Summary of Several Items Related to Time Synchronization Transport to be Decided for IEC/IEEE 60802

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Introduction - 1

- References [1], [2], and [3] were presented and discussed in the IEC/IEEE 60802 meeting of December 21, 2020
- Most of the discussion focused on the frequency offset and frequency stability requirements for the oscillator or device for a PTP Instance used for the IEC/IEEE 60802 TSN profile
  - Related to this, the discussion also covered the assumed temperature profile, and how both the requirements and assumptions should be stated or specified, both for the profile document and for the simulations
- At the end of the discussion, the author of this presentation summarized what items are outstanding and need to be decided
- This presentation summarizes what the author stated verbally

Items to be Decided - 1

- Much of the discussion concerned whether the frequency stability requirements should be stated in terms of frequency as a function of time, or frequency as a function of temperature
  - Specifically, should the requirement be on maximum frequency offset over a temperature range, or maximum frequency rate of change with respect to time along with a maximum frequency offset
    - The author of the current presentation observed that in both cases, a temperature versus time profile is needed
    - The author also indicated that, regardless of which approach is chosen, the simulations need, as input, frequency offset versus time; however, this can be derived for both approaches
    - The approach chosen will determine how the requirements are stated in the 60802 Profile Document
    - Some participants indicated that stating the frequency stability requirement in terms of time does not represent the physics of oscillators, because the frequency changes are caused by temperature changes; along with this, it was indicated that data sheets do not give specs in terms of time
    - Other participants indicated that, to constrain the transferred time error, it is the time variation of frequency that must be constrained in the end; how the vendor achieves this is up to the vendor

Items to be Decided - 2

- There also was discussion on the numerical values for the frequency stability requirement and the assumed temperature profile
- Current assumptions (e.g., for simulations so far) are stated as maximum frequency drift rate of 3 ppm/s and maximum frequency offset of ±50 ppm (or ±100 ppm in the draft and for earlier simulations)
    - These assumptions were re-stated in [3], along with temperature rates of change of 3 K/s and 0.3 K/s
    - Reference [1] included a temperature profile with a maximum rate of change of 25 K/minute = 0.4167 K/s (closer to the smaller value of [1]) and a temperature range of -40 C to + 85 C (with dwell times of 5 minutes at each of these extremes)
    - Reference [1] also included a parabolic dependence of frequency versus temperature; Reference [2] used this and the temperature profile of [1] to plot the time dependence of frequency offset and frequency drift rate
        - The result in [2] was that the maximum frequency offset range and maximum drift rate were slightly less than the 200 ppm range (i.e., ±100 ppm) and 3 ppm/s (i.e., the maximum was around 2.7 ppm/s, and the period could be taken as approximately similar to that of the sinusoidal variation assumed so far for the simulations
        - However, the periods of time spent at the maximum frequency drift rate were much less than in the simulation assumptions; for half of each period the frequency drift rate was zero using the result in [2]

Items to be Decided - 3

- In addition, Reference [4] was cited by one of the participants of the meeting (who also provided the link to the reference)
- This reference was not presented in the meeting, but was referred to in the discussion
  - Specifically, it included data on oscillator frequency stability versus temperature consistent with [1] and [2]
  - It also included data for oscillator (XO, i.e., not temperature compensated or ovenized) frequency stability indicating a much smaller range of frequency offset than 200 ppm, for the desired temperature range (-40 C to + 85 C); this data had frequency variation versus temperature that was cubic
  - It was asked whether this temperature stability could be considered, as it would lead to much less severe frequency versus time behavior than 3 ppm/s with ±50 ppm maximum frequency offset
  - The author of [2] indicated that before running additional simulations, the author would like to see the frequency offset versus time behavior corresponding to this better frequency versus temperature stability given in [4] with the temperature profile of [1]

Items to be Decided - 4

- There also was discussion of what the correct temperature profile is
- Some stated that 3 K/s is too stringent, while others seemed to indicate that it would apply in some situations (but it was then indicated that these situations are corner cases and should not be the driver for all cases)

Items to be Decided - 5

- There was brief mention of the timestamp granularity – should it be 2 ns, 4 ns, 8 ns (or something else)?
  - The timestamp error assumptions in the simulations (±8 ns with 0.5 probability for each) was not mentioned, but the author of the current presentation will mention that this has at least as big an effect as the above timestamp granularities

Items to be Decided - 6

❑ Modeling assumptions for the frequency variation at each node

- Simulations have assumed that the sinusoidal frequency modulation at each node is assumed to have random phase with respect to other nodes, and random modulation frequency
  - The random modulation frequencies at the different nodes were close to each other but not identical
    - This gave rise to low frequency beating, and was considered to be a conservative case
- However, it was pointed out that, since frequency variation is caused by temperature variation, it might be overly conservative to assume that modulation frequencies could be very different at each node, because that would imply that frequency offset could be increasing at one node and decreasing at another node
  - But this would imply very different temperatures at different nodes, which seems unlikely in industrial applications

Summary of Items to be Decided

- Should frequency stability requirements be in terms of frequency versus temperature or frequency versus time?
  - This is relevant for both how the requirements are stated in the 60802 profile and what is assumed for the simulations
  - In both cases above, a temperature profile is needed
- What should be the numerical values for assumptions for the frequency stability?
  - One of the frequency vs temperature models of [1], [2], and [4]?
  - Or, the frequency vs time assumptions made so far (and in [3])?
  - Where does the 3 ppm/s come from?
- What should the temperature profile be?
  - 25 C/minute (0.4167 K/s) between -40 C and +85 C, and dwell times of 5 minutes (for 20 minute period), assumed in [1]?
  - Or, 3 K/s of [3] (though [3] also mentions 0.3 K/s)?
- What should be assumed for timestamp granularity (e.g., 2 ns, 4 ns, 8 ns)?
- What should be assumed for phase and frequency for the frequency modulation waveforms?
  - Currently assume random phases and frequencies at each node and for each replications, but this seems unrealistic and overly conservative

Thank you

References - 1

[1] Jordan Woods, *Concerns regarding the clock model used in 60802 time synchronization simulations*, Revision 1, IEC/IEEE 60802 presentation, December 21, 2020 call (available at https://www.ieee802.org/1/files/public/docs2020/60802-woods-ClockModel-1220-v02.pdf)

[2] Geoffrey M. Garner, *Temperature, Frequency Offset, and Frequency Drift Rate Time History Plots for Model of [1]*, IEC/IEEE 60802 presentation, December 21, 2020 call (available at https://www.ieee802.org/1/files/public/docs2020/60802-garner-temp-freqoffset-freqdrift-plots-1220-v00.pdf)

[3] Guenter Steindl, *Industrial Requirements for Synchronization, Constraints Due to the Industrial Environment and the used XTALs and Oscillators for IEEE 802.1AS*, IEC/IEEE 60802 presentation, December 21, 2020 call (available at https://www.ieee802.org/1/files/public/docs2020/60802-Steindl-IndustrialRequirementsForSynchronization-1220-v1.pdf)

References - 2

[4] Rudolph Bechmann, *Frequency-Temperature-Angle Characteristics of AT-Type Resonators Made of Natural and Synthetic Quartz*, Proceedings of the IRE, vol. 44, no. 11, November 1956, pp. 1600 – 1607 (available at https://ieeexplore.ieee.org/document/4051918/authors#authors)