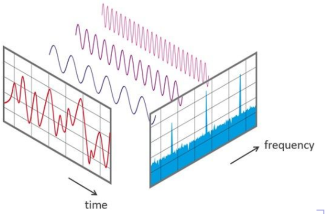
Fast Fourier Transformation (FFT)

How-to implement a FFT in Real Time

Rainer Nitsche / February 2024



DFT / FFT Objectives

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General objectives of the discrete fourier transformation

- Analyzing a time domain signa in the frequncy domain $\rightsquigarrow$ Fourier Transform
- The fast fouriet transform (FFT) is an efficient method to numerically compute a dicrete fourier transform (DFT)
- The goal is to analyze to following signal:

$$x(t) = c + a_1 \sin(\omega_1 t) + a_2 \cos(\omega_2 t);$$

discrete time

$$x[n] = c + a_1 \sin(\omega_1 n T_\mathrm{s}) + a_2 \sin(\omega_2 n T_\mathrm{s}), \quad n = 0, 1, 2, \ldots$$

with sample time T_s or sample frequency $f_\mathrm{s} = \frac{1}{T_\mathrm{s}}$.

Overview

- Objectives: time domain to frequency domain
- time signal - discrete time signal - DFT - FFT
- Sample Time / Number of Samples / Bin Width / Nyquist Frequency / Leackage effect
- Simulink Simulation
- dSpace Implementation in Real Time

Some Remarks on FFT

This is a text in second frame. For the sake of showing an example. See also [1]

- Good youtube videos from Steve Brunton about Fourier Transform: Link
- Understanding the Discrete Fourier Transform and the FFT... Link

The goal is to analyze to following signal:

$$\boxed{A(t) = c + a_1 \sin(\omega t) + a_2 \cos(\omega t)} \tag{1}$$

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- Text visible on slide 4

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Visualization

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```

% *************************************
% Umsortieren fuer einen 3 D Plot
% *************************************
% Anzahl der Zeitfenster kann man ausrechnen:
% 1sec / (1024*Ts) ; simTime = 1 sec; Ts = 6.25e-5;
%  => 16 Pakete bei 1 Sekunde...
for i = 1:length(matFFT(1,1,:))
    % t(i) = i;
    t(i,:) = matFFT(:,i);
end

figure(10); mesh(t)

f_vec = [0:1:length(matFFT(:,1))-1]*1/Ts/length(matFFT);

LW=1.5;
```

A motivating Example for FFT in Simulink

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Example

Sliding mode of the system [2]:

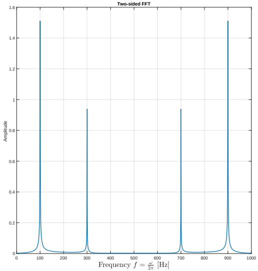
$$\ddot{x} = \sin(3t) + u \tag{2}$$

with sliding surface

$$s = c\dot{x} + x \tag{3}$$

with control law

$$u = -M \operatorname{sgn}(s) \tag{4}$$



Simulation results for $M = 3$ and $c = 1\ \mathrm{s}^{-1}$

If the system is in sliding mode, *i. e.* $s = 0$, the dynamics is $s = \dot{x} + x = 0$ and therefore indepentend of system parameters or disturbance $\rightsquigarrow$ robust !

Sample frame title

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In this slide, some important text will be highlighted because it's important. Please, don't abuse it.

Remark

Sample text

Important theorem

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Examples

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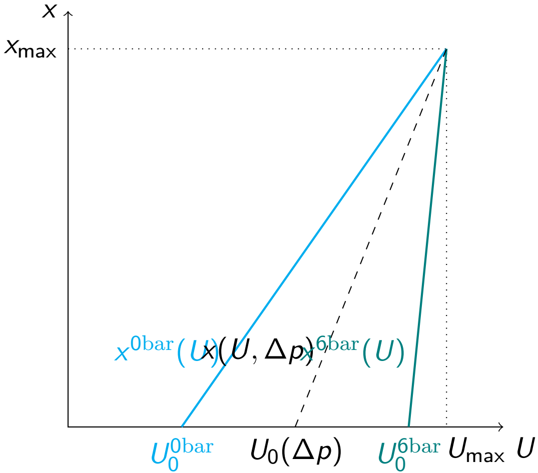
TikZ Test

Hello world



References

[1] S.L. Brunton and J.N. Kutz. *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*. Cambridge University Press, 2022. ISBN: 9781009098489. URL: https://books.google.de/books?id=rxNkEAAAQBAJ.

[2] Vadim I. Utkin et al. *Road map for sliding mode control design*. 6330 Cham, Switzerland: Springer, 2020. ISBN: 978-3030417086. DOI: 10.1007/978-3-030-41709-3.