APPLICATION NOTE

DETERMINE ABSOLUTE SIGNAL ACQUISITION ACCURACY

OF A TRION3-18XX-MULTI SERIES MEASURMENT BOARD

DEWETRON

ABSTRACT

This application note describes a method to determine the accuracy of a single sample point. Common standardized procedures that use reference multimeters have different disadvantages that cause problems especially in the frequency range above 10 kHz. Thus, we present an approach that measures the single components that affect the accuracy of a single sample point and combines the single components to an absolute signal accuracy. Real measured values from a TRION3-1820-MULTI measurement board give an indication of the practical use.

INTRODUCTION

Standard procedures for determining the absolute accuracy

The easiest way to determine the absolute accuracy would be using a reference measurement system with higher accuracy and compare the measurement points one by one. Such a system must have a higher absolute signal accuracy at least for the bandwidth of interest and it must be synchronized. Another way would be to apply an accurate input signal and compare the measured values with the supposed input.

There are problems with both methods:

- **Problem with reference measurement systems:**

Since the AC_{RMS} accuracy of the TRION3-18xx-MULTI is very high at 100 kHz, it is not easy to find a reference system with a significantly higher absolute accuracy. State-of-the-art reference multimeters such as the FLUKE 5588A 8.5 Digit Multimeter utilize also an 18-bit 5M sample ADC. *(Source: 8588A Performance Specifications)*

Furthermore, the specification of the multimeter in digitizing mode is not satisfactory.

- **Problem when using reference sources:**

Existing signal sources that can provide the required AC_{RMS} accuracy have the drawback of high noise density and pure distortion values. On the other hand, signal sources with low signal distortion typically have poor AC_{RMS} and DC accuracy.

Example

High-performance calibrator FLUKE 5522A when providing 7 V at 50 kHz:

- Absolute uncertainty: 900 ppm of reading + 1600 µV = 0.0079 V
- Distortion and noise: (0.5 % of reading +2 mV) = 0.037 V

(Source: Fluke 5522A Operators Manual)

Absolute accuracy: $$\frac{\sqrt{(0.0079^2 + 0.037^2)}}{7 \times 100} = 0.54\,\%$$

DETERMINATION METHOD

Read in the following which determination method was used for the absolute signal accuracy of a TRION3-18xx-MULTI measurement board. This method utilizes a stable low noise and distortion signal generator to provide the signal for the measurement. An 8.5 digit multimeter with high AC_{RMS} accuracy (AGILENT 3458A) is used for measuring the AC_{RMS} and the DC component of the input signal. Each component of the absolute signal accuracy will be measured separately and combined to one accuracy value.

These components are:

- AC_{RMS} accuracy
- Distortion error
- DC accuracy
- Input noise (peak to peak)
- Temperature drift

AC_{RMS} accuracy

This accuracy is determined by applying a sinusoidal signal to the TRION3-18xx-MULTI with the signal generator. The input is measured in parallel with the reference multimeter. The value of the reference multimeter (DMMRef) can be regarded as the real value. By comparing the measured AC_{RMS} value of the reference multimeter with the AC_{RMS} value measured by the TRION3-18xx-MULTI (Signal), the AC_{RMS} accuracy can be calculated. The measured signal must pass the input filter of the TRION-18xx-MULTI before the AC_{RMS} value is calculated. In this way, the filter error and the bandwidth error are automatically included in the measurement.

$$ACRMS\ accuracy\,[\%]\!:\frac{abs\left(DMM_{ref}[V]-Signal[V]\right)}{DMM_{ref}[V]}\times 100$$

Distortion error

The same setup must be used for measuring the distortion. Use an appropriate math function to determine the distortion of the measured signal.

Recommendation: Use an ultra low noise distortion function generator such as the Stanford Research DS360. Connect the signal to the input channel and calculate the signal spectrum. Measure the amplitude of the fundamental frequency Uf [V] in frequency domain and the amplitude of the first 5 harmonics (UH1 [V], UH2 [V], UH3 [V], UH4 [V], UH5 [V]).

