

Lecture 5 on Sampling & Reconstruction Part 1

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Audio Effects: Post Malone, "[Circles](#)", demonstrating use of delay, chorusing, and reverb in the vocals, and delay and reverb in the instruments. Play "Circles" starting at 34 seconds and ending at 60 seconds. "[Vocal Effects of Post Malone - Circles](#)".

- Reverb
- Chorusing
- Vibrato

...

Sampling Theorem

- Nyquist Rate = $2f_{\max}$
- Nyquist Frequency = $\frac{1}{2}f_s$

Slide 6-3

$$x(t) = \cos(2\pi f_{\max} t)$$

$$x[n] = x(t) \Big|_{t=nT_s} = \frac{n}{f_s}$$

$$x[n] = \cos\left(\underbrace{2\pi f_{\max}}_{\omega_{\max}} n\right)$$

$f_s = 2f_{\max}$

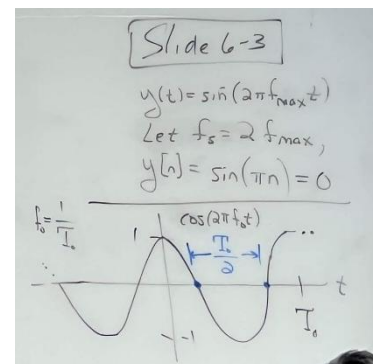
$$x[n] = \cos(\pi n) = (-1)^n$$

Highest DT freq. possible

$(-1)^n$

[Sampling & Reconstruction Demo](#)

- Rectangular Pulse/Sample-and-Hold
 - o Captures the cosine frequency correctly!
 - o Doesn't match the original signal's shape very well...
- What if we increase f_s ?
 - o More samples per period
 - o Still captures the fundamental frequency
 - o Better matching of peaks/valleys/zero-crossings
 - o Increasing f_s allows for better reconstruction of the actual signal but at a tradeoff of more samples per second and high run-time implementation complexity



Sampling of Discrete-Time Signal

- Given a sampling frequency, f_s , and a signal, x , that has frequency components equal to or greater than $f_{max} = \frac{1}{2}f_s$, how should we sample appropriately?
 - o In order to maintain the Sampling Theorem, we should filter out higher frequency components
 - o In other words, we should lowpass filter signal, x , to attenuate all frequency components greater than or equal to f_{max} (not possible to remove them)

Oversampling

- Oversample to avoid aliasing & folding effects

Undersampling

- Shifted versions of the aliased frequency
- But in Reconstruction, for this Example: we only see frequencies within $[-\pi, \pi]$
 - o This is because of the Sampling Theorem for Reconstruction

Folding by Undersampling

- Negative frequency component aliases towards positive frequency
- Positive frequency component aliases towards negative frequency

Demonstration of the Above 3 Effects

http://www.youtube.com/watch?v=uENITui5_jU&feature=share

