Integrated Device Technology

Standardizing clocks

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Agenda

- ITU-T Clock Hierarchy (G.803)
- Equipment Clocks
- Clocks for Frequency
- G.8263
- Clocks for Phase/Time
- G.8272
- G.8273.2
- Summary

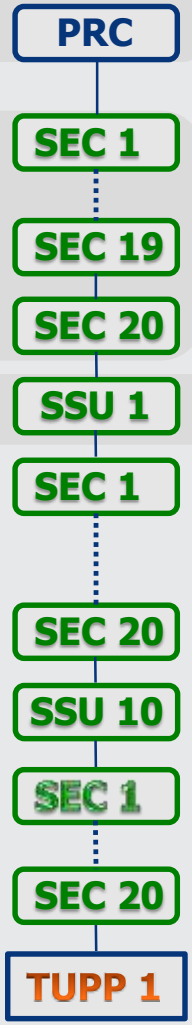
ITU-T Clock Hierarchy (G.803)

PRC – Primary Reference Clock
Highest quality clocks : Frequency accuracy < 10^{-11}
- Defined in ITU-T recommendation G.811

SEC – SDH Equipment clock
- Defined in ITU-T recommendation G.813

Used in Routers, ADMs, MSPPs etc.

SSU – Synchronization Supply Unit (high quality clocks)
- Defined in ITU-T recommendation G.812



SDH Synchronization chain is defined in ITU-T Rec. G.803
- Consists of 1 PRC followed by 20 SECs, followed by SSU
- The maximum number of SSUs is 10
- The maximum number of clocks is 60

Clocks are based on Phase Lock Loop concept
- ITU-T G.810 defines the clock modes of operation
- As clocks are cascaded, it is important to limit noise accumulation
- Proper bandwidth and gain peaking are important (wander transfer)
- Performance under failure conditions are also very important to be specified (e.g .holdover, transient response)

TUPP – Tributary Payload Processor

Equipment Clocks

- Clocks for Frequency
  - G.8262 Timing characteristics of Synchronous Ethernet Equipment slave clock (EEC)
  - G.8263 Timing Characteristics of Packet based Equipment Clocks (PEC) and Packet based Service Clocks (PSC)
  - G.8266 Timing characteristics of telecom grandmaster clocks for frequency synchronization (under development)

- Clocks for Time/Phase
  - G.8272 Primary Reference Timing Clock (PRTC) specification
  - G.8273 Clock General Requirements
  - G.8273.1 Telecom Grand Master specification (under development)
  - G.8273.2 Telecom Boundary Clock specification
  - G.8273.3 Telecom Transparent Clock specification (under development)
  - G.8273.4 Timing characteristics of assisted partial timing support slave clocks (under development)

Equipment Clocks

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G.8261.1 Hypothetical Reference Model 1 (HRM-1)

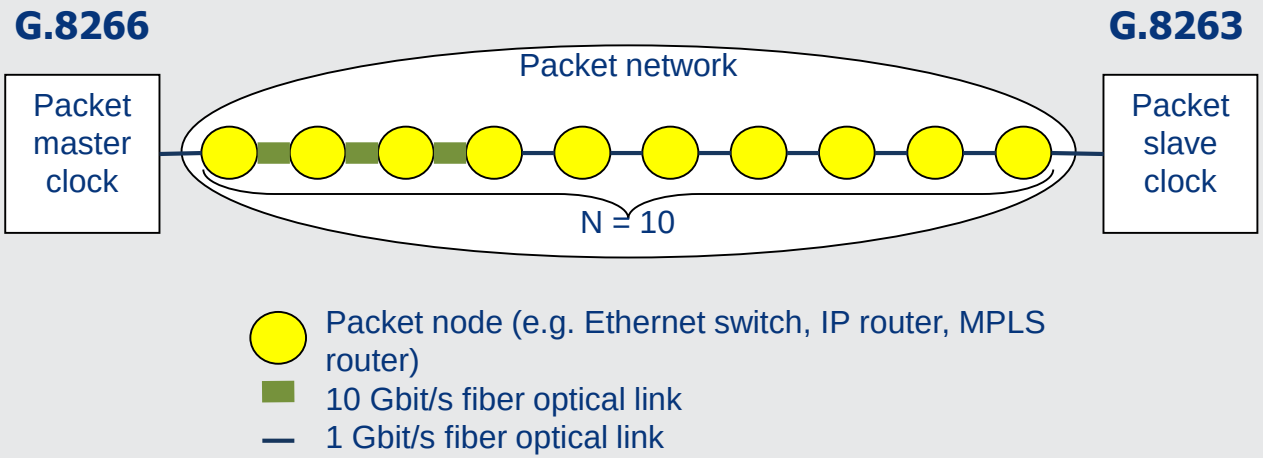

Figure 1/G.8261.1 - HRM-1 for Packet Delay Variation network limits

Note: There is an amendment of G.8261.1 for networks with lower packet delay variation (75µs FPP cluster range instead of 150µs)

