

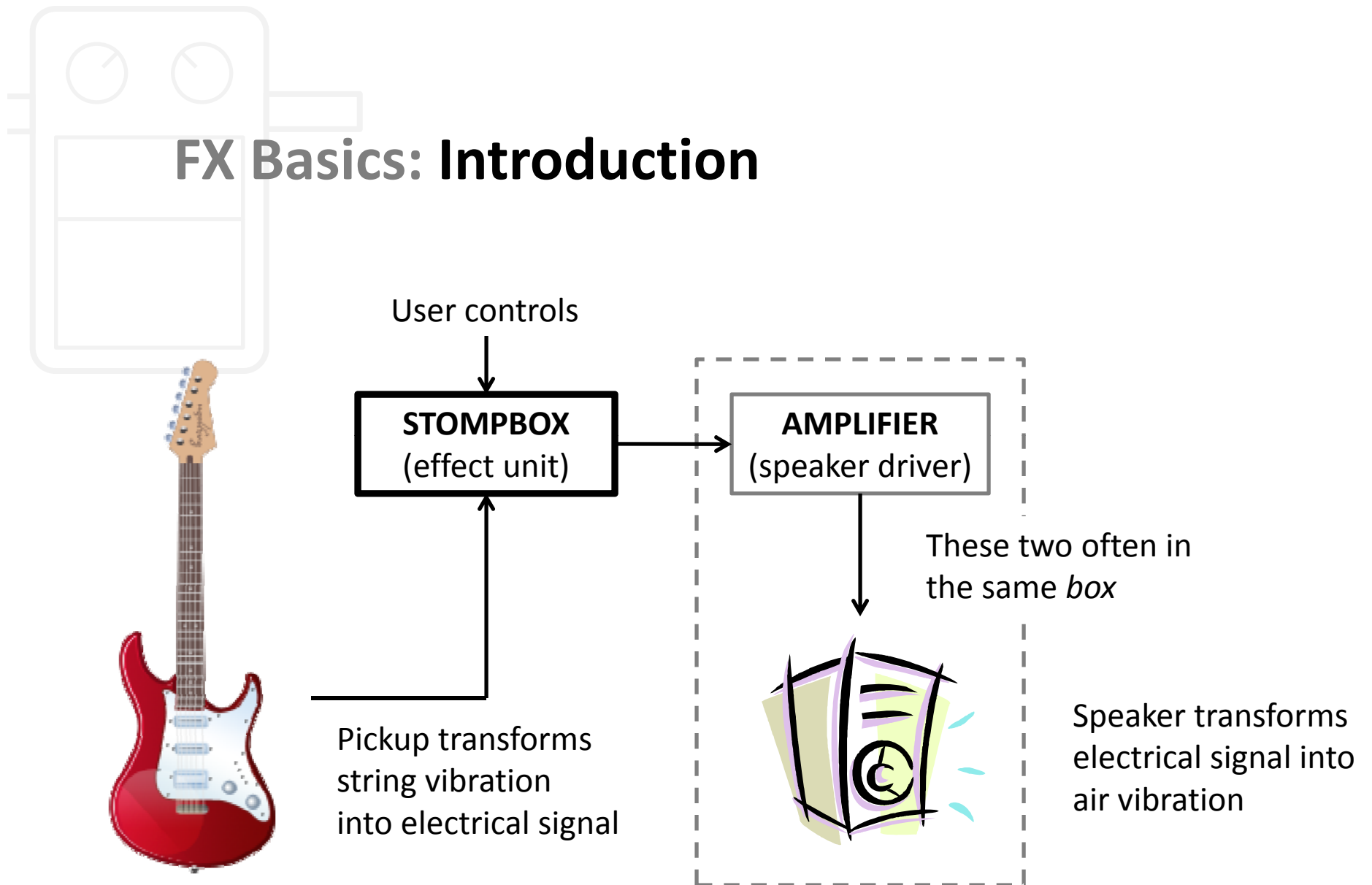
FX Basics
Introduction

STOMPBOX DESIGN WORKSHOP

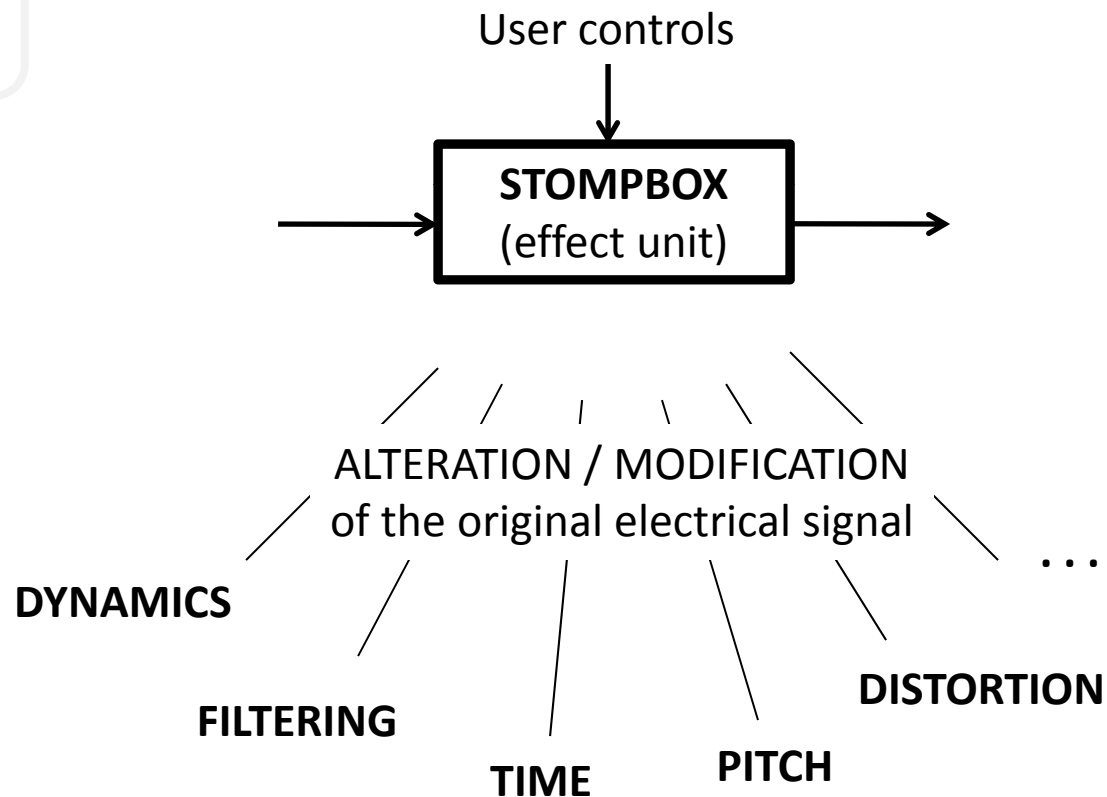
Esteban Maestre

CCRMA - Stanford University
July 2011

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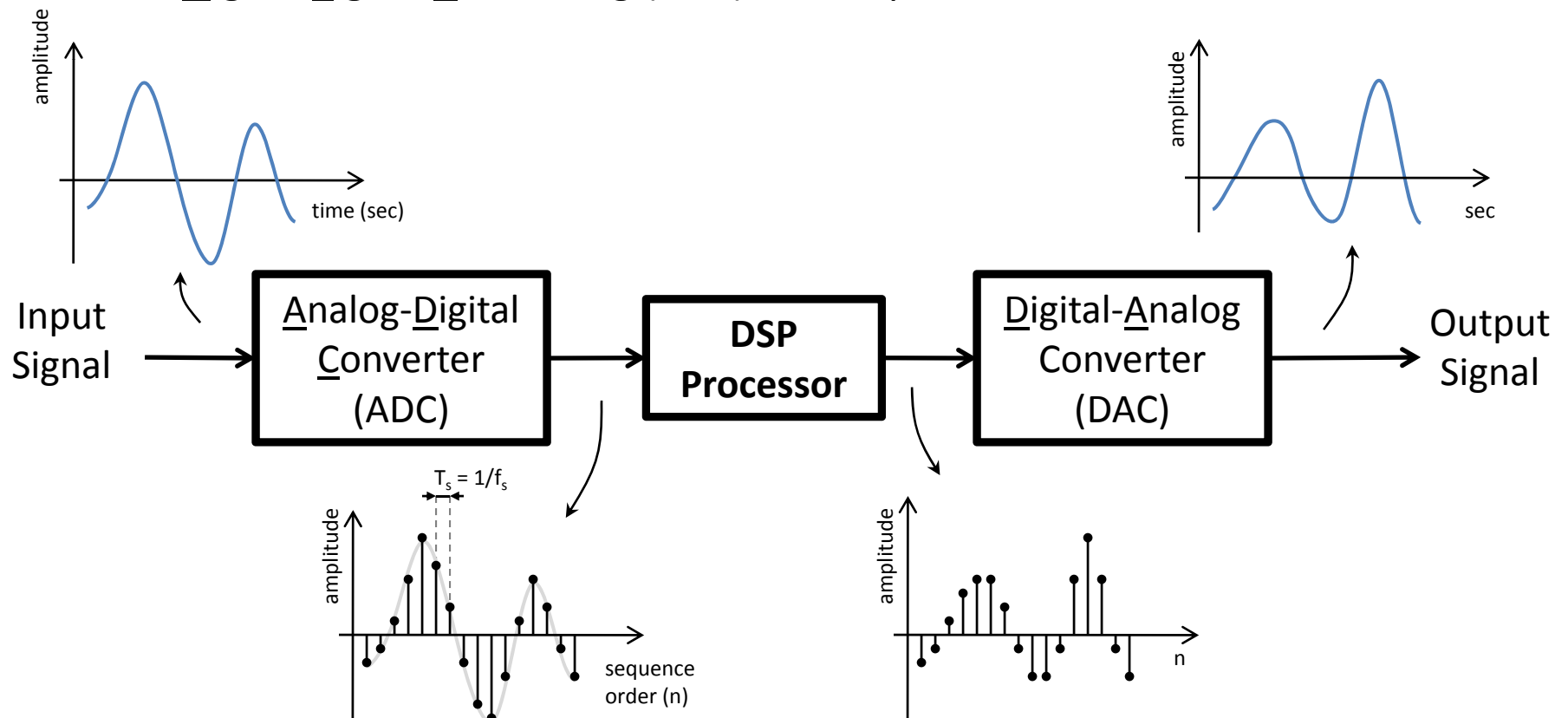


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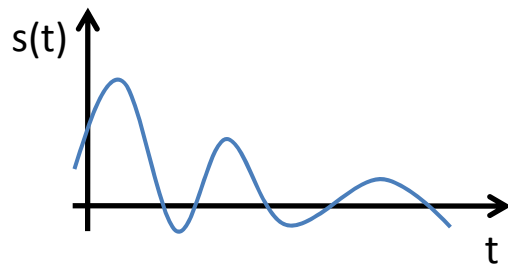
Stompboxes traditionally operated in the analog domain. Here we will work with signals in the digital domain, by means of Digital Signal Processing (**DSP**) techniques.



