**Figure 180:3D Color map of an FFT spectrum**

With a 3D RPM frequency spectrum, the variation of components of frequency with respect to the RPM can be clearly observed. A clear differentiation of the spectral components that depend on the rotational speed (forcing orders) and the spectral components that do not (resonances) is clearly shown.

## Band RMS Spectrum

In order tracking, it is also important to monitor the overall RMS level or signal power level of the measurement versus RPM. The overall level is a good tool to rapidly identify critical bands of operating RPM. Overall level can be in unit of RMS ($EU_{rms}$) or power ($EU_{rms}^2$). The horizontal axis is RPM. Below is a typical overall level display.
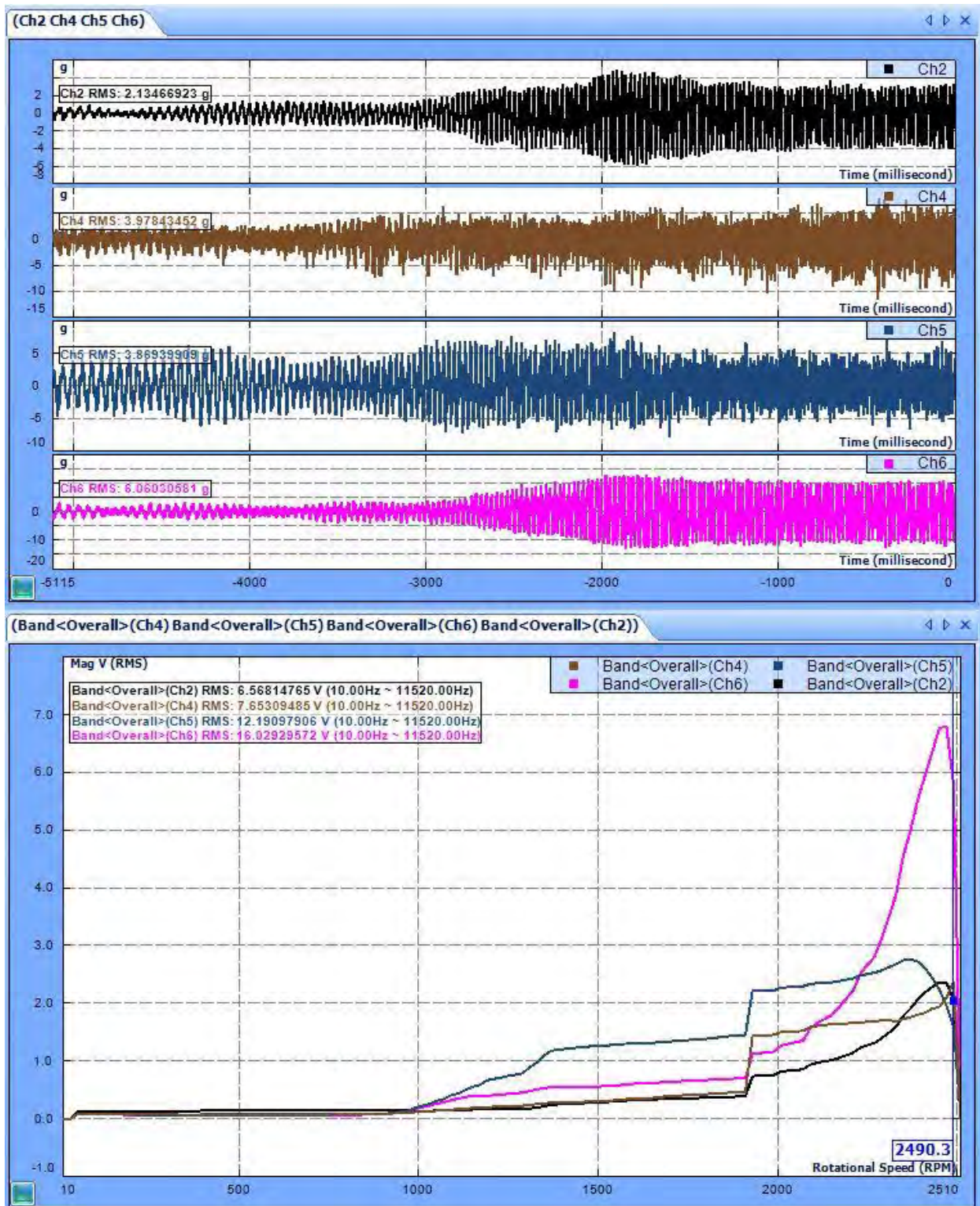
**Figure 181: Overall RMS level plot**

A list of common sources of vibration in a rotating machine includes:

| Order | Source of Problem |
|---|---|
| **0.05X~0.35X** | Diffuser Stall |
| **0.43X~0.49X** | Instability |
| **0.5X** | Rubbing |
| **0.65X~0.95X** | Impeller Stall |
| **1X** | Imbalance |
| **1X+2X** | Misalignment |
| **(#Vane)X** | Vane/Volute gap |
| **(#Blades)X** | Blade/Diffuser Gap |

## Raw Data Time Streams

In many competitive tracking software products, the user can either conduct real-time order tracking, or record the data with other tools and then post-process the order tracks, but not both. The Spider, in conjunction with the Crystal Instruments EDM software can perform real-time order analysis and tracking and simultaneously record the time streams of all channels including the dedicated tachometer channels. Crystal Instruments Order Tracking can record up to 128 signal channels and two tachometer channels while performing real-time order tracking and analysis.

Crystal Instruments Post Analyzer software can use the recorded signals to perform off-line Order tracking and Analysis. Real time processing limitations, if they exist, can be overcome using this feature.

## Phase for Order Tracks

### The Phase in Rotating Machine Analysis

Many mechanical faults are associated with certain orders, analyzing both ordermagnitude and its phase can help you detect mechanical faults directly. Forexample, a strong first order magnitude indicates imbalance in most cases.Analyzing the first order magnitude can help you identify an imbalance problem.Moreover, the magnitude and phase of the first order can help you correct the problem by adding weights on the appropriate rotor positions. While it is possible to balance a machine using magnitude-only measurements, employing measured magnitude and phase reduces the number of machine stop/starts in the balancing process by a factor of three or more.

As previously discussed, an order track is the measurement taken for an order, i.e., normalized frequency, versus RPM. In most of the applications of engine related test, the phase information of order tracks are not important. In rotating machine analysis, the phase of the signal is vitally important.

Phase is a relative quantity and can only be measured between a pair of signals. It indicates the time delay (at certain frequency) between the two signals. The phase value can be translated into the difference in relative angle, relative position or

propagation time if additional information is known. (When we refer to the single-channel phase, we speak of its phase is relative to the start point of its data block.)

In rotating machine analysis, the phase of the first order of a rotor can be directly mapped to an angular difference between a signal and a reference. The reference signal can be another channel of measurement, or the tachometer signal. The phase difference between two waveforms is often called a phase shift or phase delay. Phase shift may be considered positive or negative, i.e., one waveform may be delayed relative to another one, or may precede it in time. These conditions are called phase lag and phase lead respectively.

An example of this is the phase of an imbalance component in a rotor with reference to a fixed point on the rotating rotor, such as a shaft keyway. To measure this phase, a trigger-pulse must be generated whenever the keyway passes a fixed point. An optical, magnetic or eddy-current probe may be used to generate such a **"tach" pulse signal.**
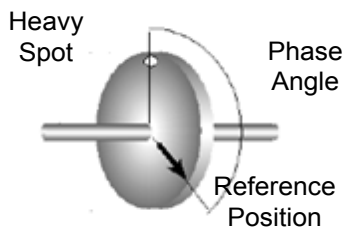


A zero degree phase delay at a frequency can be depicted as a series of pulses overlaid with a sine wave where the pulse edge is exactly located in peak position of the sine wave.
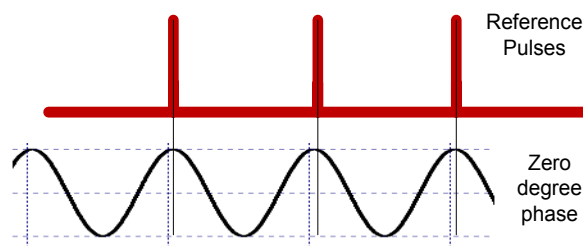


In the figure above, a section of the tachometer signal is shown on its own and then overlaid on the vibration signal. The tachometer signal in this example crosses the vibration signal at exactly the same point on each cycle. If the phase of the vibration signal were to change (as it would with a slight speed change), then its position relative to the tachometer pulse would also change. Extracting the first order magnitude and phase, gives the curves shown below. The phase is now constant near -60° as it should be for such a signal. Because the rotating period of the signal is about 20 ms, -60° corresponds to a 20*60/360=3.3 ms delay.
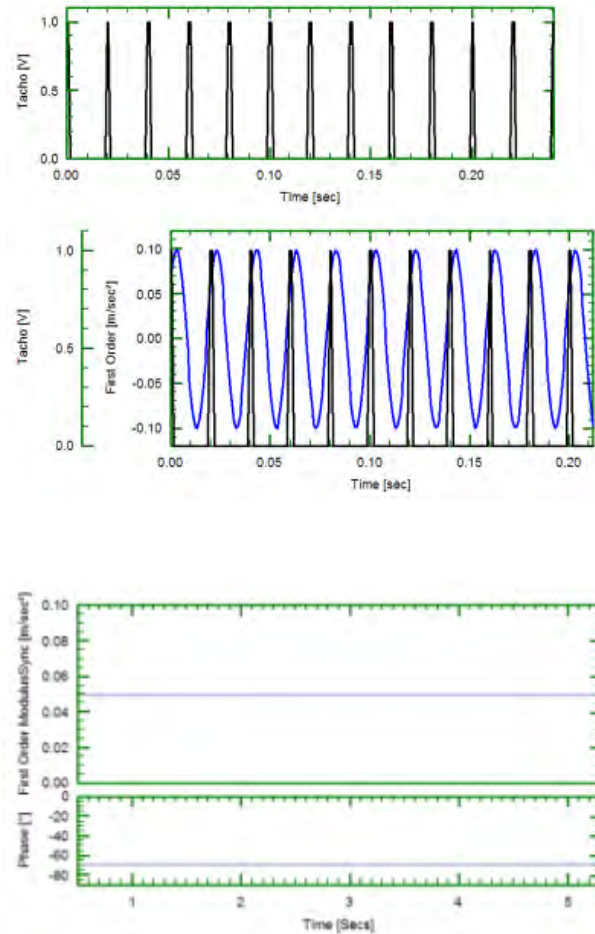
Phase measurement at higher orders will exhibit similar behavior, although they are more difficult to comprehend intuitively.

It must be noted that Complex Order Tracks order tracks with phase, are not regular complex signals as frequency response or cross spectrum. They are really auto spectra with assigned phase. These synthesized signals can certainly be viewed as a complex signal using tools including Bode Plot, polar and orbit diagram. However the user must keep in mind that the magnitude and phase of a complex order track are calculated separately.

## Bode Plot

The term Bode Plot is borrowed from the field of control theory, referring to a plot of magnitude and phase angle between the input and output verses frequency of a control system. Many in the rotating machine vibration industry have adopted this term to describe the steady-state vibration response amplitude and phase angle versus rotational speed (RPM). It turns out that the Bode Plot is the best way to describe order tracks with phase. You typically use Bode plots for transient analysis in both Run-up and coast-down conditions. A Bode plot can help to

identify the resonance speed of a rotor or examine the rotor dynamics on an order basis.

In the Spider 80X system, after the order tracks with phase are acquired, the Bode Plot can show one or multiple tracks. Spider 80x system is also capable of calculating phase plots to specifically measure the Run-up and Coast-down conditions. A typical bode plot is shown below:



**Figure 183: Typical Bode Plot**

## Operating Spider system

Crystal Instruments developed an enhanced Spider system with dedicated tachometer channels and an enhanced hardware circuitry for measuring the tachometer signal and performing order analysis. All Spider devices with hardware versions 7.5 and above possess these special capabilities. It allows them to perform Order Spectra, Order Tracks, FFT Spectra and Band RMS Spectra simultaneously.

Older Spider modules (7.4 and back) developed without the dedicated tachometer channels can also be used to perform order tracking. One or two of the input channels can be used as tachometer channels and one of them can be used as a Reference tachometer channel to perform the order analysis functions.

This section focuses on using the EDM to create a test for performing Order Analysis and tracking. Based on the previous discussion, 3 measurements are of

prime significance in Order tracking. Order Spectrum and Order tracks with phase, Continuous frequency spectrum or the FFT Spectrum and the Band RMS Spectrum.

