Annex B

(normative)

Performance requirements

B.1 LocalClock requirements

B.1.1 Frequency accuracy

The fractional frequency offset of the LocalClock relative to the TAI frequency (see ISO 80000-3:2006 and Annex C) shall be within ± 100 ppm.

B.1.2 Time measurement granularity

The granularity with which the LocalClock measures time shall be less than or equal to 40/(1-0.0001) ns.

B.1.3 Noise generation

B.1.3.1 Jitter generation

The jitter generation of the free-running LocalClock shall not exceed 2 ns peak-to-peak, when measured over a 60 s measurement interval using a band-pass filter that consists of the following low-pass and high-pass filters:

a) High-pass filter: first-order characteristic (i.e., 0 dB gain peaking), 20 dB/decade roll-off, and 3 dB bandwidth (i.e., corner frequency) of 10 Hz
b) Low-pass filter: maximally-flat (i.e., Butterworth) characteristic, 60 dB/decade roll-off, and 3 dB bandwidth equal to the Nyquist rate of the LocalClock entity (i.e., one-half the nominal frequency of the LocalClock entity)

B.1.3.2 Wander generation

Wander generation is specified using the Time Deviation (TDEV) parameter. The corresponding values of the Allan Deviation (ADEV) and PTP Deviation (PTPDEV) are given for information; the former is also useful in describing the wander generation of clocks and oscillators, and the latter is related to the offsetScaledLogVariance attribute (see 8.6.2.4). Information on ADEV and TDEV is contained in ITU-T G.810 [B21] and IEEE Std 1139™-1999 [B9]. Information on Allan Deviation and PTP Variance (PTP Deviation is the square root of PTP Variance) is contained in 7.6.3 of IEEE Std 1588-2019.

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TDEV, denoted $\sigma_x(\tau)$, is estimated from a set of measurements, as shown in Equation (B-1).

$$\sigma_x(\tau) = \sqrt{\frac{1}{6n^2(N-3n+1)} \sum_{j=1}^{N-3n+1} \left[\sum_{i=j}^{n+j-1} (x_{i+2n} - 2x_{i+n} + x_i) \right]^2}, n = 1, 2, \ldots \left\lfloor \frac{N}{3} \right\rfloor \quad \text{(B-1)}$$

where

τ is $n\tau_0$ = observation interval
τ_0 is the sampling interval
N is the total number of samples [$(N–1)\tau_0$ = measurement interval]
$\lfloor y \rfloor$ denotes the floor function, i.e., the greatest integer less than or equal to y
x_i is the measured phase (time) error at the i^{th} sampling time [the units of x_i and $\sigma_x(\tau)$ are the same]

ADEV, denoted $\sigma_y(\tau)$, is estimated from a set of measurements, as shown in Equation (B-2).

$$\sigma_y(\tau) = \sqrt{\frac{1}{2n^2\tau_0^2(N-2n)} \sum_{i=1}^{N-2n} (x_{i+2n} - 2x_{i+n} + x_i)^2}, n = 1, 2, \ldots \left\lfloor \frac{N-1}{2} \right\rfloor \quad \text{(B-2)}$$

where the notation is the same as defined above for TDEV.

PTPDEV, denoted $\sigma_{PTP}(\tau)$, is estimated from a set of measurements, as shown in Equation (B-3).

$$\sigma_{PTP}(\tau) = \sqrt{\frac{1}{6(N-2n)} \sum_{i=1}^{N-2n} (x_{i+2n} - 2x_{i+n} + x_i)^2}, n = 1, 2, \ldots \left\lfloor \frac{N-1}{2} \right\rfloor \quad \text{(B-3)}$$

where the notation is the same as defined above for TDEV.

TDEV, ADEV, and PTPDEV are second-order statistics on the phase error. All three statistics are functions of second differences of the phase error. As a result, these statistics are not affected by a constant frequency offset. This behavior is desired, because these statistics are used here to constrain noise generation.