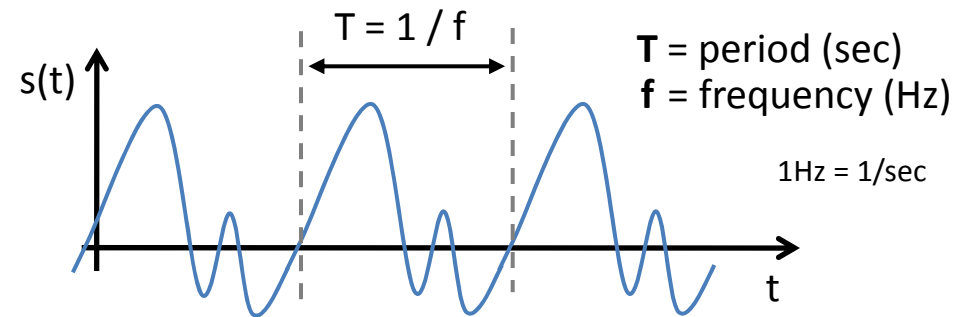
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SIGNAL | PERIODIC SIGNAL

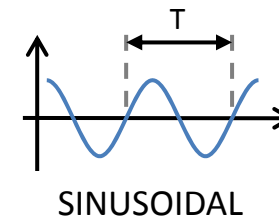
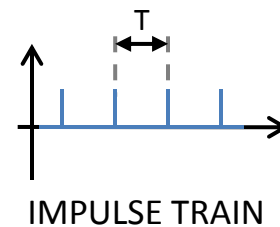
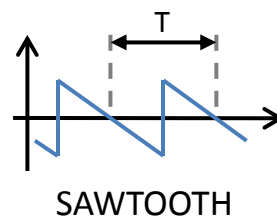
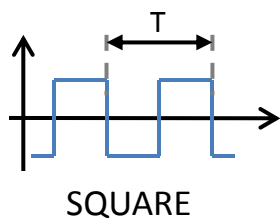
Signal: function of time, representing a given magnitude



Periodic Signal: signal whose value profile repeats over time: $s(t+T) = s(t)$

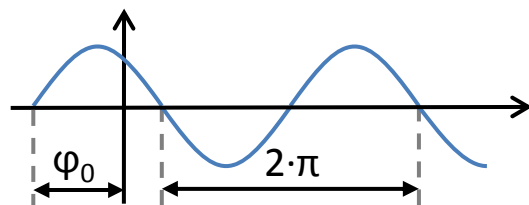
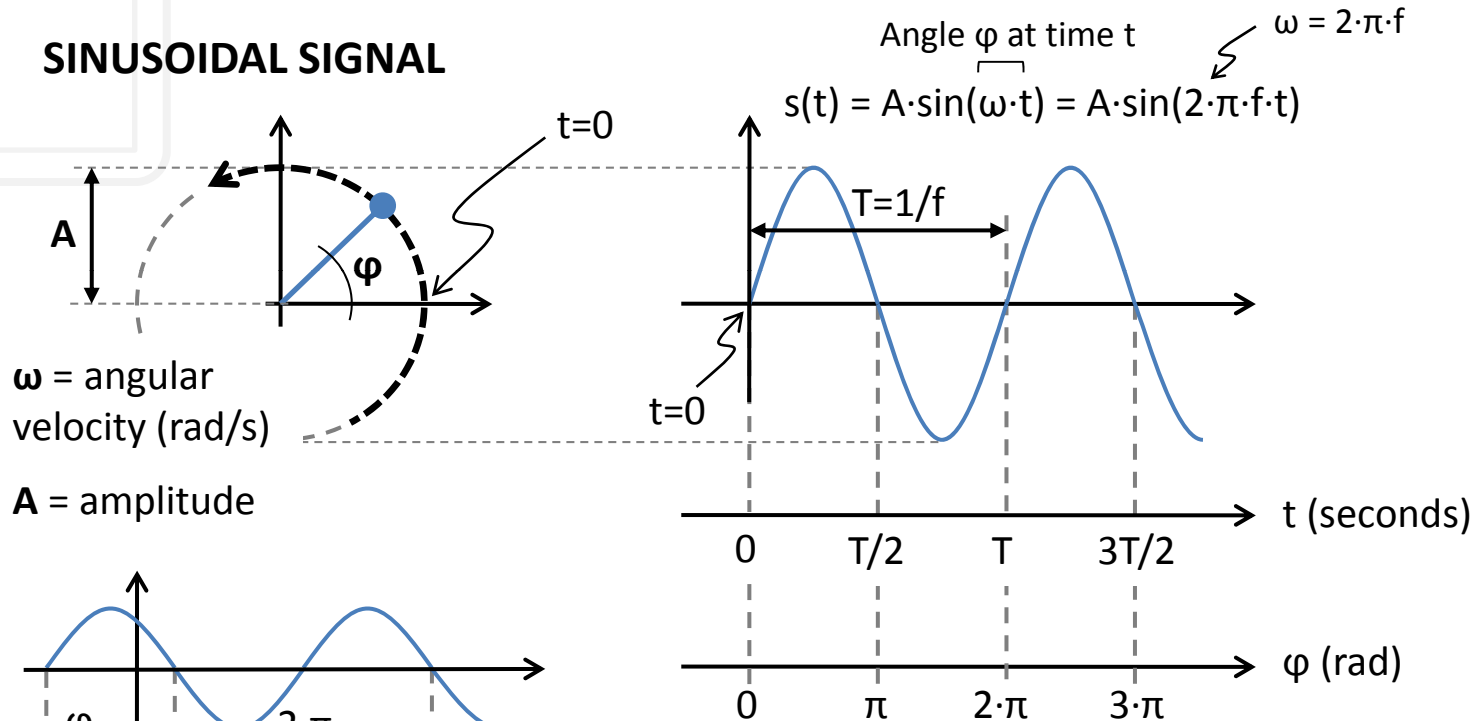


