POWERFACTORY

# PowerFactory 2021

## Technical Reference

### Fast Fourier Transformation

ElmFft

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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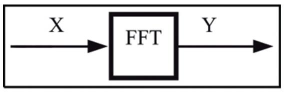
# Contents

# 1 General Description

The Fast Fourier Transformation (FFT) model is used for calculating a fast fourier transformation in the simulation. The spectral lines of the magnitude, phase, real part and imaginary part are output signals. In addition there is the option to apply a hanning window on the input signal. The fourier transformation model has the option to input three or one single signals.

## 1.1 Operation



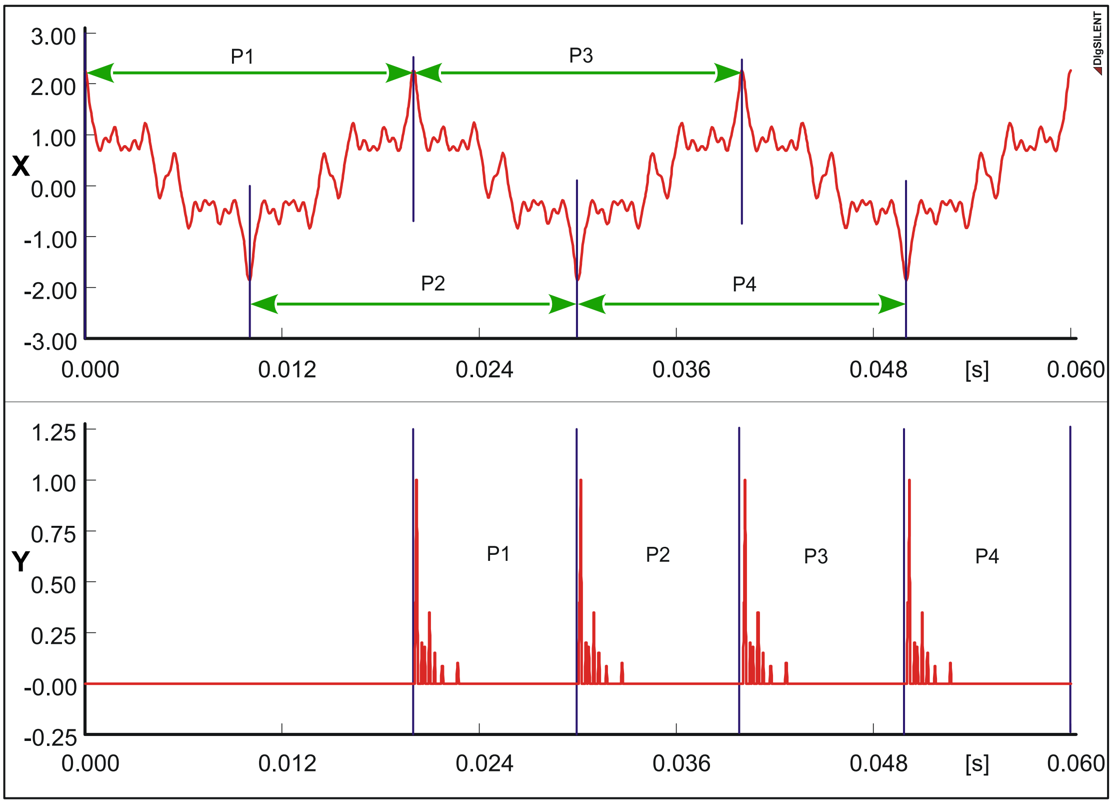




Figure 1.1: Plot operation FFT input and output

The FFT calculation outputs the left half of the spectrum. Therefore it is possible to perform a new FFT calculation every n/2 values. Up to the first n samples after starting the simulation the output is set to 0. The first calculation is performed after n samples. All following FFT calculations are performed after another n/2 samples. The plot on top shows the analyzed waveform, the one on the bottom displays the magnitude of the frequencies. *P1* in the frequency plot is calculated from the signal in *P1* in the time plot. The following equations show the relation between sampling frequency, FFT size and the output.

