Hand-in Assignment #1: Fundamental of Acoustics

7LS8M0: Architectural Acoustics

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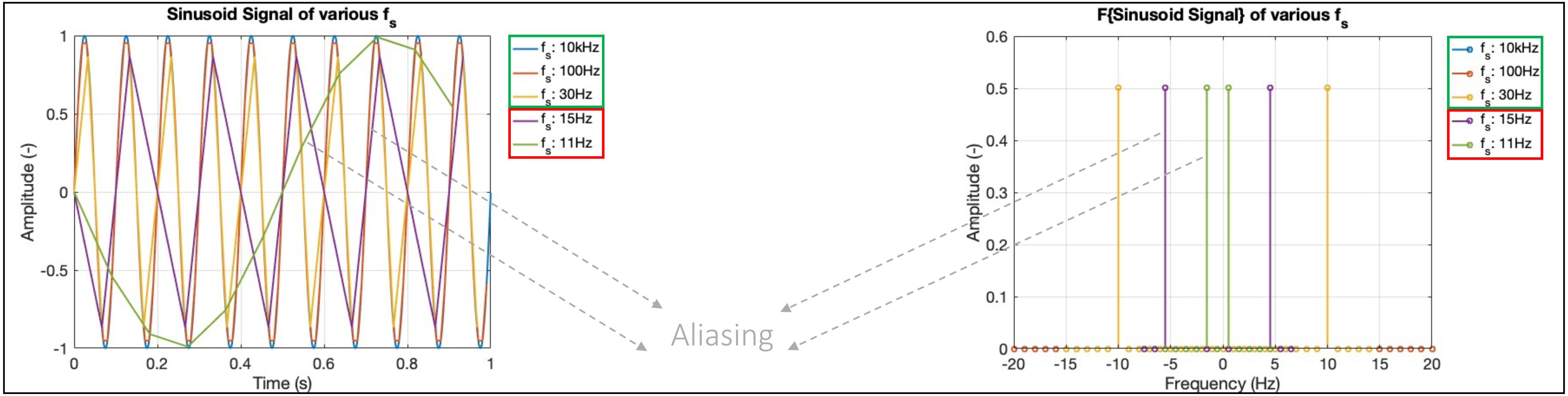
Building Acoustic Group

What did we see in the digital signal processing (DSP) tutorial?

Discretization of Signals

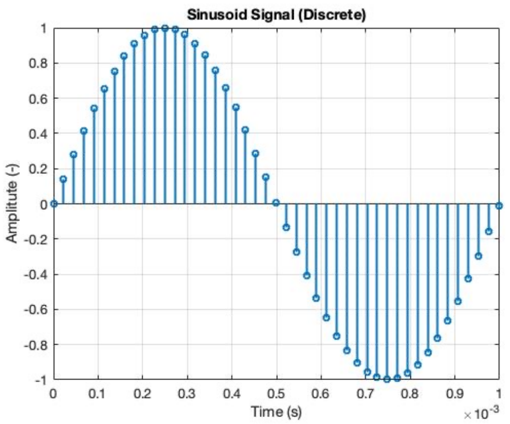
- Proper sampling of continuous signals is associated to the Shannon-Nyquist theorem, so that $f_s > 2 \cdot f_{max}$.
- Aliasing is associated to the non-proper sampling of the continuous signals, corresponding to $f_s < 2 \cdot f_{max}$
- Highest (maximum) representative frequency in a discrete singal is the Nyquist frequency, $f_N = f_{max} = f_s/2$.
- Quantization is also sampling but in the amplitude of the sampled signal ($\Delta = 2^N$ where, N: Bits).