Some examples of basic periodic signals:



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SINUSOIDAL SIGNAL

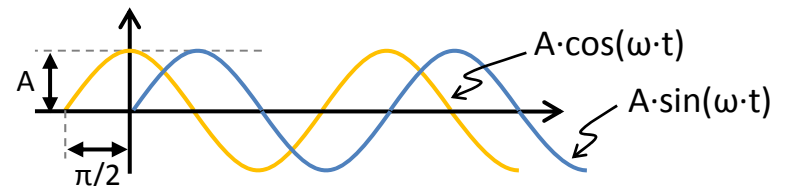


$\varphi_0 = \text{phase (initial } \varphi \text{ at time } t = 0)$

Angle φ at time t

$$s(t) = A \cdot \sin(\omega \cdot t + \varphi_0) = A \cdot \sin(2 \cdot \pi \cdot f \cdot t + \varphi_0)$$

$$A \cdot \cos(\omega \cdot t) = A \cdot \sin(\omega \cdot t + \pi/2)$$



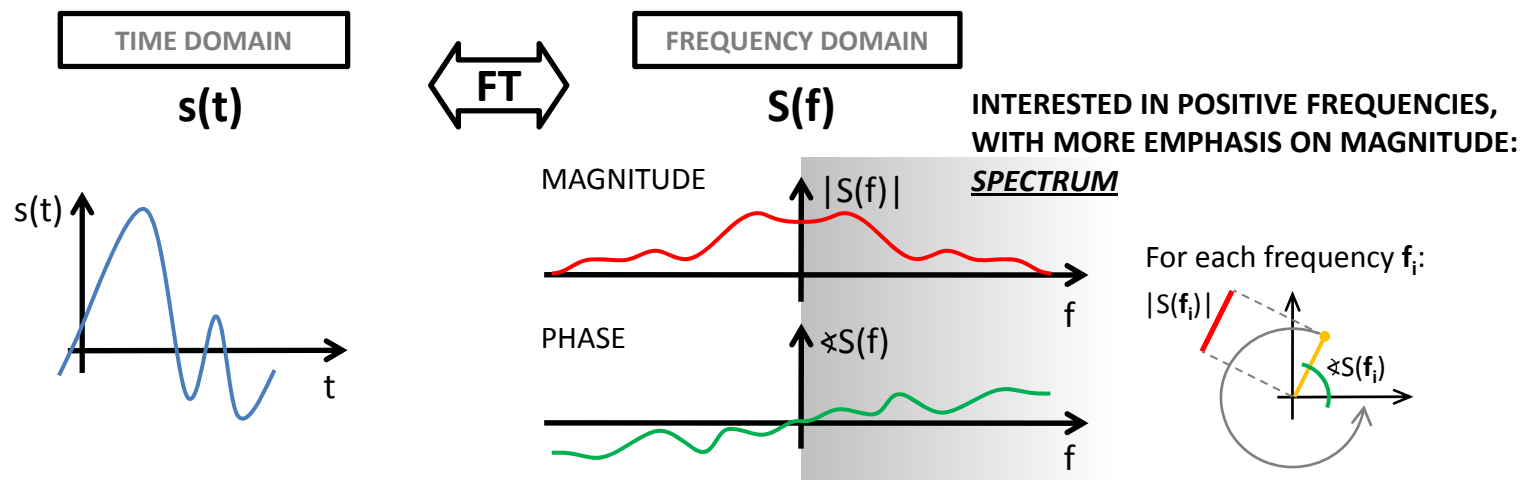
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FOURIER ANALYSIS | FREQUENCY DOMAIN

Any function of time can be expressed as an **infinite sum of sinusoidal functions** of different frequencies, each function with a particular **amplitude** and **phase**.

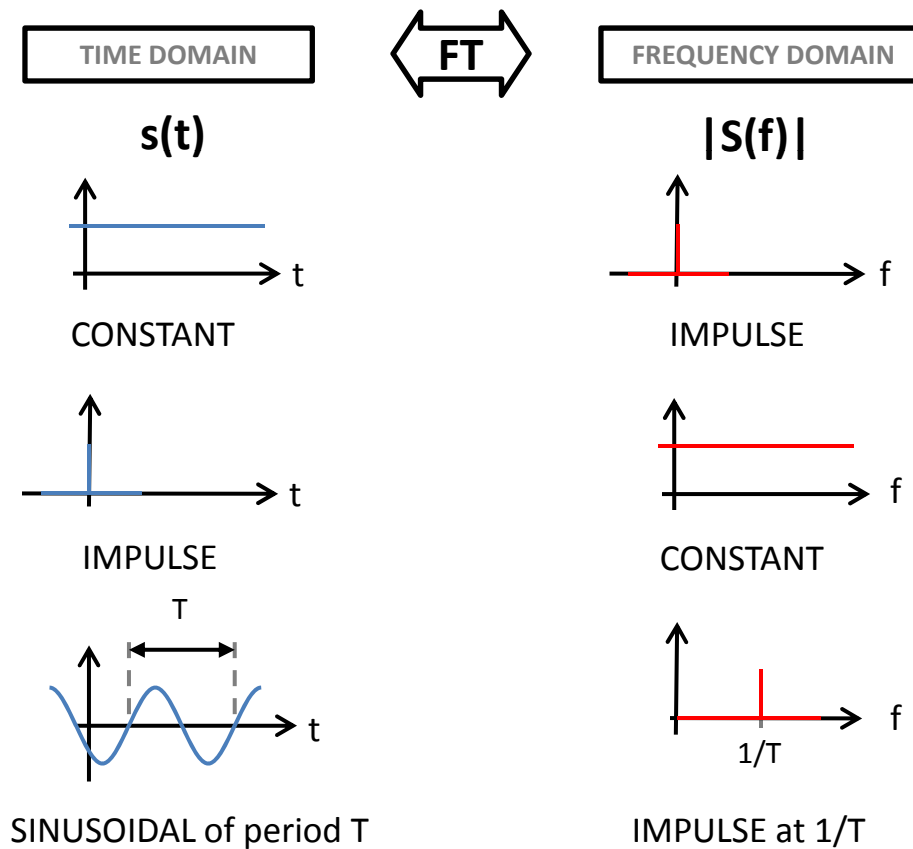
Such function, previously expressed in the **Time Domain**, can therefore be expressed in the **Frequency Domain**.