G.8263 – Packet-based equipment clocks

- Packet-based equipment clock was defined based on G.8261.1 HRM
- G.8263 includes the following requirements
  - Frequency accuracy
  - Noise generation
  - Packet delay variation noise tolerance
  - Holdover

- Packet delay variation noise tolerance
  - The clock must tolerate the PDV generated by the network
  - For the HRM-1 the clock must meet the output performance specification according to the metrics defined in G.8261.1
    - 1% of the timing packets sent by the packet master remain in the 150 µs fixed cluster range, starting at the floor delay in every observation window of 200 s.

Equipment Clocks

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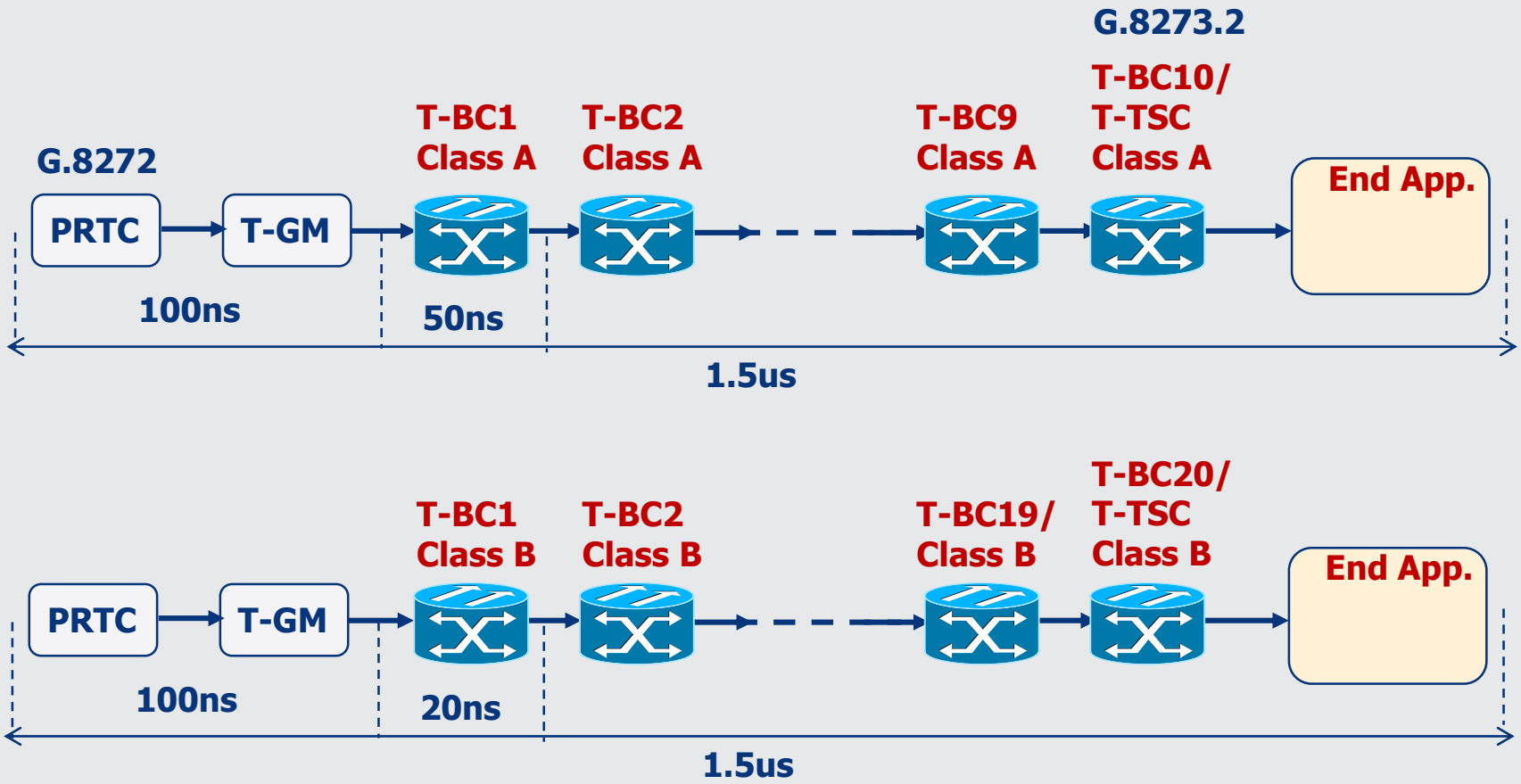
G.8271.1 Architecture

