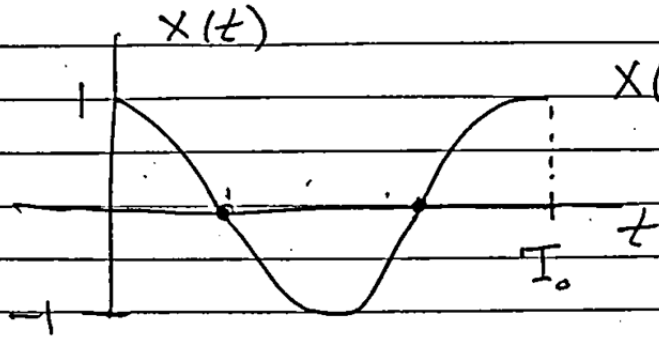
[11:00-11:35] Continuation of Lecture 1: Sampling and sound in MATLAB

Lecture Slide 1-13

EE313
August 28, 2025



$x(t) = \cos(\underbrace{2\pi f_0 t}_{\text{angle } \theta})$

periodicity every 2π

$t=0: \; x(0) = \cos(2\pi f_0 (0)) = 1$

$\cancel{2\pi} f_0 t = \cancel{2\pi} \rightsquigarrow t = \frac{1}{f_0} = T_0$

Fundamental period is $T_0 = \frac{1}{f_0}$

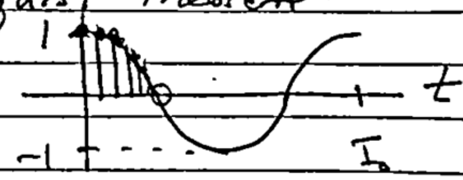
Next step is to sample x(t) at uniformly spaced points in time to create a vector of amplitude values

Choose a sampling rate $f_s = \frac{1}{T_s}$

[Hz] [s]

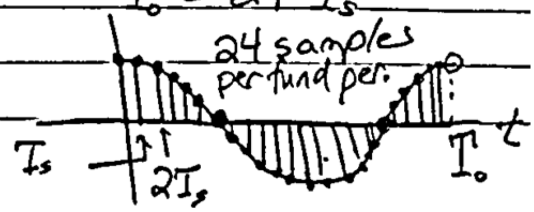
Guidance on choosing the sampling rate is from the Nyquist Theorem