The **Fourier Transform (FT)** is a **mathematical operator** that allows to go from Time Domain to Frequency Domain and vice-versa:



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FOURIER TRANSFORM OF IMPORTANT SIGNALS

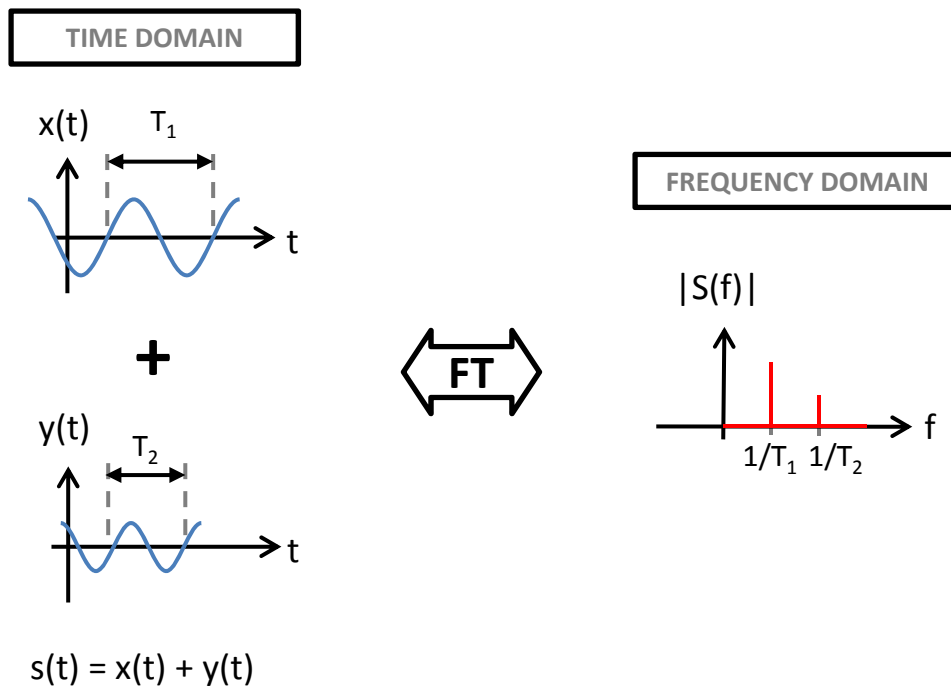


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LINEARITY

The **Fourier Transform**, $F[\cdot]$, is a **linear operation**:

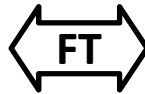
$$F[a \cdot x(t) + b \cdot y(t)] = a \cdot F[x(t)] + b \cdot F[y(t)]$$



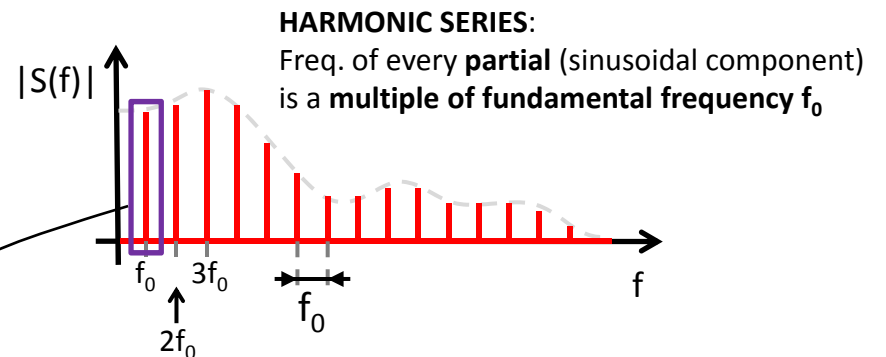
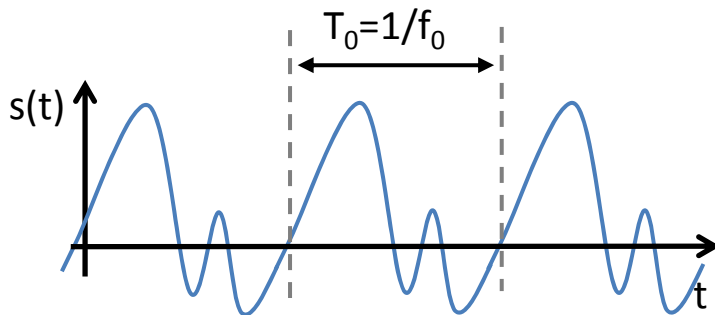
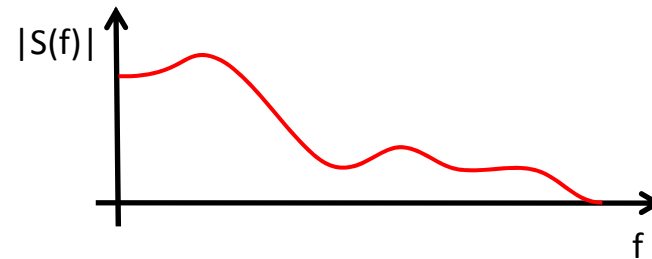
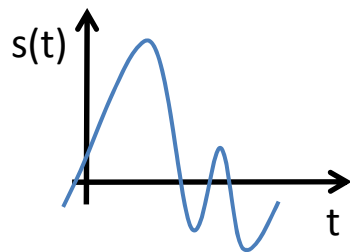
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FOURIER TRANSFORM OF PERIODIC SIGNALS