In this section, a detailed description on creating and measuring each of the measurements is given starting with creating and setting up the basic properties of an Order Tracking test. The following description is valid for both dedicated tachometer compatible hardware units (7.5 and above) and non-compatible units (7.4 and below) unless and otherwise specified. Henceforth, we designate the **dedicated tachometer compatible units as "7.5 Hardware" and the non**-compatible **units as "7.4 Hardware"**

### Creating a Test

**Order tracking is found under the "Dynamic Signal Analysis" section of the EDM.** Click on the Dynamic Signal Analysis to see the option for Order Tracking.
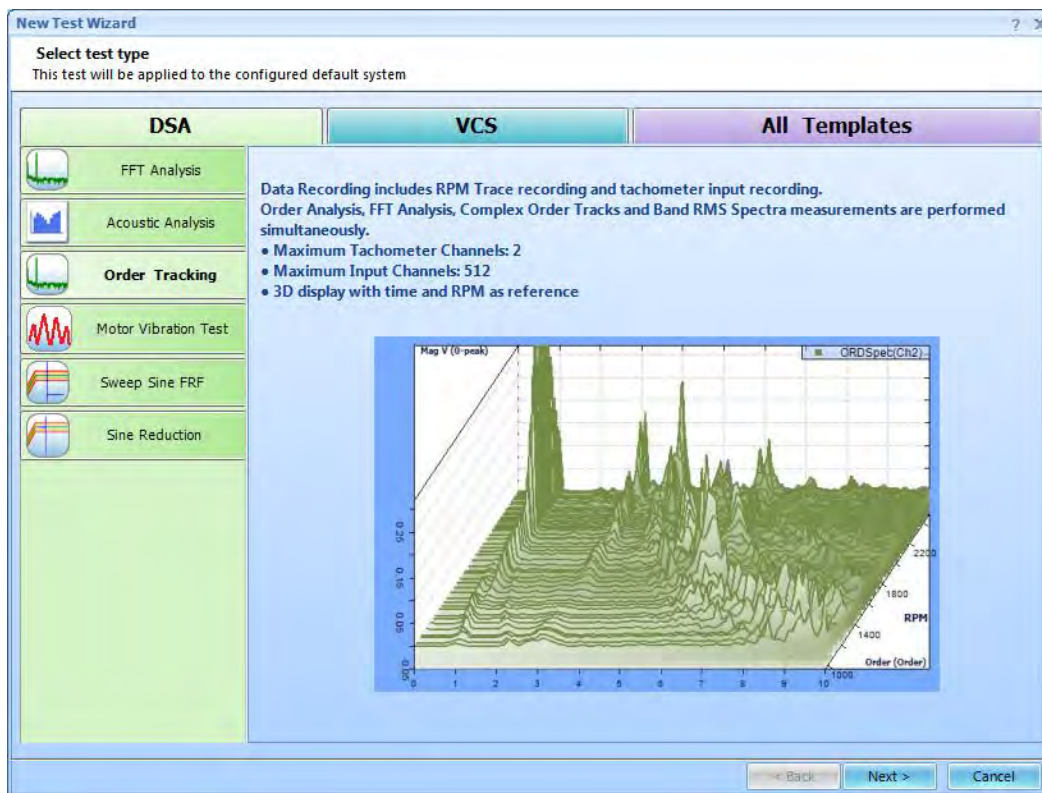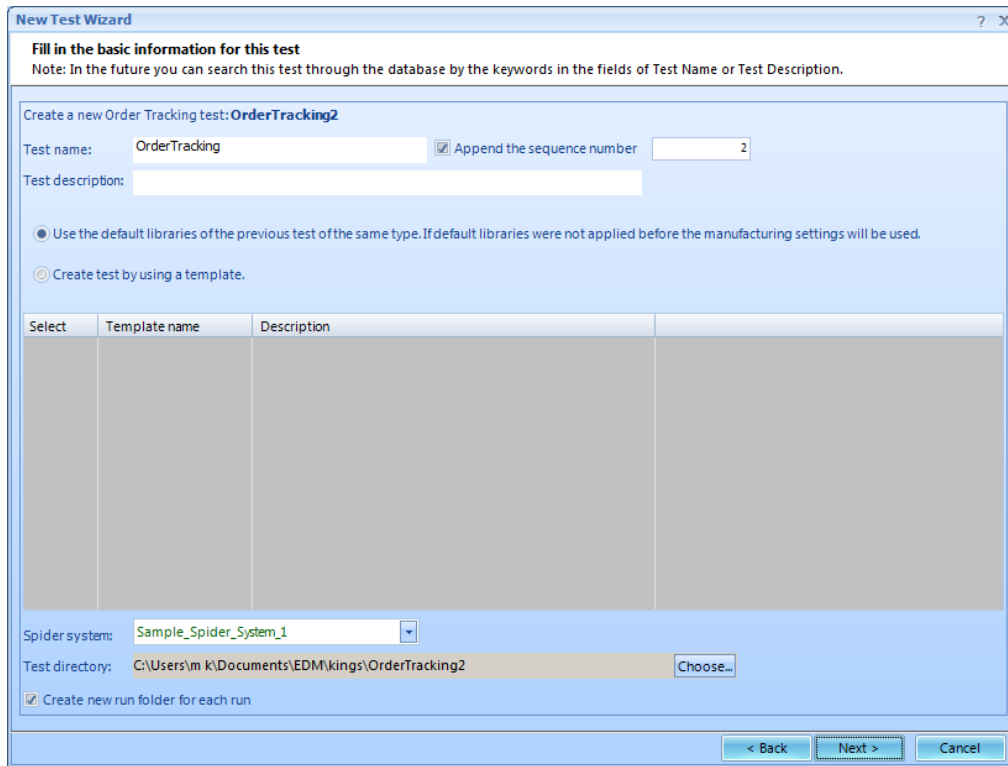


**Figure 184: New Test Wizard**

Click on Order tracking to begin the process of creating a new test in Order **Tracking and click on "Next", as shown below.**

**Figure 185: New Test Wizard – Order Tracking**

Enter a valid test name in the Test Name field and an optional description of the test can be added in the Test Description field. Select an appropriate Spider System **and test directory and click on "Next" to continue.**
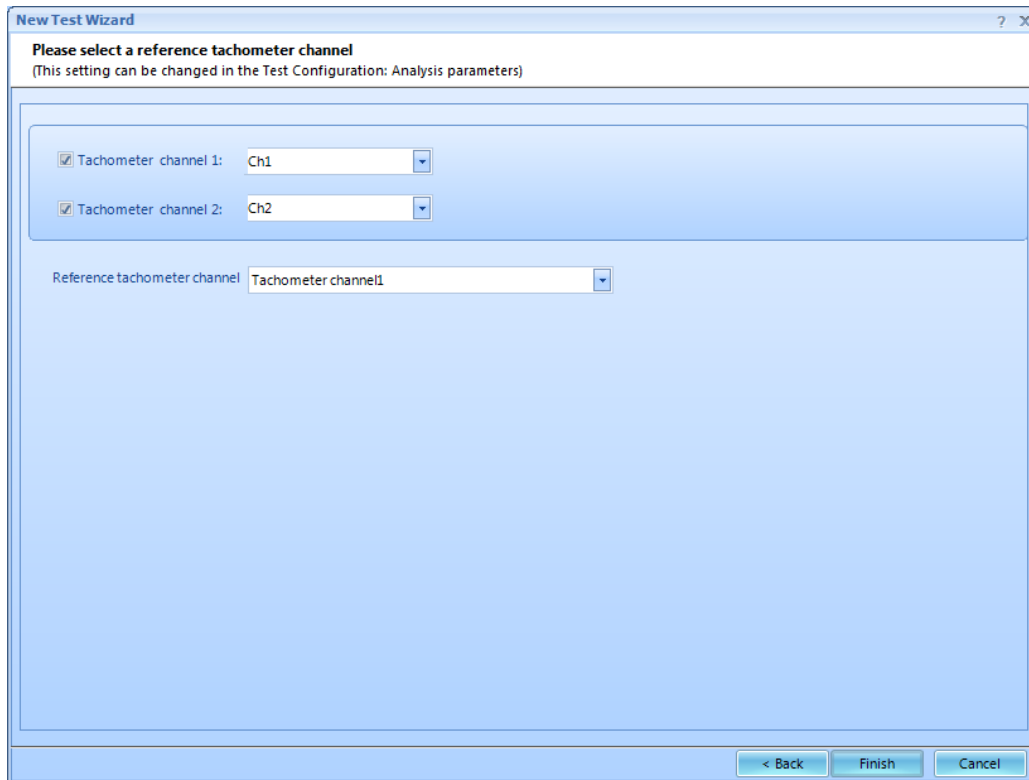
**Figure 186: New Test Wizard – Selecting Tachometer channels (7.5 Hardware and above)**

In 7.5 hardware unit(s), tachometer/output channels can be selected as the dedicated tachometer channels.  The user can turn Tachometer Channel 2 ON or Turn OFF, depending on the specific user requirement. The Reference tachometer is always Output Channel 1 or Tachometer Channel 1. Tachometer Channel 2 (Output Channel 2) can only be used to calculate RPM and does not support Order analysis functions in any other way.

In the 7.4 hardware unit(s), output channels are not capable of performing the tachometer measurements, so one or two of the input channels must be designated as a tachometer channels. The choice of selection of the tachometer channels can be made by the user. Any input channel of the master module (only) may be used.
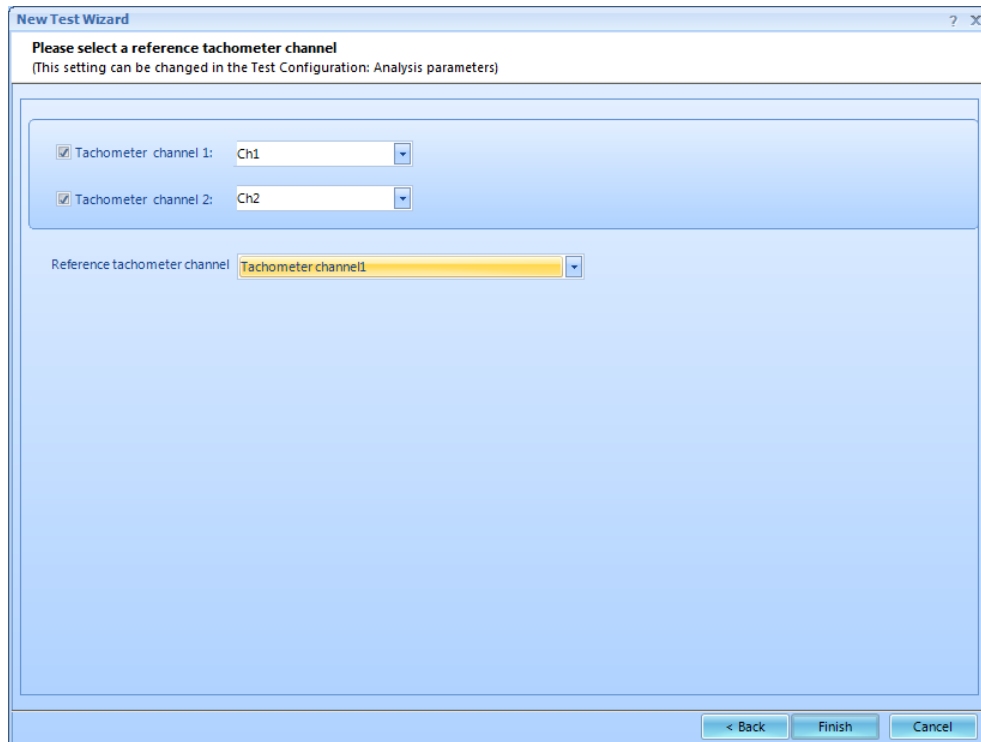
**Figure 187: New Test Wizard – Selecting Tachometer channels (7.4 Hardware and below)**

User must have at least one tachometer channel enabled to perform the order tracking functions. Use of the second tachometer is optional.

One of the tachometer channels (when tachometers are selected) must be used as a reference tachometer in order to perform the order analysis. User has the choice to select one of the two tachometers as the Reference Tachometer.