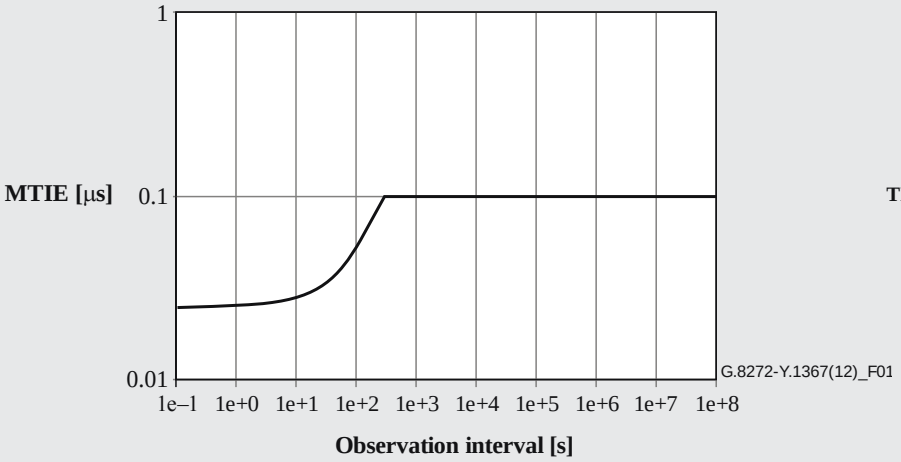


Note: The network limit of 1.5us also accounts for other sources of noise (e.g. holdover, link asymmetries, syncE rearrangements)

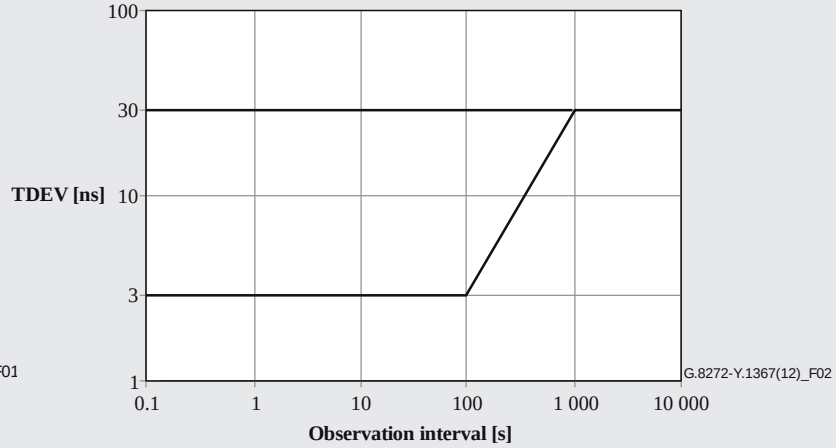
PRTC = Primary Reference Time Clocks
T-GM = Telecom Grand Master

G.8272 Primary Reference Time Clock

- G.8272 includes the following requirements
  - Time error in locked mode
  - Wander in locked mode
  - Jitter
  - Holdover is under study



G.8272/Figure 1 – MTIE as a function of an observation (integration) period t



G.8272/Figure 2 – TDEV as a function of an observation (integration) period t

G.8273.2 Telecom boundary clocks and telecom time slave clocks

- G.8273.2 includes the following requirements
  - Physical layer frequency performance requirements
  - Constant Phase/Time Error and Dynamic Time Error Noise generation
  - Constant phase/time error generation
  - Dynamic time error (dTE) noise generation
  - Noise tolerance
  - Noise transfer
  - Phase/time error due to a rearrangement of the physical layer frequency transport (e.g. SyncE, SDH)
  - Holdover is under study