$s[t] = sin(2\pi 10t)$, where $t = [0: T_s: 1 - T_S]$



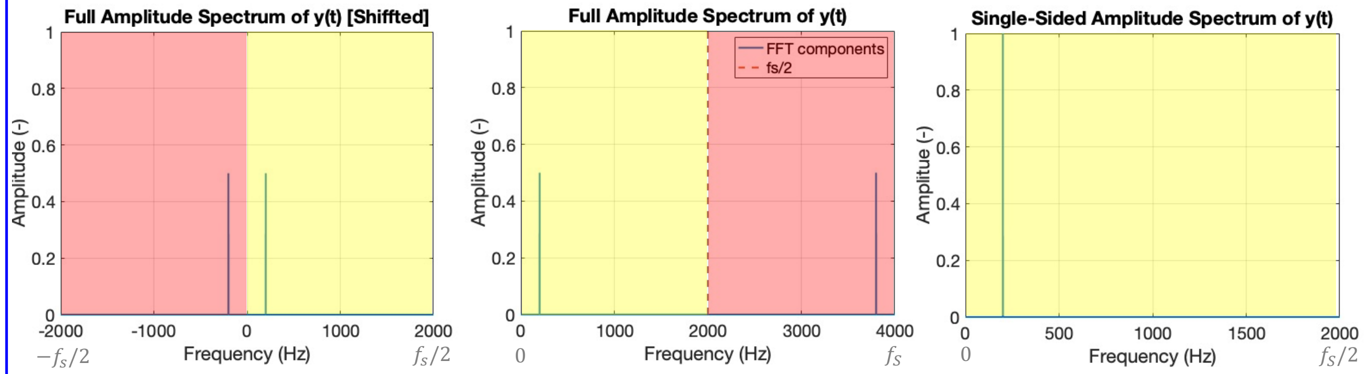
Transformation of Signals From Time Domain To Frequency Domain

- Fourier Transform: Orthonormal-base transformation of time-based signal to frequency-based signals.
- Extraction: Frequency response and components (magnitude and phase components per frequency).
- Discrete Fourier Transform is used in discrete signal, influenced on their length.
- Discontinuities (distortion) in the time signals influence the frequency response (leakage).
- Reconstruction of time signal from frequency response via the Inverese Fourier Transform.



Discrete Signal: $s[t]$

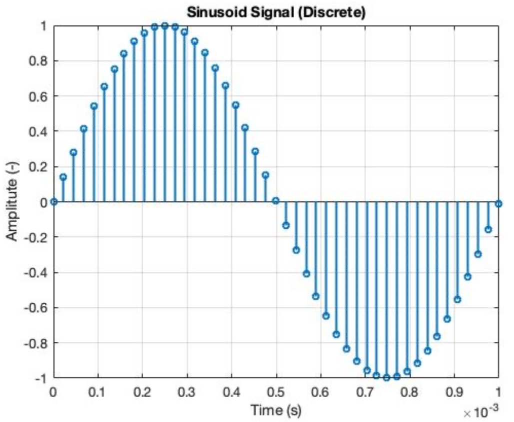
Default Output Range



$|fftshift(fft(s[t]))|$ $\quad$ $|fft(s[t])|$ $\quad$ $2 \cdot |fft(s[t(0{:}\,f_s/2)])|$

Magnitude Response: $|S[f]|$

Frequency Response: $S[f] = fft(s[t])$



Discrete Signal: $ifft(S[f])$

CD-based Quiz

The sampling fequency of the CD is $f_s = 44100Hz$, and your favorite sound in a track is 5 seconds.

- How many samples your favorite sound contain and what is the step between two samples?

f_s is in Hz(=1/sec) and indicates samples per seconds. Hence,

Total Samples $= 5\text{sec} \cdot 44100 \frac{\text{samples}}{\text{sec}} = 220500 \text{ samples}$ and $T_S = \frac{1}{f_s} = \frac{1}{44100} = 2.2676e - 05 \text{ sec} \approx 0.22\mu \text{ sec}$.

- Your favorite sound provides the values related to amplitude. How would you define the time vector, so that the time in the respective values to be extracted?

$t = [0: T_s: 5sec - T_s]$ or $t = [0: T_s: (\text{length}(\text{sound}) - 1) \cdot T_s]$.

- How many values the t vector should contain?

$220500 \text{ time values}$.

