cycle periods	
6	 Results processing, I/O and user interface	6	 Results processing, I/O and user interface	

Avoiding memory constraints

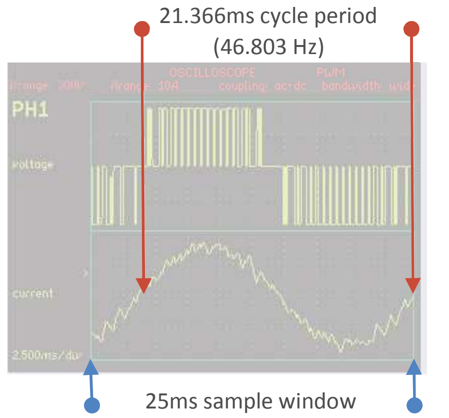
In the world of oscilloscope and DAQ designs, the ability of a measurement instrument largely depends on memory, because this dictates the resolution of graphic presentation and measured values.

This conventional digitizing technique is not ideal in the field of modern AC power electronics, both because analysis is based upon finite memory size which limits the sample rate at low frequency, and because typical measurement windows are unlikely to be synchronous with a waveform of changing frequency.

Scope / Memory based sampling

This is illustrated in the scope image from Fig 1, where a 2.5ms/div time base provides sample window (image) of just over one cycle.

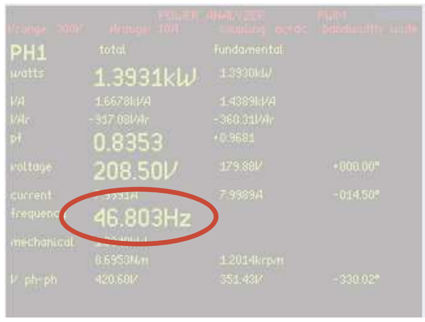
With any oscilloscope or equivalent sampling technique, measurement windows are unlikely to equal a single cycle or an integer number of cycles, therefore measurements made from this same data will inevitably include windowing error. The same problem occurs in systems with no buffer that are sometimes called “fixed windowing” or “fixed update rate”, because these processes are not sufficiently dynamic.



Real time sampling and computation

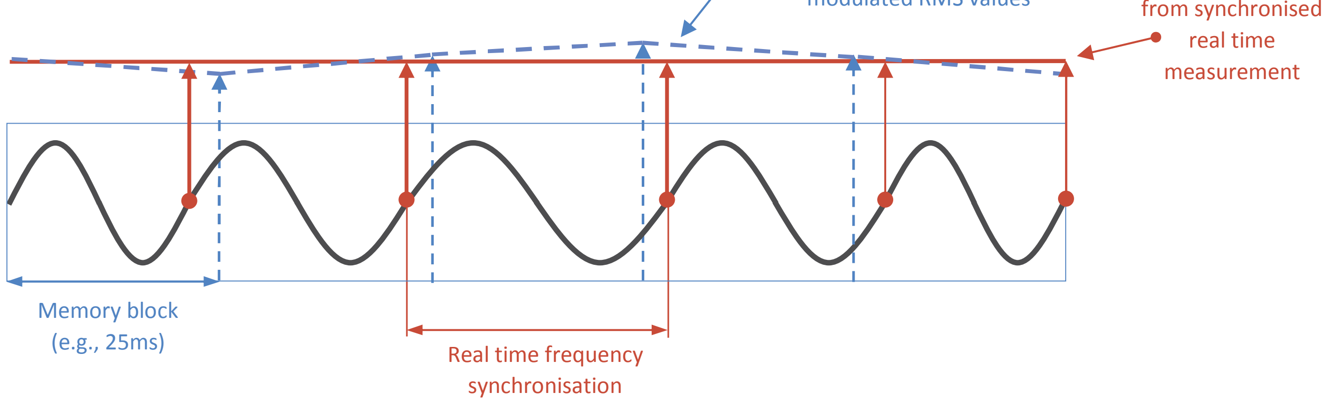
In Fig 2, real time measurements are displayed using a higher sample rate than an equivalent scope mode and DPS2 (ref. P4) ensures real time synchronisation with the fundamental frequency.

Given the correct frequency, the PPA also makes DFT computation of all fundamental power components for the same measurement window



