IEEE TC-10: Update 2008

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Keywords-IEEE Std 181™, IEEE Std 1057™, IEEE Std 1241™, IEEE Std 1658™ (Draft) IEEE Std 1696™ (draft), Digitizing Waveform Recorder, Pulse, ADC, DAC, Measurement

I. Introduction and Objectives

There is a world-wide need to standardize terms, test methods, and the computation of performance parameters for devices that generate, measure, and analyze waveforms. Users need to be able to unambiguously specify the device performance required for particular applications. Manufacturers need to be able to unambiguously state the performance of their devices (e.g., instruments, components, etc.). Metrology facilities need to perform calibrations with well-defined methods to produce reliable data expressed in clear terms. Measurement instruments need to acquire data with well-defined methods and present it clearly. Technical Committee 10 (TC-10), the Waveform Generation, Measurement, and Analysis Committee of the IEEE Instrumentation and Measurement (I&M) Society, is tasked to develop standards to address these needs. TC-10 comprises an international group of electronics engineers, mathematicians, professors and physicists with representatives from national metrology laboratories, national science laboratories, component manufacturers, the test instrumentation industry, academia, and end users.

The initial project for TC-10 was to develop the IEEE Standard for Digitizing Waveform Recorders, IEEE Std 1057-1994 [1]. During the course of developing IEEE Std 1057, TC-10 noted that while much of the standard applied to analog-to-digital converters (ADCs), there are additional terms and test methods that are unique to ADC characterization. Accordingly, TC-10 developed IEEE Std 1241-2000 [2], the IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters. The Subcommittee on Pulse Techniques (SCOPT) was formed to revise and combine two out-of-date IEEE standards dealing with pulse parameters. This work resulted in the publication of IEEE Std 181-2003, the IEEE Standard on Transitions, Pulses, and Related Waveforms [3]. The Std 181-2003 combines information from both of the withdrawn IEEE standards and supersedes both of them.

As work progressed on the ADC standard, TC-10 realized that a substantial portion of the concepts behind the ADC standard would also apply to digital-to-analog converters (DACs). As a result, the Standard for Terminology and Test Methods for Digital-to-Analog Converters (P1658) has been in development since March 2004. TC-10 became aware of a need for a standard for the probes used with electronic instruments and began developing the Standard for Terminology and Test Methods for Circuit Probes (P1696). Brief overviews of the three published standards (1057, 1241, 181) are described in the next section, Description of Published Standards. The status of ongoing work is discussed in Section III, Continuing Activity.

II. Description of Published Standards

The efforts of TC-10 have resulted in three published IEEE standards to date.

A. IEEE Std 1057-2007 [7], "Standard for Digitizing Waveform Recorders"

IEEE Std 1057 defines specifications and describes test methods for measuring the performance of electronic digitizing waveform recorders, waveform analyzers, and digitizing oscilloscopes with digital outputs. The standard is directed toward, but not restricted to, general-purpose waveform recorders and analyzers.

The main purpose of this standard is to ensure that manufactures and users of waveform recorders have a well-defined set of specifications and test methods so they can understand, describe and compare the performance of these recorders using a common language. IEEE Std 1057-2007 has been revised from the 1994 version and republished.

B. IEEE Std 1241- 2000, "Standard for Terminology and Test Methods for Analog-to-Digital Converters"

This standard identifies analog-to-digital converter (ADC) error sources and provides test methods with which to perform the required error measurements.

The information in this standard is useful both to manufacturers and to users of ADCs in that it provides a basis for evaluating and comparing existing devices, as well as providing a template for writing specifications for the procurement of new ones. In some applications, the information provided by the tests described in this standard can be used to correct ADC errors, such as, gain and offset errors. This standard also presents terminology and definitions to aid the user in defining and testing ADCs.

C. IEEE Std 181- 2003, "Standard on Transitions, Pulses, and Related Waveforms"

The purpose of Standard 181-2003 is to facilitate accurate and precise communication concerning parameters of transition, pulse, and related waveforms and the techniques and procedures for measuring them. Because of the broad applicability of electrical pulse technology in the electronics industries (such as computer, telecommunication, and test instrumentation industries), the development of unambiguous definitions for pulse terms and the presentation of methods and/or algorithms for their calculation is important for communication between manufacturers and consumers within the electronics industry.

The availability of standard terms, definitions, and methods for their computation helps improve the quality of products and helps the consumer better compare the performance of different products. Improvements to digital waveform recorders have facilitated the capturing, sharing, and processing of waveforms. Frequently these waveform recorders have the ability to process waveforms internally and provide pulse parameters. This standard is needed to ensure that the definitions and methods of computation for pulse parameters are consistent.