$$T_c = \frac{1}{fc} \tag{1}$$

$$T_1 = T_c \cdot n = \frac{n}{f_c} \tag{2}$$

$$f_{max} = \frac{f_c}{2} \tag{3}$$

$$df = \frac{1}{T_1} = \frac{f_c}{n} \tag{4}$$

The following variables have been used in the equations above:

- $T_c$ : Clock period
- $f_c$ : Clock frequency
- $n$ : Number of samples in FFT calculation
- $T_1$ : Time sampled for one complete fft calculation
- $f_{max}$ : Highest frequency in fft calculation
- $df$ : Delta f of frequency between spectral lines

With the settings used in the plots above:

$$f_c = 12.8kHz$$

$$n = 256$$

the calculated values are:

$$T_1 = \frac{n}{f_c} = \frac{256}{12.8kHz} = 20ms$$

$$f_{max} = \frac{f_c}{2} = \frac{12.8kHz}{2} = 6.4kHz$$

$$df = \frac{1}{T_1} = \frac{1}{20ms} = 50Hz$$

Therefore a new calculation is completed every 10 ms.

Every time that a spectrum has completed the ready signal is set to 1. Other models using the FFT output as input value use the ready signal to trigger their calculations. If the ready signal is shown in a plot it can be used to calculate the time period sampled by the FFT calculation or to mark the beginning of a new FFT calculation.

### 1.1.1 Calculating the frequency scale from the time scale

$$dt = t - t_{start} \tag{5}$$

$$i = dt \cdot f_c \tag{6}$$

$$f = i \cdot d_f \tag{7}$$

Calculating the time on the scale for a given frequency:

$$i = \frac{f}{df} \tag{8}$$

$$dt = \frac{i}{f_c} \tag{9}$$

$$t = t_{start} + dt \tag{10}$$

The newly invented variables are:

- $dt$ : Time difference on time scale between current time and start of current spectrum
- $t$ : Time
- $i$ : Index in spectrum
- $t_{start}$ : Time at start of current spectrum
- $f$ : Frequency

## 1.2 Window

There are two different windows for the FFT calculation. These are:

1. Rectangular (no window)
2. Hanning window, where the following filter is applied to the input:

$$y_i = x_i \left[1 - \cos\left(\frac{2\pi i}{n}\right)\right]$$

with $n$ = Number of samples in FFT calculation

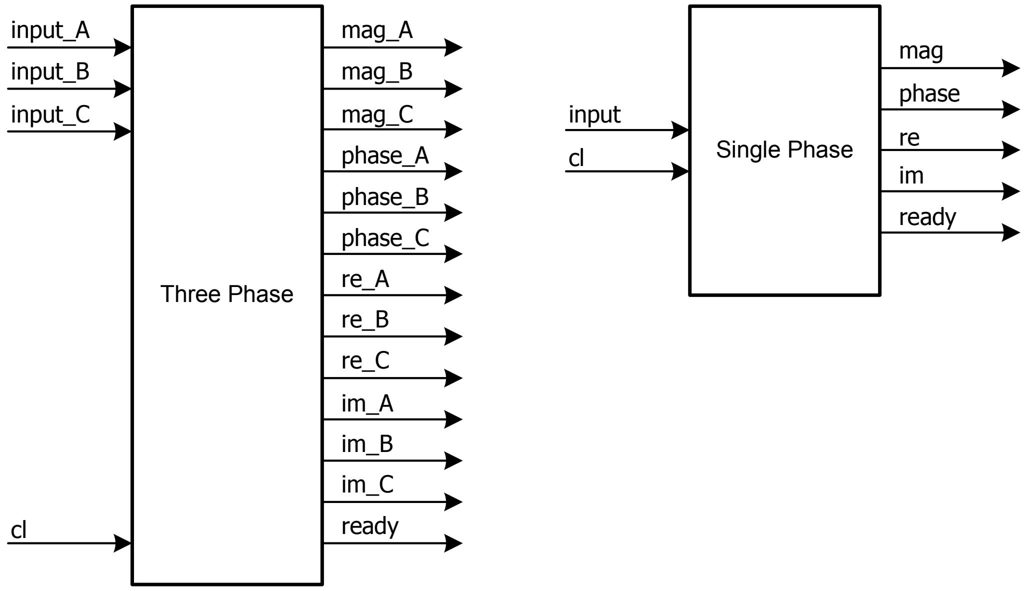



Figure 2.1: Signal definitions

# 2 Dynamic Simulation

The input signals *input* and *cl* must always be connected for using the model in the simulation. *input_A*, *input_B* and *input_C* need not to be connected. Input values not connected are set to 0.

# 3 Example Configuration

## 3.1 Overview

The following example shows a small configuration where the Fast Fourier Transformation model is used to perform a FFT analysis on a signal. The analyzed signal is created with the *Fourier Source (ElmFsrc)* model. The output *yo* of the *Fourier Source* is a waveform created from given harmonic orders and their corresponding amplitudes.