Use the following formula to calculate the THD:

$$THD[\%]\!:\frac{\sqrt{U^{2}{}_{H1}[V]+U^{2}{}_{H2}[V]+U^{2}{}_{H3}[V]+U^{2}{}_{H4}[V]+}\,U^{2}{}_{H5}[V]}{U_{f}[V]}$$

DC accuracy

To determine the DC accuracy of the TRION3-18xx-MULTI the best way is to shorten he input and measure the average value (ShortAVG) which represents the offset error. This value must be set into relation to the input range (Range).

$$DC\ accuracy\,[\%]\!:\frac{abs(Short_{AVG}[V])}{Range[V]}\times 100$$

Input noise (peak to peak)

To determine the input noise of the TRION3-18xx-MULTI, it is best to short-circuit the input and measure the peak-to-peak value (ShortP2P). This error also includes the error that occurs during digitization. Since it is an absolute error, it must be set in relation to the input range.

$$Input\ noise[\%]\colon \frac{abs(Short_{P2P}[V])}{Range[V]} \times 100$$

Temperature drift

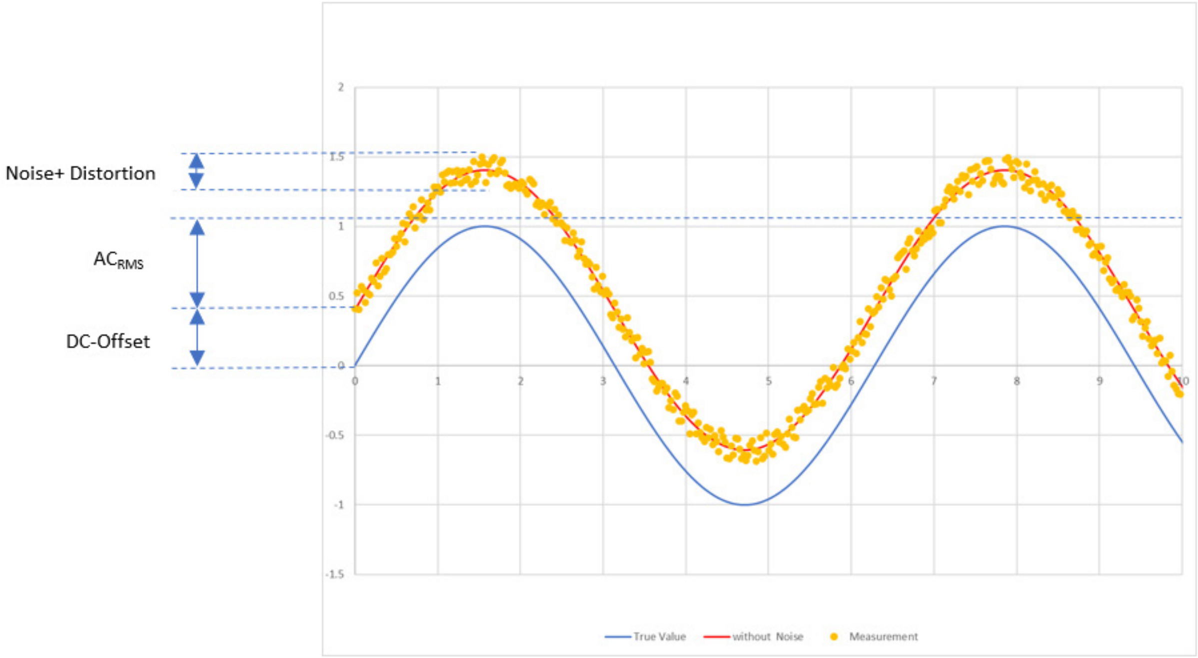
The temperature drift of the TRION3-18xx-MULTI must be considered if the environmental temperature differs more than 5 °C from room temperature. Since this test should be performed at constant room temperature it does not add an additional error.

