

**Minutes of TC-10 Waveform Recorder Subcommittee Meeting of
February 14, 2006 in Gaithersburg, Maryland**

Attendance:

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| Tom Linnenbrink | Hittite Microwave |
| Bill Boyer | Sandia National Laboratories (Retired) |
| Jerry Blair | Bechtel Nevada |
| Pasquale Daponte | University of Sannio |
| Eualia Balestrieri | University of Sannio |
| Sol Max | LTX Corporation |
| Francisco Alegria | Tech. Univ. of Lisbon |
| Steve Tilden | Texas Instruments |
| Bob Graham | Sandia National Laboratories |
| Nick Paulter | NIST |
| David Bergman | NIST |
| Don Larson | NIST |

1. Agenda

Bill Boyer distributed an agenda by email prior to the meeting. It is attached to the minutes.

2. Draft Status

All of the sections of the draft were combined into single document updated, which was updated Feb 3. It does not all follow all of the new guidelines from IEEE, but Bill Boyer is working on this. Much has been dropped that was not completed. It now has global references to equations and figures. There are probably some errors in these but they are being fixed. The plan is to ballot in about a year.

3. Review of Assignments from previous meeting.

The name in parentheses after each item is the responsible person. Items that are marked “done” on the agenda were not discussed.

Annex H. A new figure was supplied by Sol Max for the “alternate presentation” section. The figures still need to have company names removed and be made clear in black and white. (Jerry Blair)

Annex A. The new material from the previous meeting will be reviewed by Sol Max. (Sol Max)

Clause 7.4. New figures have been supplied. Sol will label horizontal axis. Change vertical label to “DNL” rather than “DNL Error”. (Sol Max)

Clause 7.6, Hysteresis. This was reviewed. The figure is to be changed to use R and 100R rather than specific resistance values. (Sol Max)

Clause 7.7 Total Harmonic Distortion. The changes to this were reviewed.

- When defining THE and saying it is useful, point out the equations it is used in.
- Use A_{rms} instead of X_{rms} in the equations.
- Add additional explanation after Equation 50 and add additional equations to make this section self contained, rather than referring to the previous section.
- In (44) put limits on sum. Convert the sentence before to passive voice.
- Starting at (44) change equations to not use frequencies where integer indices should go. (all above items: Jerry Blair)

Clause 8. This clause has a number of typo's in the equations and some inconsistency in notation. A_{vm} needs to be changed to A_{vg} everywhere. Francisco Alegria will make changes to 8.1 through 8.3 and Jerry Blair will review. Jerry Blair will make changes to 8.4 and Francisco and Sol Max will review. All of this will be reviewed in Sorrento.

Clause 8.5. Specify that the ideal quantization error is rms. Clause 8.5.2 has a lot of typo's. (Bill Boyer)

Clause 8.6. Use $FSR/2$ in the formula instead of V . (Bill Boyer)

Clause 8.7.1. Sigma squared should be defined as mean squared random noise rather than noise variance. (Bill Boyer)

Clause 8.7.2. Many minor notation and wording differences were covered, but I failed to record an action item.

Clause 16, Cycle Time. This will not have a specific test method. It will instead say that test methods are dependent on the application.

Definitions and Symbols

- The DFT should be defined as only going from time domain to frequency domain, and the inverse DFT should be defined as the other direction.
- We do not need differential input impedance to ground.
- Use BW for bandwidth, not B .
- In section 9.6.1 use $2\pi f$ instead of ω , because f is used everywhere else.
- We need to keep consistency with IEEE Std 181-2004. The necessary algorithms from 181 should be included in 1057 instead of being referred to.

- Italicize defined terms later in the standard.
- Parseval relation: Use the definition from Wikipedia (http://en.wikipedia.org/wiki/Parseval%27s_theorem): The sum (or integral) of the square of a function is equal to the sum (or integral) of the square of its transform.