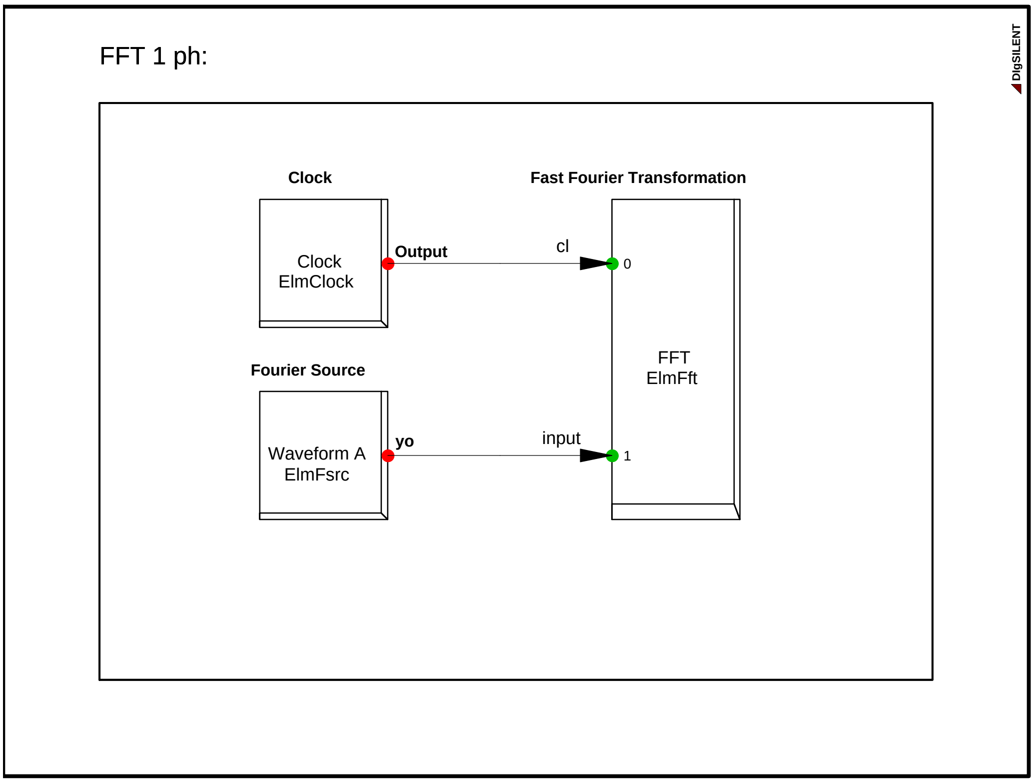



Figure 3.1: Block diagram

Table 3.1: Example settings

| | **Object** | **Variable** | **Value** |
|---|---|---|---|
| Simulation | *ComInc* | dtemt and dtout_emt | 5.0e-6 s |
| Clock | *ElmClock* | cFreq | 12.8 kHz |
| FFT | *ElmFft* | nsamp | 256 |
| | | i_win | no window |
| Fourier Source | *ElmFsrc* | Frequency | Amplitude |
| | | 0 | 0.2 |
| | | 50 | 1 |
| | | 250 | 0.2 |
| | | 350 | 0.18 |
| | | 550 | 0.35 |
| | | 750 | 0.15 |
| | | 1050 | 0.085 |
| | | 1650 | 0.1 |

## 3.2 Frequency <=> Time Scale

To get the starting times of the spectra plot ready of the FFT calculation. The output looks like:

For example it is assumed that we want to calculate the frequency of the spectral line around 40.9375ms. From the *ready* output we get the starting time of the spectrum which is 40.0781ms in the given example. The time between two consecutive FFT calculations is:

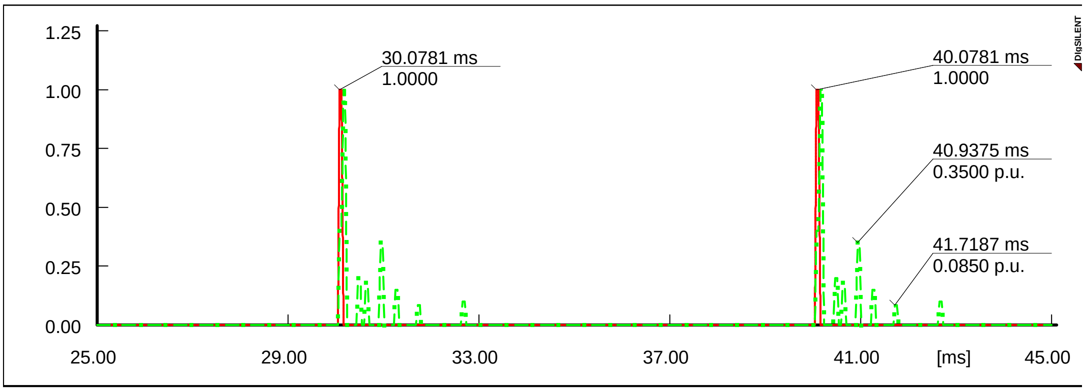



Figure 3.2: Ready output

$Tr = 40.0781ms - 30.0781ms = 10ms$

The FFT is calculated every $\frac{n}{2}$ values. Therefore $T_1 = 2 \cdot T_r = 2 \cdot 10ms = 20ms$ and $d_f = \frac{1}{T_1} = \frac{1}{20ms} = 50Hz$

Time between spectral line of interest and start $dt = t - t_{start} = 40.9375ms - 40.0781ms = 0.8594ms$

The index of the spectral line is $i = dt \cdot f_c = 0.8594ms \cdot 12.8kHz = 11$

The frequency of the spectral line around 40.9375ms in the plot is $f = i{\cdot}df = 11{\cdot}50Hz = 550Hz$

It is assumed that we want to calculate the value on the time scale for a given frequency of 1050Hz

The index of the spectral line is $i = \frac{f}{df} = \frac{1050Hz}{50Hz} = 21$

The difference on the time scale between the spectral line and the start of the FFT is $dt = \frac{i}{f_c} = \frac{21}{12.8kHz} = 1.64ms$

The value on the time scale results in $t = t_{start} + dt = 40.0781ms + 1.641ms = 41.719ms$