TIME DOMAIN



FREQUENCY DOMAIN



HARMONIC SERIES:

Freq. of every **partial** (sinusoidal component) is a **multiple of fundamental frequency f_0**

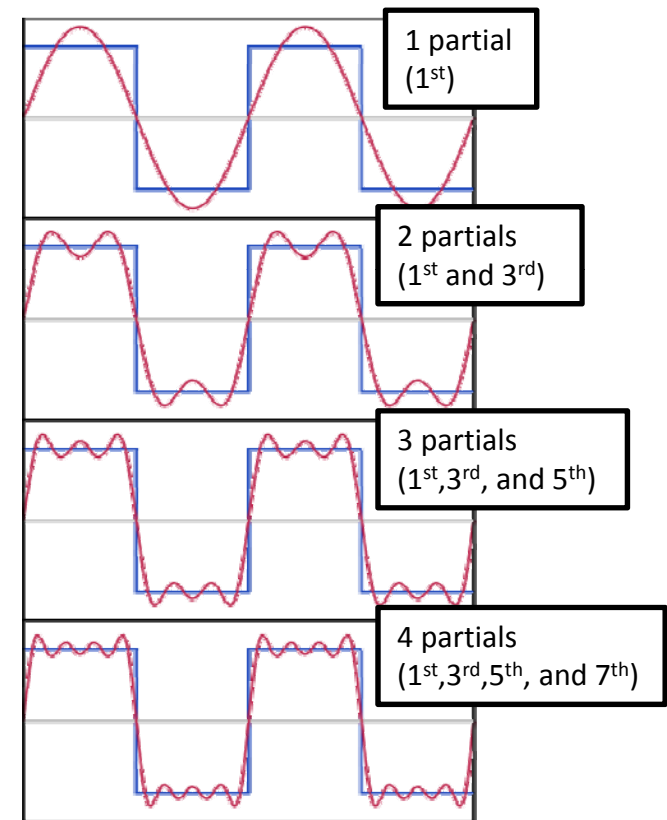
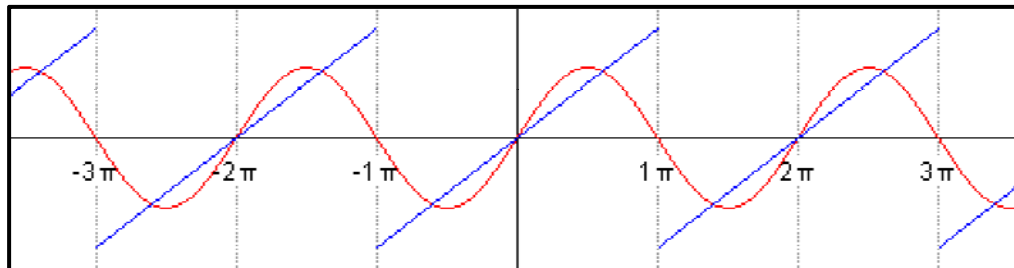
This partial should correspond to the main oscillation

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EXAMPLE

Reconstruction of periodic signals using finite number of partials / harmonics.