Clause 4.6.8. Reword the sentence concerning my paper and give specific equation numbers. (Jerry Blair)

Clause 4.6.10. Redo to replace the “synchronous with sampling clock” phrase. (Sol Max)

Clause 4.6.10.4. Is this really part of 4.6.10.3?

References. Look for more references, especially those that deal with uncertainties. (Everyone)

Spurious components.

- It seems that we have not covered spurs. In the definition harmonics are included but in Clause 4.5 they are not included. We need to put SFDR back in the standard. (Bill Boyer)
- If we define spurs to include harmonics the section on oscillator distortion will have to be changed to agree. (Jerry Blair)

Annex E. Removed - because it is redundant.

Windows. Get references for data windows (Harris or Barris?). Get correct reference for equation (12) and for (15). Check (15) to see if f_s should replace one of the f_i 's. (Jerry Blair)

Annex G. Review correctness of formulas. (Francisco Alegria)

Clause 8.5.1.1. Add to this. (Jerry Blair)

Annex A.3. Check that it has the most recent algorithm. (Jerry Blair)

Issues. A list of issues was distributed with the agenda and is included below. I have added my notes written on the issues pages during the meeting (in green).

**Agenda for Waveform Recorder Subcommittee Meeting
February 14, 2006**

1. Introductions
2. Review of status of the draft
3. Review of status of assignments per minutes of Nov 2005:
 - **Annex I, Presentation of Sinewave data** Minor fixes (Jerry Blair)
 - **Annex A, Sinewave Fitting** review changes per Kollar (Jerry Blair)
 - **Clause 7.4 INL. Provide better example figures** (Sol Max) **done**
 - **Clause 7.6 Hysteresis. Need figure. Need “alternation” in places. Need to change definition to “max value for the codes”** (Sol Max) **done**
 - **Clause 7.7 Total Harmonic Distortion. Various corrections to submitted material** (Jerry Blair, Sol Max)
 - **Clause 8 Noise notation** (Boyer) – some suggestions implemented
 - **Clause 16.1 Test method for cycle time. Eliminate?** (Blair)
 - **Scope** – insert reference to 1241 (Boyer) **done**
 - **Introduction** – add names of more people (Boyer) **started**
 - **Guidance to user:** update to talk about Annex F (Boyer) **done**
 - **Annex F:** make reference to Hungarian site (Boyer) **done**
 - **Definitions and symbols:** suggestions being made and changes made on the fly (Boyer) lots of work done, needs review
 - **PDF:** define distribution function and probability density as its derivative. (Boyer) **done**
 - **3.1.59** Separate definitions of quantization error and quantization noise. (Fang Xu).
 - Make changes to agree with 181 (Boyer) some progress
 - Italicize all defined terms in draft. (Bob Graham)
 - **4.2.2** Shorten last paragraph to apply to WF recorders rather than ADCs. (Jerry Blair)
 - **Clause 4.6.10** Check on the statement about having sufficient overdrive with only one hit in the first and last bins. (Jerry Blair)
 - **Input impedance.** Change dc resistance to low frequency impedance (Boyer) **done**
 - **Look over all material in draft in red and propose what should be done** (All)
 - **Look other issues identified in attachment** (All)
4. Other business
5. Review action items

Some issues with Feb 06 1057 draft:

New proposed first cut definitions:

aliasing: The phenomenon in sampled data systems whereby signals at input frequencies greater than half the sampling frequency are converted to frequencies in the output data record at less than half the sampling frequency [B9], B[13].

cosine data window: a data window created from a series sum of cosine functions, [B3 Barris need]

discrete fourier transform (DFT): a pair of mathematical operations that convert data between the time and frequency domains

intermodulation distortion: When there are multiple signals frequencies at the input to the recorder, the generation of distortion signals at the sum and difference frequencies of the inputs due to nonlinearities in the waveform recorder frequency response

Parseval relationship: a statement of the fact the the energy/power ? in the time domain equals that in the frequency domain (need reference B[29] for this

Need step response from 181

New symbols

η = noise

ε = general symbol for error, uncertainty or tolerance

A_{rms} = rms value of a fitted sinewave, rms signal.