## Click on "Finish" to create the test.

Once the test is created, a blank test with no signals can be viewed. The following Figure shows the basic User Interface when the test is created.
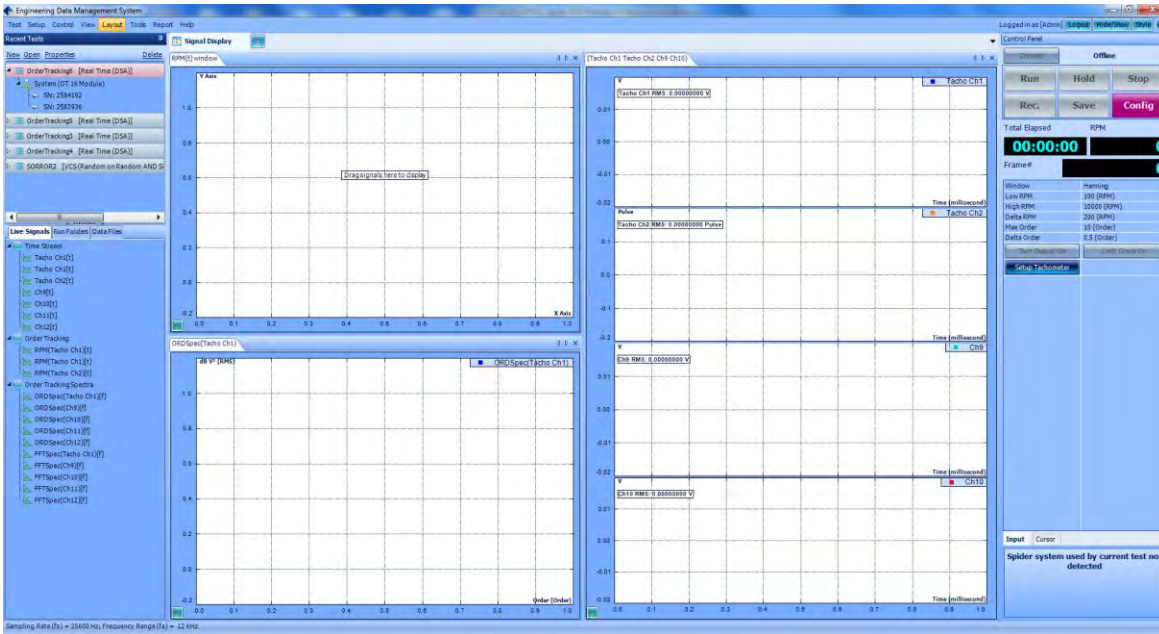
**Figure 188: Order Tracking Test – Initial EDM Screen**

The Test screen is divided into 5 parts. On the left side, there are the Recent Test List and the Signal List. On the right there are the Control Panel and the Status Window. In the middle are the Signal Display and Signal Setup tabs.
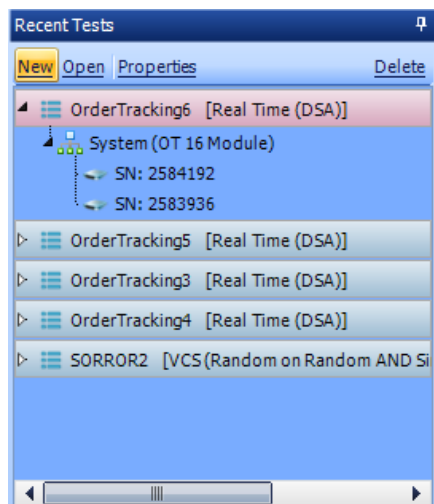
## Recent Test List



**Figure 189: Recent Tests**

On the upper left part of the screen, the Recent Tests list shows current and previous tests. Each test is listed by its name and type (VCS or DSA). Each test entry is expandable to display items underneath related to the test.

**System** lists the hardware modules associated with this test. The system is set up using the Spider Config window, described under System Configuration. The name of the system is displayed in parentheses.

## Signal List

Under the Recent Tests list is the Signal List, which shows live signals and saved data available for display.
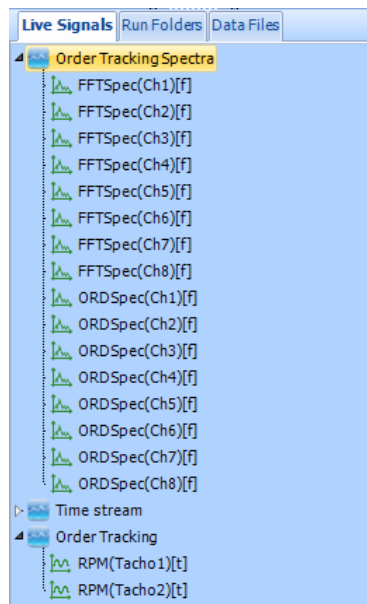


**Figure 190: Live Signals**

Live Signals include all input channels that are a part of the current system. (Depending on the test type, there may be other signals such as the control profile, associated alarm, and abort lines.) The list is divided in categories for time streams, RPM Signals and Order Tracking Spectra. It can also be viewed according to the hardware modules by right-clicking on the list and selecting Sort Signals by Spider Modules.

Run Folders tab displays the recent *Runs*:

After the user presses the Run button and the test finishes, a "run" is generated. By default, a Run folder is created on the disk.
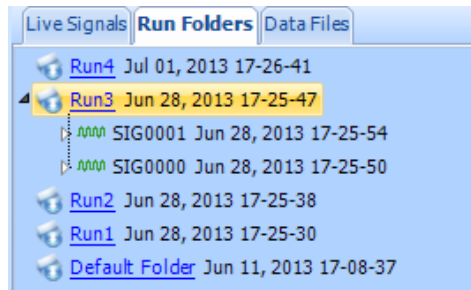
**Figure 191: Run Folders**

Data Files are time streams and block data saved or recorded to disk. All of the data files under a specific Run will be saved into that Run folder. When block signals are saved by clicking the **Save Sigs** button, a data file will be created and displayed here.
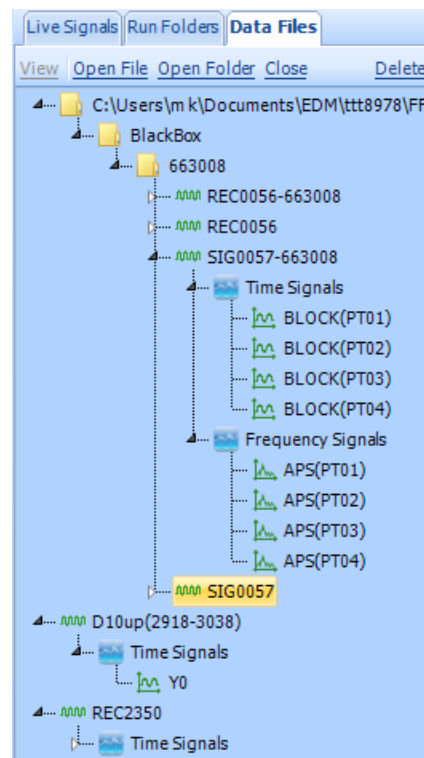


**Figure 192: Data Files**

## Control Panel

The Control Panel is used to control the test and display status information in real-time. The connection status of the hardware is shown on top, with a button to Connect/Disconnect (if no hardware is detected, this button will not be displayed). The control buttons — Run, Hold, Stop,Save— duplicate the items in the Control menu and on the Control toolbar. Config opens the Test Configuration window. **Rec./Stop** starts/stops the recording after test runs.
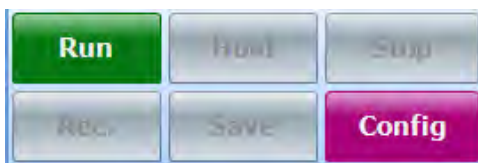
Below the control buttons, information on the state of the test is displayed. For a typical Order tracking test, the total elapsed time and the RPM of the enabled tachometer channels is displayed.

A few key parameters that are important to the Order Analysis are also displayed. These settings can be changed from the Test Configuration Setup which will be dealt with later in this section.



The function buttons are used to undertake specific functionalities.

**Turn Output On / Off**: Output channels can be used as output when 7.4 hardware units are used or when a tachometer is disabled in a 7.5 hardware unit. This button turns an available output channel(s) On or Off.

**Limit Check On / Off**: Turns ON or OFF the limit checking capability of the test. Limits can be enabled on all the order analysis signals to trigger a user defined event when the signal crosses a limit. The limits can be defined individually for each signal. Limit functionality will be revisited later in this section. This button determines when the limit checking is enabled.

**Setup Tachometer** navigates to the "Tachometer" section of Test Configuration page where the parameters for the tachometer channel(s) can be set.

There are tabs on the bottom of the control panel for viewing different pages of information. The Cursor tab shows the abscissa and ordinate values for all displayed cursors and peak and harmonic markers.

There are Input, Output, and Cursor tabs. The Input tab is shown above. The Output tab controls the output function generator. Cursor shows the details of the cursor when a cursor is placed on displayed signal.

On the very bottom of the control panel the system connection status is shown, along with any messages related to test events.

## Tachometer Setup

Spider-80X units are capable of handling two tachometer channels. The 7.5 hardware units have dedicated tachometer 1 to perform Order Analysis and tracking as well RPM measurement and recording. Tachometer channel 2 only performs RPM measurement and recording. The 7.4 hardware units can have any of the input channels up to two can be used as the tachometer channel(s) with one of those channels being used to perform the order analysis.

In 7.4 hardware units, only 1 Or 2 input channels from the master module can be used as a tachometer channels. In version 7.5 hardware units, only the tachometer channels from the master module can be used as tachometer channels.

Tachometer parameters need to be set for the tachometer to detect the tachometer pulses correctly and generate an accurate RPM signal.

**To setup or modify the tachometer settings, click on "Config" from the Control Panel and select "Analysis Parameters" on the left or click on "Setup Tachometer"** from the control panel function buttons. They both open the same page which is shown below:
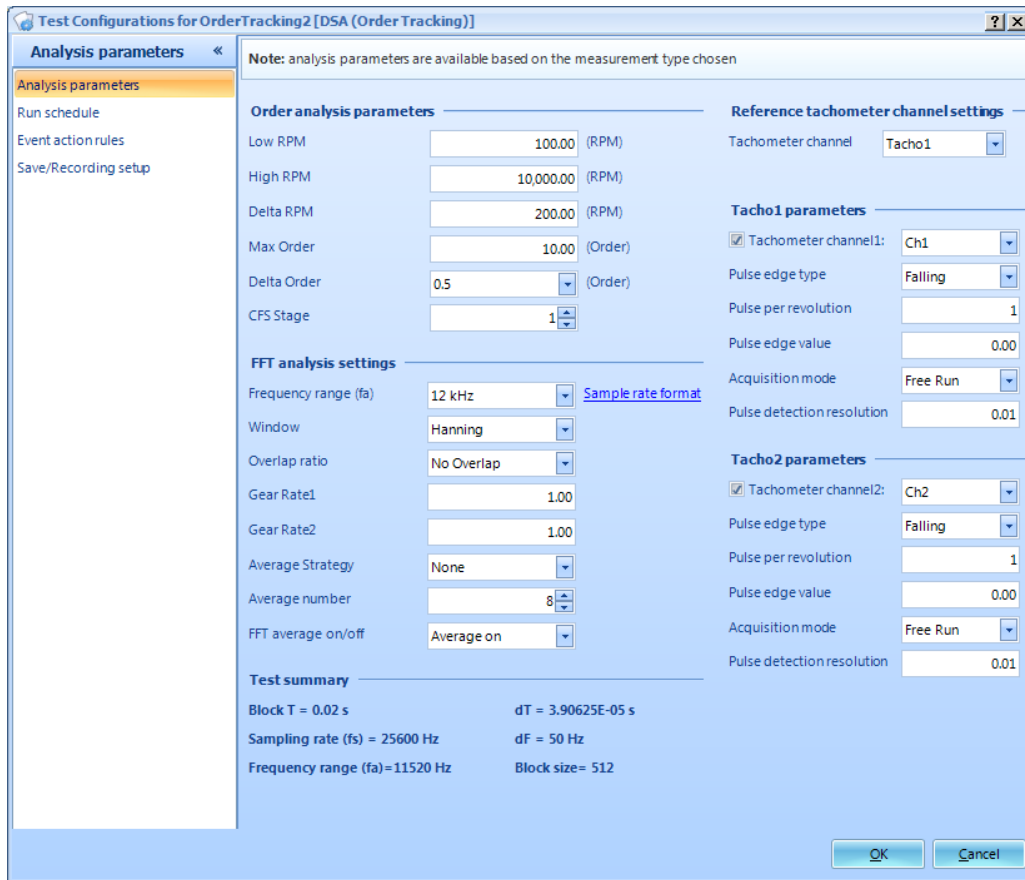
**Figure 193: Test Configuration for Order Tracking**

The Right side of this page deals with the tachometer settings.

**Reference Tachometer Channel**: Identifies the Reference Tachometer channel that is used for calculating the Order spectrum, Order Tracking. This setting is only useful when using a 7.4 hardware units in which one of the two tachometer channels can be used as a reference tachometer channel. In the 7.5 hardware units, the Tachometer channel 1 / Output channel 1, is always used as the Reference Tachometer.