Absolute signal accuracy

The single accuracy components can now be combined to an absolute signal accuracy by using the following formula:

$$Absolute\ accuracy\ [\%]^{*} = 2 \times \sqrt{\left(\frac{ACRMS\ accuracy[\%]}{\sqrt{3}}\right)^2 + \left(\frac{DC\ accuracy[\%]}{\sqrt{3}}\right)^2 + \left(\frac{Input\ noise[\%]}{3}\right)^2 + \left(\frac{THD[\%]}{\sqrt{2}}\right)^2}$$

*) Accuracy of a single sampled measurement value



For the calculation, the following distributions were assumed:

- Uniform distribution for AC$_{RMS}$ accuracy and DC accuracy: $\frac{\text{Amplitude}}{\sqrt{3}}$
- Normal distribution for input noise: $\frac{\text{Amplitude}}{3}$
- Arcsine distribution with a standard deviation for THD: $\frac{\text{Amplitude}}{\sqrt{2}}$

EXAMPLE

- Input signal: 7 V, 50 kHz
- Input channel configuration: 10 V range, 80 kHz bandwidth

Theoretical maximum

To calculate the theoretical maximum error, the respective specifications from the data sheet are used for the individual components.

	Specification	
AC_{RMS} accuracy	±(0.005 % * f) of reading	= 0.25 %
DC accuracy	±0.02 % of range ±20 µV	= 0.0205 %
Distortion	108 dB	= 0.00039 %
Noise	0.26 mV_{PP}	= 0.0026 %
Absolute accuracy	**0.29 % theoretical maximum**	

Actual value

To determine the actual accuracy of the input, the specifications must be replaced by real measured values.

	Specification	
AC_{RMS} accuracy	7.00523 V	= 0.0747 %
DC accuracy	0.4 mV	= 0.004 %
Distortion	110 dB	= 0.00032 %
Noise	0.24 mV_{PP}	= 0.0024 %
Absolute accuracy	**0.09 % actual value**	

CALCULATION

The calculation is based on real measurement values.

Measurement point 1:
- ±10 V input range
- Input signal: 10 kHz/7 V_{RMS}

Acceptable limit: 1 %	
AC_{RMS} accuracy	0.018 %
DC accuracy	0.0004 %
Distortion	0.008 %
Noise	0.004 %
Absolute accuracy	**0.02 %**

Measurement point 2: ▸ ±10 V input range ▸ Input signal: 30 kHz/7 V_{RMS}

Acceptable limit: 3 %	
AC_{RMS} accuracy	0.106 %
DC accuracy	0.0003 %
Distortion	0.019 %
Noise	0.005 %
Absolute accuracy	**0.13 %**

Measurement point 3: ▸ ±10 V input range ▸ Input signal: 60 kHz/7 V_{RMS}

Acceptable limit: 3 %	
AC_{RMS} accuracy	0.373 %
DC accuracy	0.001 %
Distortion	0.042 %
Noise	0.005 %
Absolute accuracy	**0.44 %**

Measurement point 4: ▸ ±1 V input range ▸ Input signal: 10 kHz/700 mV_{RMS}

Acceptable limit: 1 %	
AC_{RMS} accuracy	0.029 %
DC accuracy	0.005 %
Distortion	0.011 %
Noise	0.007 %
Absolute accuracy	**0.04 %**

Measurement point 5: ▸ ±1 V input range ▸ Input signal: 30 kHz/700 mV_{RMS}

Acceptable limit: 3 %	
AC_{RMS} accuracy	0.112 %
DC accuracy	0.005 %
Distortion	0.020 %
Noise	0.007 %
Absolute accuracy	**0.13 %**