B = bandwidth (also used to be f_{CO})

$N_{CHG}[i]$ = cumulative number of samples up to bin j in sinewave histogram code transition level test

$N_{HG}[i]$ = the average number of histogram samples received in each of the code bins that share the given transition level

NAD_{rms} = rms noise and distortion

$BWSNR (SNR_{BW})$ = bandwidth signal-to-noise ratio

$SSBWSNR (SNR_{SSBW})$ = small signal bandwidth signal-to-noise ratio

Style issue. Need to resolve using x_n or $x[n]$ and t_n or $t[n]$. Example below

$$x[n] = A_0 \cos(\omega_0 t_n) + B_0 \sin(\omega_0 t_n) + C_0$$

Text issues

From 4.2.2

A sinewave generator provides the test signal while a clock generator provides the clock (or conversion) signal. Also, combining the output of two (or more) sinewave generators can produce two-tone (or multi-tone) test signals for intermodulation distortion testing. Additionally, a noise generator's output can be...

From 4.4.4 uncertain about what equation is being referenced?

"Using the frequency domain formula for *NNPG* given in (A9 missing??) we obtain

ρ is a factor in maximum phase difference?? Ill-defined in equation 18

Need reference for equation 18 "Tables are available [B2]reference to web site]"

In 4.6.2 -- "The DAC's input (output??) is decremented or incremented by ΔV after each data record of length M , is collected based on the result of the

In 4.6.10.1 and 4.6.10.3 "The input ramp or triangle wave should be generated synchronously with the sampling clock, by a high" implies we are testing an ADC.

In 4.6.10.1.1 May need a reference for equation 29.

In 4.6.10.2 uncertain about equation referenced is steps 3 and 4 or algorithm.

And need to fix notation in Fig. 10. (Also do we really need the figure? This is one of very few places where we diagram an algorithm.)

4.6.10.4 unknown reference for uncertainties in values of the code transition levels

7.9.2 Are B10 and B15 appropriate references. **There is no clause 7.9.2.**

8.4 Do normalized SNR measures need to be reworked now that noise does not include distortion.

8.5.2 Low noise test method for ENOB. Is reference [B7] proper

9.2.1 Test method for transition duration. Propose putting algorithm in our text instead of simply referencing 181. **Yes, covered in the minutes.**

9.4.1 Test method for overshoot. Propose putting algorithm in our text instead of simply referencing 181. **Yes, covered in the minutes.**

Should replace "width" with "duration" everywhere? **Yes, covered in the minutes.**

10.2 Gain Error. Propose replacing $G(f)$ with $H(\omega)$ or at least the magnitude. Also don't understand statement "same frequency used in the bandwidth test...". Looks like we missed something in carrying this over from 1241. **Covered in the minutes.**

Annex A –

Need a reference for Q-R algorithm. Suggest G W Stewart "Introduction to Matrix Calculations" however it is old ~1973.
Can we eliminate the non-matrix algorithms?
Should we move the material on estimating frequency and phase for the 4 parameter fit to the beginning of the matrix method?

Annex B Phase Noise:

Need HP and Tek application notes
Need Mathematica program for computing integral (4 places)
Undefined variables in Eq B-4
Are equation numbers correct in 1st paragraph of B.4.1

Annex C Errors associated with word error rate:

Undefined variables in Eq C-2
Is this material important enough to be included in the main text?

Annex E Aliasing effects on pulse measurements:

Is material already covered in main text. If so we can eliminate this.

Annex F Software considerations:

Need reference to Budapest software site. Propose eliminating old "toolkit" text.

Annex G Triangle Wave considerations:

Rand M ??
What is correct equation reference in item (3).

Annex H Presentation of sinewave data:

Need cleaner plots.
Is reference [B15] correct