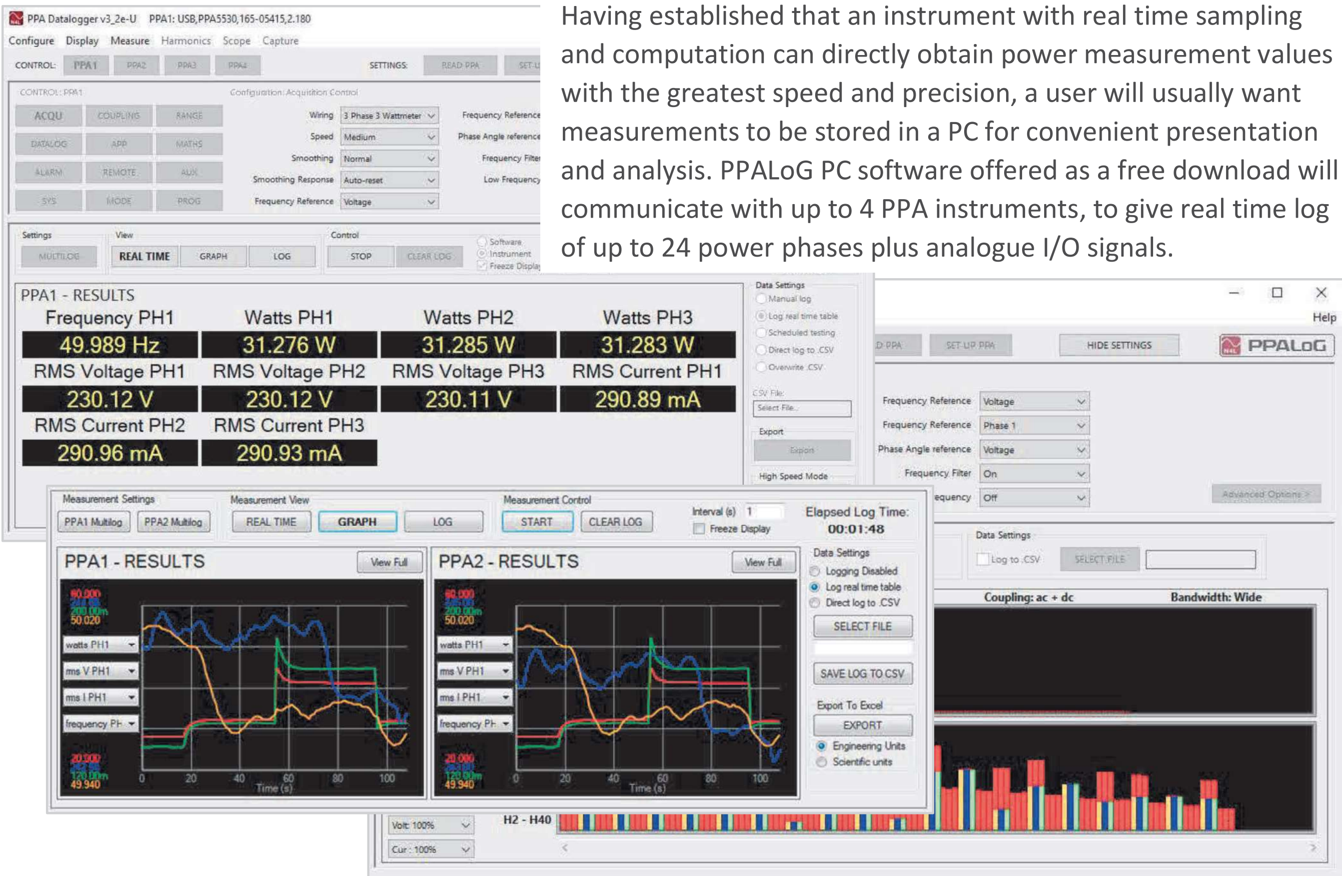
Memory window (or fixed window) measurement versus Real Time computation

Asynchronous measurement windows will inevitably give an RMS value that is not equal to one cycle of an AC waveform under test. In this case, a correct value can only be obtained by averaging many windows. Conversely, Real Time computation using the dual DSP design of a PPA, directly gives the correct RMS value of cycles or cycle groups.



The subject of sample windows and asynchronous measurements is discussed in **White paper D000120**

Presentation of data – Numbers and Images



Having established that an instrument with real time sampling and computation can directly obtain power measurement values with the greatest speed and precision, a user will usually want measurements to be stored in a PC for convenient presentation and analysis. PPALoG PC software offered as a free download will communicate with up to 4 PPA instruments, to give real time log of up to 24 power phases plus analogue I/O signals.

Why is post processing of raw data not the ideal solution?

The appeal of processing raw data points in programs like MATLAB is clear and it is quite common for N4L to be asked if we support the direct transfer of samples made available to the FPGA of PPA series power analyzers, directly to a PC.

In the case of single shot raw data sample block, the answer is yes, but this is time and sample speed limited. The PPA architecture enables our instruments to provide directly computed values of all primary power parameters, derived from a gapless high speed sample rate and real time frequency synchronisation that is not possible via a communication port and external PC program.

So, while the raw data sample block is a useful feature for the post-capture analysis of a transient event, the architecture of the PPA provides direct and traceable measurement of power parameters that is usually the ultimate objective of external sample computation anyway.

Conclusions

- Digital sampling techniques commonly used in Oscilloscopes / DAQ's while ideal for visual inspection and development, are not ideal for precision power analysis.
- Modern power applications represent both analogue and digital challenges not easily met by conventional digital sampling instruments.
- Post processing is suitable for transient analysis but not continuous power measurement
- Separate instruments are the ideal and usually the most economical solution, where quantitative measurement is via a Real Time analyzer, and transient or visual analysis is via an oscilloscope.