Measurement point 6: ▸ ±1 V input range ▸ Input signal: 60 kHz/700 mV_{RMS}

Acceptable limit: 3 %	
AC_{RMS} accuracy	0.407 %
DC accuracy	0.005 %
Distortion	0.016 %
Noise	0.007 %
Absolute accuracy	**0.47 %**

Measurement point 7: ▶ ±100 mV input range ▶ Input signal: 10 kHz/70 mV$_{RMS}$

Acceptable limit: 2 %	
AC$_{RMS}$ accuracy	0.046 %
DC accuracy	0.005 %
Distortion	0.015 %
Noise	0.023 %
Absolute accuracy	**0.06 %**

Measurement point 8: ▶ ±100 mV input range ▶ Input signal: 30 kHz/70 mV$_{RMS}$

Acceptable limit: 5 %	
AC$_{RMS}$ accuracy	0.163 %
DC accuracy	0.006 %
Distortion	0.112 %
Noise	0.026 %
Absolute accuracy	**0.25%**

Measurement point 9: ▶ ±100 mV input range ▶ Input signal: 60 kHz/70 mV$_{RMS}$

Acceptable limit: 5 %	
AC$_{RMS}$ accuracy	0.373 %
DC accuracy	0.001 %
Distortion	0.042 %
Noise	0.005 %
Absolute accuracy	**0.44 %**

Measurement point 10: ▶ ±10 mV input range ▶ Input signal: 10 kHz/7 mV$_{RMS}$

Acceptable limit: 2 %	
AC$_{RMS}$ accuracy	0.121 %
DC accuracy	0.060 %
Distortion	0.654 %
Noise	0.256 %
Absolute accuracy	**0.95 %**

Measurement point 11: ▶ ±10 mV input range ▶ Input signal: 30 kHz/7 mV$_{RMS}$

Acceptable limit: 5 %	
AC$_{RMS}$ accuracy	0.230 %
DC accuracy	0.009 %
Distortion	0.212 %
Noise	0.243 %
Absolute accuracy	**0.43 %**

Measurement point 12: ▸ ±10 mV input range ▸ Input signal: 60 kHz/7 mV_{RMS}

Acceptable limit: 5 %	
AC_{RMS} accuracy	0.725 %
DC accuracy	0.059 %
Distortion	0.942 %
Noise	0.264 %
Absolute accuracy	**1.58 %**

AUTHORS

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Joachim Rieger is the Head of Hardware Development at DEWETRON and brings more than two decades of experience to the forefront of the company's technological innovations. With his background in communications engineering and his passion for cutting-edge hardware solutions, he has played a crucial role in the development of state-of-the-art measurement systems. His expertise has contributed significantly to the company's success, establishing DEWETRON as a leading provider of high quality measurement solutions trusted by the industry worldwide.

Rafael Ludwig

Rafael Ludwig studied electrical engineering as well as audio engineering at the University of Music and Performing Arts Graz and the Graz University of Technology. During his master's studies, he specialized in acoustics and audio recording. After graduating, he worked as an acoustics engineer in the R&D department of a mechanical engineering company before he joined DEWETRON in 2017 as Application Engineer. Since 2022 he has been responsible for Product Management and Application Engineering.

ABOUT DEWETRON

DEWETRON is a manufacturer of precision test & measurement systems designed to help our customers make the world more predictable, efficient and safe. Our strengths lie in customized solutions that are immediately ready for use while also being quickly adaptable to the changing needs of the test environment and sophisticated technology of the energy, automotive, transportation and aerospace industries.

More than 30 years of experience and innovation have awarded DEWETRON the trust and respect of the global market. There are more than 25,000 DEWETRON measurement systems and over 400,000 measurement channels in use in well-known companies worldwide.

DEWETRON employs over 120 people in 25 countries and is part of the TKH Group, a global corporation, that specializes in the development and supply of innovative solutions worldwide.

DEWETRON's quality is certified in compliance with ISO9001 and ISO14001. The high integrity of the measurement data is guaranteed by our own accredited calibration lab according to ISO17025.

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