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TDEV for the LocalClock entity shall not exceed the mask of Table B-1 and Figure B-1, when measured using:

a) A measurement interval that is at least 120 s (i.e., at least 12 times the longest observation interval),
b) A low-pass filter with 3 dB bandwidth of 10 Hz, first-order characteristic, and 20 dB/decade roll-off, and
c) A sampling interval τ_0 that does not exceed 1/30 s.

Table B-1—Wander generation TDEV requirement for LocalClock entity

TDEV limit	Observation interval τ
No requirement	$\tau < 0.05$ s
5.0τ ns	$0.05 \le \tau \le 10$ s
No requirement	$\tau > 10$ s

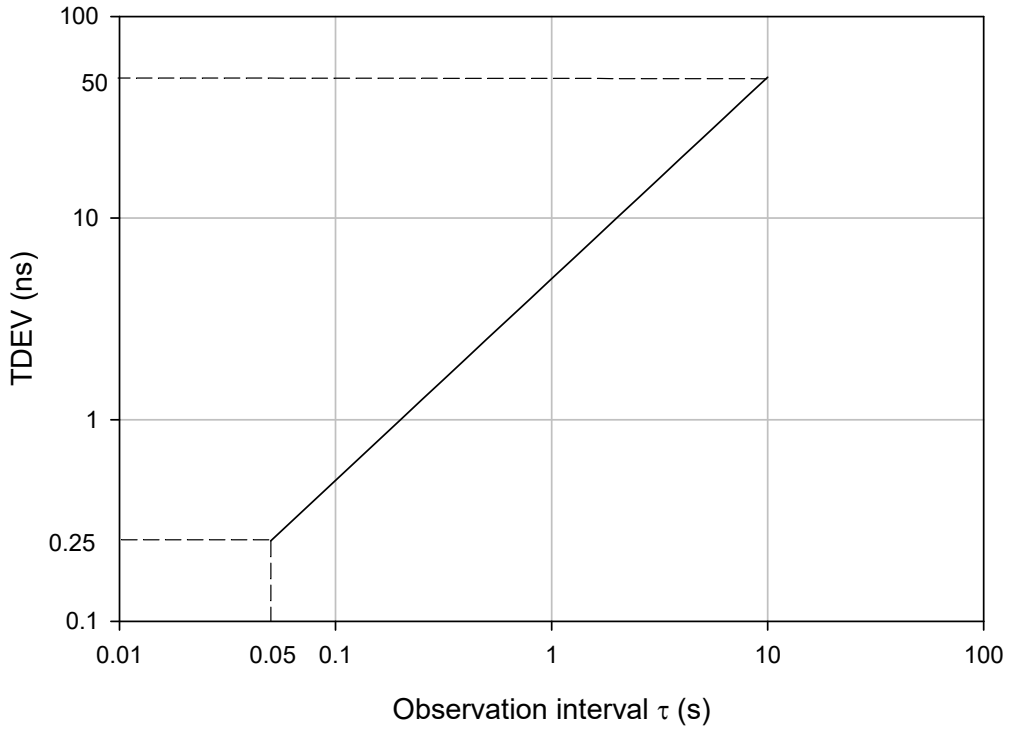

Figure B-1—Wander generation (TDEV) requirement for LocalClock entity

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The ADEV limit that corresponds to the TDEV requirement of Table B-1 and Figure B-1 is shown in Table B-2 and Figure B-2, respectively.

Table B-2—ADEV limit corresponding to wander generation requirement of Table B-1

ADEV limit	Observation interval τ
No requirement	$\tau < 0.05$ s
1.054×10^{-8}	$0.05 \leq \tau \leq 10$ s
No requirement	$\tau > 10$ s