— ORIGINAL SIGNAL
— RECONSTRUCTED

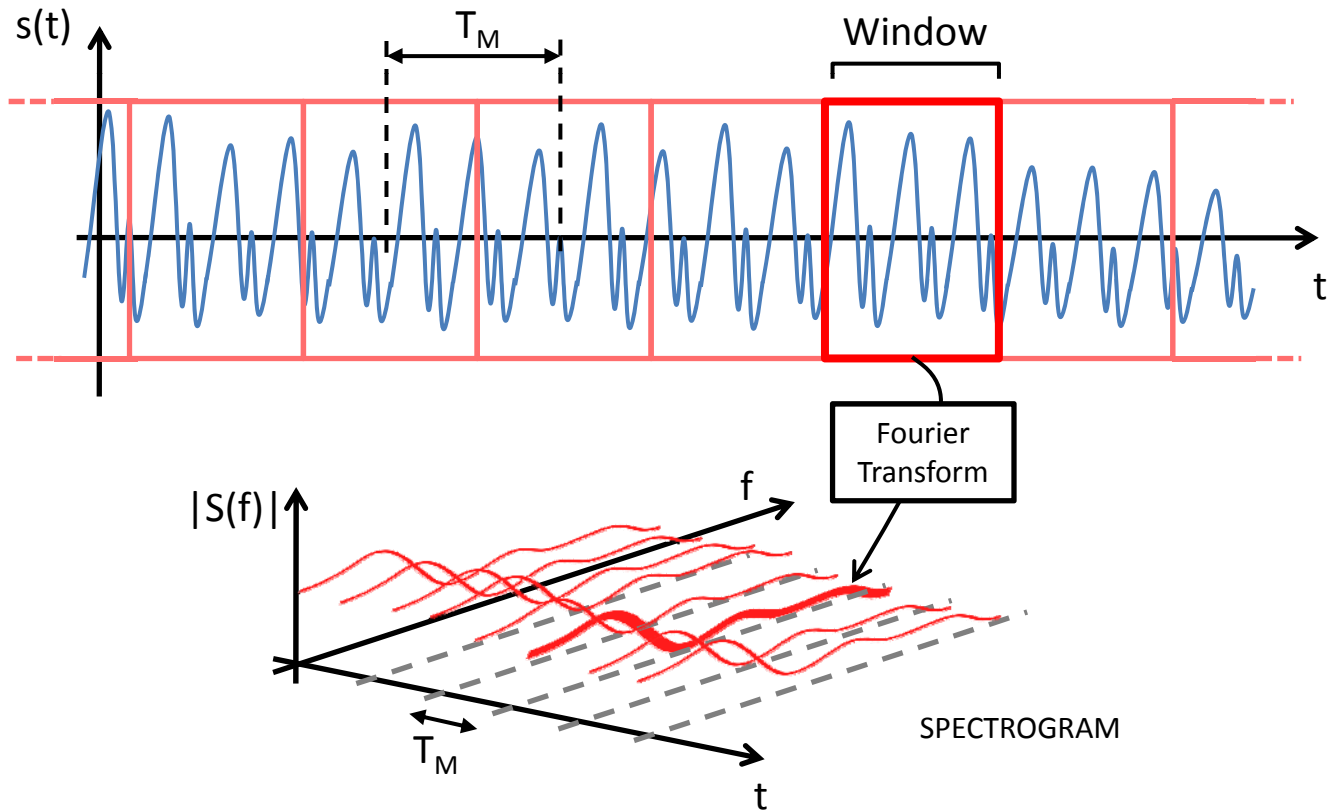


<http://www.youtube.com/watch?v=Lu2nnvYORec>
<http://www.youtube.com/watch?v=SpzNQO0BeRg>

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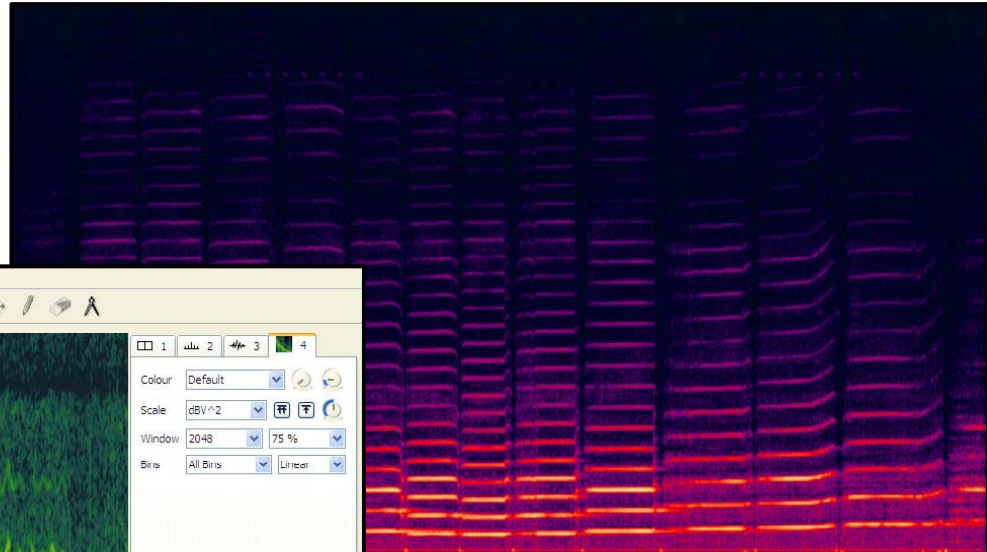
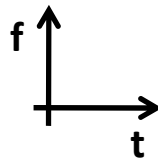
SHORT-TIME FOURIER TRANSFORM | SPECTROGRAM