The typical settings of the tachometer are listed below:
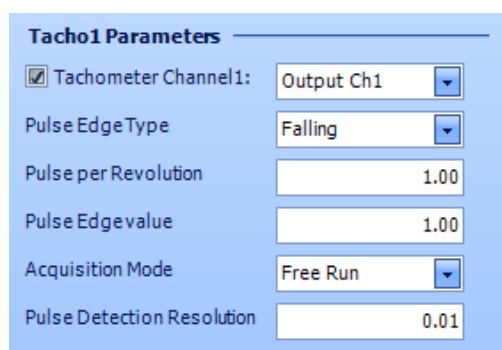
**Tachometer Channel** identifies the channel used as Tacho **1** (or 2). The checkbox can be used to enable or disable the tachometer channel and the dropdown menu lists all the channels that can be used as a tachometer channel.

For the 7.4 hardware units, any input channel from the master module can be used as a tachometer channel. For the 7.5 hardware units, the dedicated tachometer 1 channel is used as the Tachometer channel 1 and is enabled at all times. The dedicated tachometer channel 2 is used as tachometer channel 2 and the user has an option to enable it or disable it.

**Pulse Edge Type** specifies triggering upon the rising or falling edge of the tachometer pulse.

**Pulse per Revolution** is assumed from each revolution. The tachometer may generate one or multiple pulses per revolution of the rotating machine. The number of tachometer pulses that need to be counted to complete one machine revolution is set using this parameter. The minimum value of this parameter has to be 1.

**Pulse Edge Value** is the threshold voltage level that the input tachometer pulse needs to exceed to be detected as a pulse.

**Acquisition Mode** controls the processing of the tachometer signal.

> *Free Run –* data is acquired regardless of the direction of the RPM as long as the RPM is between the low and high RPM limits.

> *Run Up –* data is only acquired when RPM starts below low RPM limit and then increases. Acquisition stops when RPM exceeds high RPM limit.

> *Run Down –* data is only acquired when RPM starts above high RPM limit and then decreases. Acquisition stops when RPM exceeds low RPM limit.

> *Up Down –* data is only acquired when RPM starts below low RPM limit and increasing. Acquisition continues as RPM increases past high RPM limit and then as RPM decreases past the low RPM limit.

> *Down Up –* data is only acquired when RPM starts above high RPM limit and decreasing. Acquisition continues as RPM decreases past low RPM limit and then as RPM increases past the high RPM limit.

**Pulse Detection Resolution** is a hysteresis value applied to the trigger transition voltage. If a rising edge is specified, a low state must be at least the pulse detection resolution below the pulse edge value. If a falling edge trigger is specified, this constraint applies to the pre-trigger high state.
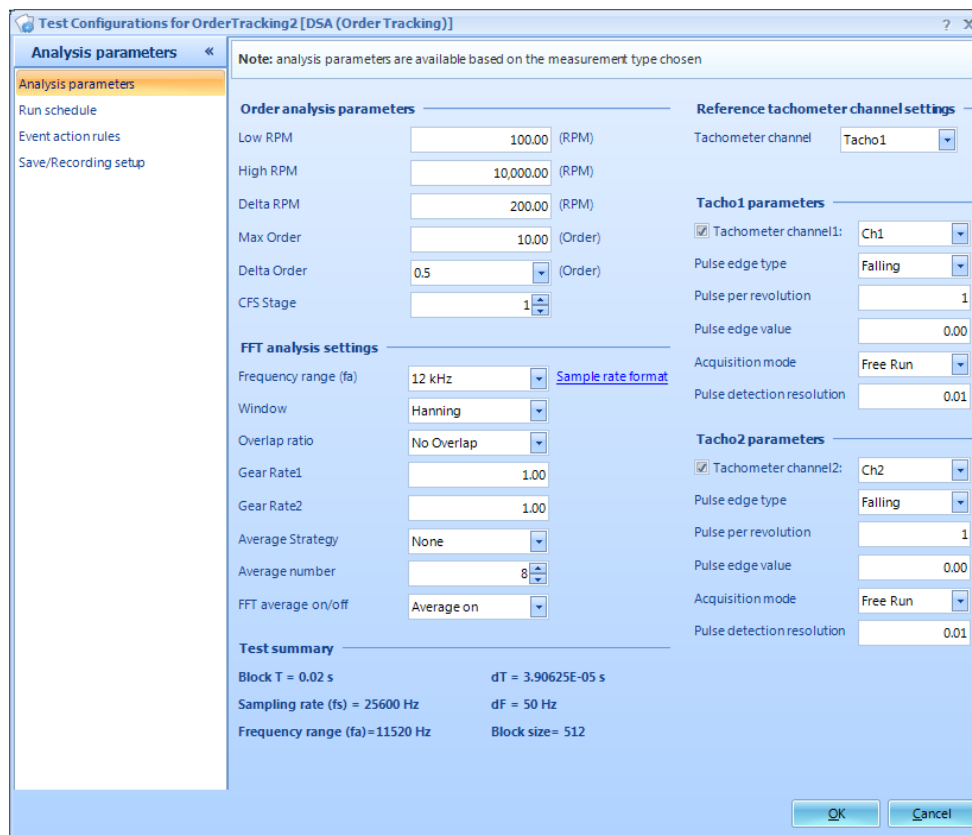
The same settings are also applicable for the Tachometer 2, if enabled.

## Order Analysis Parameters Setup

To setup the Order Analysis parameters, click on the "Config" button on the Control panel or navigate to "Test Configuration" from the "Setup" menu item. This will open the same page which is used for the tachometer setup.

The left side consists of two important sections for settings, the upper one is the Order Analysis parameters setup and the lower one is the FFT Analysis parameters setup.

In this section, we will discuss the Order Analysis parameters setup. These parameters are used for calculating the Order Spectrum, Order Tracks and Band RMS Spectrum.
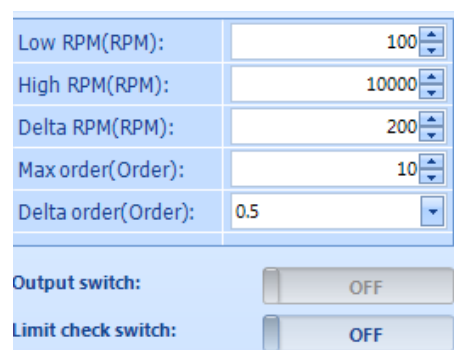
**Figure 194: Order analysis parameters**

**Low/High RPM**:The Low and High RPM define the range of RPM for RPM measurements, Calculation of Order tracks and Band RMS Spectra. If the Spider-80X detects that the current RPM is between the Low and High RPM, it will take the measurement and display it. Otherwise, the RPM readings on the control panel will always display 0 and the RPM time streams will always display the value of Low RPM.

**Delta RPM**: The Delta RPM defines the resolution of the RPM trace or the resolution of the RPM axis for Order tracks and Band RMS Spectra. The smaller the delta RPM, the more frequently the signals will be stored and displayed along the RPM axis and the more storage that will be required. Typically the Delta RPM is chosen between 25 and 100 RPM.

**Max Order**: The Max Order defines the highest order number for an Order Spectrum.  This is similar to defining the maximum frequency in an FFT analysis. EDM uses this value to determine the analysis frequency range. You should define the minimum Max Order that the application needs. If the Max Order too high, the system must sample at a very high frequency to cover the whole frequency range and the accuracy of lower order estimations may be poor.

**Delta Order**: The delta Order defines the resolution of an Order Spectrum. The Max Order and Delta Order together define the number of points in a normalized order spectrum. The smaller the value of Delta Order, the better will be the resolution and more computational resources are required to process the order spectra.

The Order Analysis parameters can also be viewed or edited on the control panel (when the test is not in the running). This enabled the users to quickly access and modify the Order Analysis parameters which are the most important parameters for an Order Tracking test.

## FFT Analysis Parameters Setup

As mentioned in the previous section, it is frequently important to measure the FFT Spectrum alongside the Order spectrum during an Order Analysis. FFT parameters can be modified by navigating to the Test Configuration, by either clicking on **"Config" from control panel or clicking on "Test Configuration" from the "Setup"** menu item.

The frequency range and other FFT parameters are usually determined using the max order and the max RPM of the order analysis settings. Some key parameters can be changed by the user to e**nable the FFT spectrum as per the user's choice.**

**Frequency Range** is defined as the maximum frequency range for the FFT analysis. Frequency range determines the sampling rate required. A minimum frequency range is set depending on the maximum order and the maximum RPM of the Order analysis. The user will be able to set the Frequency range higher than this range to obtain a higher frequency range for FFT analysis. The user cannot decrease the Frequency range below the minimum value set by the EDM using the Order analysis parameters.

**Overlap Ratio** is the ratio of the overlap between two consecutive frames of data. A 50% overlap signifies a 50% data in a frame is filled by the existing data and the remaining part of the frame is filled by the new data.

**Window Type** defines the data windowing function used in the FFT and order analysis.

**Average Strategy –** defines the averaging type used in the FFT and order analysis: exponential, linear or peak hold.

**Average Number –** defines the number of averages in a linear average or the weighting factor for exponential averaging.

**FFT Average On/Off** turns the averaging defined by the above two parameters On or Off. When the Averaging is On, averaging is done on the data and when Off, averaging is not performed.

## Input Channels Setup

The Input channel setting for an Order tracking test is same as the general setting for any other test, Refer to Input Channels Setup for the complete setup details.

## Output Channels Setup

The Output channels for the 7.5 hardware units of Spider 80X hardware are also designed to act as tachometer channels.

The Output channel 1 is a dedicated tachometer channel which can support Order analysis functions and must be used as a tachometer.

The Output Channel 2 can either be used as a Tachometer to calculate the RPM or **use it as an output channel to generate the desired output. Click on "Setup" menu** item and select the Output Channels to view the Output Channel settings.
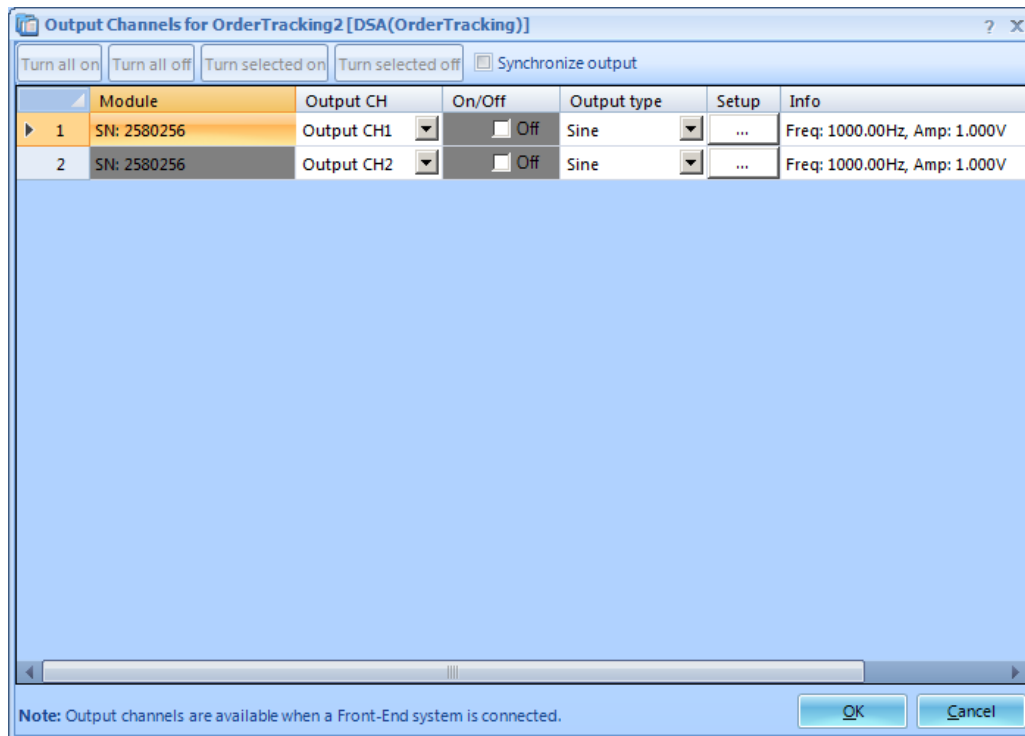