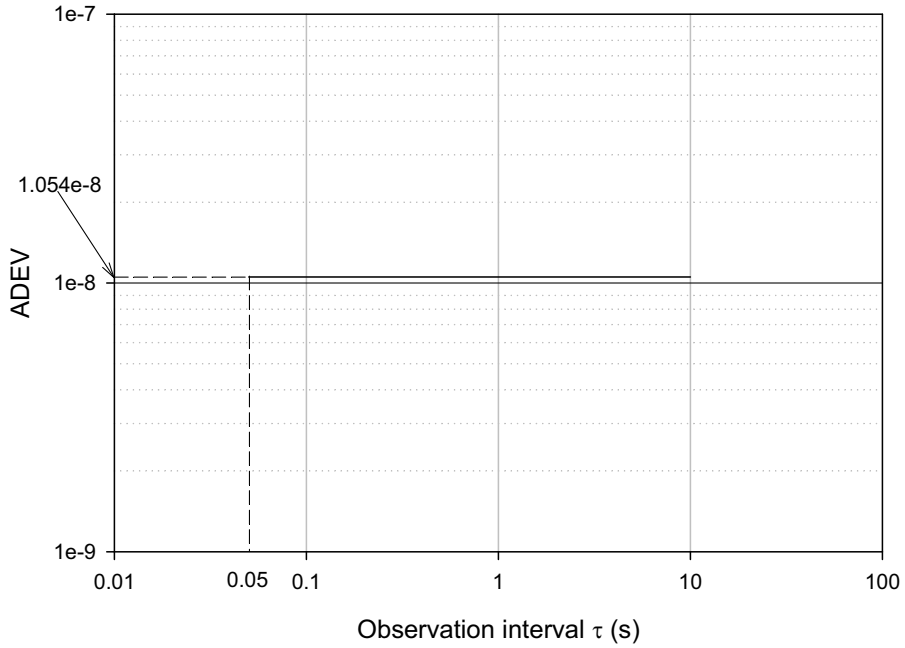

Figure B-2—ADEV limit corresponding to wander generation requirement of Figure B-1

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The PTPDEV limit that corresponds to the TDEV requirement of Table B-1 and Figure B-1 is shown in Table B-3 and Figure B-3, respectively.

Table B-3—PTPDEV limit corresponding to wander generation requirement of Table B-1

PTPDEV limit	Observation interval τ
No requirement	$\tau < 0.05$ s
6.08τ ns	$0.05 \leq \tau \leq 10$ s
No requirement	$\tau > 10$ s

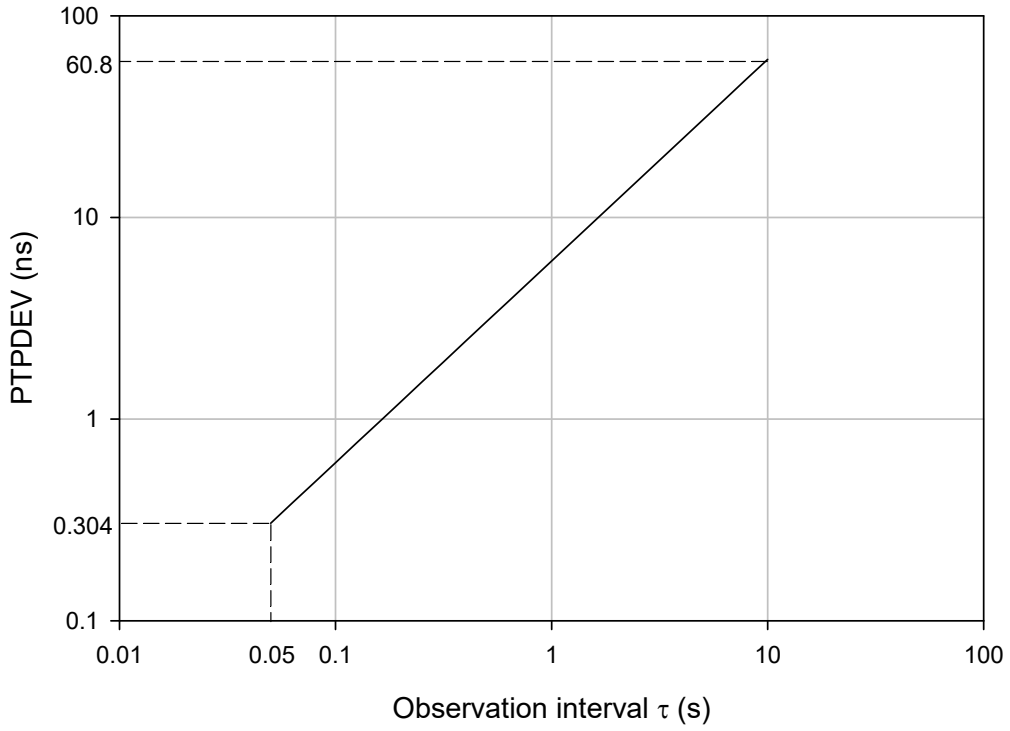

Figure B-3—PTPDEV limit corresponding to wander generation requirement of Figure B-1