- What is the maximum frequency which can be properly reproduced from the CD?

$$f_{max} = f_N = \frac{f_s}{2} = \frac{44100}{2} = 22050 = 22.05kHz.$$

Assignment HA1

Assignments Instructions

- Report
  - No-need of including theoretical background or repeating the questions writen in the guideline.
  - Include the plots in a high quality.
  - Answer the questions in a motivated way.
- Report structure (proposal)
  - Introduction (in-short): What is the purpose of the assignment.
  - Tasks: with a short description + answers.
  - Conclusion (in-short): Summary of the main reamarks with respect to the purpose of the assignment.
  - References.
  - Appendix: MATLAB codes, including comments.

Evaluation Criteria

Introduction to Tutorials

Assignments Evaluation Criteria

- MATLAB-based Assignments
  - Clear structure and language in the report.
  - High quality of references and correct citation.
  - Correct approach and results.
  - Clear and well illustrated figures, including all the information (i.e., title, axes labels, and legends).
  - Correct implementation in MATLAB.
  - Inclusion of explanation comments in MATLAB.
  - Correct intepretation of the results supported by literature.
- Concept Presentation Assignment
  - To be announced later.

Tasks of the Assignments

- Discrete (Time) Signals
  - Generation of simple sinusoidal signals.
  - Distortion of simple sinusoidal signals.
  - Generation of complex signals based on simple sinusoids.
  - Reading audio files.
- From Time Domain to Frequency Domain
  - Frequency response (magnitude reponse) of simple sinusoidal signals.
  - Frequency response (magnitude reponse) of distorted simple sinusoidal signals.
  - Frequency response (magnitude reponse) complex signals based on simple sinusoids.
  - Frequency response (magnitude reponse) audio files.
  - Representations of magnitude responses in Acoustics.
- From Frequency Domain (Back) to Time Domain.
  - Inverese Fourier Transformation of a the frequency response of a simple sinusoidal signal.

Representations of magnitude responses in Acoustics

Introduction to Digital Signal Processing

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How the magnitude response is used in Acoustics?

- Continuous magnitude response:

$$|S(f)|_{Pa} = 2\times|S(f)|\ ,\ f\in\left[0,\frac{f_s}{2}\right]$$

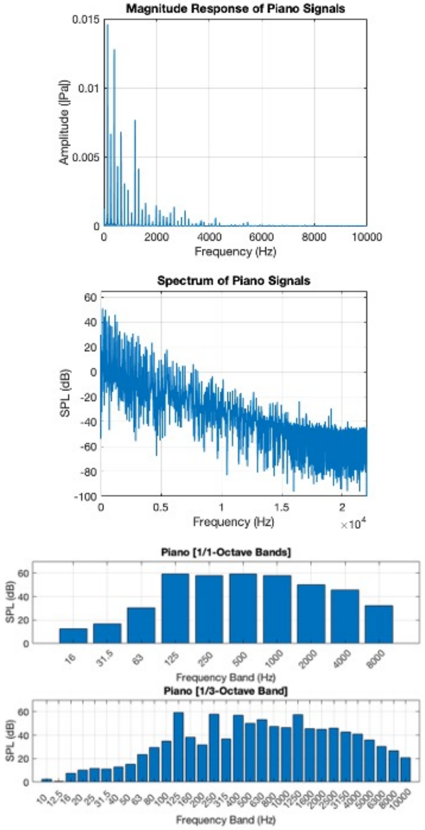
- Continuous, sound pressure level (SPL), magnitude response:

$$|S(f)|_{dB} = 10\log_{10}\left(\frac{2\times\left|\tilde{S}(f)\right|^2}{p_{ref}^2}\right), f\in\left[0,\frac{f_s}{2}\right]$$