**Figure 195: Output channels setup**

Output 2, as described can be toggled between the Output Ch2 or Tach Ch2. Select Output Ch2 when it is supposed to be used as an Output Channel.
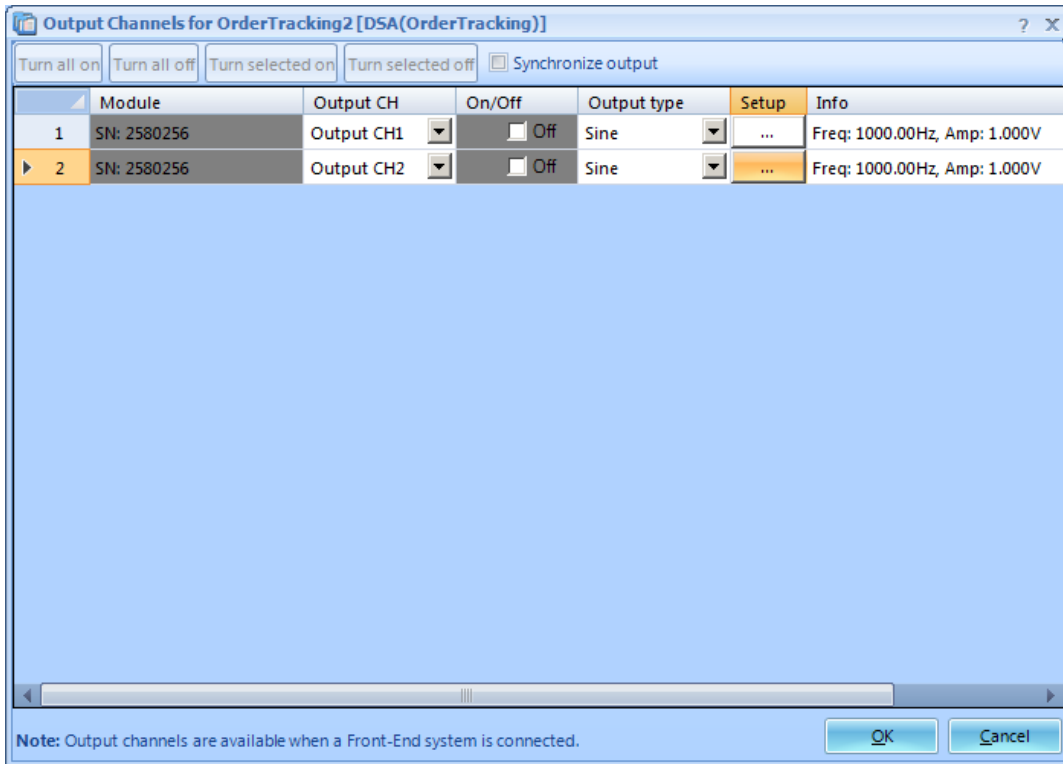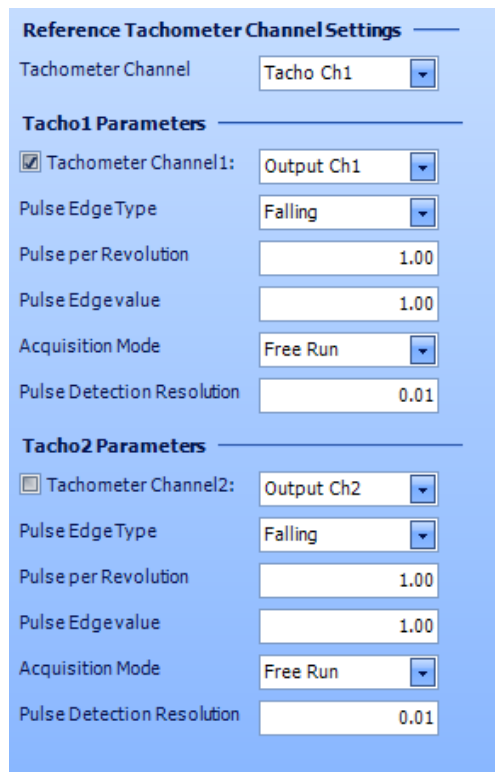
**Figure 196: Output channel configuration in Order Tracking**

The Output channel can also be enabled by simply disabling the tachometer 2 from the tachometer settings in the Test Configuration.

As mentioned earlier, unchecking the box next to Tachometer Channel 2 disables the channel 2 as a tachometer input and channel 2 is set to Output.

For the 7.4, hardware units, the output channels can only be used for generating outputs and the output channel settings can be viewed or set using the control panel **output tab or the navigating to the Output Channels setup from "Setup" menu item and clicking on "Output Channels".**

A more detailed description of the specific usage of the output channels to generate different types of signals as output is described in the Output Channels section of this manual.

### Measured Signals Setup

Signals that need to be measured including the option to include selected signals in the Record or Save list is done using the Measured Signal setup. Additionally, Order spectrum, configuring Order tracks and RMS Band spectra can also be done using the measured signals setup.

**To open the measured signals setup page, Click on the menu item, "Setup" and click on "Measured Signals".**

The following figure shows the Measured Signals setup page for a typical Order tracking test with one Spider module.
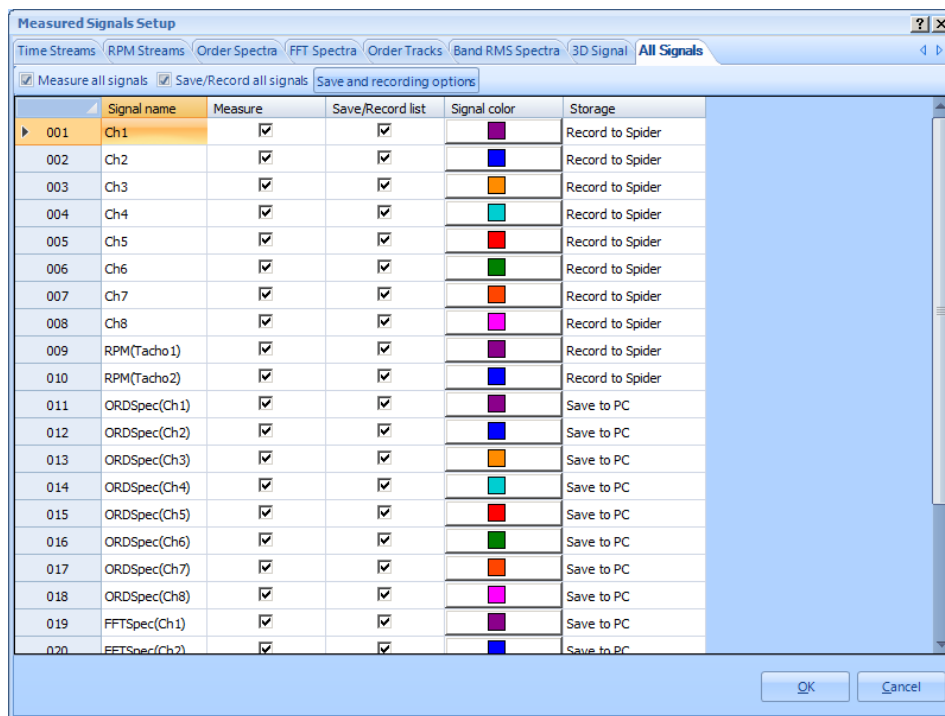


**Figure 198: Measured signals setup**

The signals are categorized into multiple tabs each signifying a particular class of signals.

**Time Streams** deals with the raw time stream data from the input channels. For the 7.5 hardware units, there will be up to two tachometer channels in addition to the input channels.

**RPM Streams** measure the instantaneous RPM of the tachometer channels and displays continuously with respect to time similar to a time stream

**Order Spectra** measure the Order spectrum of each of the channels with the selected reference tachometer channel for the 7.4 hardware units or with the dedicated tachometer 1 as reference channel for the 7.5 hardware units.

**FFT Spectra** defines the spectrum of the channels with respect to the frequency as the X axis. This is identical to the conventional FFT spectrum on an FFT test.

**Order Tracks** can configure and measure order tracked signals for a particular channel and a particular order. One input channel can generate multiple order tracked signals, each for a different order.

**Band RMS Spectra** plots the RMS amplitude in a user defined band of frequencies versus the RPM.

**3D Signal** displays the signal plots in 3D.

**All Signals** gives a view of signals from all the tabs to the user.

Similar to the measured signals in any of the DSA or VCS tests on EDM, the time stream signals can be recorded continuously and the other signals that appear as blocks or frames of data can be saved to the PC or to the internal flash of the Spider.

### Time stream Signals

The time stream signals are the raw time waveforms applied to the input channels. They are displayed with relative time on the Y-axis.
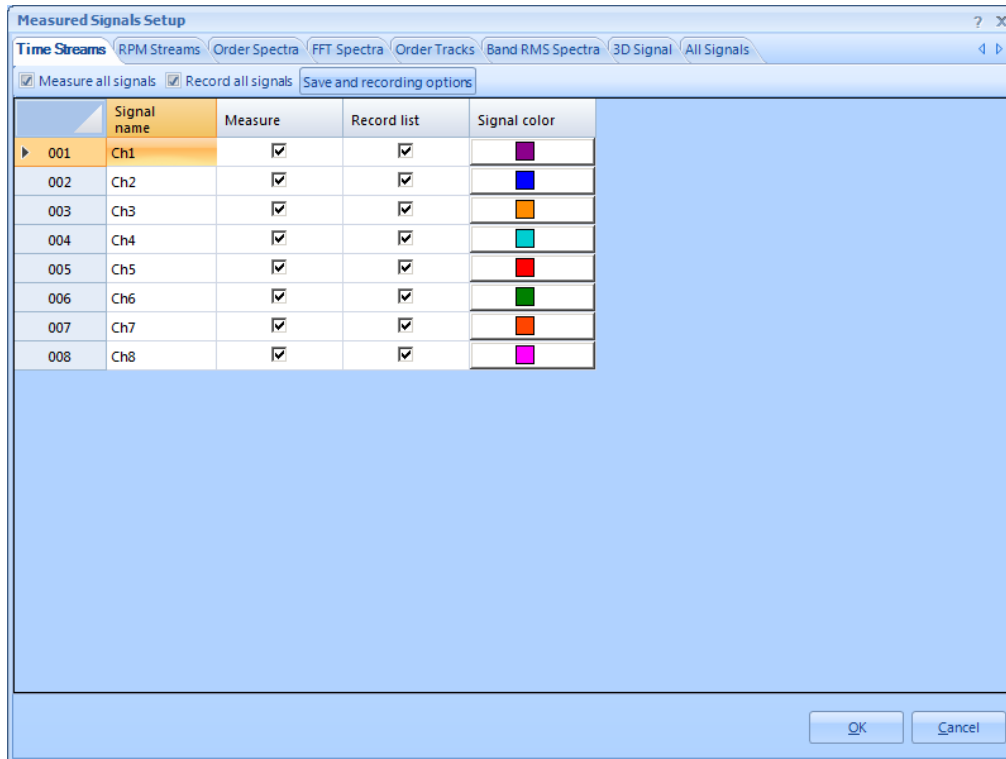
**Figure 199: Measured signals setup – Time Stream for 7.5 hardware and above**

For the 7.5 hardware units, the output channels can also be used as the tachometer input channels. Therefore, an additional two tachometer channels can be viewed in addition to the input channels. All input channels and the tachometer channel 1 provide the raw time stream signals which are the same as the signals received at the input channels. Tachometer channel 2, however, generates a reconstructed tachometer signal with a unit pulse of 1V whenever a pulse in the tachometer is detected. What does this mean?

For 7.4 hardware units, since an input channel must be used as the tachometer channel, there is no individual tachometer channel listed.
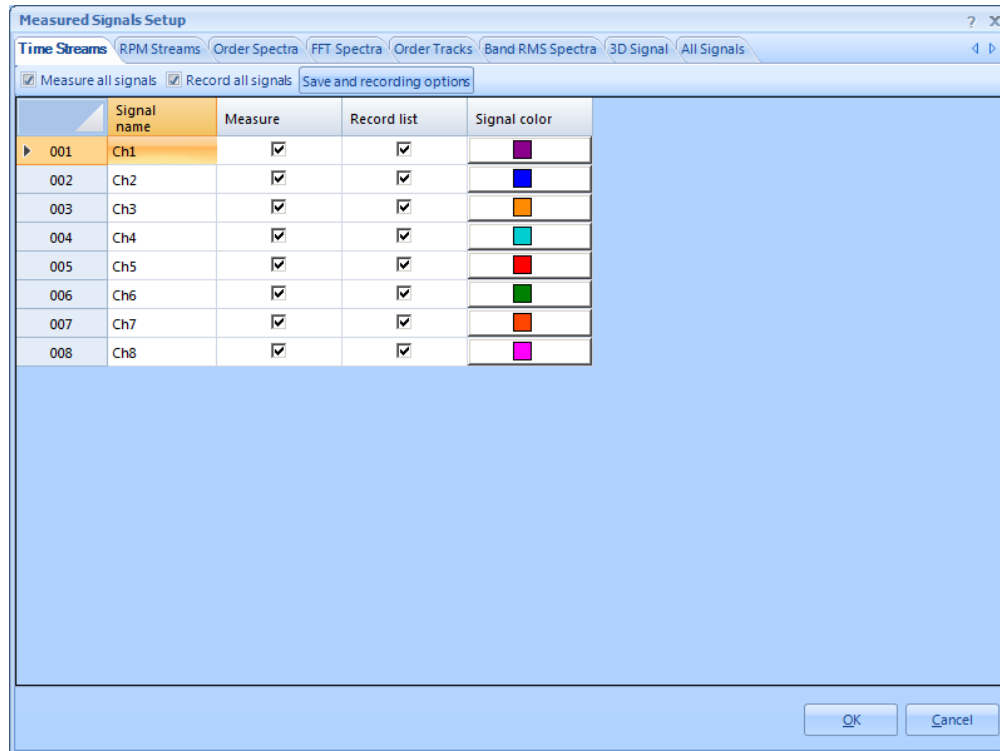
**Figure 200: Measured signals setup – Time Stream for 7.4 hardware and below**

The input time stream signals can be **Enabled/Disabled** by checking the checkboxes under the "Measure" attribute. Disabling channels which are not necessary can save memory and processing time.

