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Timing characteristics of telecom boundary clocks and telecom time slave clocks

Recommendation ITU-T G.8273.2/Y.1368.2

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Recommendation ITU-T G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks and telecom time slave clocks

Summary

Recommendation ITU-T G.8273.2/Y.1368.2 specifies minimum requirements for time and phase for telecom boundary clocks and telecom time slave clocks used in synchronization network equipment that operates in the network architecture as defined in Recommendations ITU-T G.8271, ITU-T G.8271.1, ITU-T G.8275 and ITU-T G.8275.1. It supports time and/or phase synchronization distribution for packet based networks.

This version of the Recommendation only applies to full timing support from the network.

These requirements apply under the normal environmental conditions specified for the equipment.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.8273.2/Y.1368.2	2014-05-14	15	11.1002/1000/12196

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Recommendation ITU-T G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks and telecom time slave clocks

1 Scope

This Recommendation specifies minimum requirements for time and phase synchronization devices used in synchronization network equipment that operates in the network architecture as defined in [ITU-T G.8271], [ITU-T G.8271.1] and [ITU-T G.8275]. It supports time and/or phase synchronization distribution for packet based networks.

This Recommendation allows for proper network operation for phase/time synchronization distribution when network equipment embedding a telecom boundary clock (T-BC) and telecom time slave clock (T-TSC) is timed from another T-BC or a telecom grandmaster (T-GM). The current version of this Recommendation addresses only the distribution of phase/time synchronization with the full timing support architecture defined in [ITU-T G.8275] and the related profile defined in [ITU-T G.8275.1]; the definition of a T-BC for the future partial timing support architecture is for further study.

This Recommendation defines the minimum requirements for telecom boundary clocks and telecom time slave clocks in network elements. These requirements apply under the normal environmental conditions specified for the equipment. The current version of this Recommendation focuses on the case of physical layer frequency support. Requirements related to the case without physical layer frequency support are for further study.

This Recommendation includes noise generation, noise tolerance, noise transfer, and transient response for telecom boundary clocks and telecom time slave clocks.

This version of the Recommendation was developed based on the simulations done for time transport via precision time protocol (PTP) and frequency transport via [ITU-T G.8262] EEC-Option 1 (and [ITU-T G.813] SEC-Option 1 as the requirements are identical). [ITU-T G.8262] EEC-Option 2 and [ITU-T G.813] SEC-Option 2 are for further study.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.781] Recommendation ITU-T G.781 (1999), *Synchronization layer functions*.

[ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[ITU-T G.813] Recommendation ITU-T G.813 (2003), *Timing characteristics of SDH equipment slave clocks (SEC)*.

[ITU-T G.8260] Recommendation ITU-T G.8260 (2012), *Definitions and terminology for synchronization in packet networks*.

[ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2010), *Timing characteristics of a synchronous Ethernet equipment slave clock*.

[ITU-T G.8264] Recommendation ITU-T G.8264/Y1364 (2008), *Distribution of timing information through packet networks*.

[ITU-T G.8271] Recommendation ITU-T G.8271/Y1366 (2012), *Time and phase synchronization aspects of packet networks*.

[ITU-T G.8271.1] Recommendation ITU-T G.8271.1/Y.1366.1 (2013), *Network limits for time synchronization in packet networks*.

[ITU-T G.8275] Recommendation ITU-T G.8275/Y.1369 (2013), *Architecture and requirements for packet-based time and phase* distribution.

[ITU-T G.8275.1] Recommendation ITU-T G.8275.1/Y.1369.1 (2014), *Precision time protocol telecom profile for phase/time synchronization with full timing support from the network*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

Definitions related to synchronization are contained in [ITU-T G.810] and [ITU-T G.8260].

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

cTE Constant phase/Time Error

dTE Dynamic Time Error

EEC synchronous Ethernet Equipment Clock

ESMC Ethernet Synchronization Messaging Channel

GbE Gigabit Ethernet

MTIE Maximum Time Interval Error

NE Network Element

PEC Packet-based Equipment Clock

PPS Pulse Per Second

PRC Primary Reference Clock

PTP Precision Time Protocol

SDH Synchronous Digital Hierarchy

SEC SDH equipment slave clock

SSM Synchronization Status Message

SyncE Synchronous Ethernet

T-BC Telecom Boundary Clock

TDEV Time Deviation

TE Time Error

ToD	Time of Day

T-TSC	Telecom Time Slave Clock

5 Conventions

None.

6 Physical layer frequency performance requirements

Synchronous Ethernet (SyncE) interfaces and synchronous Ethernet equipment clock (EEC) used on the telecom boundary clock (T-BC) shall meet the performance requirements specified in [ITU-T G.8262], and shall generate and process Ethernet synchronization messaging channel (ESMC) messages as specified in [ITU-T G.8264].

Synchronous digital hierarchy (SDH) interfaces and SDH equipment slave clocks (SECs) used on the T-BC shall meet the performance requirements specified in [ITU-T G.813], and shall generate and process synchronization status message (SSM) messages as specified in [ITU-T G.781].

7 T-BC packet layer performance requirements for full timing support from the network

See Appendix III for background information on performance requirements of the T-BC.

7.1 Constant phase/time error and dynamic time error noise generation

The noise generation of a T-BC represents the amount of noise produced at the output of the T-BC when there is an ideal input reference packet timing signal.

Under normal, locked operating conditions, the time output of the T-BC should be accurate to within the maximum absolute time error (TE) (max|TE|). This value includes all the noise components, i.e., the constant phase/time error (cTE) and the dynamic time error (dTE) noise generation.

In order to support different performance requirements at the end application specified in Table 1 of [ITU-T G.8271] using different network topologies and network technologies, the maximum absolute time error, the phase/time error and dTE noise generation requirements for T-BCs are divided into two classes: Class A and Class B.

At the precision time protocol (PTP) and 1 pulse per second (PPS) outputs, the maximum absolute time error (max|TE|) for Class A and Class B is shown in Table 7-1. This includes all time error components (unfiltered).

Table 7-1 – Maximum absolute time error (max|TE|)

T-BC class	Maximum absolute time error – max|TE| (ns)
A	100 ns
B	70 ns

NOTE – The values in Table 7-1 are valid for 1 PPS, 1 gigabit Ethernet (GbE) and 10 GbE interfaces. Above 10 GbE is for further study.

The noise generation is divided into two components, the cTE and the dTE noise generation.

7.1.1 Constant phase/time error generation

At the PTP and 1 PPS outputs, the cTE generation for Class A and Class B is shown in Table 7-2.

Table 7-2 – T-BC permissible range of constant phase/time error

T-BC Class	Permissible Range of constant phase/time error – cTE(ns)
A	±50
B	±20

NOTE 1 – The values in Table 7-2 are valid for 1 PPS, 1 GbE and 10 GbE interfaces. Above 10 GbE is for further study.

NOTE 2 – Constant time error definition and the method to estimate constant time error are defined in [ITU-T G.8260]. For the purpose of testing the limits in Table 7-2, an estimate of constant time error should be obtained by averaging the time error sequence over 1'000 s.

7.1.2 Dynamic time error noise generation

For a T-BC Class A or Class B containing an EEC-Option 1 clock, and operating in locked mode synchronized to both a wander-free time reference at the PTP input, and a wander-free frequency reference at the SyncE/SDH input, the maximum time interval error (MTIE) at the PTP and 1 PPS outputs, measured through a first-order low-pass filter with bandwidth of 0.1 Hz, should meet the limits in Table 7-3 under constant temperature (within ±1 K).

Table 7-3 – Dynamic time error noise generation (MTIE) for T-BC with constant temperature

MTIE limit [ns]	Observation interval τ [s]
40	$m < \tau \le 1'000$ (Notes 1, 2)
NOTE 1 – The minimum τ value *m* is determined by packet rate of 16 packet per second (*m*=1/16) or 1 PPS signal (*m*=1). NOTE 2 – The values in this table are valid for 1 PPS, 1 GbE and 10 GbE interfaces. Interface rates above 10 GbE are for further study.	

When temperature effects are included, the MTIE requirement is defined in Table 7-4 for a T-BC with physical layer frequency support; in this case the maximum observation interval is increased to 10'000 s.

Table 7-4 – Dynamic time error noise generation (MTIE) for T-BC with variable temperature

MTIE limit [ns]	Observation interval τ [s]
40	$m < \tau \le 10'000$ (Notes 1, 2)
NOTE 1 – the minimum τ value *m* is determined by packet rate of 16 packet per second (*m*=1/16) or 1 PPS signal (*m*=1). NOTE 2 – the values in this table are valid for 1 PPS, 1 GbE and 10 GbE interfaces. Above 10 GbE is for further study.	

The applicable time deviation (TDEV) is for further study.

NOTE 1 – This Recommendation is expected to include a normative TDEV mask similar to that contained in Appendix IV in order to constrain the frequency distribution of the noise. It is strongly suggested that implementations based on this Recommendation limit dTE noise generation to meet at least the requirements of the TDEV mask contained in Appendix IV.

NOTE 2 – The specification for the high frequency noise is for further study.