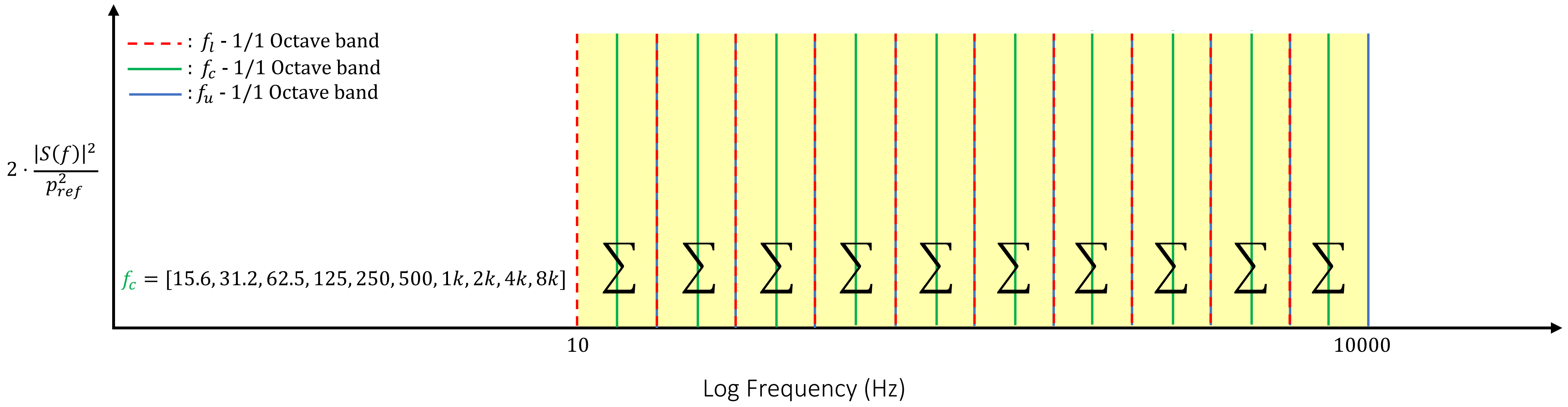
- Discrete, sound pressure level (SPL), magnitude response:

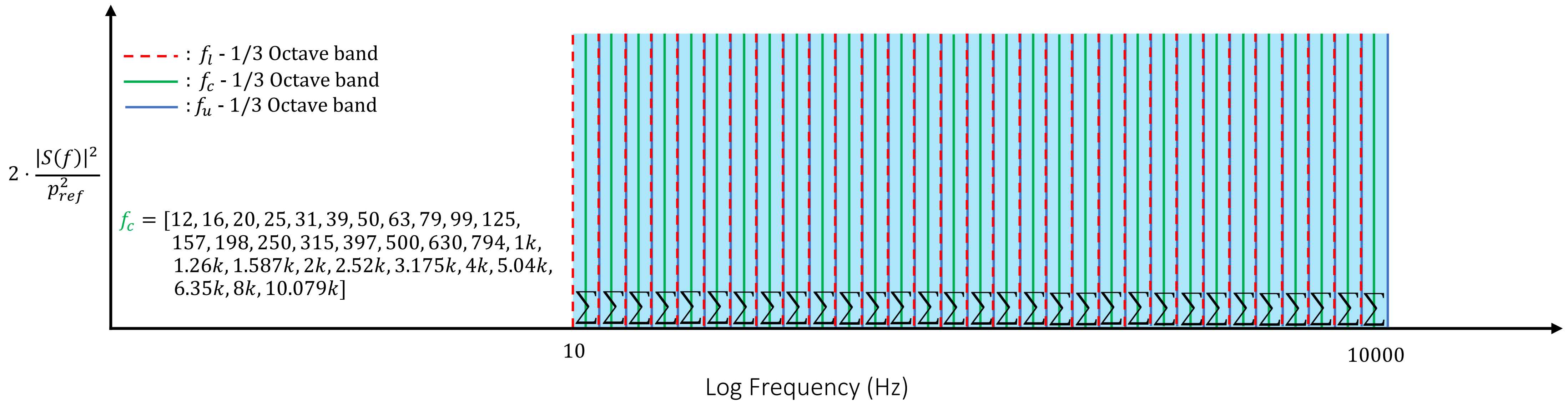
$$\tilde{S}(f) = \frac{S(f)}{\sqrt{2}}$$

$$|S(f)|_{n^{th}-oct,dB} = 10\log_{10}\sum_{f_l}^{f_u}\left(\frac{2\times\left|\tilde{S}(f)\right|^2}{p_{ref}^2}\right), f\in\left[0,\frac{f_s}{2}\right]$$