III. Continuing Activity

TC-10 is promoting awareness of its activities and soliciting involvement from interested people. To that end, papers have been presented at IMTC, IMEKO, and other conferences over the past several years. It also has a general interest in incorporating IEEE standard terms, definition, and test methods into IEC standards. Specific activities of its TC-10 subcommittees follow.

A. Subcommittee on Digital Waveform Recorders (1057)

IEEE Std. 1057-1994 has been revised and republished as IEEE Std 1057-2007. To the extent applicable, portions of IEEE Std 1241-2000 were incorporated. In common areas between the standards, terms and methods originally published in IEEE Std 1057 were refined and enhanced in IEEE Std 1241. IEEE Std 1057 leveraged these advances. In a similar manner, pulse terms, definitions, and test methods developed in IEEE Std 181 were also incorporated. Pulse techniques are especially important since many digital oscilloscopes directly report pulse parameters. The subcommittee generated improved definitions and test methods for critical metrics, such as, Effective Number of Bits (ENOB), total harmonic distortion, noise, locating code transitions. Other improvements include detailed discussion of requirements for and errors in signal sources.

IEEE 1057-2007 also includes several appendices that provide detailed guidance for implementing and interpreting the results from some of the test methods. For example, one appendix covers methods for the presentation of sine-wave testing data. One method is the modulo time plot in which all of the data from a sine fit test are remapped into one sine wave cycle. An example is shown in Figure 1a. A second is the Power Spectral Distribution (PSD) plot. The PSD is the integral of the power spectral density. An example is shown in Figure 1b. A jump in the PSD represents energy concentrated at a single frequency. Please see IEEE Std 1057-2007 for more details and references concerning these plots.

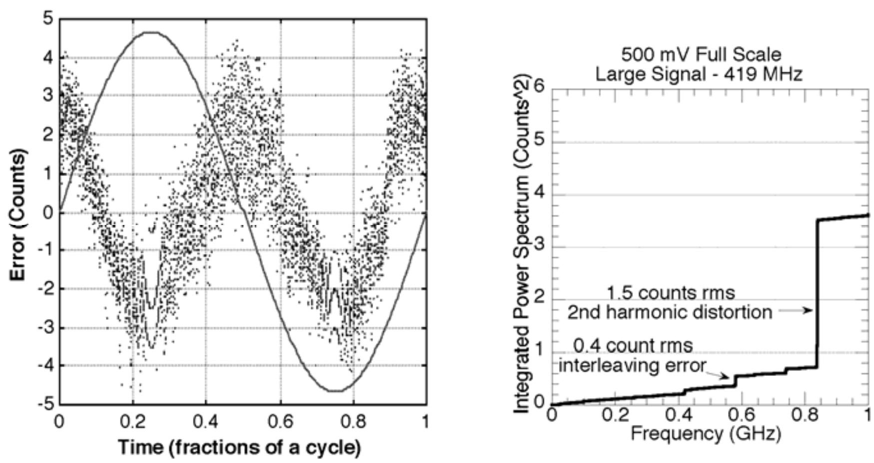

Figure 1a (left). Example modulo time plot showing the digitized sine wave and the residuals
Figure 1b (right). Example PSD plot (both figures were generated from the same data)

B. Subcommittee on ADC (1241)

The subcommittee opened a new PAR in 2005 to revise IEEE Std 1241- 2000. It is scheduled to ballot before the end of 2009 and publish a revised standard by summer of 2010. While the subcommittee collected responses to IEEE Std 1241-2000, it also supported the development of terms, definitions from IEEE Std 181- 2003 and techniques and definitions recently included in IEEE Std 1057- 2007 and in the future release of the DAC standard, IEEE Std 1658 (draft). It is promoting awareness of IEEE Std 1241-2000 through papers, ADC Forum's at conferences, a special tutorial on ADC's in I&M magazine [4][5][6], and in trade journals.

The subcommittee is currently addressing comments received from users since the publication of 1241 in 2001. It will encompass common terminology and definitions of terms in related standards 1057 and 181. It is also endeavoring to include some additional and alternate test methods under review and rewrite at this time. A new annex is being drafted that will include many known ADC architectures and guidance on how to select the best test methods to characterize these different architectures. Figure 2 is one such architecture used to increase the speed of the basic sub-ranging ADC, which has become very popular. This pipelined ADC has a digitally corrected sub-ranging architecture in which each of the two stages operates on the data for one half of the conversion cycle and then passes its residue output to the next stage in the pipeline prior to the next phase of the sampling clock. The inter-stage track-and-hold (T/H) serves as an analog delay line. It is timed to enter the hold mode when the first-stage conversion is complete. This allows more settling time for the internal SADCs, SDACs, and amplifiers. It allows the pipelined converter to operate at a much higher overall sampling rate than a non-pipelined version.