## 3.3 Plots

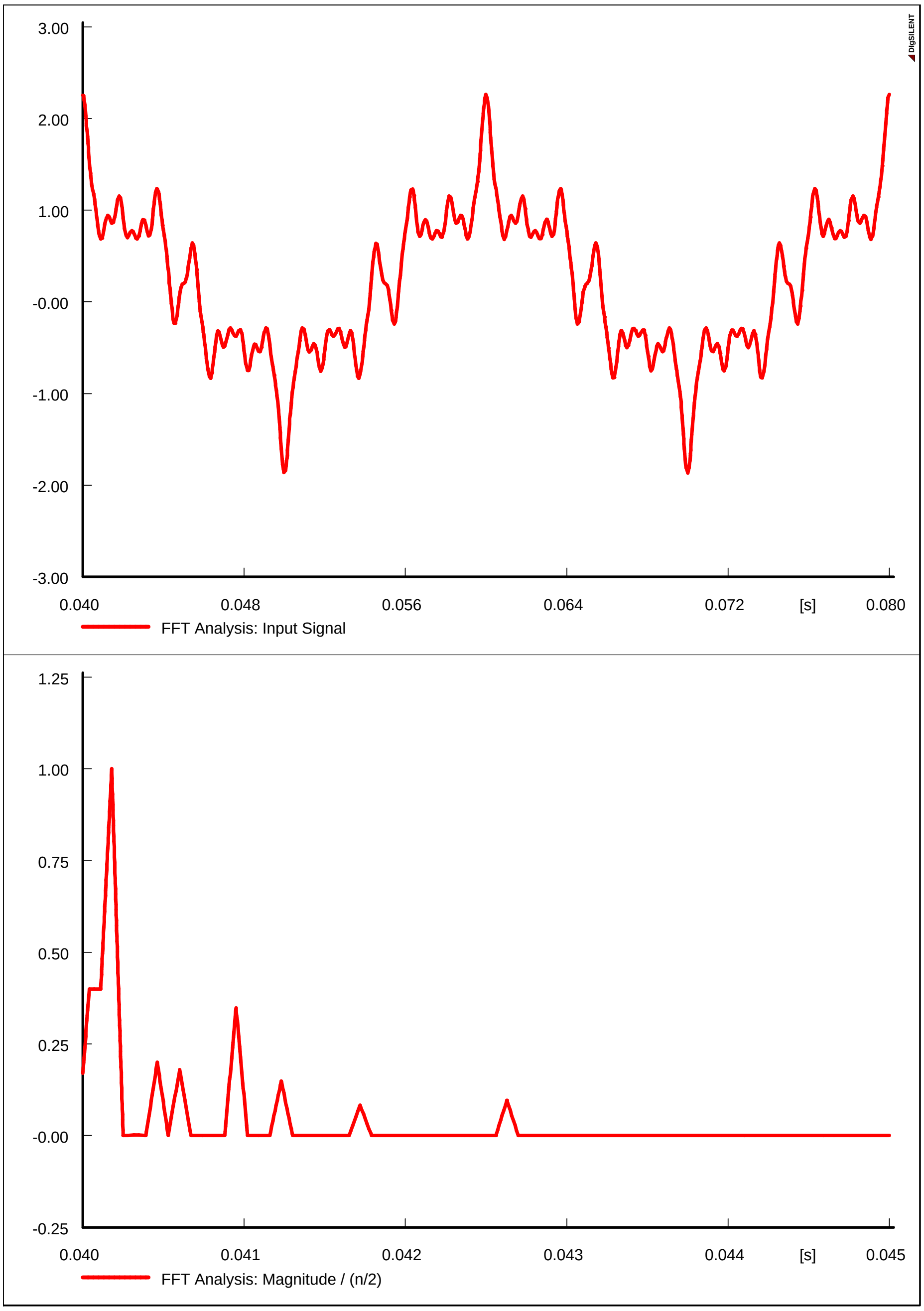



Figure 3.3: FFT plot

# A Parameter Definitions

Table A.1: Fast Fourier Transformation Parameters

| Parameter | Description | Unit |
|---|---|---|
| loc_name | Name | |
| nphase | Number of phases | |
| nsamp | Buffer size | |
| I_win | Window | |

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