Cockpit Spectral Analyzer

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This article describes how to use the Spectral Analyzer of imperix Cockpit to interact with the user code running on imperix power converter controllers, namely the B-Box RCP the B-Board PRO, the Programmable Inverter and the B-Box Micro. This page provides a detailed explanation of all of its features, along with some usage examples.

For new users, it is recommended to read the following articles beforehand to get started with the imperix software development kit (SDK) and imperix Cockpit monitoring software:

- Cockpit – User guide
- Cockpit – Scope module
- Programming and operating imperix controllers

Spectral Analyzer basics

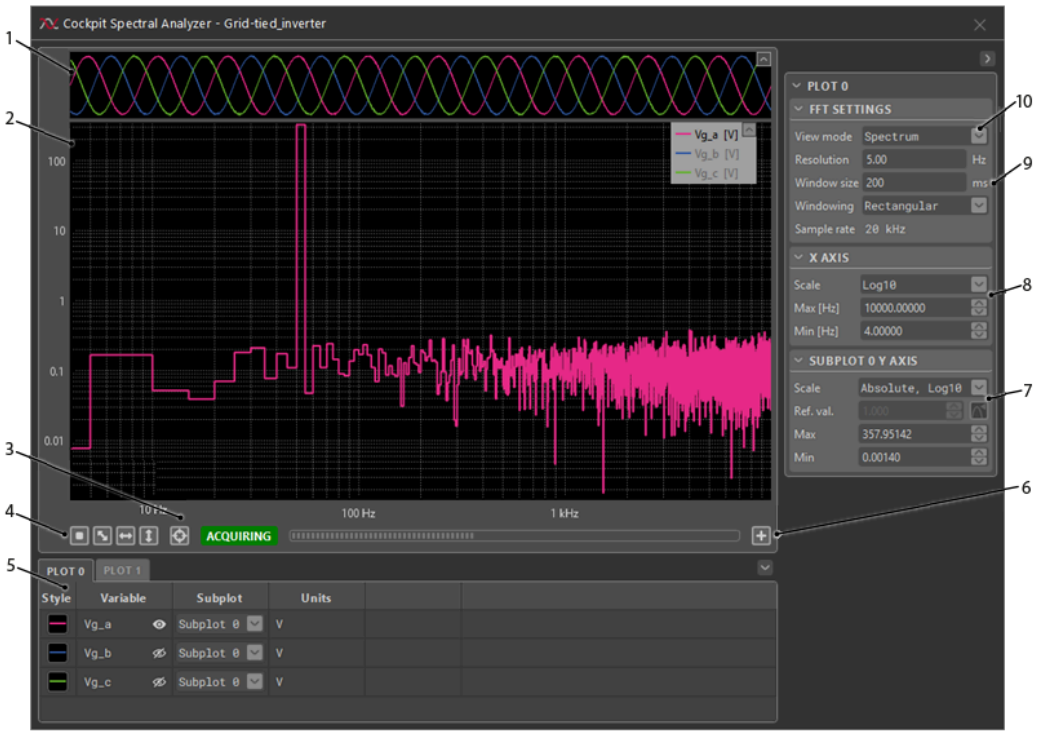
The Spectral Analyzer window allows the user to examine Scope module variables in the frequency domain. This includes all of the user and math variables that are currently present in the module.

The window is fully dependent on the data acquired by the Scope Module. Closing the Scope will also close all opened Spectral Analyzers.

To start the Spectral Analyzer, click on its icon in the Scope module footer.

The Spectral Analyzer window is organized into tabs, each one corresponding to a plot area in the Scope module. The tabs can be switched through the bottom bar header. All tabs' settings are independent of each other. To observe a variable in the Spectral Analyzer, add or move it to a Scope module plot area and it will show up in the corresponding tab. Conversely, moving or removing a variable from a Scope plot area will remove it from the corresponding Spectral Analyzer tab.

Spectral Analyzer interface



1 – Time domain signal preview

This area shows an overview of all of the signals scoped in the corresponding Scope module plot area. The preview can also be used to visually adjust the size and position of the window in time over which the Fourier transform is performed.

2 – Plot

The plot shows the scoped signals in the frequency domain. When first opening the Spectral Analyzer from the Scope, typically only one spectrum will be shown.
The user can control the visibility of all of the spectra from the corresponding bottom bar tab or through the variable plot context menu accessed by right-clicking on the plotted signal.

3 – Annotation mode toggle

When switched on, an annotation box for the spectral value closest to the mouse cursor is shown. The annotation contains the x and y axis position corresponding to the closest sample and the name of the variable to whom the sample belongs to.

4 – Start/stop button

Starts or stops the acquisition of the Scope. The button in the Spectral Analyzer and the start/stop button in the Scope module always have the same state. The same holds for the Acquisition state and the Acquisition loading bar.