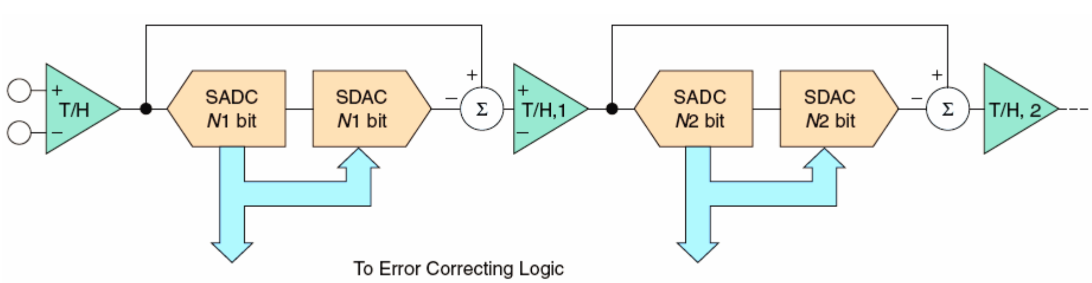

Figure 2. Pipelined ADC architecture

For pipelined converter architectures, the user might consider using near full-scale sine-wave tests for spectral performance parameters such as SFDR and IMD using DFT analysis. For linearity testing, use the cumulative histogram test method with an over-driven sine wave as is typically used in communications applications. Unlike other architectures that have specific anomalies requiring specific test methods (e.g., Sigma-Delta requires tonal tests and flash requires sparkle code or metastability test methods), the pipelined architecture in itself does not drive unique test requirements.

C. Subcommittee on Pulse Techniques (SCOPT) (181)

SCOPT began revising IEEE Std 181-2003 in May 2008. SCOPT will revise IEEE Std 181-2003 to include additional terms and definitions, correct errors, and add information for generating reference waveforms that can be used in algorithm comparison. The fundamental waveform parameters are presented in Figure 3. Figure 4 shows common variations of a signal from ideal or expected values.

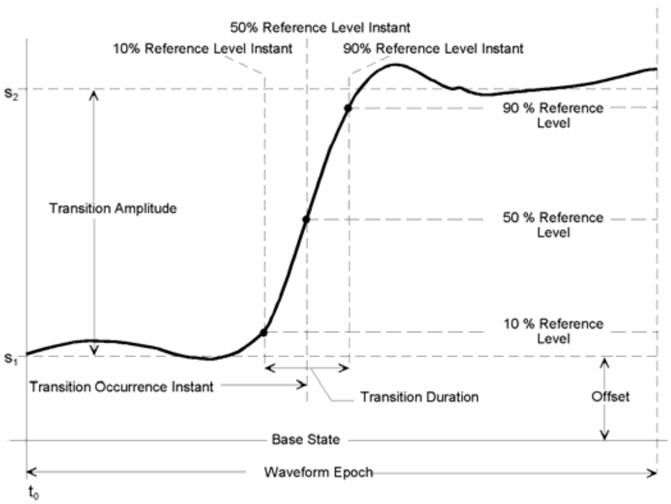

Figure 3. Fundamental waveform parameters
These parameters form the basis upon which many other parameters are derived.

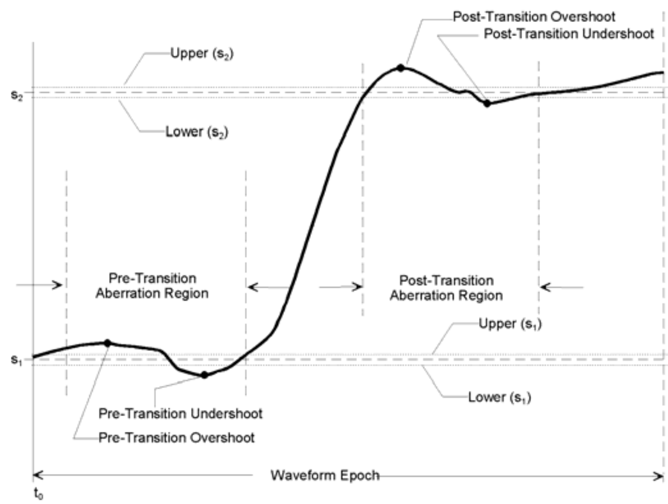

Figure 4. Waveform parameters used to describe variations of a signal from ideal or expected values