7.2 Noise tolerance

The noise tolerance of a T-BC indicates the minimum dynamic phase/time error level at the input of the clock that should be accommodated while:

– not causing any alarms;

– not causing the clock to switch reference;

– not causing the clock to go into holdover.

NOTE 1 – There is no requirement related to cTE tolerance.

A T-BC for use in the full timing support profile should be capable of tolerating the following levels of dTE and phase wander simultaneously:

- dTE according to [ITU-T G.8271.1] network limit, clause 7.3 at the PTP input;
- wander tolerance according to [ITU-T G.8262], clause 9.1 at the SyncE input;
- wander tolerance according to [ITU-T G.813], clause 8.1 at the SDH input.

NOTE 2 – The noise tolerance for high frequency noise is for further study.

7.3 Noise transfer

7.3.1 PTP to PTP noise transfer

The bandwidth of a T-BC should not exceed 0.1 Hz and should not be less than 0.05 Hz.

The gain peaking of a T-BC should not exceed 0.1 dB.

NOTE – Noise transfer only applies to dynamic phase/time noise; there is no requirement related to cTE transfer.

7.3.2 Physical layer frequency to PTP noise transfer

The output PTP signal must correspond to the input SyncE/SDH input signal on which a band-pass filter whose lower corner frequency is between 0.05 Hz and 0.1 Hz, and whose upper corner frequency is between 1 Hz and 10 Hz has been applied.

The maximum phase gain must not exceed 0.2 dB.

7.4 Transient response and holdover performance

7.4.1 Transient response

7.4.1.1 PTP to PTP transient response

The PTP to PTP transient response requirements applicable to a T-BC are for further study.

7.4.1.2 Physical layer frequency to PTP transient response

The physical layer frequency to PTP transient response due to a rearrangement of the physical layer frequency transport is specified in Annex B.

7.4.2 Holdover performance

When a T-BC loses all of its input phase and time references, it enters the phase/time holdover state. Under these circumstances, the T-BC may either rely on the holdover of a local oscillator, or on a physical layer frequency reference traceable to a primary reference clock (PRC), or on a combination of both.

This requirement reflects the performance of the clock in cases when the packet signal input is ideal (without any constant time error, time noise or timestamp noise) followed by disconnection of the packet signal input. For the case of phase/time holdover requirements based on physical layer frequency, the frequency physical layer input is ideal.

This requirement bounds the maximum excursions in the output timing signal. Additionally, it restricts the accumulation of the phase movement during input signal impairments or internal disturbances.

7.4.2.1 T-BC holdover

The phase/time holdover requirements applicable to a T-BC are for further study.

7.4.2.2 T-BC holdover based on physical layer frequency

The phase/time holdover requirements based on physical layer frequency applicable to a T-BC is for further study.

7.5 Interfaces

The requirements in this Recommendation are related to reference points which may be internal to the equipment or network element (NE) in which the T-BC is embedded and are therefore not necessarily available for measurement or analysis by the user. Consequently, the performance of the T-BC is not specified at these internal reference points, but rather at the external interfaces of the equipment.

Note that not all of the interfaces below need to be implemented on all equipment.

7.5.1 Phase and time interfaces

The phase and time interfaces specified for the equipment in which the T-BC may be contained are:

– Ethernet interface carrying PTP messages;

  NOTE – Ethernet interfaces can combine synchronous Ethernet for frequency and PTP messages.

– ITU-T V.11-based time/phase distribution interface, as defined in [ITU-T G.703] and [ITU-T G.8271];

– 1 PPS 50 Ω phase-synchronization measurement interface, as defined in [ITU-T G.703] and [ITU-T G.8271];

– other interfaces are for further study.

7.5.2 Frequency interfaces

The frequency interfaces specified for the equipment in which the T-BC may be contained are:

– 2'048 kHz interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– 1'544 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– 2'048 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– synchronous Ethernet interfaces;

  (NOTE – Ethernet interfaces can combine PTP and synchronous Ethernet.)

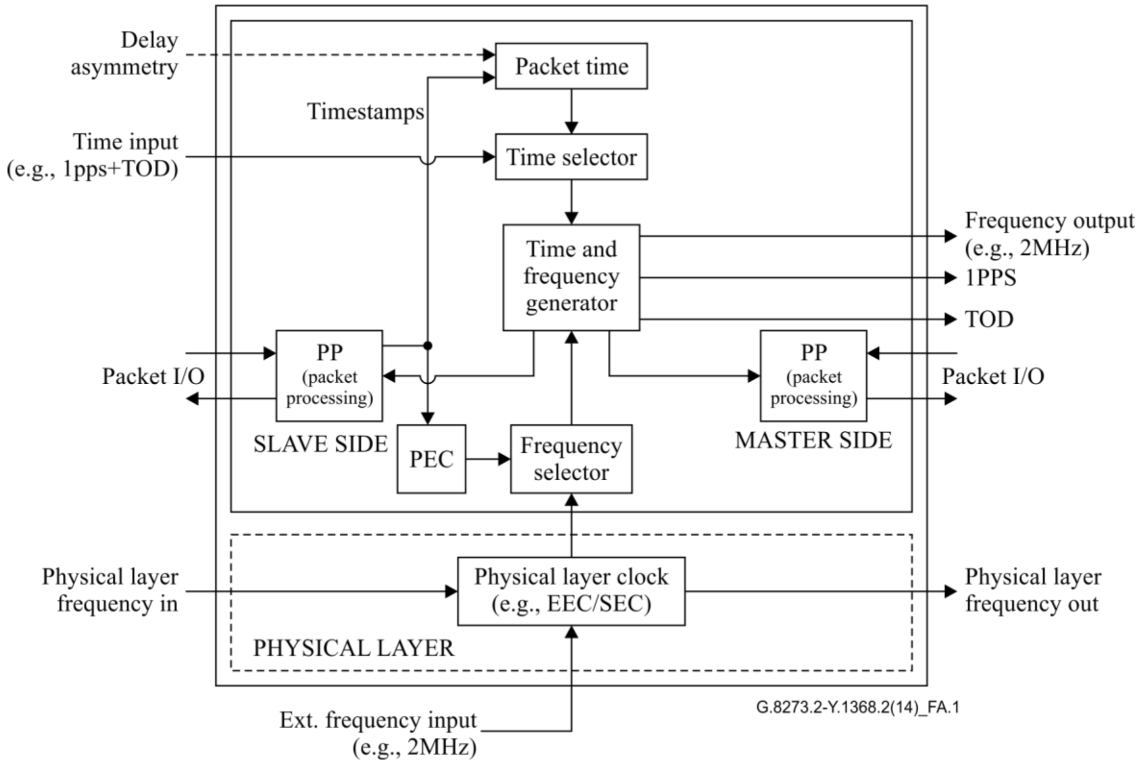
– other interfaces are for further study.

Annex A

Telecom boundary clock model

(This annex forms an integral part of this Recommendation.)

Figure A.1 illustrates a telecom boundary clock model.



NOTE 1 –The physical layer frequency signal may be bidirectional for SyncE.
NOTE 2 – The "Physical Layer Clock" includes a selection mechanism as there may be multiple inputs.

Figure A.1 – Boundary clock model

Figure A.1 shows a functional model of a telecom boundary clock. It is not intended to specify any specific implementation. Any implementation specific detail is outside the scope of this Recommendation.

The packet timing signal is processed by the packet processing block, the timestamps are sent to the packet time and to the packet-based equipment clock (PEC) blocks for further processing. The time information carried in the timestamps are used as an input to the time control to generate the time information to control the local time scales. Delay asymmetry established by means beyond the scope of the protocol-layer messages can be provided as a correction term. The frequency information carried in the timestamps is used in the PEC to generate the local frequency.

The time selector block may select either the time information recovered from the timestamps, or the local time input (e.g., 1 PPS+ time of day (ToD)).

The frequency selector block may select either the frequency information recovered from the timestamps, or the frequency recovered from a physical layer clock (e.g., synchronous Ethernet, synchronous optical network (SONET), or SDH).

Annex B

Control of transient due to rearrangements in the synchronous Ethernet network

(This annex forms an integral part of this Recommendation.)

A T-BC shall properly limit the generation of phase/time error due to a rearrangement of the physical layer frequency transport (e.g., SyncE, SDH) by using ingress quality level (QL) information (e.g., ESMC message). In the worst-case, the input SyncE frequency will experience a re-arrangement transient as detailed in Figure 12 of [ITU-T G.8262] and Figure 12 of [ITU-T G.813]. When a SyncE/SDH rearrangement occurs, the T-BC may experience an initial output transient when the SyncE/SDH loses PRC-traceability, and a second output transient when or after the SyncE/SDH again becomes PRC-traceable. The T-BC output phase error shall meet the following requirements when these transients occur:

a) The T-BC output phase error at the PTP and 1 PPS outputs shall not exceed the mask of Figure B.1 and Table B.1 below, during the period between the start of the SyncE/SDH transient and the occurrence of a second output phase error transient (see (b) below) that occurs when or after the SyncE/SDH again becomes PRC-traceable. This is the first SyncE/SDH output phase error transient.