The input time stream signal can also be recorded by checking the box under the **Record List** against each signal. Multiple channels can be selected for recording including the tachometer channels for a 7.5 hardware unit.

## RPM Streams

RPM Streams provide the instantaneous RPM value calculated from tachometer channel(s). This may be displayed as a time stream (versus the relative time on the X axis).

The number of channel in this list depends on the number of enabled tachometer channels. The following figure shows this tab's contents when both the tachometer channels are enabled.
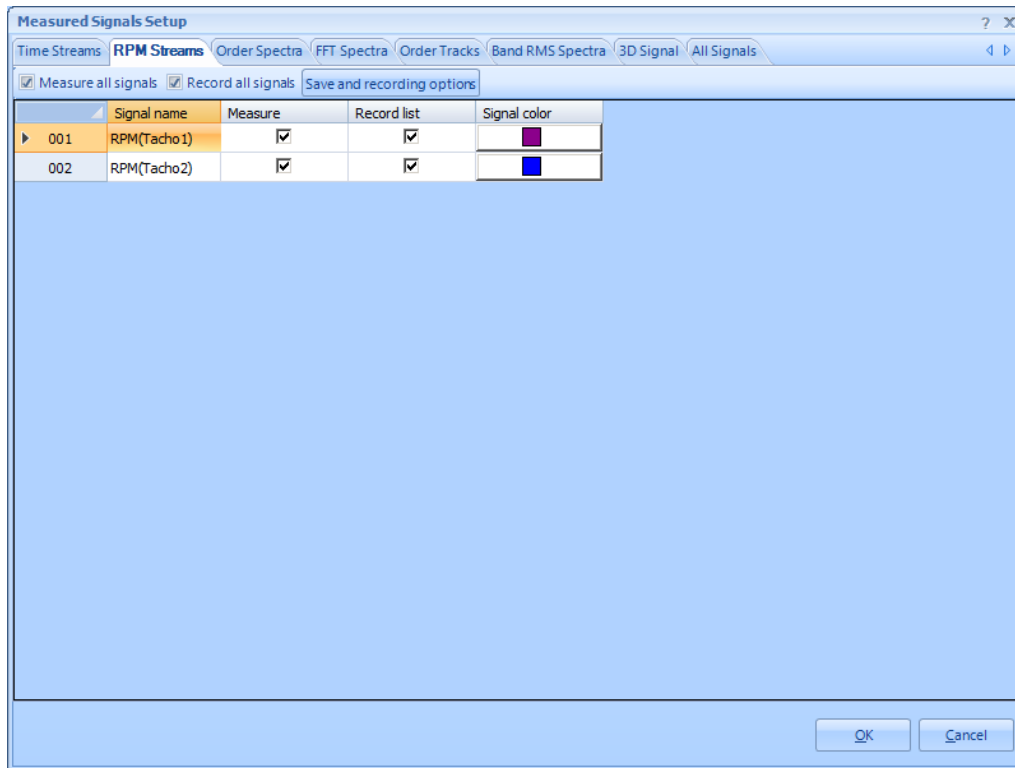
**Figure 201: Measured signals setup – RPM Streams**

Similar to time streams, the **Measure** attribute for each signal can be checked / unchecked to enable / disable measuring the RPM time stream signal.

The signal can also be recorded as a time stream to the internal flash when the **Record List** attribute is selected for the signals that are required for recording.

## Order Spectra

Order Spectra provide the spectra of the channels in terms of Orders. The following picture shows the Measured Signals setup for the Order Spectra from a single Spider-80X module. When multiple modules are used, the number of Order Spectra is increased by 8 per module (up to a maximum of 128 channels).
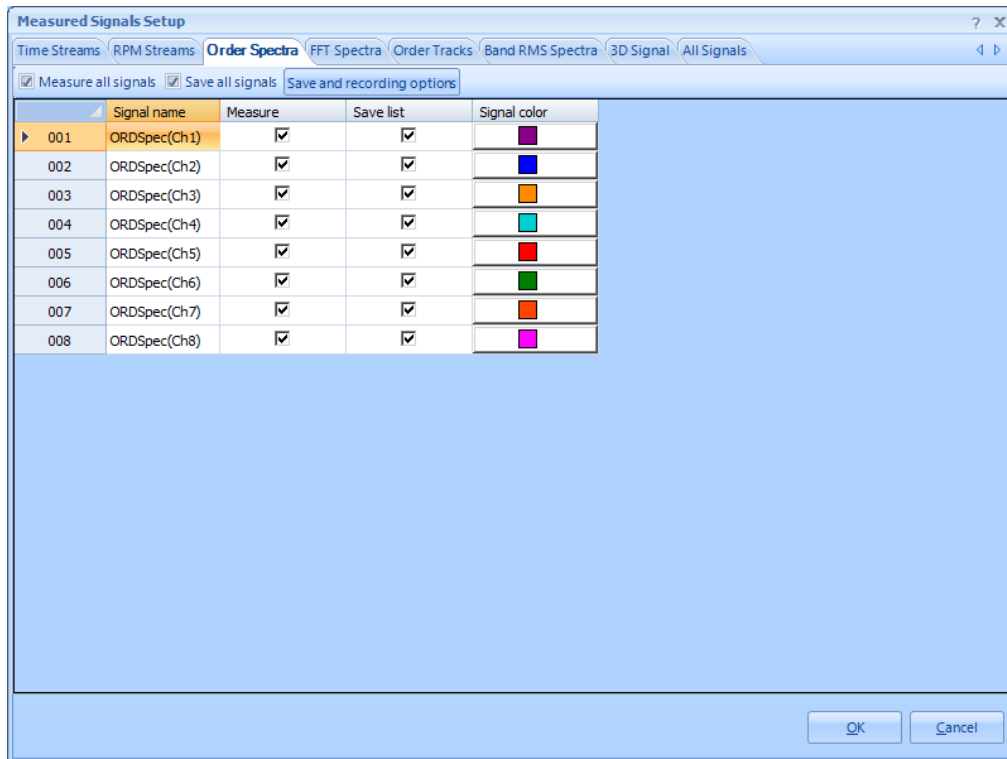
**Figure 202: Measured signals setup – Order Spectra**

Any channel for which the Order Spectrum is required must be enabled by checking the corresponding Measure box for that channel.

Since the Order Spectra are block signals calculated every frame, each frame of the order spectral signal can be saved by enabling the order spectra of a channel in the **Save list**. Checking the Save List saves the signals when the User clicks on the **Save Signals** button in the Control Panel, or when save signals is otherwise executed.

## FFT spectra

FFT spectrum is identical to the FFT calculation in an FFT Analysis test.

The following figure shows the FFT Spectra for a 16 channel (2 module) system. The FFT Spectral signals can be measured on both Master and slave units.
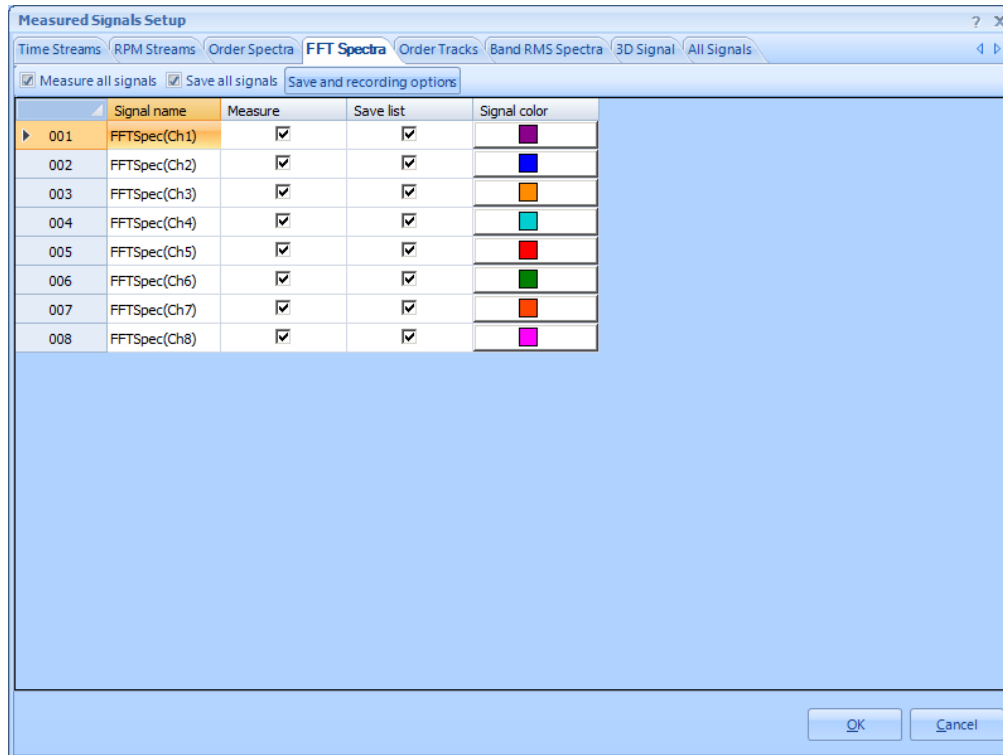
**Figure 203: Measured signals setup – FFT Spectra**

Similar to the Order spectra, the signals with checked **Measure** attribute are calculated by the hardware and when enabled (checked) in the **Save List** can be saved when the user clicks on Save Signals from the control panel or when save signals are configured through the built-in function.

## Order Tracks

Order Track signals are also of prime importance for an Order tracking test. Each Order track retains the amplitude and phase of the selected and channel as RPM changes. Each channel can have multiple orders that are tracked.

Since each Order Track signal **needs to be configured by the User's, EDM software** does not enable any Order tracks by default. The required Order Tracks must be added by the user. The following figure shows the default Order Tracks tab of the Measured Signals setup page.
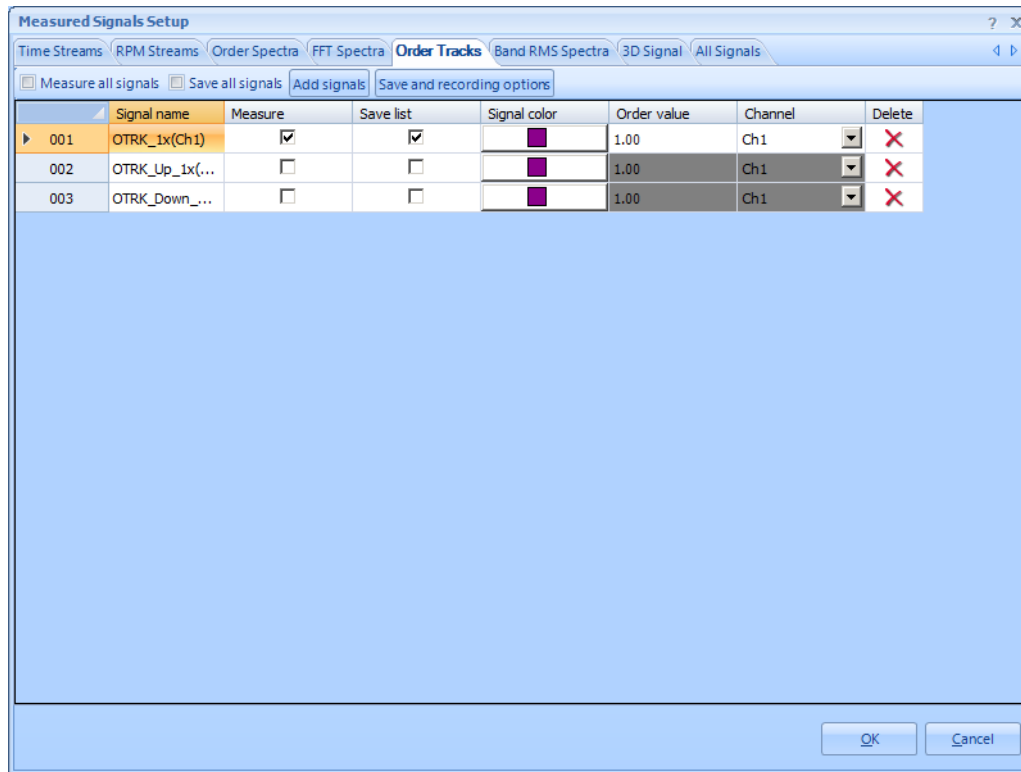
**Figure 204: Measured signals setup – Order Tracks initial setup**

Click on the Add Signal button on the top to start configuring the required Order Track signals.
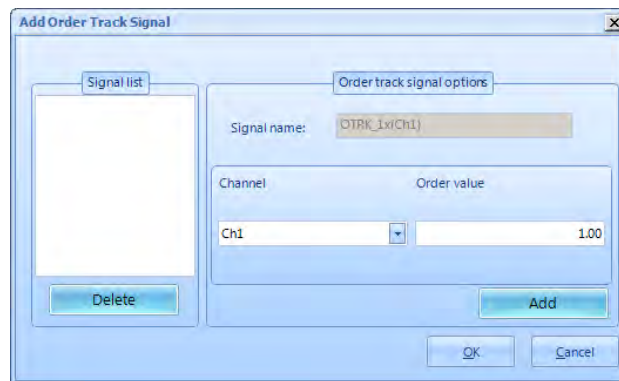


**Figure 205: Adding complex order track signals**

Select the **Channel** for which an order needs to be measured and select an **Order Value**. The Order value can also be a decimal number which tracks, for e.g., 1.5 order of channel 1. Click on **Add** to add the order tracked signal.