5 – Bottom bar

The scoped variables for a given Scope plot area are displayed here. To switch between Scope plots areas, click on the tabs in the header of the bottom bar.
The bottom bar variable controls allow the user to:

- Modify each variable's display style
- Toggle a variable's visibility
- Move variables between sublots

In addition to this, the THD and WTHD metrics calculated in the *Harmonics* mode are displayed here.

6 – Add subplot button

Creates an empty plot area at the bottom of the scope module. The area is labeled as Subplot so as not to be confused with the Scope plot areas that are used for sorting the spectral signals into tabs.

7 – Y-axis scaling options

Besides the usual fields that allow the precise definition of the displayed y-axis range, the Spectral Analyzer offers the option to switch between different scaling settings for the value axis:

- *'Absolute, linear'*, which displays the magnitudes of the calculated Fourier transform, without any visual or mathematical rescaling
- *'Absolute, log10'*, which arranges the magnitude values in a log-scale
- *'Relative, dB'*, which transforms the magnitude values according to the Amplitude dB formula: $20\log_{10}\left(\frac{|X|}{X_{ref}}\right)$, where $|X|$ is the magnitude calculated by the Fourier transform for any given $f \in [0, \frac{f_s}{2}]$
- *'Relative, log10'*, which divides all of the magnitude values with X_{ref} and arranges the resulting values in a log-scale

For the scaling options that require it, X_{ref} can be set manually in the corresponding field below. If the continuous normalization option is toggled on, X_{ref} will be set automatically to the biggest magnitude value seen since the option was turned on.

8 – X-axis scaling options

Besides the usual fields that allow the precise definition of the displayed x-axis range, the Spectral Analyzer offers the option to switch between linear and log-scaling for the frequency axis.

9 – FFT window settings

The precise window size can be set through this menu, either directly or by setting the desired frequency resolution. The typical windowing functions (Rectangular, Hann, Hamming, Blackman, Blackman-Harris and Flat top) are provided and can be applied to the samples within the window before transform.

10 – Spectrum view mode

Allows switching between two aspects of viewing the same spectral content:

- *Spectrum mode*, where the spectra are plotted as continuous lines
- *Harmonics mode*, where the spectral content is plotted as bars

Calculating and displaying spectral content

In the Spectral Analyzer, the signal spectra are calculated using a variation of the Fast Fourier Transform (FFT) algorithm. Similarly to math variables in the Scope module, the calculations are performed on the PC side, after the acquisition of a scope window.

Spectrum mode

The *Spectrum* mode gives the best visual overview of the spectral content of the scoped signals. Since the widest window results in the highest frequency resolution, the default FFT window in this mode is the same as the acquisition window.

Technical details

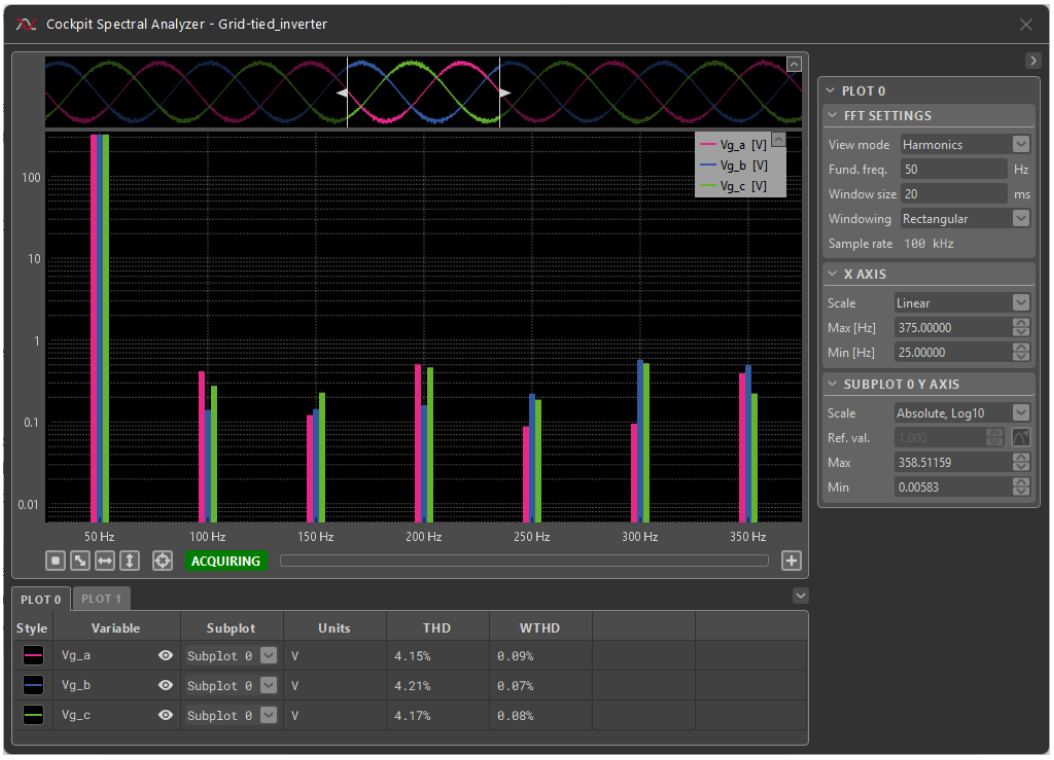
The displayed frequency domain signal is the **magnitude of the one-sided spectrum** of the scoped variable, with the frequency range $f \in [0, \frac{f_s}{2}]$. The Scope sampling rate, f_s, corresponds to the control task frequency defined in the user code. The frequency resolution of the resulting spectra depends on the window in time over which the

Fourier transform is performed and can be adjusted in the FFT Settings menu in the right bar.