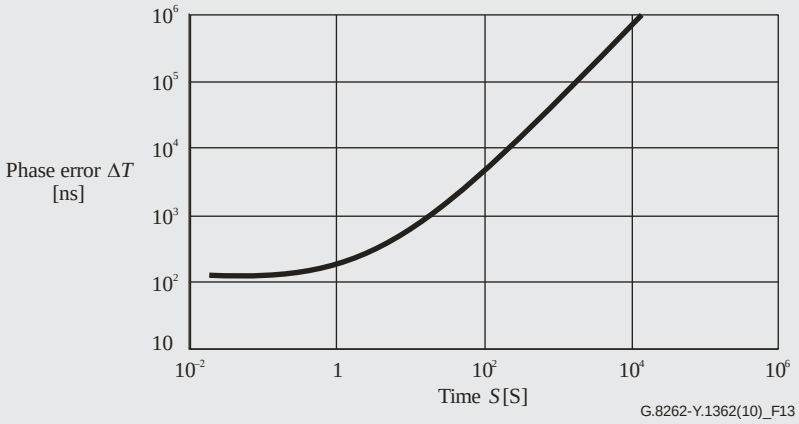
- Two classes of Telecom Boundary Clock (T-BC) and Telecom Time Slave Clock (T-TSC)

T-BC /T-TSC Constant TE Classes	Maximum Constant Time Error (ns)
A	50
B	20

G.8273.2/Table 1 – T-BC Constant Time Error Classes

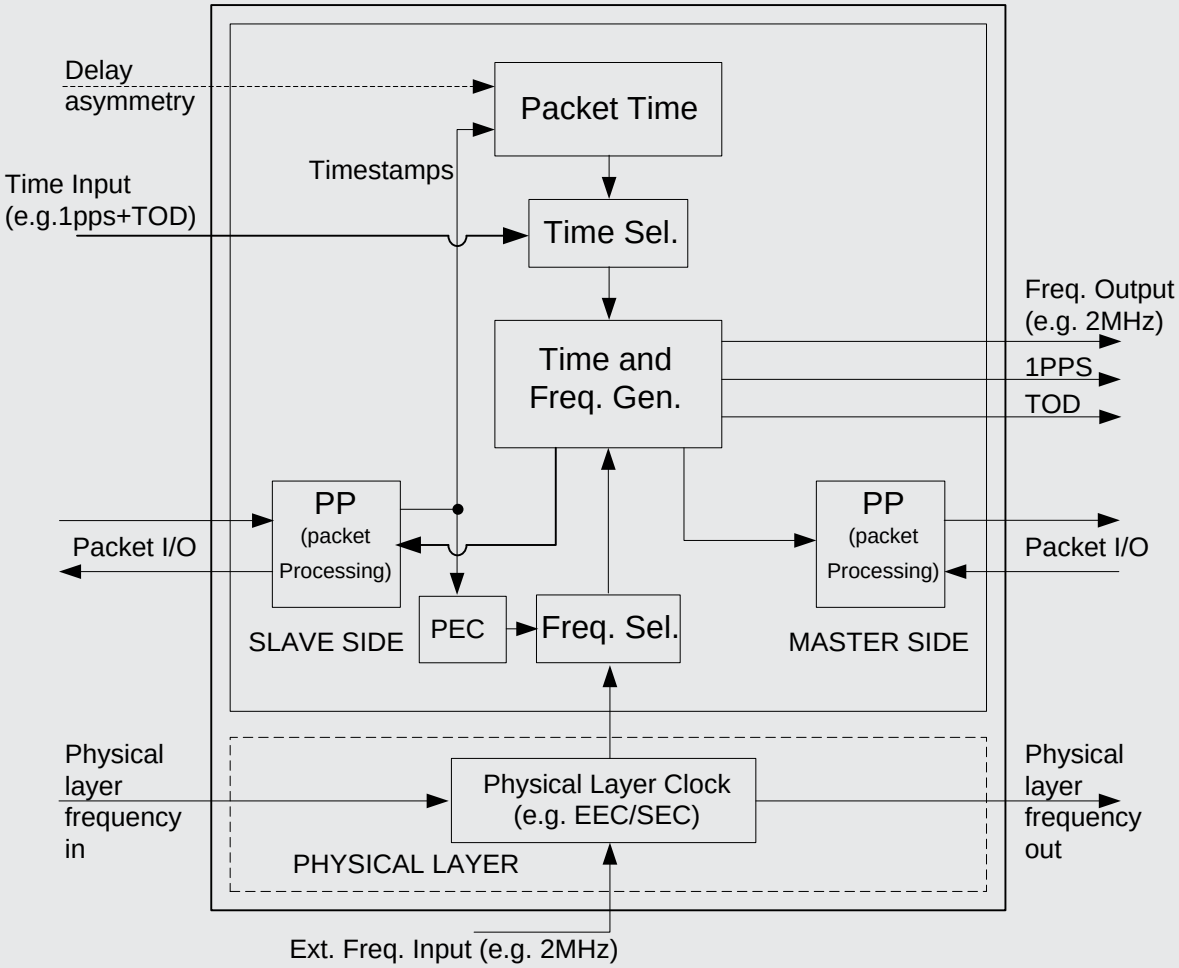
Physical Layer Assistance

- G.8273.2 uses PTP to transport of time, and physical layer clock (SyncE/SDH) to transport frequency
- The use of physical layer clock is important for Time holdover