The Upper portion of this page, shows the **Signal Name**. The default name of each signal has the form, OTRK_*OrderValue*(*Channel Number*).

Multiple orders for a single channel and multiple orders for multiple channels can be added at the same time by selecting the channel, entering the order value and

clicking on the Add button. The added signals list is shown at the left side of the pane. Unnecessary signals can be removed using the "Delete" button.

It has to be noted that the *Order Value* can take a maximum value as specified in the Order Analysis settings and must be within the resolution selected in the Order Analysis settings. For e.g. with Max Order setting of 10 and a Delta Order setting of 0.5, an order with a value more than 10 or an order value which is not a integer multiple of 0.5 cannot be entered.
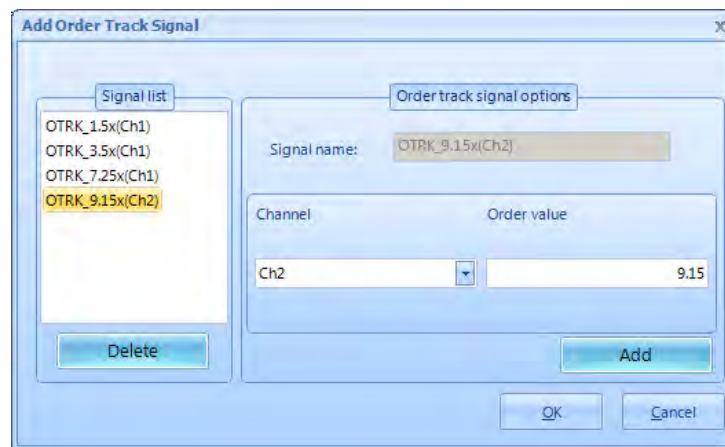


**Figure 206: Adding complex order track signals**

When all the required signals are added, click on "OK" to create all the signals that are configured by this pane.

This pane can be opened multiple times to add or modify the Order Tracks. Once the signals are added, they appear in the Measured Signals setup window under the Order Tracks tab as shown:
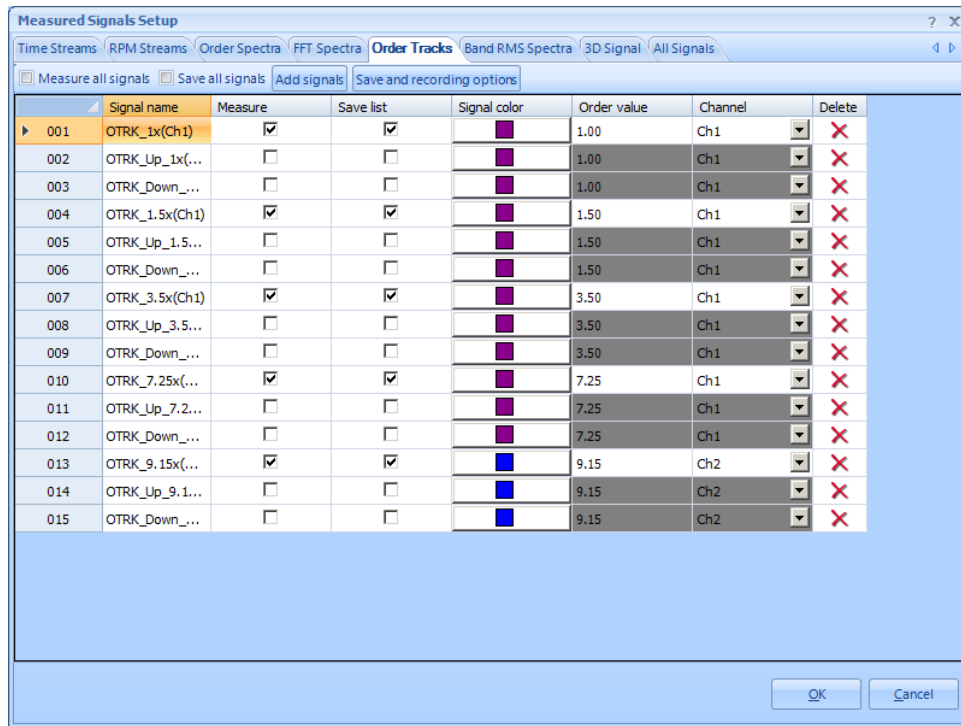
**Figure 207: Measured signals setup – Order tracks**

As it can be seen, each order track entry creates 3 signals:

*OTRK* denotes the continuous Order Track of the selected order for the selected input channel.

*OTRK_Up* denotes the signal that is only updated when the RPM is going up. When the RPM is going down, this signal is unchanged.

*OTRK_Down* denotes the signal that is updated only when the RPM is decreasing or going down and remains unchanged with the increasing RPM.

**Order value** can also be **changed** by clicking on the Order Value column of the order tracked signal and entering a new value. It has to be noted that changing the Order value for an order tracked signal will also change the order value for the corresponding Up and Down signals.

The signals that are not necessary can be deleted using the delete column towards the rightmost side.

## Band RMS Spectra

A band RMS Spectrum measures the Overall RMS level in a frequency band specified by the user. It is tracked with respect to the change in the RPM.

Configuring the Band RMS Spectra is similar to configuring the Order Tracks. It requires the channel and the frequency range of the band. By default, the EDM does

not have any signals under this tab and the signals need to be defined according to user requirements.

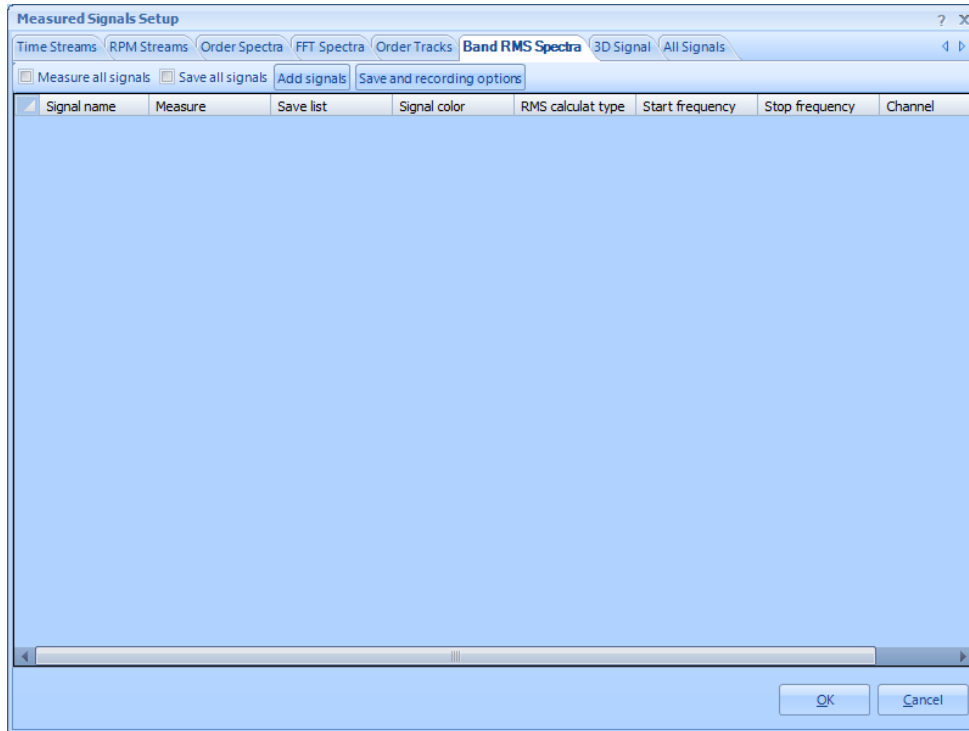The following figure shows the default Band RMS spectra.



**Figure 208: Measured signals setup – Band RMS Spectra initial setup**

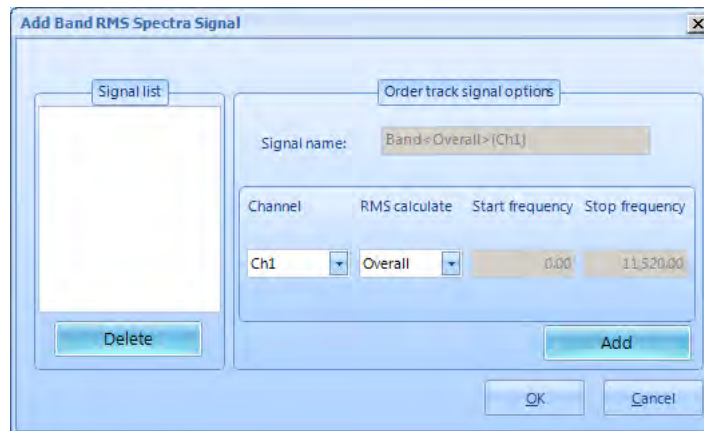Click on "Add Signals" button to start configuring the Band RMS Spectrum signals.



**Figure 209: Adding Band RMS Spectra**

While adding the Band RMS signals,

**Channel** refers to the channel which needs to be measured.

**RMS Calculate** refers to the band of frequencies over which the RMS needs to be measured. The user can select *Overall* which spans all the frequencies governed by the frequency range of the test.

**Start and Stop Frequencies** denote the start and stop frequencies of the band.

Click on **Add** to add the signals, the added signals can be viewed (and deleted) from the left side section of the window.
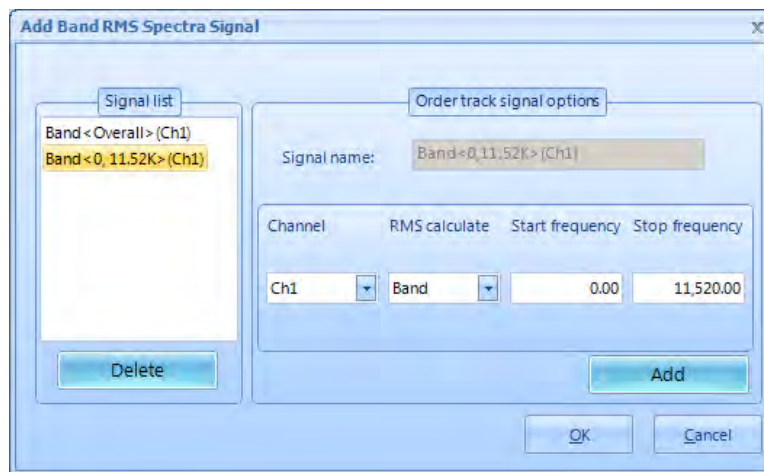


**Figure 210: Adding Band RMS Spectra**

Multiple bands for the same channel can be added as shown in the Figure above. When all the **required Band RMS signals have been added, click on "OK" to** navigate to the Measured Signal setup page with all the added Band RMS signals as shown in the Figure below.
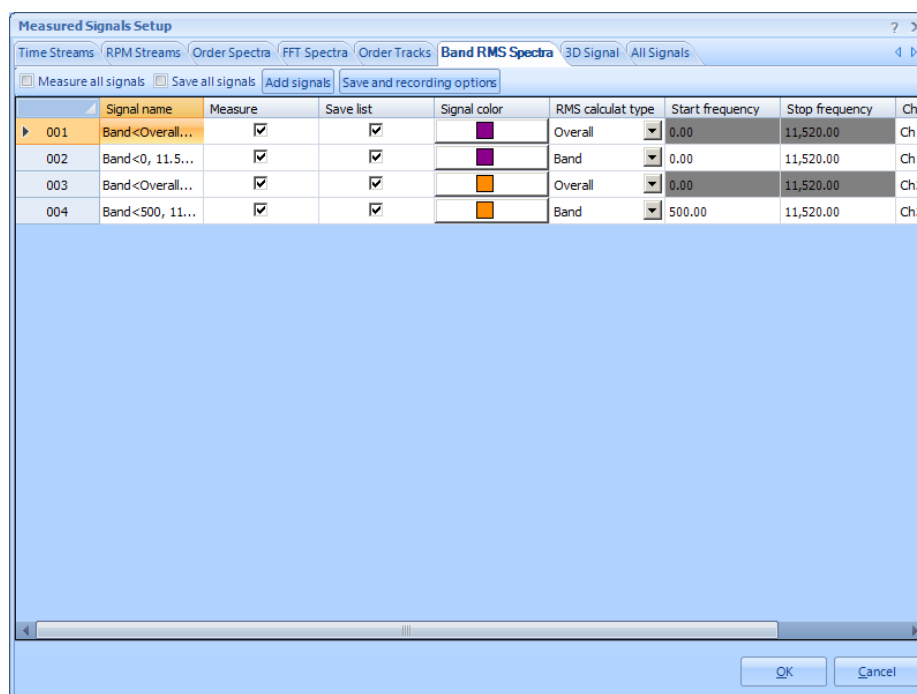
**Figure 211: Measured signals setup – Band RMS Spectra**

The *Start* and *Stop* frequencies can be edited from the Start and Stop Frequency columns on this window. The measurement *channel* can also be edited. The *Delete* key can be used to delete any unnecessary signals from this list.