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B.2 PTP Instance requirements

B.2.1 General

In order to achieve the accuracy goals, certain constraints are placed on the responsiveness and accuracy of PTP Instances.

B.2.2 Residence time

The residence time (see 3.27) of a PTP Instance, measured relative to the TAI second (see 8.2), should be less than or equal to 10 ms.

Any error in the measured frequency offset relative to the Grandmaster Clock (i.e., error in accumulated rateRatio) results in an error in the transported synchronized time that is equal to the frequency offset error multiplied by the residence time (see 7.3.3 and 11.1.3).

B.2.3 Pdelay turnaround time

The pdelay turnaround time is the duration of the interval between the receipt of a Pdelay_Req message by a port of a time-aware system, and the sending of the corresponding Pdelay_Resp message.

The pdelay turnaround time of a time-aware system, measured relative to the TAI second (see 8.2), should be less than or equal to 10 ms.

A nonzero pdelay turnaround time and any error in the measured frequency offset between the peer delay initiator and peer delay responder (i.e., error in neighborRateRatio) results in an error in the measured mean propagation delay. This in turn results in an error in the transported synchronized time (see 11.1.2 for more details).

NOTE—While a larger value of pdelay turnaround time can result in worse time-synchronization performance, the peer delay protocol will still operate as long as the peer delay initiator receives Pdelay_Resp and Pdelay_Resp_Follow_Up within a time interval since sending Pdelay_Req that is less than the current Pdelay_Req message transmission interval (see 11.2.19.4 and 11.5.2.2).

B.2.4 Measurement of rate ratio

This standard requires the measurement of rate ratio or, equivalently, frequency offset, in several subclauses (see 10.2.10, 10.2.11, 11.2.19, 12.5.2, 16.4.2, and 16.4.3.2). The error inherent in any scheme used to measure rate ratio shall not exceed $\pm$ 0.1 ppm.

NOTE—This requirement is consistent with a rate ratio measurement made by measuring the default Pdelay_Req message transmission interval (the nominal interval duration is 1 s; see 11.5.2.2) relative to the clocks whose rate ratio is desired, assuming the clocks meet the time measurement granularity requirement of B.1.2 (i.e., no worse than 40 ns).

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B.3 End-to-end time-synchronization performance

Assuming that the requirements of this standard and of standards referenced for each medium are met, any two PTP Instances separated by six or fewer PTP Instances (i.e., seven or fewer hops) will be synchronized to within 1 microsecond peak-to-peak of each other during steady-state operation (i.e., each PTP Instance receives time-synchronization information every sync interval).

B.4 End-to-end jitter and wander performance

The requirements of this standard and standards referenced by this standard ensure that the synchronized time at a PTP Instance that is separated from the Grandmaster PTP Instance by six or fewer PTP Instances (i.e., seven or fewer hops) will, when filtered by a reference endpoint filter with rolloff of 20 dB/decade, gain peaking that does not exceed 0.1 dB, and bandwidth that does not exceed the value given in each entry of Table B-4, have maximum time interval error (MTIE) (see ITU-T G.810 [B21]) that does not exceed the MTIE for that entry of Table B-4, and jitter that does not exceed the peak-to-peak jitter of Table B-4 when measured through the corresponding high-pass jitter measurement filter given in Table B-4.