  - If an G.8262 EEC-option 1 type of oscillator is used for T-BC, and if the holdover relies only on the oscillator, then the phase will be out of spec in less than a 100 seconds



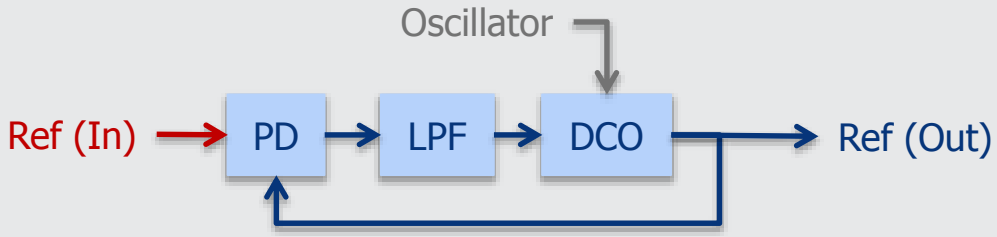
G.8262/Figure 13 – Permissible phase error for an EEC-Option 1 under holdover operation at constant temperature

T-BC Functional Model

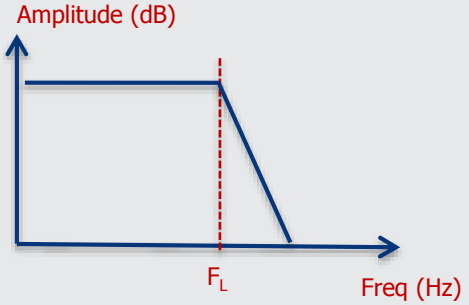


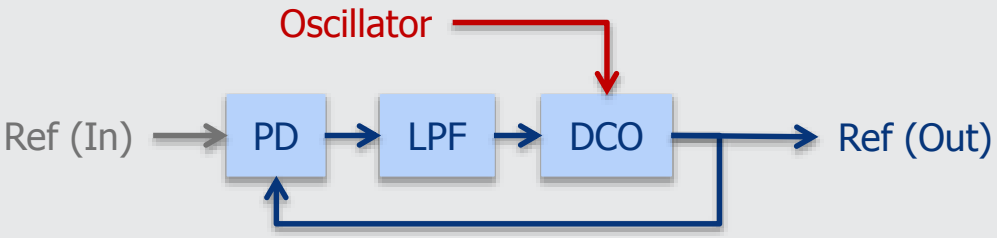
G.8273.2/Figure A. 1: Boundary Clock Model

