



# Technical Notes

## Product and Technology Application Notes

### Stratum Levels Defined

An American National Standards Institute (ANSI) standard entitled "Synchronization Interface Standards for Digital Networks" (ANSI/T1.101-1987) was first released in 1987. This document defines the stratum levels and minimum performance requirements for digital network synchronization. The requirements for the stratum levels are shown in Table A, which provides a comparison and summary of the drift and slip rates for the strata clock systems.

Stratum 1 is defined as a completely autonomous source of timing, which has no other input, other than perhaps a yearly calibration. The usual source of Stratum 1 timing is an atomic standard (Cesium Beam or Hydrogen Maser) or reference oscillator (OCXO). The minimum adjustable range and maximum drift is defined as a fractional frequency offset  $f/f$  of  $1 \times 10^{-11}$  or less. At this minimum accuracy, a properly calibrated source will provide bit-stream timing that will not slip relative to an absolute or perfect standard more than once every 4 to 5 months. Atomic standards, such as Cesium clocks, have far better performance.

A Stratum 1 clock is an example of a Primary Reference Source (PRS) as defined in ANSI/T1.101. Alternatively, a PRS source can be a clock system employing direct control from Coordinated Universal Time (UTC) frequency and time services, such as Global Positioning System (GPS) navigational systems. The GPS System may be used to provide high accuracy, low cost timing of Stratum 1 quality.

A Stratum 2 clock system tracks an input under normal operating conditions, and holds to the last best estimate of the input reference frequency during impaired operating conditions. A Stratum 2 clock system requires a minimum adjustment (tracking) range of  $1.6 \times 10^{-8}$ . The drift of a Stratum 2 with no input reference is less than  $1.6 \times 10^{-8}$  in one year. The short-term drift of the system is less than  $1 \times 10^{-10}$  in 24 hours. If one interprets this specification as a drift of  $1 \times 10^{-10}$  each 24 hours, this amounts to a frame slip rate of approximately 1 slip in 7 days when the Stratum 2 clock system is in the hold mode. A Stratum 2 clock with a drift of less than  $2.5 \times 10^{-11}$  per day will result in a time to the first frame slip of more than 2 months. Typical examples of Stratum 2 clocks are Rubidium Standards and Double Oven OCXO's.

Stratum 3 is defined as a clock system which tracks an input as in Stratum 2, but over a wider range. A Stratum 3 clock system requires a minimum adjustment (tracking) range of  $4.6 \times 10^{-6}$ . The short term drift of the system is less than  $3.7 \times 10^{-7}$  in 24 hours. This amounts to approximately 255 frame slips in 24 hours while the system is holding. Some Stratum 3 clock equipment is not adequate to time SONET network elements.

Stratum 3E, that was defined in Bellcore documents [References 3, 7 and 8], is a new standard created as a result of SONET equipment requirements. Stratum 3E tracks input signals within 7.1 Hz of 1.544 MHz from a Stratum 3 or better source. The drift with no input reference is less than  $1 \times 10^{-8}$  in 24 hours. This is less than four frame slips in 24 hours, compared to 255 slips for Stratum 3.

Stratum 4 is defined as a clock system, which tracks an input as in Stratum 2 or 3, except that the adjustment and drift range is  $3.2 \times 10^{-5}$ . Also, a Stratum 4 clock has no holdover capability and, in the absence of a reference, free runs within the adjustment range limits. The time between frame slips can be as little as 4 seconds.

Stratum 4E is a proposed new customer premises clock standard which allows a holdover characteristic that is not free running. This new level, intended for use by customer provided equipment in extending their networks, is not yet standardized.

## The Stratum Hierarchy

A Stratum 1 clock may control strata 2, 3E, 3, 4E, or 4 clocks. A Stratum 2 clock may drive strata 2, 3E, 3, 4E, or 4 clocks. A Stratum 3E clock may drive strata 3E, 3, 4E or 4 clocks. A Stratum 3 clock may drive strata 3, 4E or 4 clocks. A Stratum 4E or 4 clock is not recommended as a source of timing for any other clock system.

Because of the narrower capture and adjustment range of the higher strata clock systems (2 is higher than 3, and so on), driving a Stratum 2 clock from a Stratum 3E or 3 clock is not recommended. In fact, it will not work under some transmission impaired conditions. Also, extreme care must be taken in network applications where more than one Stratum 1 source is used to ensure that these sources are accurate and traceable to some other standard. Another standard commonly used to check on a Stratum 1 clock source's accuracy is the GPS System. A GPS receiver can also be used directly as a source of Stratum 1 quality.

Stratum 1 clock administration, operation, and maintenance can be a costly effort. Atomic sources may not have long maintenance-free operating intervals, and may experience failures without giving an indication that the source is off frequency. In addition, if a Stratum 1 source of timing is shown to be inaccurate, the network must be able to accept another network's timing until the problem is corrected. Thus, GPS is attractive in order to assure accuracy and minimize cost.

**Table A: Stratum Clock Requirements and Hierarchy**

Stratum	Accuracy/Adjust Range	Pull-In-Range	Stability	Time To First Frame Slip *
1	$1 \times 10^{-11}$	N/A	N/A	72 Days
2	$1.6 \times 10^{-8}$	Must be capable of synchronizing to clock with accuracy of $\pm 1.6 \times 10^{-8}$	$1 \times 10^{-10}/\text{day}$	7 Days
3E	$1.0 \times 10^{-6}$	Must be capable of synchronizing to clock with accuracy of $\pm 4.6 \times 10^{-6}$	$1 \times 10^{-8}/\text{day}$	3.5 Hours
3	$4.6 \times 10^{-6}$	Must be capable of synchronizing to clock with accuracy of $\pm 4.6 \times 10^{-6}$	$3.7 \times 10^{-7}/\text{day}$	6 Minutes (255 in 24 Hrs)
4E	$32 \times 10^{-6}$	Must be capable of synchronizing to clock with accuracy of $\pm 32 \times 10^{-6}$	Same as Accuracy	Not Yet Specified
4	$32 \times 10^{-6}$	Must be capable of synchronizing to clock with accuracy of $\pm 32 \times 10^{-6}$	Same as Accuracy	N/A

**Notes:**

\* To calculate slip rate from drift, one assumes a frequency offset equal to the above drift in 24 hours, which accumulates bit slips until 193 bits have been accumulated. Drift rates for various atomic and crystal oscillators are well known, and are not usually linear or not necessarily continually increasing.

### A Network Slip, What Happens?

If a frame slip occurs due to a clock system in the holdover condition, what is the penalty? Does the connected equipment stop working? Not usually. Voice equipment tends to re-acquire frame synchronization quickly, resulting in a pop or click, which is not usually a problem. Data circuits lose some number of bits depending on the data rate being transmitted, and on whether or not forward error correction is being used.

Some multiplex equipment that provides add and drop services interrupt all output trunks while a new source of synchronization is acquired. Such interruptions, if due to circuit noise, may render a network temporarily useless, as the slip causes further slips downstream (error or slip multiplication).

A clock system provides a stable frequency source during circuit impairments. The connected equipment will not be affected until the clock holdover drift results in a slip. A stable clock will change a network that experiences problems two or three times a day to one that maintains timing through a major trunk outage. The network will continue to operate without impairment until the outage is repaired, as long as the repair time is comparable to the time of the first frame slip (see Table A).

Since occasional slips will always occur, the best one can do is to minimize their rate of occurrence. Through careful network engineering of the clock systems, near perfect timing may be achieved at a reasonable cost with excellent reliability and maintainability.