$f_s > 2 f_0$



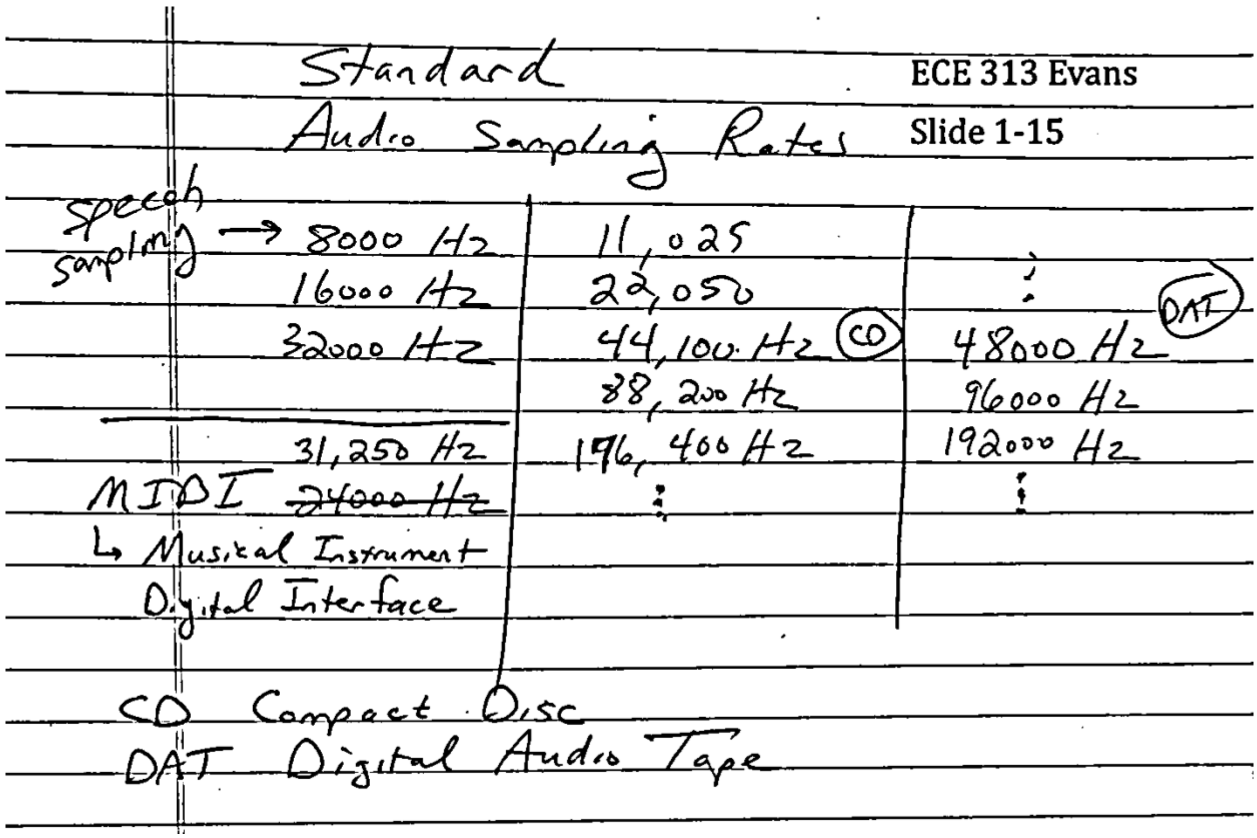
E.g. Pick $f_s = 24 f_0$

$\frac{1}{T_s} = 24 \frac{1}{T_0} \rightsquigarrow T_0 = 24 T_s$



To reconstruct a frequency f, a signal must be sampled at a rate strictly greater than $2f$.

It's common to sample much higher than $2f$. Audio is often sampled at 48,000 Hz or higher, even though the maximum audible frequency is between 15,000 Hz and 17,000 Hz for most adults.



MATLAB's `sound(x)` command will play an audio signal represented by an array `x` using the default sample rate of 8192 Hz. A different sampling rate fs can be specified using `sound(x,fs)`, in which case MATLAB will automatically [resample](https://) the sound to a rate that is compatible with the computer's sound system.

The `soundsc` command will scale the range of the signal to [-1, 1] prior to playing it. This increases the volume of small amplitude signals and prevents clipping when playing a signal whose amplitude exceeds the range [-1,1].

[11:35 – 12:05] Systems

Systems operate on one or more input signals to produce one or more output signals.

Examples:

Averaging a continuoussignal with a one-second delayed version of itself:

$$y(t) = \frac{1}{2}x(t) + \frac{1}{2}x(t-1)$$

Discrete time low-pass averaging filter:

$$y[n] = \frac{1}{2}x[n] + \frac{1}{2}x[n-1]$$

Squaring block:

$$y(t) = x(t)^2$$

The squaring block is nonlinear and changes the frequency or frequencies of the input signal $x(t)$. The output $y(t)$ of the squaring block contains:

- Double the frequency (or frequencies) of $x(t)$
- A DC offset (zero Hertz)

[11:55-12:05] Lecture 2: Periodic signals

A signal $x(t)$ is periodic with period T if $x(t - nT) = x(t)$ for any integer n.

A periodic signal can have multiple periods. The smallest positive period is the fundamental period.

Time shift and phase shift

A common system involves shifting a signal $x(t)$ in time by T seconds. If T is positive, this system is also called a delay.

$$D_T\{x(t)\} = x(t-T)$$

For sinusoids, a time shift causes a phase shift:

$$D_T\{A\cos(2\pi f_0 t)\} = A\cos(2\pi f_0(t-T)) = A\cos(2\pi f_0 t - 2\pi f_0 T)$$

Phase shifts are commonly used in wireless communications, sonar, and radar systems to separate signals spatially.