   NOTE 1 – The mask of Figure B.1 is extended to 25 s, because this is approximately 10 s after the SyncE/SDH signal at the first EEC in a ring of 20 EECs/SECs re-establishes PRC-traceability. The re-establishment of PRC-traceability will be earlier in smaller rings; the exact time depends on the number of EECs/SECs in the ring and the exact values of the SSM message delays.

b) After the SyncE/SDH again becomes PRC-traceable, a second T-BC output phase error transient may occur. This transient may begin at any time during the 10 s period that begins when the SyncE/SDH again becomes traceable. Once the transient begins, the T-BC output phase error at the PTP and 1 PPS outputs shall not exceed the mask of Figure B.2 and Table B.2 below.

   NOTE 2 – The mask of Figure B.2 assumes that the second output phase error transient occurs after the first output phase error transient has decayed to a value small compared to the second output phase error transient magnitude. If it has not decayed to a respectively small value, any residual phase error from the first output phase error transient must be subtracted from the total phase error before comparing with the mask of Figure B.2 and Table B.2.

See Appendix II for background on the assumptions and derivations for the masks of Figures B.1 and B.2.

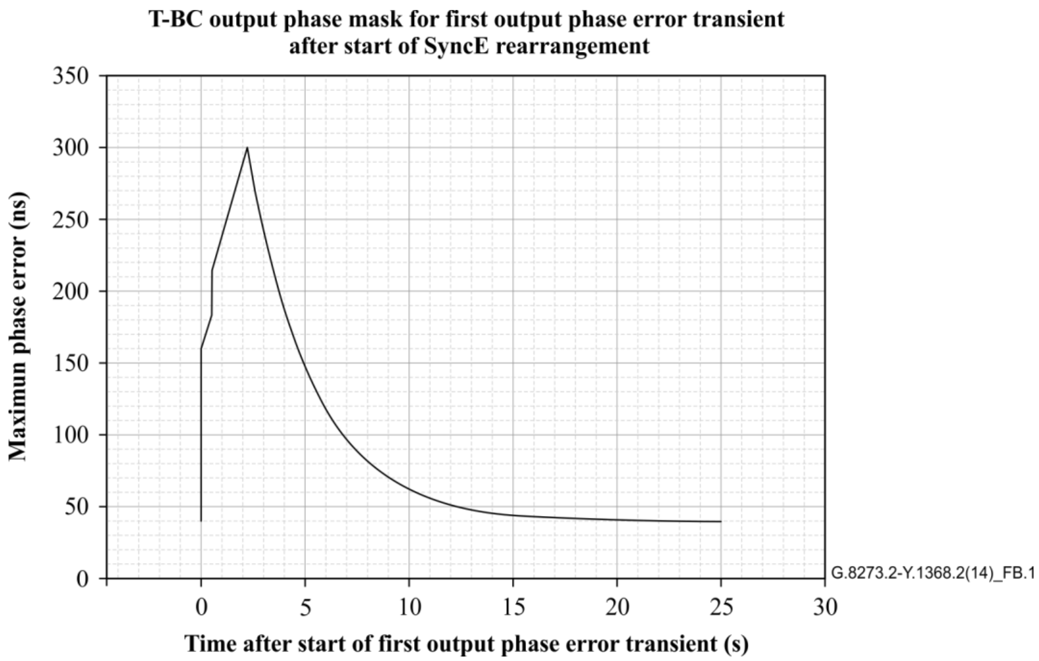


Figure B.1 – Phase error limit for first output phase error transient after the start of the SyncE/SDH rearrangement

Table B.1 – T-BC output phase transient mask for first transient after start of SyncE/SDH rearrangement (at and just after loss of PRC-traceability by the SyncE/SDH signal)

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC Output Phase Error (ns)
$0 \le S < 0.016$	$40 + 7'500S$
$0.016 \le S < 0.5$	$160 + 50(S - 0.016)$
$0.5 \le S < 2.2$	$214.2 + 50(S - 0.5)$
$2.2 \le S < 25$	$40 + 259.2e^{-2\pi(0.05)(S - 2.2)}$

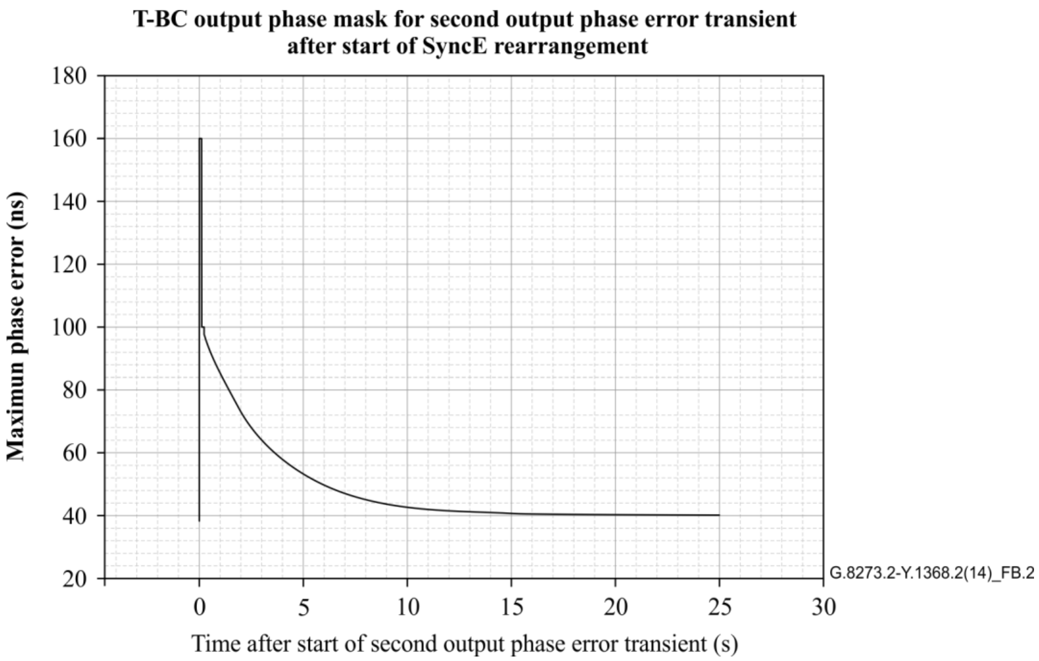


Figure B.2 – Phase error limit for second output phase error transient after the start of the SyncE/SDH rearrangement

Table B.2 – T-BC output phase transient mask for second transient after start of SyncE/SDH rearrangement (after PRC-traceability is re-established)

Time *S* after start of second transient (s)	**T-BC Output Phase Error (ns)**
$0 \le S < 0.016$	$40 + 7'500S$
$0.016 \le S < 0.141$	160
$0.141 \le S < 25$	$40 + 60\, e^{-2\pi(0.05)(S - 0.141)}$

NOTE – As per [ITU-T G.8264] SSM might be disabled by the operator. The impact on the mitigation of time error due to SyncE/SDH rearrangement when not using SSM is under the responsibility of the operator and is for further study.

Annex C

Telecom time slave clock requirements

(This annex forms an integral part of this Recommendation.)

C.1 Physical layer frequency performance requirements

Synchronous Ethernet interfaces and EEC used on the telecom time slave clock (T-TSC) shall meet the performance requirements specified in [ITU-T G.8262], and shall generate and process ESMC messages as specified in [ITU-T G.8264].

SDH interfaces and SECs used on the T-BC shall meet the performance requirements specified in [ITU-T G.813], and shall generate and process SSM messages as specified in [ITU-T G.781].

C.2 T-TSC packet layer performance requirements for full timing support from the network

C.2.1 Phase/time error and dynamic time error noise generation

The noise generation of a T-TSC represents the amount of noise produced at the output of the T-TSC when there is an ideal input reference packet timing signal.

Under normal, locked operating conditions, the time output of the T-TSC should be accurate to within the maximum absolute time error (max|TE|). This value includes all the noise components, i.e., the cTE and the dTE noise generation.

In order to support different performance requirements at the end application specified in Table 1 of [ITU-T G.8271] using different network topologies and network technologies, the maximum absolute time error, the phase/time error and the dTE noise generation requirements for T-TSCs are divided into two classes: Class A and Class B.

At the 1 PPS output, the maximum absolute time error (max|TE|) for Class A and Class B is shown in Table C.1. This includes all time error and components (unfiltered).

Table C.1 – Maximum absolute time error (max|TE|)

T-TSC Class	Maximum absolute time error – max|TE| (ns)
A	100 ns
B	70 ns

The noise generation is divided into two components, the cTE and the dTE noise generation.

C.2.1.1 Constant phase/time error generation

At the 1 PPS output, the cTE generation for Class A and Class B is shown in Table C.2.

Table C.2 – T-TSC permissible range of constant phase/time error

T-TSC Class	Permissible range of constant phase/time error – cTE(ns))
A	±50
B	±20

NOTE – Constant time error definition and the method to estimate constant time error are defined in [ITU-T G.8260]. For the purpose of testing the limits in Table C.2, an estimate of constant time error should be obtained by averaging the time error sequence over 1'000 s.

