Temperature, Frequency Offset, and Frequency Drift Rate Time History Plots for Model of [1]

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Introduction - 1

- Reference [1] presents a model for temperature history and resulting frequency offset, for a crystal oscillator
  - The oscillator is assumed to have no temperature compensation and is not ovenized (i.e., it is a simple XO, and not a TCXO or OCXO)
- The purpose of this presentation is to show the time history of frequency offset and frequency drift rate that results from the temperature history and relation between frequency offset and temperature given in [1]

Model of [1] - Temperature Variation

- The temperature history of [1] is assumed to vary between – 40 C and +85 C, at a rate of 25 C/minute, or 0.41666667 C/s
- When the temperature is increasing and reaches +85 C, it remains at +85 C for 5 minutes (300 s)
- The temperature then decreases from +85 C to – 40 C at a rate of 25 C/minute; this takes 5 minutes (300 s)
- The temperature then remains at – 40 C for 5 minutes
- The temperature then increases to +85 C at a rate of 25 C/minute; this takes 5 minutes
- The duration of the entire cycle (i.e., the period) is therefore 20 minutes (1200 s)

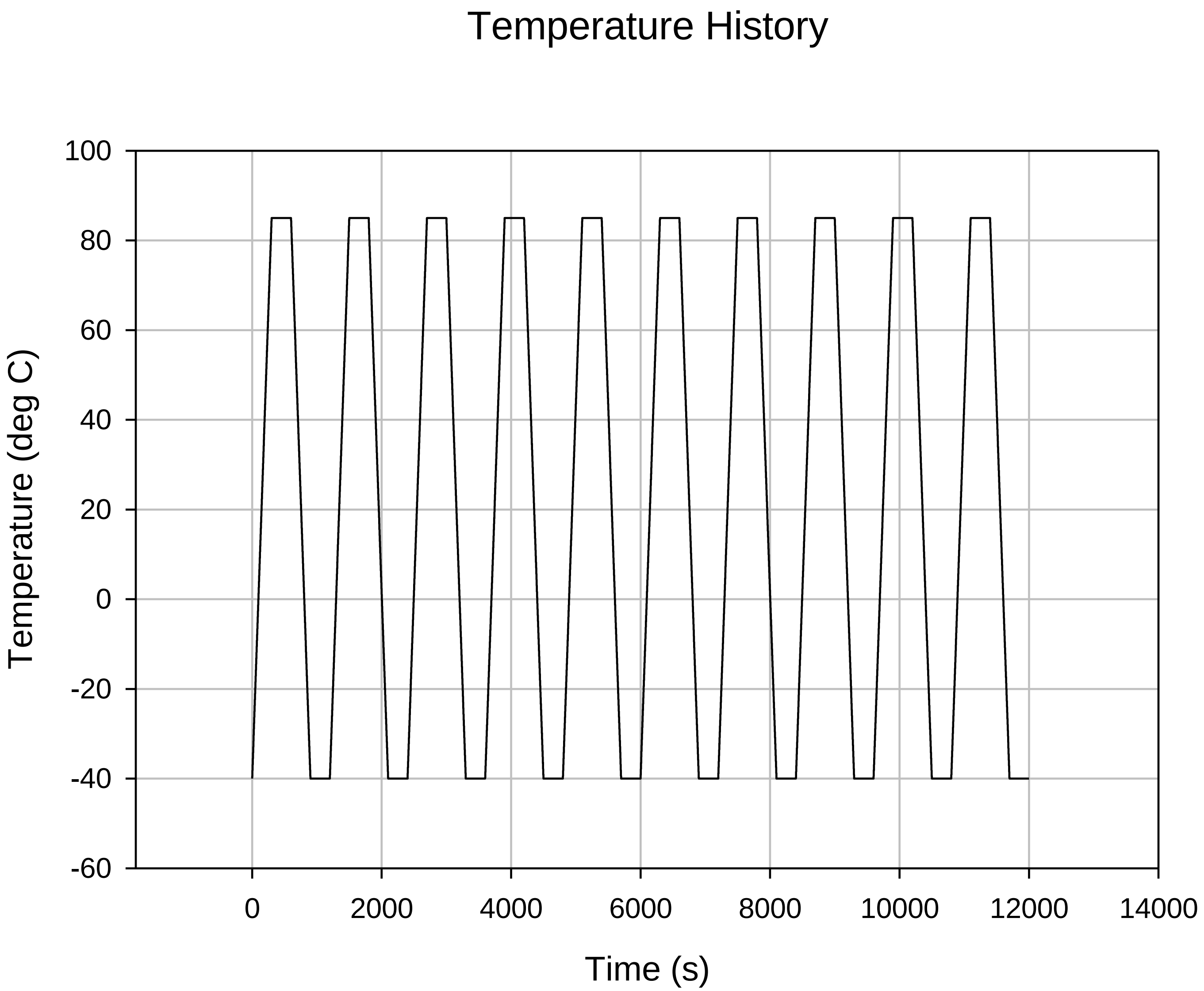
Model of [1] – Dependence of Frequency Offset on Temperature