SCOPT is promoting awareness of IEEE Std 181-2003 through publications and communication at technical meetings. It is seeking assistance in this process and welcomes your suggestions and participation. SCOPT has also been interacting with the IEC for the purpose of having IEEE Std 181-2003 considered as a replacement for IEC 60469-1 and IEC 60469-2, which are almost verbatim copies of the now obsolete IEEE Std 194-1977 and Std 181-1977. SCOPT will also participate with the maintenance team of the IEC TC85, which is the technical committee responsible for maintenance of IEC 60469-1 and -2.

D. Subcommittee on DAC (1658)

This subcommittee was formed in 2004 and is currently working feverishly to complete the first draft of IEEE Std 1658, “Standard for Terminology and Test Methods for Digital-to-Analog Converters.” A wide range of working group members has been working from many international companies, universities and laboratories to develop a working draft for ballot. It is expected that this standard will be balloted and approved before the end of 2010. Continuing efforts are ensuing. Additional hard working members are always welcome and encouraged to participate during the coming months. P1658 will also contain an annex on different DAC architectures.

Although ADCs employ DAC architectures, it is not always intuitively obvious to the new user how different ADCs and DACs are. This draft will emphasize these differences through use of side-by-side comparisons like those shown in Figure 8 below.

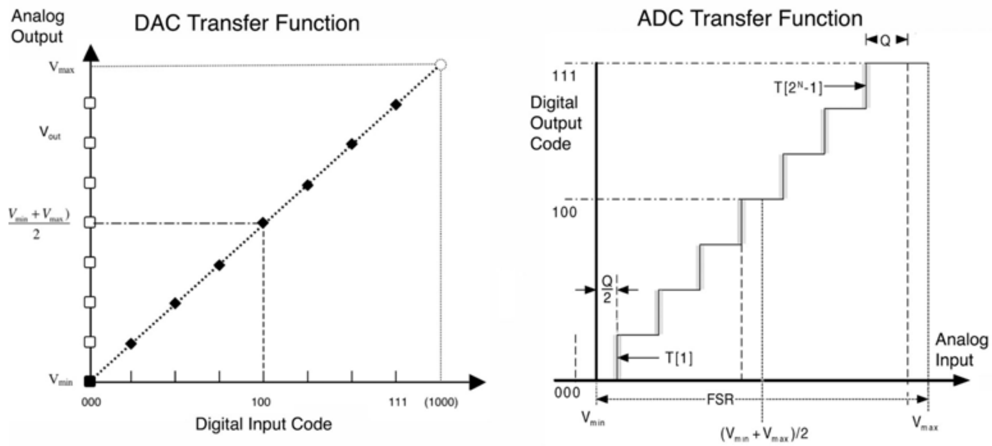

Figure 8. Transfer functions of ideal 3-bit unipolar DAC and ADC

Also, like in the ADC standard, an important aspect and function of the DAC standard is to guide the user to understand what DAC parameters is important for differing DAC applications. It will contain some typical applications, suggested critical DAC parameters and their related performance issues. For example; for audio applications, the critical DAC parameters might be SNR, THD, SINAD and SFDR since the user would like to have high dynamic range with little or no distortion because these parameters directly affect the sound quality.

E. Subcommittee on Probe Standard (SCOPS) (1696)

One of the major challenges of observing electrical waveforms in high-speed electrical circuits is being able to connect a measurement device (oscilloscope, digitizing waveform recorder, etc) to the circuit of interest without disturbing its electrical characteristics and/or causing the waveform to change. In the early days of low-frequency, high-impedance oscilloscopes and probes, it was relatively easy to monitor and/or record waveform data without perturbing the system. But with the newer, high-frequency, low-impedance systems, maintaining signal integrity has become much more difficult. Probing circuits running at several gigahertz without distorting the signal is extremely challenging.

A major consideration in testing circuit probes it the ability to apply a known standard signal to the probe input. For high-frequency applications, a test fixture with known S-parameters is used (Figure 9 shows an example fixture).