C.2.1.2 Dynamic time error noise generation

For a T-TSC Class A or Class B containing an EEC-Option 1 clock, and operating in the locked mode of operation synchronized to both a wander-free time reference at the PTP input, and a wander-free frequency reference at the SyncE/SDH input, the MTIE at the 1 PPS output, measured through a first order low-pass filter with bandwidth of 0.1 Hz, should meet the limits in Table C.3 under constant temperature (within ±1 K).

Table C.3 – Dynamic time error noise generation (MTIE) for T-TSC with constant temperature

MTIE limit [ns]	Observation interval τ [s]
40	$1 < \tau \le 1'000$

When temperature effects are included, the MTIE requirement is defined in Table C.4 for a T-TSC with physical layer frequency support; in this case the maximum observation interval is increased to 10'000 s.

Table C.4 – Dynamic time error noise generation (MTIE) for T-TSC with variable temperature

MTIE limit [ns]	Observation interval τ [s]
40	$1 < \tau \le 10'000$

The applicable TDEV is for further study.

NOTE 1 – This Recommendation is expected to include a normative TDEV mask similar to that contained in Appendix V in order to constrain the frequency distribution of the noise. It is strongly suggested that implementations based on this recommendation limit dTE noise generation to meet at least the requirements of the TDEV mask contained in Appendix V.

NOTE 2 – The specification for the high frequency noise is for further study.

C.2.2 Noise tolerance

The noise tolerance of a T-TSC indicates the minimum dynamic phase/time error level at the input of the clock that should be accommodated while:

– not causing any alarms;

– not causing the clock to switch reference;

– not causing the clock to go into holdover.

NOTE – There is no requirement related to cTE tolerance.

A T-TSC for use in the full timing support profile should be capable of tolerating the following levels of dTE and phase wander simultaneously:

- dTE according to [ITU-T G.8271.1] network limit, clause 7.3 at the PTP input;

- wander tolerance according to [ITU-T G.8262], clause 9.1 at the SyncE input;
- wander tolerance according to [ITU-T G.813], clause 8.1 at the SDH input.

C.2.3 Noise transfer

C.2.3.1 PTP to 1 PPS noise transfer

The bandwidth of a T-TSC should not exceed 0.1 Hz and should not be less than 0.05 Hz.

The gain peaking of a T-TSC should not exceed 0.1 dB.

NOTE – Noise transfer only applies to dynamic phase/time error noise; there is no requirement related to cTE transfer.

C.2.3.2 Physical layer frequency to 1 PPS noise transfer

The output 1 PPS signal must correspond to the input SyncE/SDH input signal on which a band-pass filter whose lower corner frequency is between 0.05 Hz and 0.1 Hz, and whose upper corner frequency is between 1 Hz and 10 Hz has been applied.

The maximum phase gain must not exceed 0.2 dB.

C.2.4 Transient response and holdover performance

C.2.4.1 Physical layer frequency to 1 PPS transient response

The physical layer frequency to 1 PPS transient response due to a rearrangement of the physical layer frequency transport is specified in Annex B of this Recommendation.

C.2.4.2 Holdover performance

When a T-TSC loses all its input phase and time references, it enters the phase/time holdover state. Under these circumstances, the T-TSC may either rely on the holdover of a local oscillator, or on a physical layer frequency reference traceable to a PRC, or on a combination of both.

This requirement reflects the performance of the clock in cases when the packet signal input is ideal (without any constant time error, time noise or timestamp noise) followed by disconnection of the packet signal input. For the case of phase/time holdover requirements based on physical layer frequency, the frequency physical layer input is ideal.

This requirement bounds the maximum excursions in the output timing signal. Additionally, it restricts the accumulation of the phase movement during input signal impairments or internal disturbances.

C.2.4.2.1 T-TSC holdover

The phase/time holdover requirements applicable to a T-TSC are for further study.

C.2.4.2.2 T-TSC holdover based on physical layer frequency

The phase/time holdover requirements based on physical layer frequency applicable to a T-TSC is for further study.

C.2.5 Interfaces

The requirements in this Recommendation are related to reference points which may be internal to the equipment or NE in which the T-TSC is embedded and are therefore not necessarily available for measurement or analysis by the user. Consequently, the performance of the T-TSC is not specified at these internal reference points, but rather at the external interfaces of the equipment.

Note that not all of the interfaces below need to be implemented on all equipment.

C.2.5.1 Phase and time interfaces

The phase and time interfaces specified for the equipment in which the T-TSC may be contained are:

– Ethernet interface carrying PTP messages;

  NOTE – Ethernet interfaces can combine Synchronous Ethernet for frequency and PTP messages.

– ITU-T V.11-based time/phase distribution interface, as defined in [ITU-T G.703] and [ITU-T G.8271];

– 1 PPS 50 Ω phase-synchronization measurement interface, as defined in [ITU-T G.703] and [ITU-T G.8271];

– other interfaces are for further study.

C.2.5.2 Frequency interfaces

The frequency interfaces specified for the equipment in which the T-TSC may be contained are:

– 2'048 kHz interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– 1'544 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– 2'048 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;

– synchronous Ethernet interfaces;

– other interfaces are for further study.

Appendix I

Mitigation of time error due to SyncE/SDH transients

(This appendix does not form an integral part of this Recommendation.)

Appendix II, clause II.1.2 of [ITU-T G.8271.1], illustrates hypothetical reference models for the transport of phase/time via PTP with physical layer frequency support. Figure II.2 of [ITU-T G.8271.1] illustrates the congruent scenario, where the frequency and phase/time transports follow the same synchronization path. Figure II.3 of [ITU-T G.8271.1] illustrates the non-congruent scenario, where the frequency and phase/time transports follow different synchronization paths. A rearrangement of the physical layer frequency, e.g., SyncE, transport results in phase/time error at each T-BC, the T-TSC, and the end application.

In the congruent scenario, the time error due to the SyncE/SDH rearrangement can be reduced to an acceptable level if the physical layer signal is rejected after the physical layer transient is detected. Note that the rejection of the physical layer signal is an implementation method. This method permits switching temporarily, for a short period, upon detection of a SyncE/SDH failure (e.g., using the SSM information), from a mode where SyncE/SDH support is used for frequency transport to a mode where only the PTP messages are used to recover frequency; after the SyncE/SDH reconfiguration is completed, the mode of operation is still expected to become again based on SyncE/SDH for frequency transport. Specifically, the SyncE/SDH signal is rejected when the SSM indicating the SyncE/SDH signal is no longer PRC-traceable is received by the EEC collocated with that T-BC, and the SyncE/SDH signal is again used at a time T_{reacq} after receipt of the SSM indicating the SyncE signal is again PRC-traceable is received by the EEC/SEC collocated with that T-BC.

In the non-congruent scenario, the time error will be acceptable if the T-BCs, T-TSC, and end application have maximum bandwidth of 0.1 Hz and maximum gain peaking of 0.1 dB, and if the frequency plane clocks collocated with the T-BCs, T-TSC, and end application are EECs/SECs. This is true whether or not the SyncE/SDH transient is rejected at each T-BC.

Appendix II

Derivation of T-BC output transient mask due to SyncE/SDH rearrangement

(This appendix does not form an integral part of this Recommendation.)

The T-BC output phase transient due to a SyncE/SDH rearrangement is derived for the following two mitigation scheme:

a) reject the SyncE/SDH signal on receipt of the SSM that indicates the SyncE/SDH is no longer PRC-traceable; and

b) turn off the T-BC filter on receipt of the SSM that indicates the SyncE/SDH is no longer PRC-traceable.

In the derivation, each transient is split into two portions: (1) a portion at and immediately after the SyncE/SDH loses PRC traceability, and (2) a portion at and immediately after the SyncE/SDH signal is reacquired (scheme (a)) or the T-BC filter is turned on (scheme (b)). It is assumed that the ring is large enough that the two portions of the transient are distinguishable, i.e., the time error settles down to a steady-state after either the SyncE/SDH signal is rejected or the T-BC filter is turned off, and a second transient occurs when the SyncE/SDH is reacquired or the T-BC filter is turned on. The first portion of the transient for schemes (a) and (b) are aligned, and the transient mask for the portion at and right after PRC-traceability is lost is taken as the upper envelope of these two first portions. Likewise, the second portion of the transient for schemes (a) and (b) are aligned, and the transient mask for the portion at and right after either the SyncE/SDH is reacquired or the T-TBC filter is turned back on is taken as the upper envelope of these two second portions.