- The frequency, f, is assumed to depend on temperature as given by the relation
  - $f = f0[1 – (TC)(T – T0)^2]$
  - where
    - T = temperature
    - f = frequency at temperature T
    - f0 = nominal frequency, at temperature T0
    - T0 = 25 C
    - TC = thermal coefficient, taken as 0.05 ppm/C^2
- From the above, the fractional frequency offset, y, is given by
  - $y = (f – f0)/f0 = (f/f0) – 1 = – (TC)(T – T0)^2$
- The rate of change of fractional frequency offset with respect to time, dy/dt, is obtained by differentiating the above with respect to time
  - $dy/dt = – 2(TC)(T – T0)(dT/dt)$

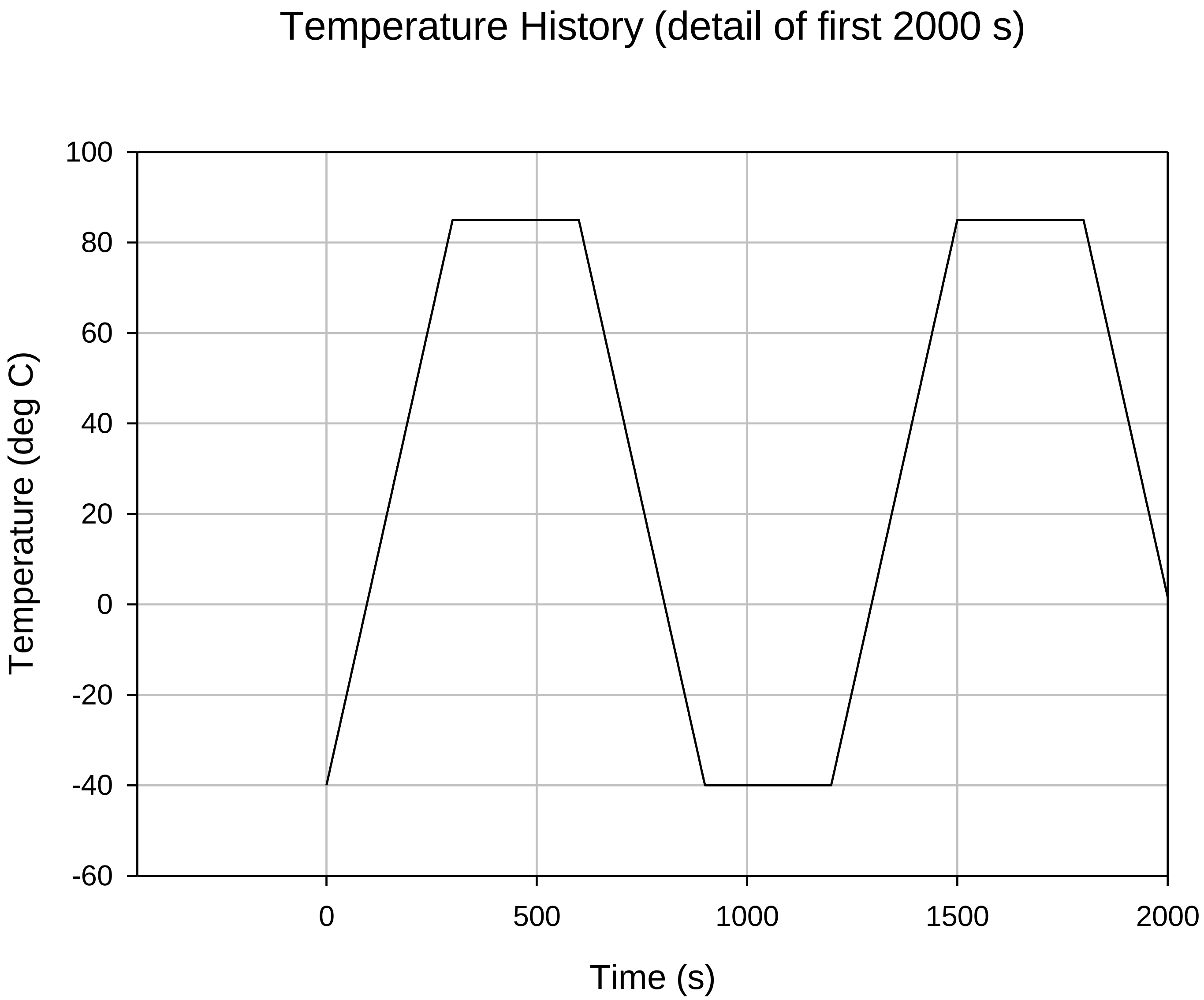
Plots of T, y, and dy/dt versus time

- The following slides show plots of T, y, and dy/dt as a function of time
  - Plots are given for 0 – 12000 s (10 cycles) and 0 – 2000 s (between 1 and 2 cycles, so that detailed behavior is more evident)
- In computing dy/dt, the value of dT/dt is taken as zero when the temperature is not changing, and 0.41666667 C/s when the temperature is changing at this rate

