

# CHARACTERIZATION OF A WIDEBAND DIGITIZER FOR POWER MEASUREMENTS UP TO 1 MHz

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**Abstract**— A two-channel high-speed digitizer has been extensively characterized in the frequency range of 50 Hz to 1 MHz. The measurements involved ac flatness, phase, linearity, input impedance and the effects of dc offsets, temperature, and internal self-calibration routine. The digital anti-aliasing filter inside the digitizer negatively affects the ac flatness in the low-frequency region. An inverse compensation filter has been designed and applied which improves the frequency response with a factor 25 to 60 and makes it flat within 25  $\mu\text{V/V}$  up to 100 kHz and within 100  $\mu\text{V/V}$  up to 1 MHz. The phase difference between the two channels can be modeled by a constant time delay between the two channels, which for the 2  $V_{pp}$  range equals (250  $\pm$  30) ps. The overall results of the characterization indicate that the digitizer can be applied in wideband power measurements under practical circumstances with ( $k=1$ ) uncertainty contributions of not more than 70  $\mu\text{W/WA}$  and 400  $\mu\text{W/WA}$  at 10 kHz and 1 MHz respectively. This uncertainty excludes loading effects which are significant at frequencies above 100 kHz. At low frequencies up to three times lower uncertainties are achieved when the digitizer is calibrated at the signal level and temperature at which it is subsequently used.

**Index Terms**— digitizer, digital-analog conversion, wideband power, frequency response, phase measurement, digital filters, power measurement

## I. INTRODUCTION

THE area of low frequency power measurements is expanding to higher frequencies since in applications as for example lighting and switched power supplies these higher frequencies are used in order to achieve better efficiency and lower losses. The heart of wideband commercial power meters consists of a fast digitizer combined with wideband voltage dividers and current shunts, used to convert the input voltage and current signals to the input voltage levels of the digitizer. For calibration of such power meters, a reference system is

needed where again a digitizer plays an important role.

As part of a European joint research project on "Power and Energy", a commercial wideband digitizer is extensively characterized for possible use in a reference system for power measurements up to 1 MHz. This paper describes the digitizer together with the characterization set-up and the evaluation results.

## II. DIGITIZER

A commercially available digitizer, the National Instruments PXI-5922<sup>1</sup> two-channel high-speed digitizer [1], housed in a PXI-1033 chassis, was selected for evaluation as possible digitizer in wideband power measurements. The digitizer has two ranges, 2  $V_{pp}$  and 10  $V_{pp}$ , and can be operated at sampling rates from 50 kSa/s with 24-bit resolution up to 15 MSa/s with 16-bit resolution. Since the precise properties of the digitizer have been found to depend on the sampling rate, the major part of the characterization is performed at a limited number of sampling rate – frequency combinations. The combinations chosen are 100 kSa/s for frequencies up to 10 kHz, 1 MSa/s for frequencies between 10 kHz and 100 kHz, and 10 MSa/s for frequencies from 100 kHz up to 1 MHz. In this way, an oversampling ratio of at least 5 is reached over the complete measurement frequency range. For all measurements the input impedance is set to 1 M $\Omega$ , since the alternative 50  $\Omega$  setting would result in too high loading errors in the final application.

## III. MEASUREMENT SET-UP

Measurement software has been developed providing simultaneous readout of the two digitizer channels. The software subsequently calculates the rms voltage and, using an FFT, the phase between the two channels. Further features of the software are determination of dc offsets in the current and voltage signals, calculation of the harmonics spectrum, and the possibility of using gain correction factors and phase offset correction. For sampling rates up to 1 MSa/s the sampling and calculations are performed continuously ("streaming mode"); at 10 MSa/s the samples are taken at certain intervals to allow for sufficient computation time of all signal parameters in between these intervals.

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<sup>1</sup> The manufacturers and types of instrumentation mentioned in this paper do not indicate any preference by the authors, nor does it indicate that these are the best available for the application discussed.

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### **Table of Contents Characterization Of A Wideband Digitizer For Power**

1. Understanding the eBook Characterization Of A Wideband Digitizer For Power
  - The Rise of Digital Reading Characterization Of A Wideband Digitizer For Power
  - Advantages of eBooks Over Traditional Books
2. Identifying Characterization Of A Wideband Digitizer For Power
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in a Characterization Of A Wideband Digitizer For Power
  - User-Friendly Interface
4. Exploring eBook Recommendations from Characterization Of A Wideband Digitizer For Power
  - Personalized Recommendations
  - Characterization Of A Wideband Digitizer For Power User Reviews and Ratings

- Characterization Of A Wideband Digitizer For Power and Bestseller Lists
- 5. Accessing Characterization Of A Wideband Digitizer For Power Free and Paid eBooks
  - Characterization Of A Wideband Digitizer For Power Public Domain eBooks
  - Characterization Of A Wideband Digitizer For Power eBook Subscription Services
  - Characterization Of A Wideband Digitizer For Power Budget-Friendly Options
- 6. Navigating Characterization Of A Wideband Digitizer For Power eBook Formats
  - ePub, PDF, MOBI, and More
  - Characterization Of A Wideband Digitizer For Power Compatibility with Devices
  - Characterization Of A Wideband Digitizer For Power Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Characterization Of A Wideband Digitizer For Power
  - Highlighting and Note-Taking Characterization Of A Wideband Digitizer For Power
  - Interactive Elements Characterization Of A Wideband Digitizer For Power
- 8. Staying Engaged with Characterization Of A Wideband Digitizer For Power
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Characterization Of A Wideband Digitizer For Power
- 9. Balancing eBooks and Physical Books Characterization Of A Wideband Digitizer For Power
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Characterization Of A Wideband Digitizer For Power
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Characterization Of A Wideband Digitizer For Power
  - Setting Reading Goals Characterization Of A Wideband Digitizer For Power
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Characterization Of A Wideband Digitizer For Power
  - Fact-Checking eBook Content of Characterization Of A Wideband Digitizer For Power
  - Distinguishing Credible Sources

13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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