II.1 Background on assumptions for, and derivation of, T-BC output phase error due to a SyncE/SDH rearrangement

The T-BC output phase error masks of Figures B.1 and B.2 of Annex B of this Recommendation are based on two possible techniques for mitigating the output phase error due to the hypothetical reference model-2 (HRM-2) rearrangement. With the first technique, the EEC collocated with the T-BC informs the T-BC that the SyncE/SDH is no longer PRC-traceable when the EEC receives the SSM indicating this. When the T-BC is notified, it rejects the SyncE/SDH transient and operates in the pure PTP mode (i.e., without the use of SyncE/SDH to recover frequency). When the EEC switches a second time and is again PRC-traceable, it informs the T-BC. The T-BC then reacquires the SyncE/SDH signal. The T-BC typically waits at least 10 s to after it is informed that the SyncE/SDH is again traceable to reacquire the SyncE/SDH, to ensure that the SyncE/SDH transient is completed; however, the important condition is that the mask of Figure B.1 is satisfied (i.e., the T-BC can reacquire the SyncE/SDH signal sooner than 10 s has elapsed if it can satisfy the mask).

With the second technique, the T-BC filter is turned off when the T-BC is notified by the EEC that the SyncE/SDH is no longer traceable (i.e., when the EEC receives the SSM indicating this). The turning off of the filter means that it is no longer applied to the incoming PTP signal (as a low-pass filter) or to the SyncE/SDH signal (as a high-pass filter). When the T-BC is notified by the EEC that the SyncE/SEC is again traceable, the filter is again turned on. As with the first technique, the T-BC typically waits at least 10 s after it is informed that the SyncE/SDH is again traceable to turn the filter on, to ensure that the SyncE/SDH transient is completed; however, the important condition is that the mask of Figure B.1 is satisfied (i.e., the T-BC can turn the filter back on sooner than 10 s has elapsed if it can satisfy the mask). To avoid a transient when the T-BC filter is turned back on, the filter continues to operate on the SyncE/SDH signal (with the SyncE/SDH transient present) and the PTP signal, and the state of the filter is computed throughout the transient (i.e., at each sampling instant). However, the filter output is not used while the filter is turned off; the computations are done only so that the filter state will be known. When the filter is turned back on, the computed filter state at that instant is used as the initial state.

The masks of Figures B.1 and B.2 are obtained by computing the T-BC filter output phase error history, for each of the above techniques, assuming the SyncE/SDH undergoes the transient of Figure 12 of [ITU-T G.8262]. With each technique, it is found that the T-BC filter output history contains an initial transient when SyncE/SDH traceability is lost, and a second transient when or shortly after SyncE/SDH traceability is regained. The duration of the time interval between the two transients depends on how large the EEC ring is (the interval is longer for larger rings). Since the start time of the second transient depends on the ring size and which of the techniques is used, a separate mask will be created for each transient (see clause II.2). For each of the two transients (i.e., when the SyncE/SDH loses traceability and when it again becomes traceable), the respective mask is obtained by computing the upper envelope of the phase error outputs for each of the two techniques.

The steady-state T-BC noise generation MTIE is 40 ns according to clause 7.1.2. This 40 ns includes the effect of EEC noise generation and timestamp granularity. This means that the component of phase error in the masks due to steady-state SyncE/SDH wander accumulation and timestamp granularity should be 40 ns.

Therefore, it is assumed that the maximum phase error has a component of 40 ns due to steady-state SyncE/SDH noise accumulation and timestamp granularity. Any phase error due to the SyncE/SDH rearrangement is added to this. Note that this value does not include the inherent random noise generation in the T-BC, as this has not yet been specified in [ITU-T G.8273.2]; once it is specified, it needs to be considered.

In all cases, it is assumed that the T-BC input is a PTP packet timing signal with mean Sync message rate of 16 messages/s. If other assumptions were made, e.g., if the input timing signal were 1 PPS instead of PTP, or if packet selection were performed that caused the mean rate of selected Sync message to be less than 16 messages/s, these cases would need to be analysed. In addition, the T-BC output phase computed is the actual phase (time) error; there is no additional measurement filter.

The following are the assumptions made in computing the T-BC output phase error due to the SyncE/SDH rearrangement, using the first technique, i.e., rejection of the SyncE/SDH transient:

a) The T-BC that is analysed is the first T-BC in the chain. This means that the SyncE/SDH transient input is the Figure 12 of [ITU-T G.8262] mask (i.e., rather than the result of filtering this mask by one or more EECs, as would be the case if this were a downstream T-BC).

b) The input PTP packet signal (i.e., carried by Sync and Delay_Req messages) is perfect, i.e., there is no phase error associated with this signal.

c) The T-BC filter is 0.05 Hz. This is the minimum T-BC and T-TSC bandwidth. It is modelled as a first-order filter, and gain peaking is not modelled.

d) The EEC collocated with the first T-BC sends an SSM indicating it is no longer PRC-traceable 2'000 ms after it loses traceability, i.e., the holdover message delay T_{HM} is 2'000 ms. [ITU-T G.781] specifies in clause 5.14 that T_{HM} is in the range 500-2'000 ms. 2'000 ms is used as a conservative value. The SSM is sent to both the T-BC and the next EEC in the SyncE/SDH chain.

e) The SyncE/SDH transient is rejected by the T-BC after a time interval has elapsed following the receipt of the SSM. This delay is due to software processes; it is taken to have an upper bound equal to the non-switching message delay, i.e., 200 ms as specified in clause 5.14 of [ITU-T G.781], and a lower bound of zero.

f) There is a 30 ns phase jump at the T-BC input when the SyncE/SDH is rejected, and a 60 ns phase jump when it is reacquired (simulations showed that max|TE| for HRM-2, for a chain of 20 T-BCs, could be kept to within 200 ns with these phase jumps).

g) The initial part of the SyncE/SDH transient is a 7.5 ppm phase ramp over 16 ms, followed by a 50 ns/s phase ramp, followed by a 30 ns phase jump when the SyncE/SDH signal is rejected. Based on (d) and (e), the earliest the rejection can occur is at 0.5 s (500 ms) after the PRC-traceability is lost. The latest the rejection can occur is at 2.2 s (2'200 ms) after PRC-traceability is lost. The 30 ns phase jump can therefore occur anywhere between 500 ms and 2.2 s; to accommodate the worst case, the envelope of all possibilities is taken. For this envelope, an initial 7'500 ns/s slope is needed until the time error changes by 120 ns, followed by a 50 ns/s slope to time 500 ms, followed by a 30 ns phase step, followed by a 50 ns/s slope to time 2'200 ms. A constant 40 ns phase is added to this entire transient to account for the phase error due to steady-state SyncE/SDH phase noise (see above).

h) The phase increases described in (g) are assumed to be rapid enough that they are above the 0.1 Hz T-BC filter corner frequency. Since the T-BC filter acts as a high-pass filter on the SyncE/SDH signal, this initial part of the SyncE/SDH transient is passed through the filter approximately unaffected, and the effect of the high-pass filtering can be ignored. This assumption is conservative, as accounting for the high-pass filter could only decrease the output phase error.

i) At 2.2 s, the SSM is received by the T-BC and the SyncE/SDH signal is rejected. The T-BC output phase error is an exponential decay with time constant 1/(2π)(0.0.05 Hz) due to the relaxation of the filter; the phase error decreases until it reaches the assumed floor of 40 ns due to SyncE/SDH wander accumulation and timestamp granularity. The T-BC output phase error remains at this 40 ns value, representing a worst-case steady-state phase error.

j) At time 10 s after the SyncE/SDH is again traceable, there is a 60 ns phase step, followed by an exponential decay with time constant 1/(2π)(0.05 Hz) to the 40 ns level.

The following assumptions were made in computing the T-BC output phase error due to the SyncE/SDH rearrangement, using the second technique, i.e., turning off the T-BC filter:

k) This assumption is the same as assumption (a) above for rejection of the SyncE/SDH signal.

l) This assumption is the same as assumption (b) above for rejection of the SyncE/SDH signal.

m) This assumption is the same as assumption (c) above for rejection of the SyncE/SDH signal.

n) This assumption is the same as assumption (d) above for rejection of the SyncE/SDH signal.

o) The T-BC filter is turned off after a time interval has elapsed following the receipt of the SSM. This delay is due to software processes; it is taken to have an upper bound equal to the non-switching message delay, i.e., 200 ms as specified in clause 5.14 of [ITU-T G.781], and a lower bound of zero. When the next Sync message is received, an immediate correction to the time is made. While this Sync message carries the grandmaster (GM) time, the T-BC phase error immediately after the correction is not zero because the most recent mean propagation delay computation was, in worst-case, based previously on received Sync and Delay_Req messages whose arrival and departure, respectively, were time stamped during the SyncE/SDH transient. The mean propagation delay is given by[$(T_4 - T_1) - (T_3 - T_2)$]/2. Assuming that the time interval between the receipt of the most recent Sync and the most recent Delay_Req is, in worst case, two mean Delay_Req intervals, then the error in mean propagation delay is equal to the accumulated phase error over these two mean Delay_Req intervals, divided by 2. This value is (2)(0.0625 s)(50 ns/s)/2 = 3.125 ns. Therefore, the T-BC phase error due to the SyncE/SDH transient decreases to 3.125 ns above the 40 ns steady-state error, or 43.125 ns, when this next Sync message is received. This occurs at most 0.125 s later, or at 2.325 s (i.e., at most two mean Sync intervals, since it is assumed that the actual time between Sync messages is bounded by two mean Sync intervals). When the next Sync message after this one is received, which is at most 0.125 s after 2.325 s, or 2.45 s, the T-BC phase error decreases to 40 ns.

p) When the SyncE/SDH is again traceable, the second 120 ns phase change over 16 ms interval (i.e., a 7'500 ppm phase ramp) appears on the T-BC output. This 120 ns phase error lasts for at most 2 Sync intervals (i.e., the longest interval that elapses before the next Sync message is received, and then the error is immediately corrected because the T-BC filter is still turned off. The SSM is received indicating the SyncE/SDH is again traceable, and the T-BC filter is turned back on 10 s later. As was the case when the T-BC filter was turned off (see (o) above), there is still phase error due to the fact that the most recent Sync and Delay_Req messages, which were used for the most recent propagation delay measurement, occurred during the transient when the SyncE/SDH reacquires its reference. In this case, the worst-case is when T_2 was taken just when the SyncE/SDH again became traceable, and T_3 was taken 0.125 s later. The phase error during this interval between the T_3 and T_2 timestamps is [(0.016 s)(7'500 ns/s) + (0.125 s − 0.016 s)(0 ns/s)]/2 = 60 ns. Then, on receipt of the next Sync message after the T-BC filter is turned on, the T-BC phase error decreases to 40 ns + 60 ns = 100 ns. When the next Sync message is received 0.125 s after this, the T-BC phase error decreases to 40 ns.