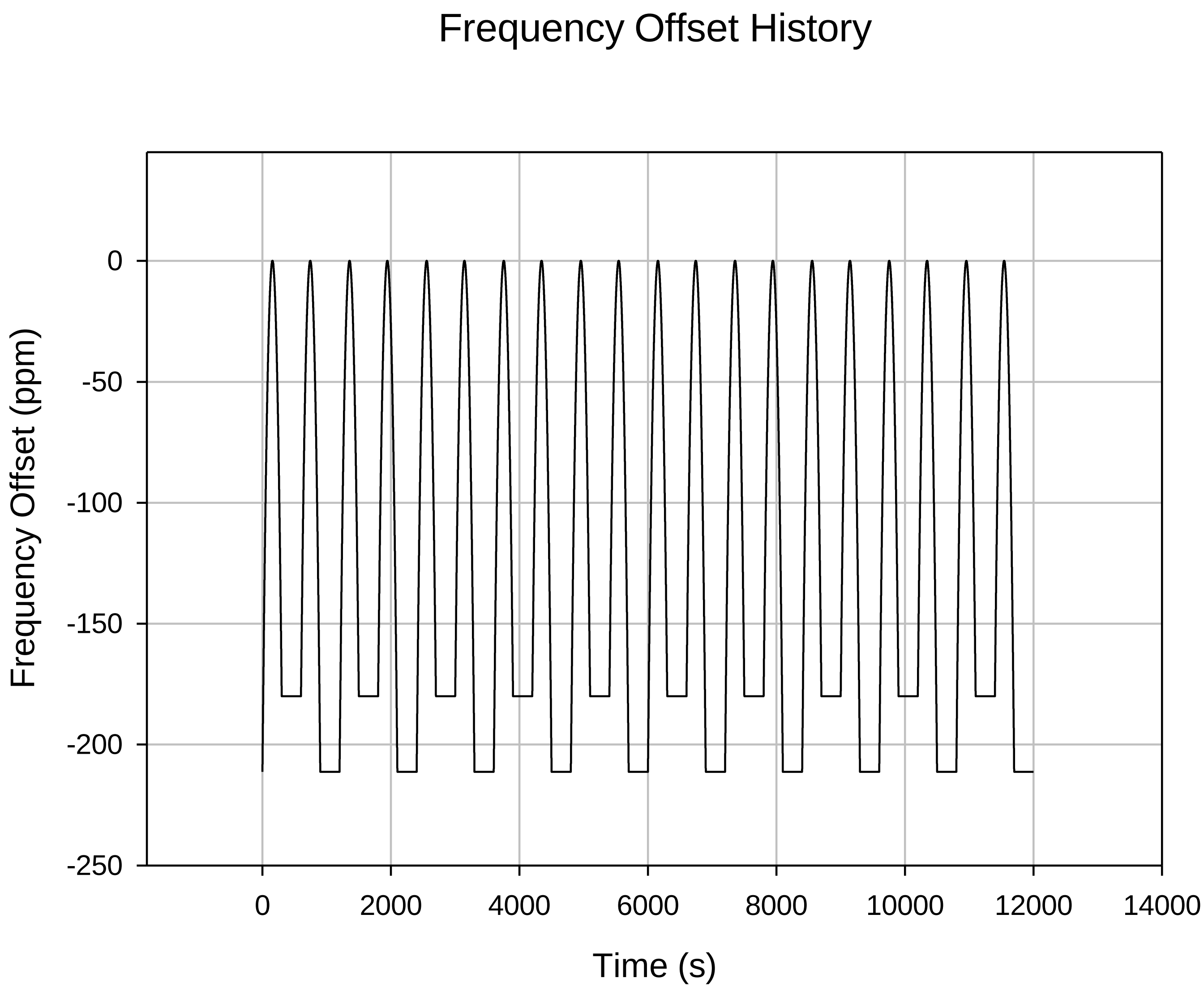
Temperature, 0 - 12000 s



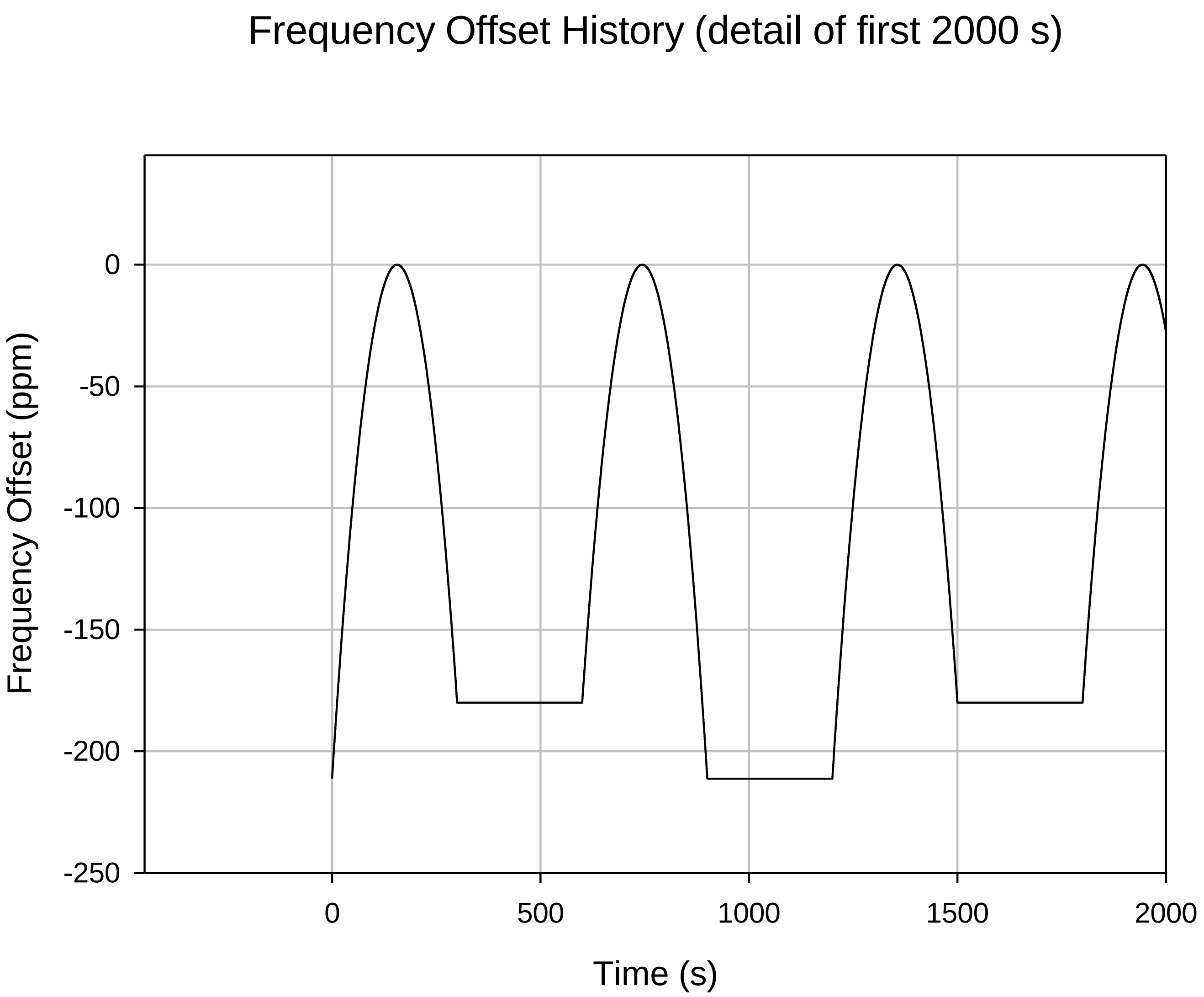
Temperature, 0 - 2000 s



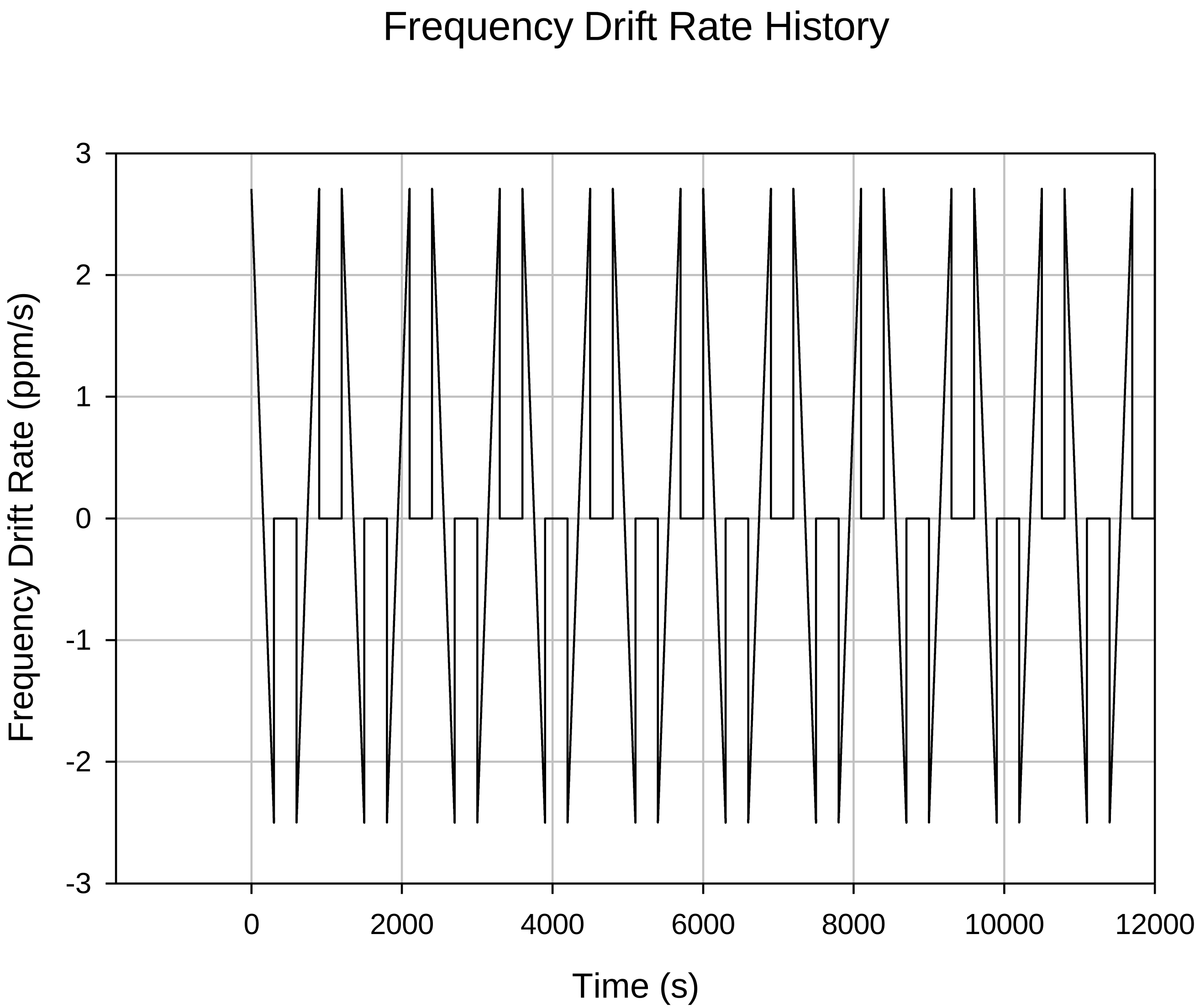
Frequency Offset, 0 - 12000 s



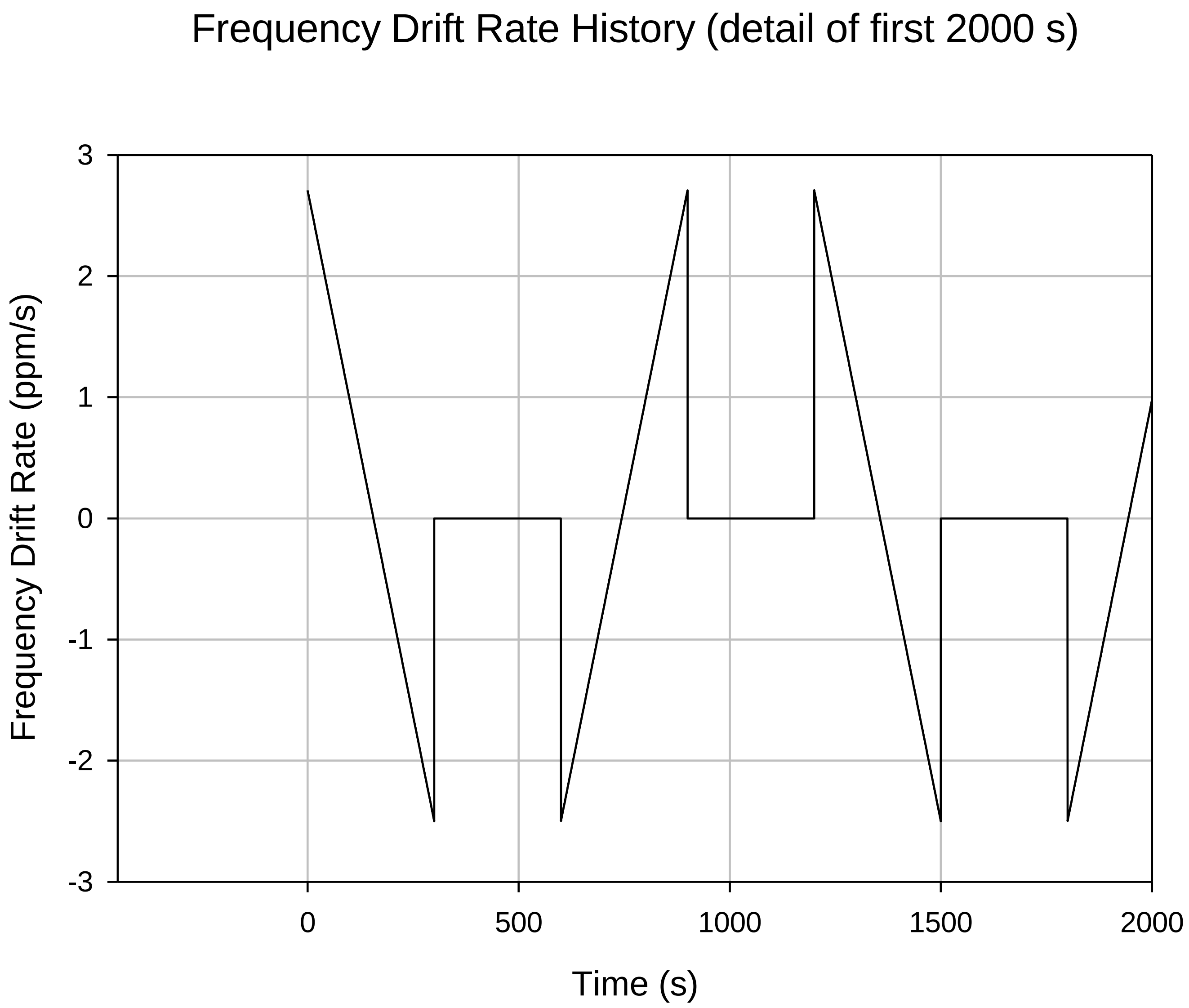
Frequency Offset, 0 - 2000 s



Frequency Drift Rate, 0 - 12000 s



Frequency Drift Rate, 0 - 2000 s



Observations

- The range of frequency offset variation is in the vicinity of 200 ppm, but is not centered as is the ±100 ppm (but the fixed offset does not matter because it is measured in 802.1AS-2020)
- The period is somewhat longer than the periods for frequency waveforms used in the simulations (the latter were slightly more than 100 s)
  - The period in this model is 1200 s, or 600 s if the flat part of the waveform is ignored
- The frequency drift is much less severe than in the simulation model; in the current presentation it is 0 half of the time and close to its extremes (approximately ±2.7 ppm/s) for relatively short periods
- The model here, at least in its current form, would be somewhat more complicated to introduce in the simulator (though it can be done).
  - Ideally, the frequency offset history would need to be integrated to obtain phase offset history

Thank you

References - 1

[1] Jordan Woods, *Concerns regarding the clock model used in 60802 timesynchronization 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)