PLL Response to Different Noise Sources

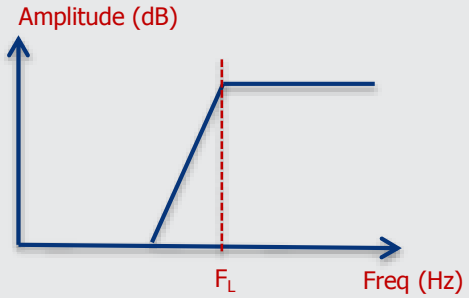


PLL is a low-pass filter for input noise

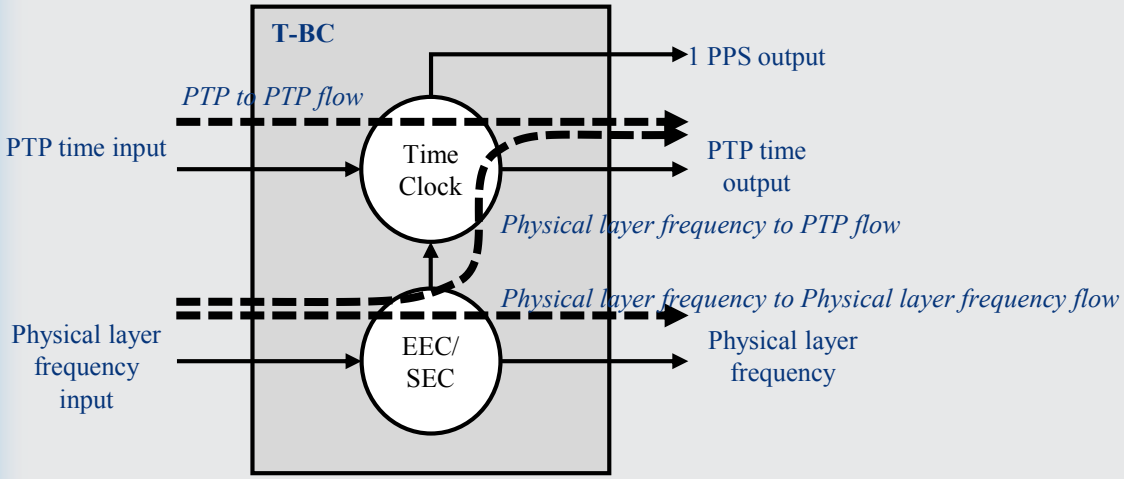




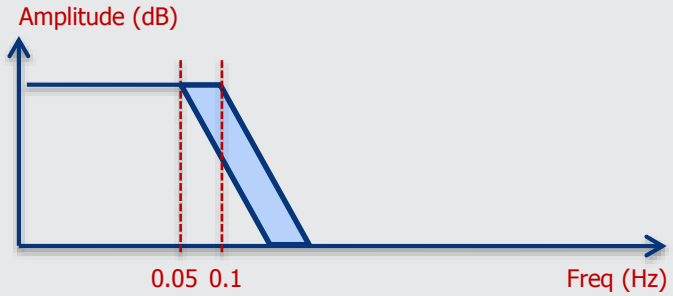
PLL is a high-pass filter for oscillator noise



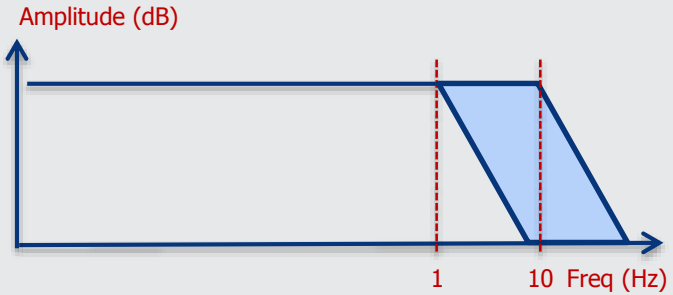
T-BC, T-TSC Transfer Function



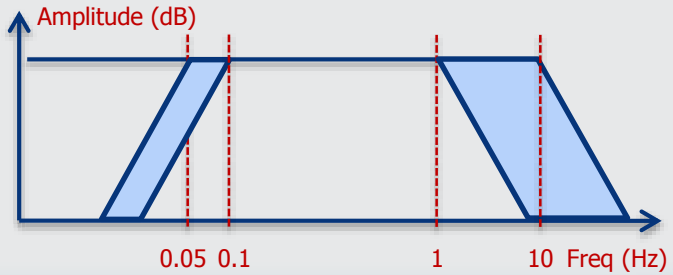
PTP input to PTP/1PPS output: 0.05-0.1 Hz low-pass filter



SyncE input to SyncE output: 1-10 Hz low-pass filter



SyncE input to PTP/1PPS output



Summary

- Standardizing clocks is not trivial, but it is very important
  - Allows interoperability, limits noise accumulation in a chain of clocks
- It is dependent on the Network Architecture
- Several parameters of the clock are dependent on the number of clocks that are in tandem
  - Control of wander and jitter are important
  - Proper PLL design are important (e.g. gain peaking)
- Clocks for Frequency has been standardized
- Clocks for phase/time for full support from the network has been standardized
- ITU is still working on standardizing clocks for phase/time with partial support from the network