The above assumptions (a) – (p) produce the T-BC output transients given in Tables II.1 and II.2. In addition to these assumptions, the SyncE/SDH signal was assumed to again be PRC-traceable after 15 s. This is the approximate SyncE/SDH ring rearrangement time for a ring of 20 EECs. This means that for scheme (a) the SyncE/SDH is reacquired 10 s later, or 25 s after the SyncE/SDH loses PRC-traceability. The transients are continued to 50 s after the loss of traceability. The transients are shown in Figure II.1. As indicated above, each technique produces two transients, one right after traceability is lost and one when or after it is regained. Note that the final transients do not occur at the same time for the two techniques.

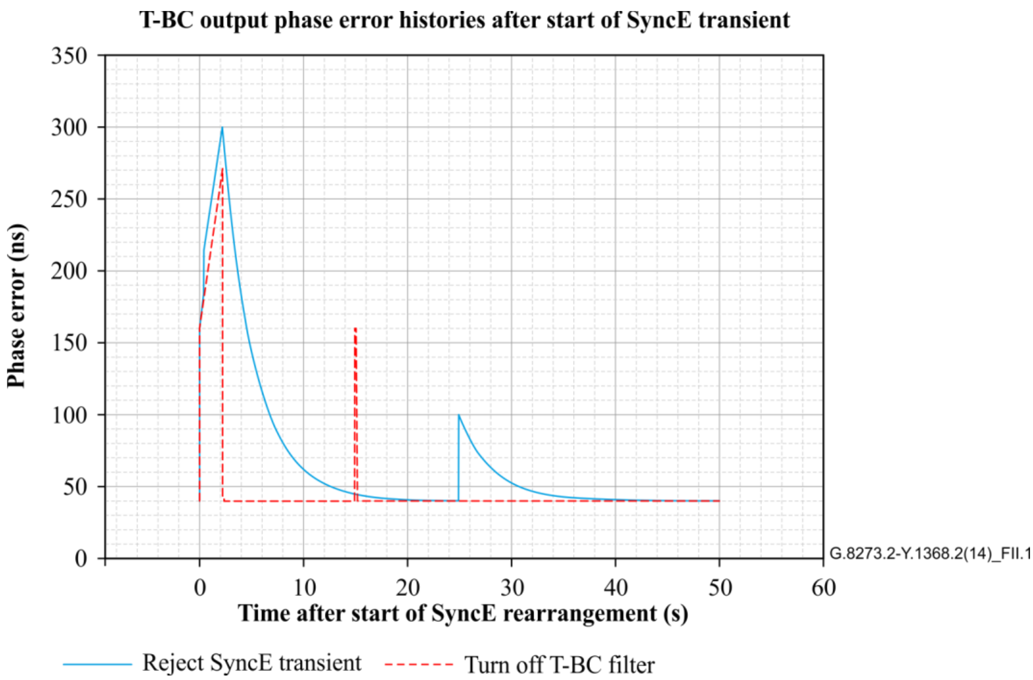


Figure II.1 – T-BC output phase error histories for each of the two techniques, assuming SyncE/SDH transient starts at time zero

Table II.1 – T-BC output phase error history using scheme (a) (rejection of SyncE/SDH transient)

Time *S* after start of SyncE/SDH rearrangement (s)	**T-BC output phase error (ns)**
$0 \le S < 0.016$	$40 + 7'500S$
$0.016 \le S < 0.5$	$160 + 50(S - 0.016)$
$0.5 \le S < 2.2$	$214.2 + 50(S - 0.5)$
$2.2 \le S < 25$	$40 + 259.2e^{-2\pi(0.05)(S-2.2)}$
$25 \le S \le 50$	$40.2 + 60\,e^{-2\pi(0.05)(S-25)}$

Table II.2 – T-BC output phase error history using scheme (b) (turning off T-BC filter during SyncE/SDH transient)

Time *S* after start of SyncE/SDH rearrangement (s)	**T-BC output phase error (ns)**
$0 \le S < 0.016$	$40 + 7'500S$
$0.016 \le S < 2.325$	$160 + 50(S - 0.016)$
$2.325 \le S < 2.45$	43.125
$2.45 \le S < 15$	40
$15 \le S < 15.016$	$40 + 7'500(S - 15)$
$15.016 \le S < 15.141$	160
$15.141 \le S < 15.266$	80'100
$15.266 \le S \le 50$	40

II.2 T-BC output phase transient masks

The T-BC output phase transient mask for the portion of the SyncE/SDH rearrangement at and just following loss of PRC-traceability is taken as the upper envelope of the first portion of each of the two output transients of Tables II.1 and II.2 and Figure II.1 above. This is given by the mask of Figure B.1 and Table B.1.

The T-BC output phase transient mask for second transient, when PRC-traceability is re-established, is taken as the upper envelope of the second portion of each of the two output transients of Tables II.1 and II.2 and Figure II.1 above. This is given by the mask of Figure B.2 and Table B.2.

Appendix III

Background to performance requirements of the T-BC

(This appendix does not form an integral part of this Recommendation.)

Annex A describes a detailed model of a telecom boundary clock. Figure III.1 is a simpler representation showing the timing signal flows between the main functional blocks during normal operation.

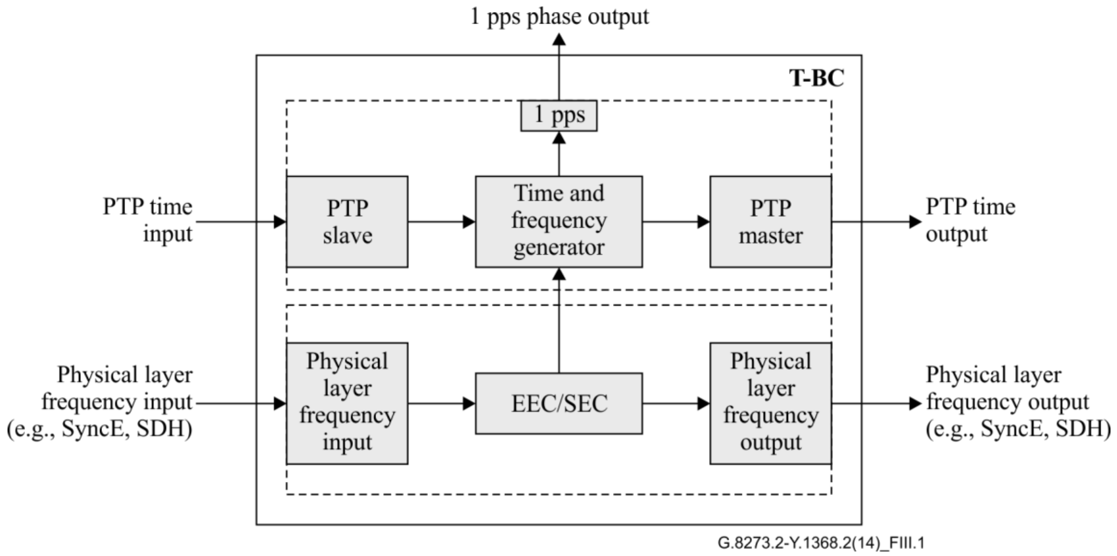


Figure III.1 – Model of T-BC showing signal flows in normal operation

From this diagram, it can be seen that there are basically two clocks in a T-BC, a frequency clock locked to the physical layer frequency input, and a time clock locked to the PTP input. In most cases, the frequency reference is SyncE based rather than SDH or PDH, and hence the frequency clock is an EEC. The two clocks are shown in Figure III.2:

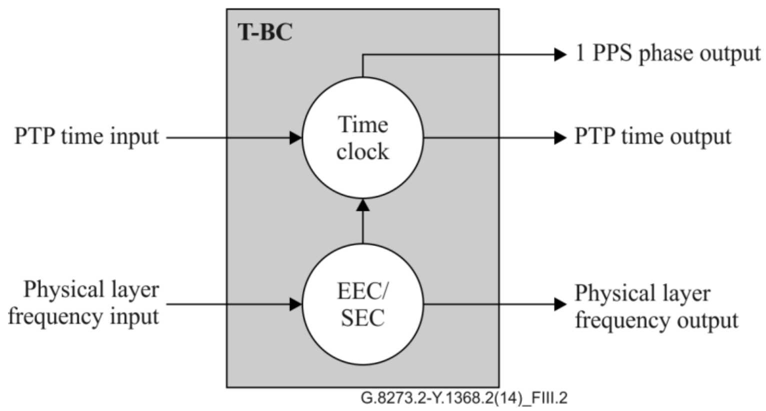


Figure III.2 – Simplified model of T-BC showing clocks

Since the 1 PPS output is a measurement point intended to reflect the performance of the time clock, it is expected that it should be broadly equivalent to the PTP output, aside from the different noise characteristics of the respective signal types.

