

Limits to Frequency: The Nyquist Theorem

- Because the FID is Digitally Sampled, the Rate of Sampling Sets Limits on the Detectable Frequency
- The Sampling Rate Must be at Least Twice the Frequency of the FID. For example, to sample a 2000 Hz signal, you need to sample 4,000 times per second.

In other words, you need **two samples per cycle** of the signal you are measuring: one at each peak and one at each trough of the sine wave. This is the minimum number of samples needed to accurately measure the frequency of the signal. The frequency of the signal corresponds to the chemical shift of the NMR peak.

- The Sampling Rate is Set by the Parameter SW (Spectral Width). SW is the full width of the spectral window measured in Hz (e.g., for audio frequencies -2000 to +2000 Hz, SW is 4000).

$$\text{Sampling Rate} = 2 \times \text{SW}$$

- The Dwell Time is the delay time between successive samples (the spacing between samples in time). Dwell Time is the reciprocal of Sampling Rate:

$$\text{Dwell Time} = 1 / (\text{Sampling Rate}) = 1 / (2 \times \text{SW})$$

$$\text{Example: } \text{SW} = 4000 \text{ Hz, } \text{DW} = 1 / (8000) = 125 \mu\text{s}$$