Time sequence frequency domain representations

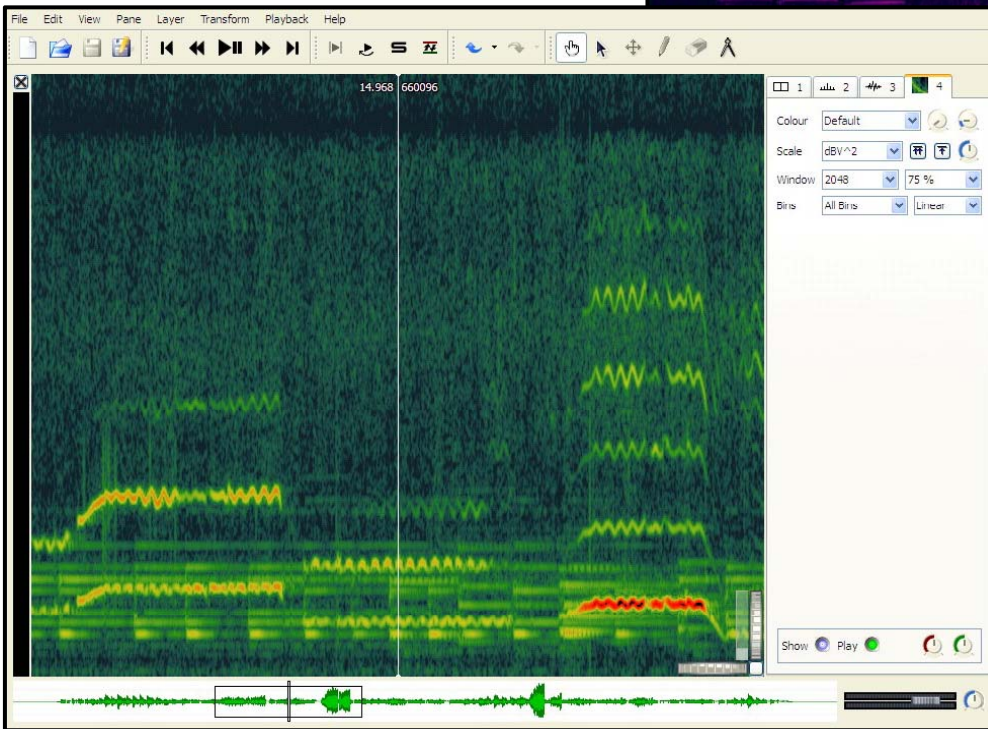


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EXAMPLE
SPECTROGRAMS



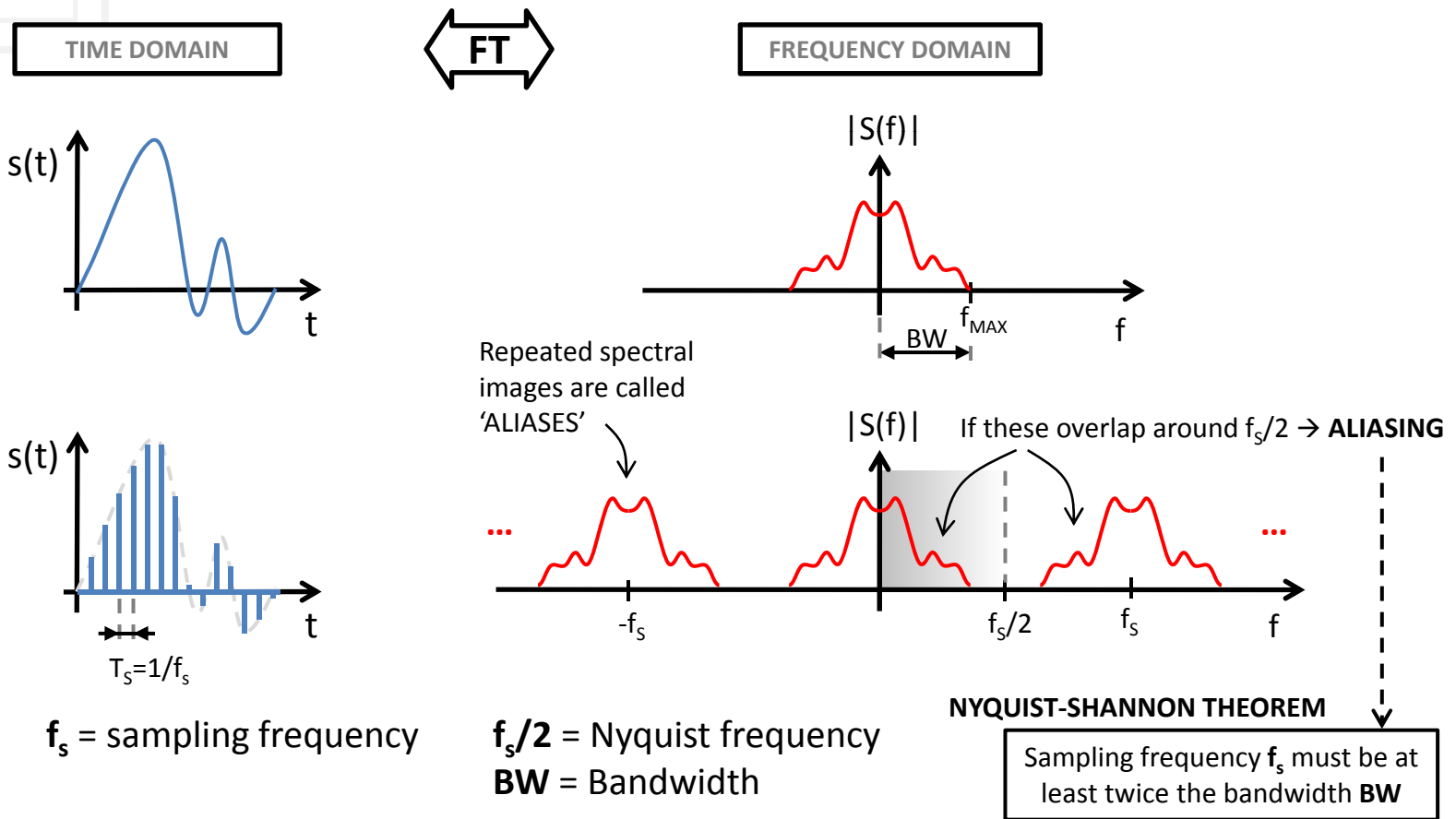
CELLO PLAYING LOW NOTES
LOW FUNDAMENTAL FREQUENCY
NO VIBRATO



SOPRANO SINGING VOICE (in very old recording)
HIGH FUNDAMENTAL FREQUENCY
VIBRATO [software *SonicVisualizer*]

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FOURIER TRANSFORM OF SAMPLED SIGNALS



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DECIBELS | LOGARITHMIC SCALES

decibel (dB)

[1920s - *Bell Labs* defined it to measure losses in telephone cable]

Logarithmic unit indicating the ratio of a physical quantity (power or intensity) relative to a specified/implied reference level:

- Power units (e.g. Watts): $L_{dB} = 10 \cdot \log_{10}(P/P_{ref})$
- Amplitude units (e.g. Volts): $L_{dB} = 20 \cdot \log_{10}(V/V_{ref})$

→ Logarithmic scales (intensity and frequency) are more representative of **human perception**.