Therefore there are three primary timing flows in a T-BC:

1) PTP time input to PTP and 1 PPS time/phase outputs;

2) physical layer frequency input to physical layer frequency output;

3) physical layer frequency input to PTP and 1 PPS outputs.

III.1 Noise generation requirements

The noise generation of a clock is defined as the noise (normally phase wander) at the output of the clock, with a wander-free reference at the input of the clock.

The noise generation at the physical layer frequency output is only affected by the physical layer frequency input, and is defined by [ITU-T G.8262] and [ITU-T G.813], the clock specifications for an EEC or SEC respectively.

The PTP and 1 PPS signals are the output of the time clock within the T-BC. For these outputs noise basically means time error. This can be defined by three parameters:

1) cTE – the mean value of the time error function, measured over a long observation interval;

2) dTE – the variation of the time error function;

3) maximum time error (max|TE|) – the maximum absolute value of the time error.

For a T-BC, the maximum noise generation is defined in terms of cTE and dTE. The max|TE| parameter is generally used for network limits.

There are two inputs that can affect the output of the Time Clock, the physical layer frequency input and the PTP input. Therefore the noise generation at the PTP and 1 PPS outputs is defined as the noise present at the output with a time-error free time reference at the PTP input, and a wander-free frequency reference at the physical layer frequency input. This is shown in Figure III.3:

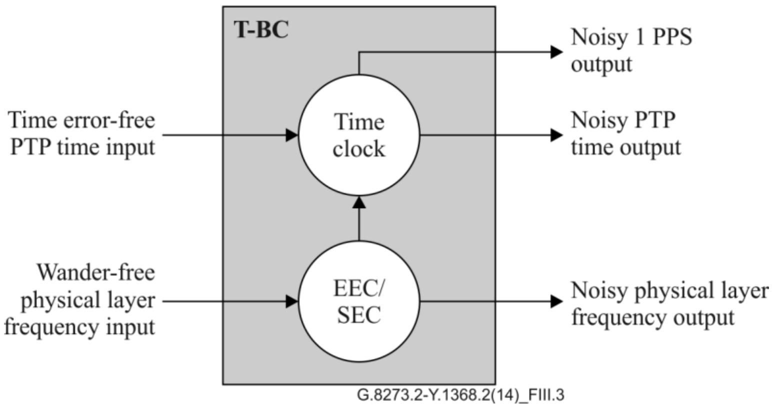


Figure III.3 – Noise generation of a T-BC

III.2 Noise tolerance

The noise tolerance of a T-BC is the maximum level of noise at the inputs of a T-BC that must be tolerated while continuing to work normally. In the real network, both inputs of a clock may be noisy at the same time, therefore the noise tolerance requirements are defined to apply simultaneously on both inputs.

For the PTP input, noise tolerance is defined in terms of the dTE of the input signal. cTE is not considered, since PTP is effectively "blind" to cTE; it cannot detect constant time error at its input without additional information (e.g., asymmetry measurements). The amount of dTE is based on network limit in [ITU-T G.8271.1].

For the physical layer frequency input, the maximum phase wander that should be tolerated is described in [ITU-T G.8262].

There are no output performance requirements on the output of the T-BC during a noise tolerance test. This is because the T-BC is a node within a chain. The noise accumulation through the chain is governed by the noise generation of the clock, and the network limits provide the overall limit on the performance of the chain. A clock is merely expected to work normally during a noise tolerance test, i.e., not switch references, generate any alarms, or go into holdover.

Noise tolerance is shown in Figure III.4:

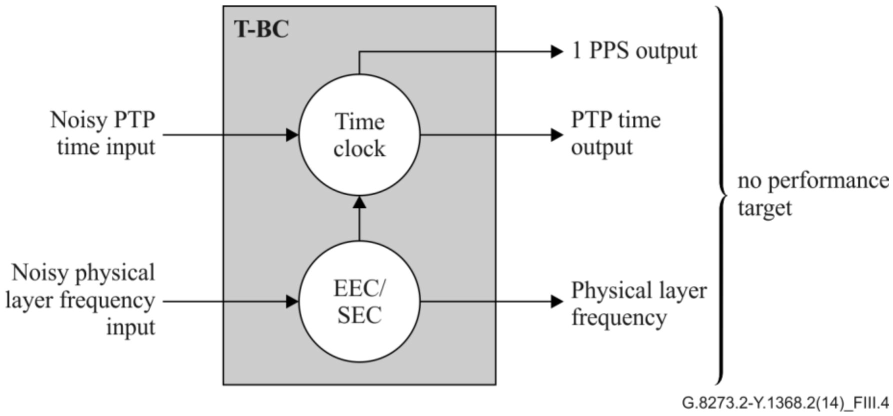


Figure III.4 – Noise tolerance of a T-BC

III.3 Noise transfer

The noise transfer of a clock describes how any noise present on the input of a clock is passed to the output of the clock. It is basically the transfer function of the clock, and is usually expressed in terms of bandwidth, since the clock acts a filter to the noise.

As discussed before, there are three primary signal flows through a T-BC, as shown in Figure III.5:

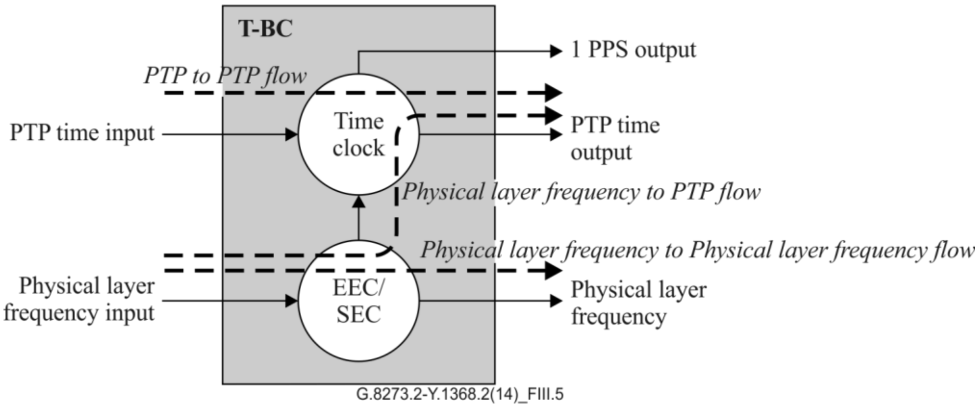


Figure III.5 – Signal flows through a T-BC

Each of these flows has a bandwidth associated with it. The PTP to PTP (and PTP to 1 PPS) bandwidth is explicitly defined in clause 7.3.1, as a low-pass filter with a maximum bandwidth of 0.1 Hz, and a minimum bandwidth of 0.05 Hz.

The physical layer to physical layer frequency bandwidth is defined in [ITU-T G.8262] and [ITU-T G.813], as this is a standard EEC and SEC function respectively. This is also a low-pass filter, with a maximum bandwidth of 10 Hz, and a minimum bandwidth of 1 Hz.

For the physical layer frequency to PTP (and physical layer frequency to 1 PPS) path, the physical layer frequency signal is first low-pass filtered by the EEC or SEC, then high-pass filtered by the time clock. This is because the time clock acts a low-pass filter to its time input, but a high-pass filter to its frequency input. This is a natural consequence of how the clock functions – basically it follows the time input at low frequencies, to stay locked to the time reference, but follows the frequency input at high frequencies (e.g., in between PTP packets, the frequency input provides the "ticking" to maintain the time output).

Therefore the cumulative effect is a band-pass function, with the lower cutoff at 0.05-0.1 Hz, and the upper cutoff at 1-10 Hz. Table III.1 summarizes the transfer functions, while Figure III.6 shows generalized schematics of the transfer functions.