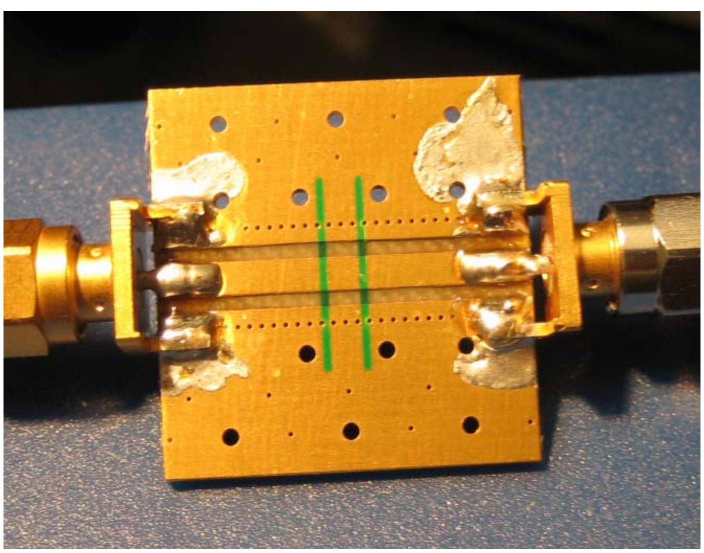

Figure 9. Example of circuit probe test fixture, showing marked probing point

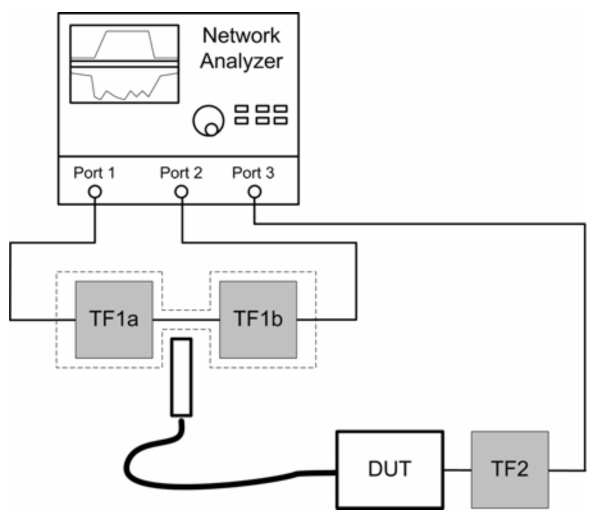

Figure 10. Example circuit probe test setup for a single-ended probe, using a Vector Network Analyzer

Figure 10 shows one possible test setup using the test fixture (shown as TF1a and TF1b in the figure). The fixture is divided into two sections to allow both sides to be characterized separately, so the effects on the signal to the circuit probe can be accurately calculated and proper compensation made to the probe test results. By using a fully-characterized test fixture, it should be possible to accurately determine the circuit probe characteristics.

The Subcommittee on Probe Standards (SCOPS) was formed in 2006 to draft the Standard for Terminology and Test Methods for Circuit Probes, IEEE Std 1696 (draft). This standard will provide standardized terminology, definitions, and test methods. It also describes transfer (artifact) standards for characterizing electrical circuit probes and probes systems. The systems may include waveform acquisition hardware and software and signal/waveform analysis software. The probe will include the mechanism by which the circuit is contacted. This method and standard will be applicable to probes having one signal conductor and one ground conductor or two signal conductors, and having an input impedance greater than the impedance of the circuit under test.

F. Jitter

Unambiguous terms and definitions describing jitter and its components, algorithms for computing jitter values, jitter measurements methods, and jitter artifact standards have long been an issue. Over the last few years, NIST has received several requests to assist in the resolution of disagreements and disputes concerning jitter definitions and measurement methods. Because of the nature of these requests, NIST informed the TC-10 of the need to resolve, in the least, jitter definitional issues. The TC-10 is evaluating whether it should address any of these jitter-related issues. If it should do so, then to what extent, how to integrate with other standards development organizations the level of participation required to achieve timely success, etc. If any of these jitter topic areas are of interest, please contact Tom Linnenbrink at toml@hittite.com.

IV. Conclusions

IEEE standards are continuously evolving. Every standard is reviewed every five years to see if changes and/or improvements are needed. For example, TC-10 determined to use consistent terminology and definitions among related standards to minimize confusion among users. The need for new standards arises from time to time providing the opportunity to expand our activities. TC-10 is always interested in fresh ideas and people willing to engage in developing standards. For more information on TC-10 activities and membership, please visit the TC-10 home page at http://grouper.ieee.org/groups/1057/ and/or contact the subcommittee chairs. All of them are co-authors of this paper. Their contact information is shown following their names below the paper title.

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