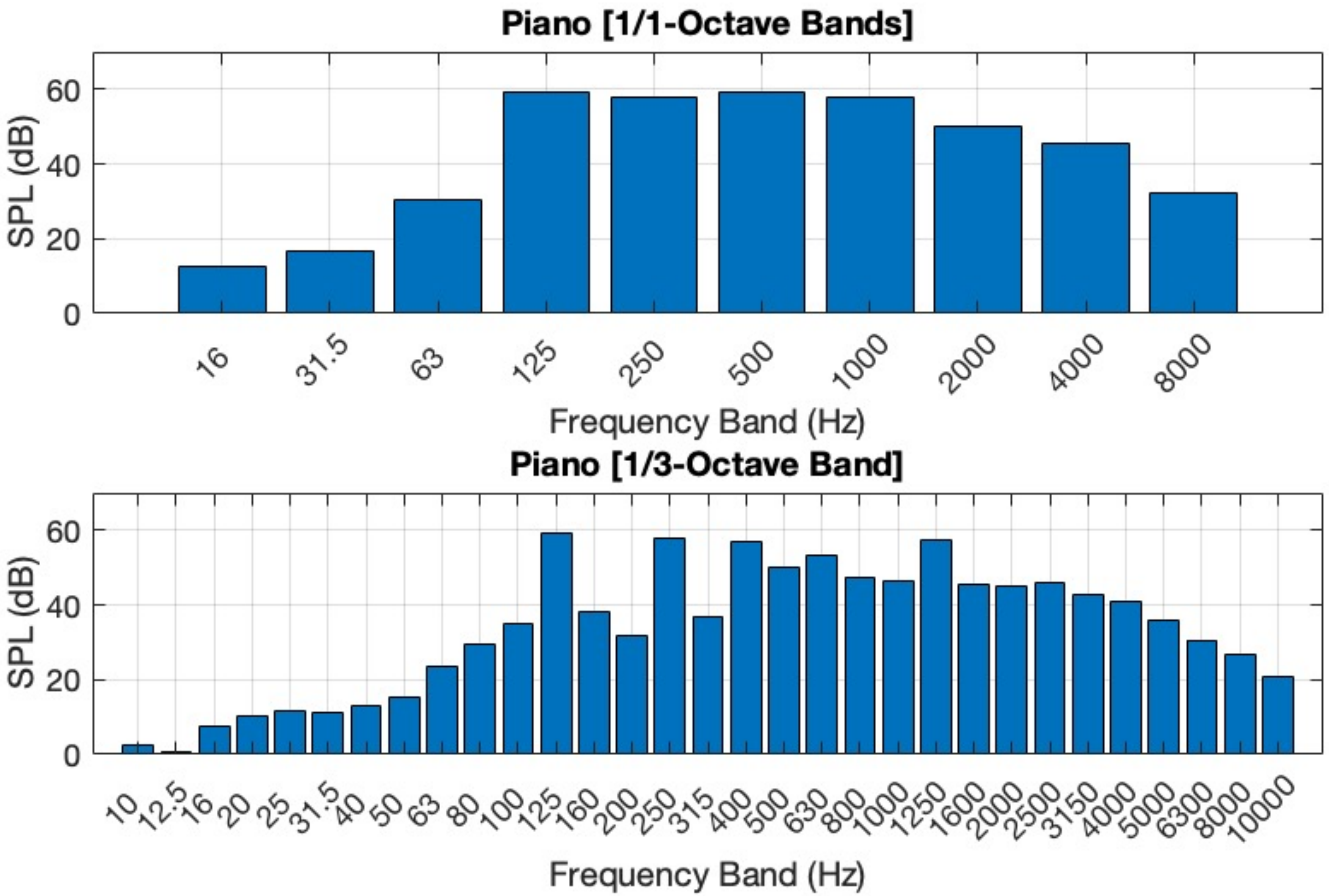


Discrete SPL Magnitude Response





Discrete SPL Magnitude Response



To sum up

- Read carefully the *guideline*.
- Read carefully the *examples*.
- For questions [email and/or StudyHub Hours on Fridays].
- HA1 deadline: 09-03-2022 @ 23:59.