Table III.1 – Transfer functions applicable to a T-BC

Input/output on the T-BC	Transfer function
PTP input to PTP output PTP input to 1 PPS output	0.05-0.1 Hz low-pass filter
Physical layer frequency input to physical layer frequency output	1-10 Hz low-pass filter
Physical layer frequency input to PTP output Physical layer frequency input to 1 PPS output	[0.05-0.1; 1-10] Hz band-pass filter

a) PTP to PTP (or 1 PPS) transfer function schematic

b) Physical layer frequency to physical layer frequency transfer function schematic

c) Physical layer frequency to PTP (or 1 PPS) transfer function schematic

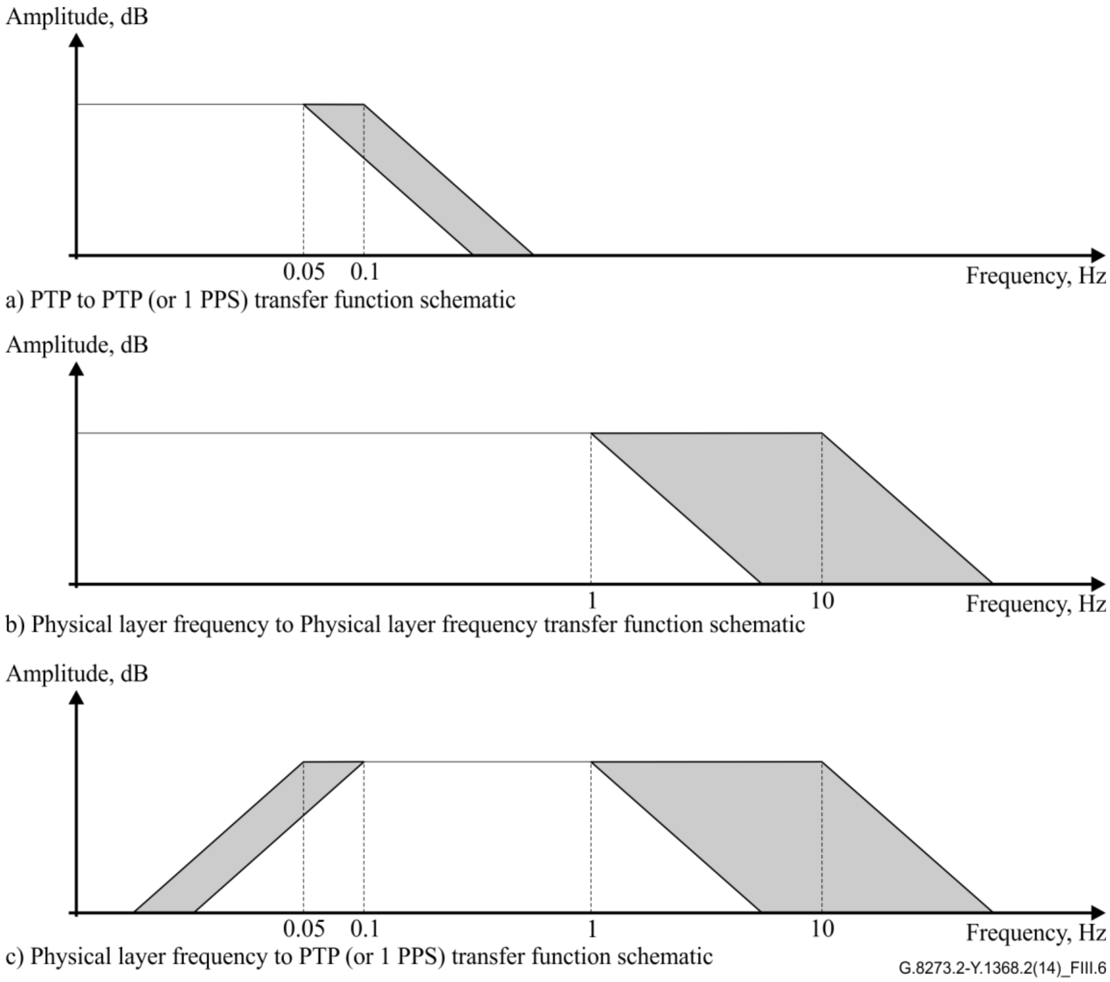


Figure III.6 – Generalized transfer function schematics of a T-BC

It should be noted that the diagrams in Figure III.6 are generalized schematics. The actual transfer function will be more rounded, and include the gain peaking defined in clause 7.3. In particular, the band-pass filter may not contain a flat area due to the closeness of the low-pass and high-pass corner frequencies.

III.4 Holdover

There are two types of holdover available in a T-BC. The first is where the T-BC loses its PTP time reference, but not the physical layer frequency reference, as shown in Figure III.7. In this case, the stable frequency reference is used to keep the time output "ticking" at approximately the correct rate. Since the long-term frequency of the physical layer frequency is traceable to a PRC, this is likely to maintain the correct time over a reasonable period of time.

The performance requirements to be met in this physical layer frequency-assisted holdover mode are not defined at present, and are for further study.

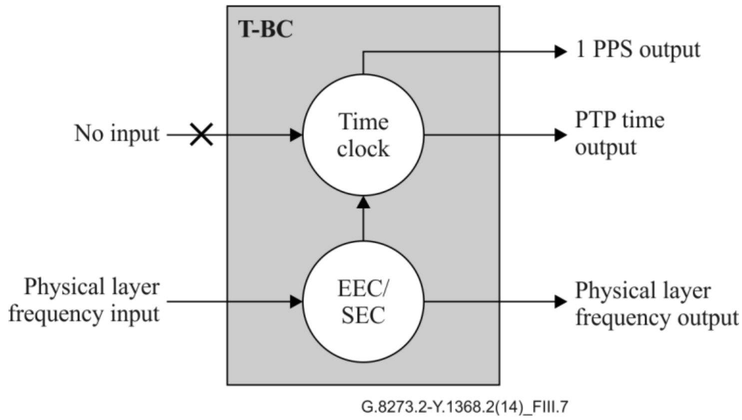


Figure III.7 – Physical layer frequency-assisted holdover

The second type is where both inputs are lost simultaneously, as shown in Figure III.8. The time output is then maintained using the local oscillator, but this is not expected to maintain accurate time for more than a few seconds, due to the drift rate of the oscillator. The performance requirements to meet in unassisted holdover are for further study.

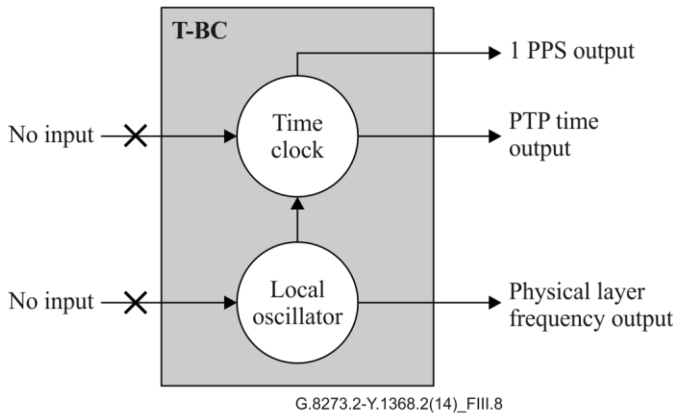


Figure III.8 – Unassisted holdover

Appendix IV

T-BC dynamic time error noise generation TDEV

(This appendix does not form an integral part of this Recommendation.)

For a Class A or Class B T-BC containing an EEC-Option 1 clock, and operating in locked mode synchronized to both a wander-free time reference at the PTP input and a wander-free frequency reference at the SyncE/SDH input, the TDEV at the PTP and 1 PPS outputs, measured through a first-order low-pass filter with bandwidth of 0.1Hz, should meet the limits in Table IV.1 under constant temperature (within ±1K).

Table IV.1 is based on preliminary simulations. These simulations did not cover the case for a 1 PPS output. Also, note that the requirement in Table IV.1 may be updated based on newer simulations and actual tests.

Table IV.1 – Dynamic time error noise generation (TDEV) for T-BC with constant temperature

TDEV limit [ns]	Observation interval τ [s]
4	$m < \tau \leq$ 1'000 (Notes 1, 2)
NOTE 1 – The minimum τ value *m* is determined by packet rate of 16 packet per second (*m*=1/16) or 1 PPS signal (*m*=1) NOTE 2 – The values in this table are valid for 1 PPS, 1 GbE and 10 GbE interfaces. Interfaces for rates above 10 GbE are for further study.	

Appendix V

T-TSC dynamic time error noise generation TDEV

(This appendix does not form an integral part of this Recommendation.)

For a Class A or Class B T-TSC containing an EEC-Option 1 clock, and operating in locked mode synchronized to both a wander-free time reference at the PTP input and a wander-free frequency reference at the SyncE/SDH input, the TDEV at the 1 PPS output, measured through a first-order low-pass filter with bandwidth of 0.1Hz, should meet the limits in Table V.1 under constant temperature (within ±1K).

Table V.1 is based on preliminary simulations. These simulations did not cover the case of a 1 PPS output, and therefore the TDEV is an estimate. Also, note that the requirement in Table V.1 may be updated based on newer simulations and actual tests.

Table V.1 – Dynamic time error noise generation (TDEV) for T-TSC with constant temperature

TDEV limit [ns]	Observation interval τ [s]
4	$1 < \tau \leq 1'000$

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