The size of the Fourier Transform window can also be set by zooming on the time domain signal preview, while dragging the window with the mouse pointer can set its position within the acquisition window.

Harmonics mode

In the *Harmonics* mode the spectral content is calculated with the same method as in the *Spectrum* mode, but is plotted in a way that makes it easier to visualize and compare the individual harmonics between of different signals. In addition to this, the Total Harmonic Distortion (THD) and Weighted THD (WTHD) metrics are calculated and updated in the bottom bar menu for the variables that are currently displayed in the plot. As is typical for the Power Electronics domain, the default FFT window is such that the frequency resolution is 50 Hz.



Technical details

THD is defined as ratio of the root-mean-square of the harmonic content and the fundamental frequency, typically taken to be 50 or 60 Hz. In the Cockpit Spectral Analyzer, THD is calculated according to the following formula:

$$\mathrm{THD} = \frac{1}{V_1}\sqrt{\sum_{i=2,3,\ldots}^{\infty} V_i^2},$$

where V_1 is the amplitude of the harmonic at the fundamental frequency and

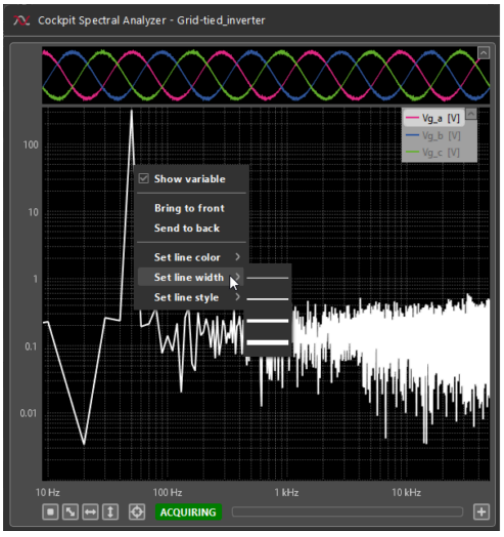
$V_i, i \in \{2, 3, \ldots\}$ are the amplitudes of the harmonics at the i-th multiple of the fundamental frequency.

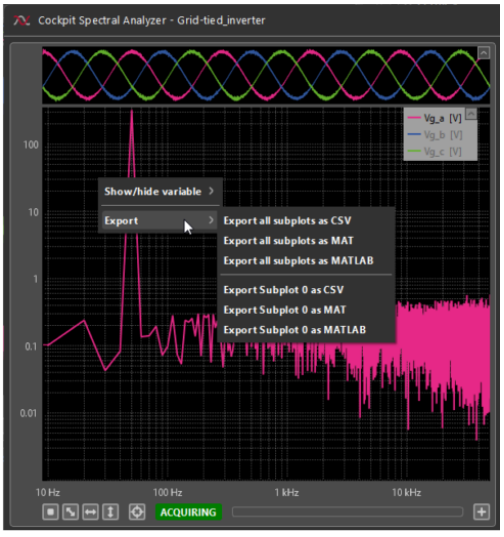
WTHD is calculated in a similar manner, except the harmonics are weighted to be inversely proportional to their order:

$$\mathrm{WTHD} = \frac{1}{V_1}\sqrt{\sum_{i=2,3,\ldots}^{\infty} \left(\frac{V_i}{i}\right)^2}$$

Spectral Analyzer tips and tricks

- To **zoom in and out along the horizontal axis**, place the mouse cursor where to zoom. Then, use the mouse wheel to zoom in or out around the location of the mouse cursor.
- To zoom in and out along the vertical axis, place the mouse cursor where to zoom. Then press the ctrl key and use the mouse wheel to zoom in or out around the location of the mouse cursor.
- To **zoom on a specific area**, click and drag to draw a blue rectangle over the zoom area.
- To achieve a **horizontal autoscale**, right-click and drag horizontally. A light grey horizontal strip will appear. Release the mouse button to perform the horizontal autoscale.
- To achieve a **vertical autoscale**, right-click and drag vertically. A light grey vertical strip will appear. Release the mouse button to perform the vertical autoscale.
- Even though the Spectral Analyzer is not available in the Import/Export tab, spectral plots can still be exported through the subplot **context menus** by right-clicking on the empty space in the plots.
- Other Spectral Analyzer functionalities can also be accessed through through **context menus** by right-clicking on a plotted variable or on the empty space in the plots.





Spectral plot variable context menu and subplot area context menu