NOTE—For example, the endpoint filter can be of the following form:

$$y_k = a_1 y_{k-1} + a_2 y_{k-2} + \ldots + a_n y_{k-n} + b_0 x_k + b_1 x_{k-1} + \ldots + b_n x_{k-n}$$

where the x_k are the unfiltered synchronized time values, the y_k are the filtered synchronized time values, and the a_k and b_k are filter coefficients. The a_k and b_k are chosen such that the filter has desired bandwidth and gain peaking that does not exceed 0.1 dB. The preceding equation is a general infinite impulse response (IIR) digital filter. Simplified forms, e.g., a second order IIR filter obtained by setting $n = 2$, or a finite impulse response (FIR) filter obtained by setting the a_k to zero are possible.

Table B-4—Maximum endpoint filter bandwidths needed to meet respective MTIE masks and peak-to-peak jitter limits

Endpoint filter maximum bandwidth (Hz)	Corresponding MTIE mask of Figure B-4 that is not exceeded	Corresponding jitter high-pass measurement filter (Hz)	Corresponding peak-to-peak jitter that is not exceeded (ns)
10	Mask 2 (Figure B-4,Table B-6)	8000	10.2
1	Mask 1 (Figure B-4,Table B-5)	200	11.1

Mask 1 of Table B-4 and Figure B-4 corresponds to consumer digital audio applications. Mask 2 of Table B-4 and Figure B-4 corresponds to professional digital audio applications. Mask 1 is derived from the requirements given in IEC 60958-3 [B6]. Mask 2 is derived from the requirements given in IEC 60958-4 [B7], AES3-2009 [B1], and AES11-2009 [B2]. Garner [B5] describes the methodology for deriving MTIE from the various jitter and synchronization requirements and presents the detailed derivations for masks 1 and 2.

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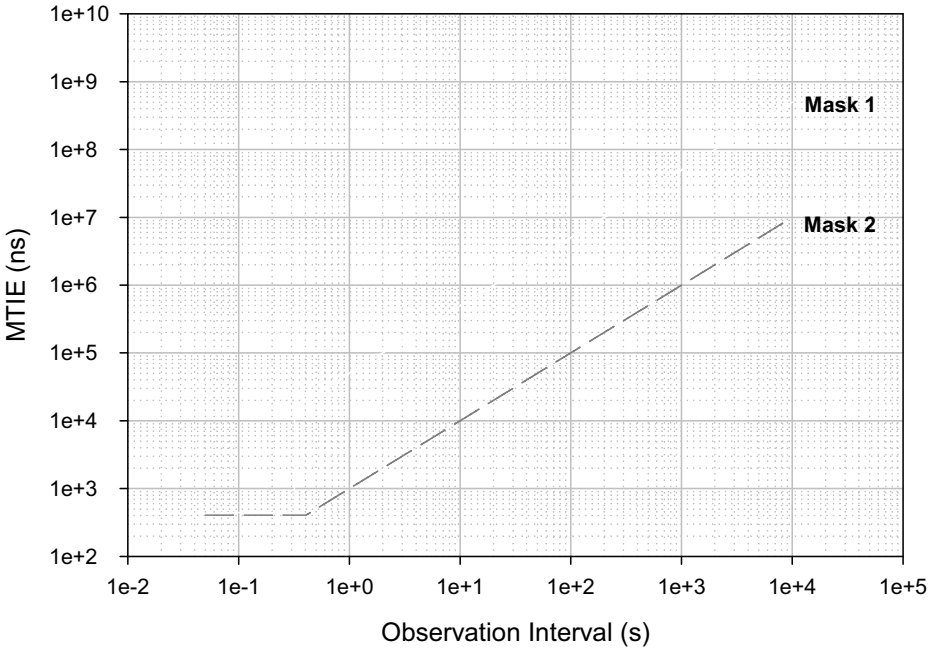

Figure B-4—MTIE masks met for maximum endpoint filter bandwidths of Table B-4

Table B-5—Breakpoints for Mask 1

Observation interval S (s)	MTIE (ns)
$0.05 \le S < 0.0637$	6954.8S
$0.0637 \le S < 0.3183$	443
$0.3183 \le S \le 10000$	50000S

Table B-6—Breakpoints for Mask 2

Observation interval S (s)	MTIE (ns)
$0.05 \le S < 0.4069$	407
$0.4069 \le S < 10000$	1000S

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