Vibrato Effect

$$y(t) = x(t - \tau(t))$$

where $\tau(t) = T + W \sin(2\pi f_0 t)$

This is a time-varying delay

$$x(t) \longrightarrow \boxed{\text{Delay}} \longrightarrow y(t)$$

$$T - W \leq \tau(t) \leq T + W$$

- must have $T - W \geq 0$ for this system to be causal!

Discrete-Time Vibrato..

$$y(n) = x(n - \tau(n))$$

where $\tau(n) = T + W \sin(2\pi f_n n)$

f_n ↑ normalized freq.

Usually $\tau(n)$ will <u>not</u> be integer.

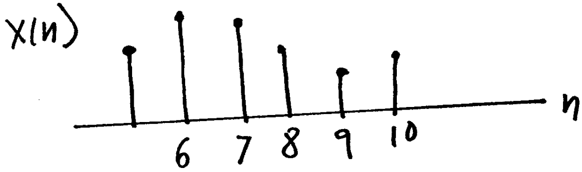
How can we evaluate $x(n-\tau)$ when τ is not an integer?

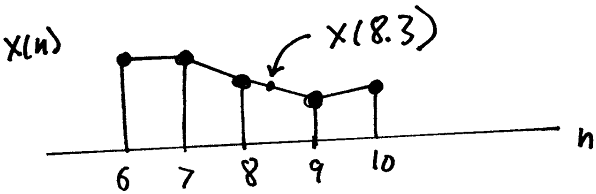
For example, how do we calculate

$x(8.3)$?

- Simple method is to round 8.3 to 8.
  use $x(8)$ instead of $x(8.3)$ which <u>does not exist.</u>

- better method: interpolation:





straight-line segments: "linear interpolation"

model x(8.3) as

$$x(8.3) = 0.7\, x(8) + 0.3\, x(9)$$

or

$$x(8.3) = (1-\alpha)\, x(8) + \alpha\, x(9)$$

or in general

$$x(n+\alpha) = (1-\alpha)\, x(n) + \alpha\, x(n+1)$$

$$\boxed{0 \le \alpha < 1}$$

$$y(n) = x(n - \tau(n))$$

$$x(n) \longrightarrow \boxed{\text{Delay } \tau(n)} \longrightarrow y(n)$$

when we use a circular buffer we need to attend to two issues:

- $\tau(n) < 0$ for any n. AVOID!

  The system will be non-causal. Actually, the program may run, but will generate artifacts.

- $\tau(n) >$ Buffer length. AVOID!

  We can not implement a delay longer than the oldest signal value in the buffer. The program may run, but will generate artifacts.