**The "Measure" and "Save List" checkboxes work exactly the same** as the corresponding attributes for Order Spectra or FFT Spectra signals.

## All Signals

The All Signals tab displays all the signals at one place for the user to view, as shown:
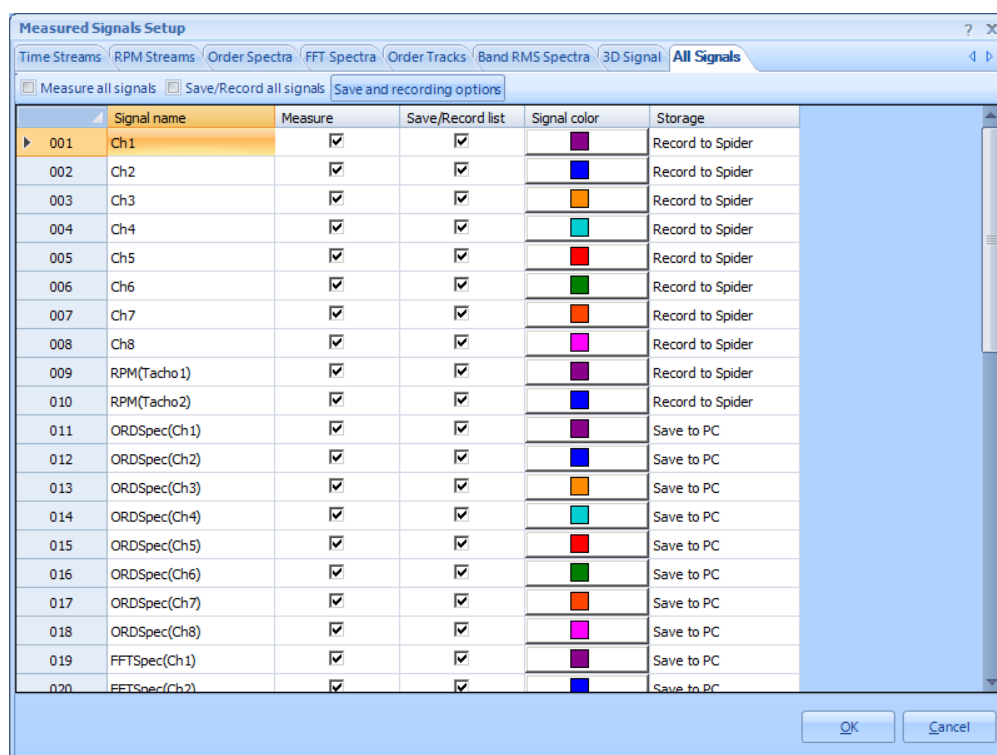


**Figure 212: Measured signals setup – All Signals**

The user can enable or disable each signal by checking or un-checking the Measure attribute. The user can also modify the Save / Record attribute for each signal.

The additional attributes with signals, such as Order Tracks and Band RMS Spectra cannot be edited or viewed from this tab.

## Running a test

The following key aspects must be verified before running a test:

1. The analysis settings are configured correctly. The settings include the Tachometer settings, Order Analysis settings and FFT analysis settings.

2. The Input channels have been configured appropriately

3. The Measured Signals have been augmented with all desired signals added to the Measured list and Save/Record list.

4. The tachometer is connected correctly and the physical connections with all the input channels are appropriately set.

Once the above settings are verified, the test can be run.
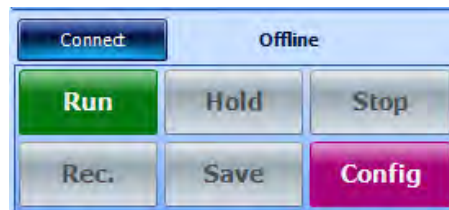


Make sure the device is connected, if the device is not connected, then the Connect button would be enabled. Click on **Connect** to connect the Spider-80X module to the EDM.

Once the module is connected, click on **Run** to start running the test.

Click on **Hold** to suspend processing at any point of time, this will freeze all the **calculations and the existing displayed signals will "freeze". Click on Continue** to continue the test into the running state again.

The **Record** button initiates recording of all time stream signals selected for record in Measured Signals. Pressing the **Save** button triggers saves all the current block signals to the Spider Internal flash or the PC. For further information, navigate to Save and Record Settings in this manual.

**Stop** completely stops the test and the recorded and saved signals from the Spider hardware module can be downloaded to the PC.

### Display signals

As seen from the previous section, the left hand bottom pane of the EDM default screen consists of the **Live Signals** tab which contains all the required signals that may need to be viewed.

All the signals that have the **Measure** attribute enabled are displayed here.

The following Figure shows the typical **Live Sig**nals tab for an Order tracking test with all categories of enabled signals.
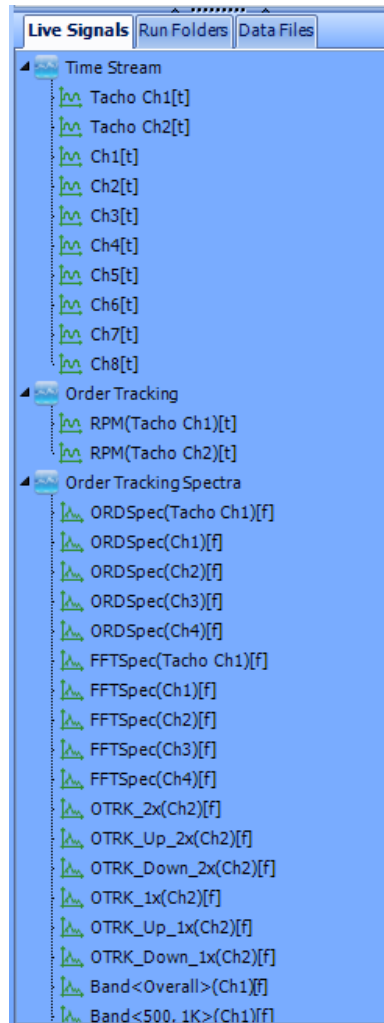
**Figure 213: Live signals for a typical Order tracking test**

The signals are by default sorted according to the type of the signals. When multiple modules are used, the signals can be sorted according to each module can be set by **right clicking on the Pane and click on "Sort Signals by Spider module".**

### 3D Signals Display

3D signals are of particular importance in Order tracking and enable convenient analysis by plotting the consecutive blocks of data in the 3rd dimension to analyze the changes in the block signal. Typically the Z-axis or the Reference axis can be Time or RPM.

EDM has a capability to plot the signals in 3D by either using time or RPM as the reference axis. 3D signals can typically be displayed in two different ways:

**3D Waterfall Trace** is used to display order spectra and order tracks vs. RPM or time in three dimensions.

**Color Spectrogram** is used to display order spectra and order tracks vs. RPM or time in 2 dimensions using color to represent the magnitude of the signal.

The limits of the 3D waterfall and color spectrogram depend on the Analysis Parameters such as low and high RPM and max order. The resolution of the plots depends on the Analysis Parameters delta RPM and delta order. Note that a larger RPM or order span or a higher resolution will affect the acquisition of the data and the memory required. Best quality results can be obtained by selecting optimum resolutions.
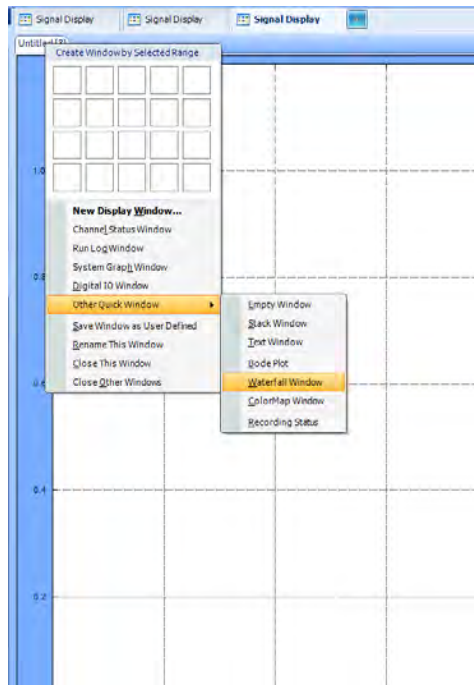


**Figure 214: Create 3D display**

To create a 3D signal plot. Right click on the title of any chart. Click on Other Quick Window and the options would contain Waterfall Window which creates a 3d Waterfall plot and a Colormap Window which creates a 3D Spectrogram.

Alternatively, right click on any signal from the live signals that support 3D signals display and click on 3D waterfall display or the 3D Colormap display.
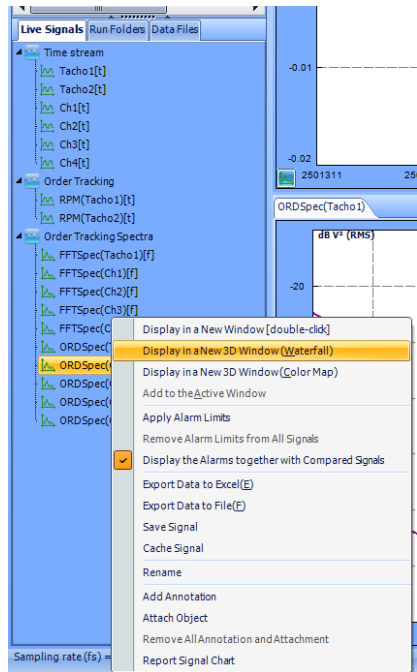
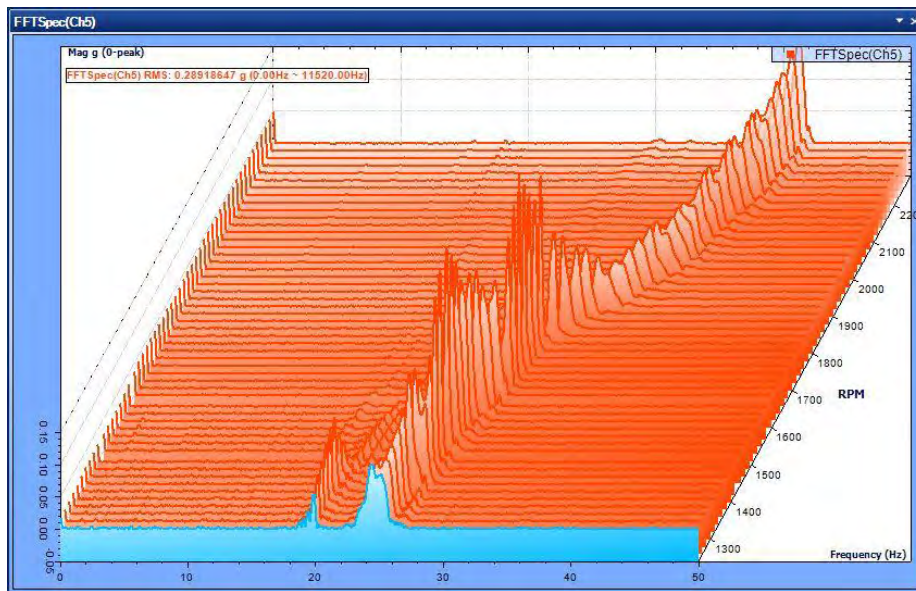**Figure 215: Create a 3D Waterfall or 3D Color Map display**



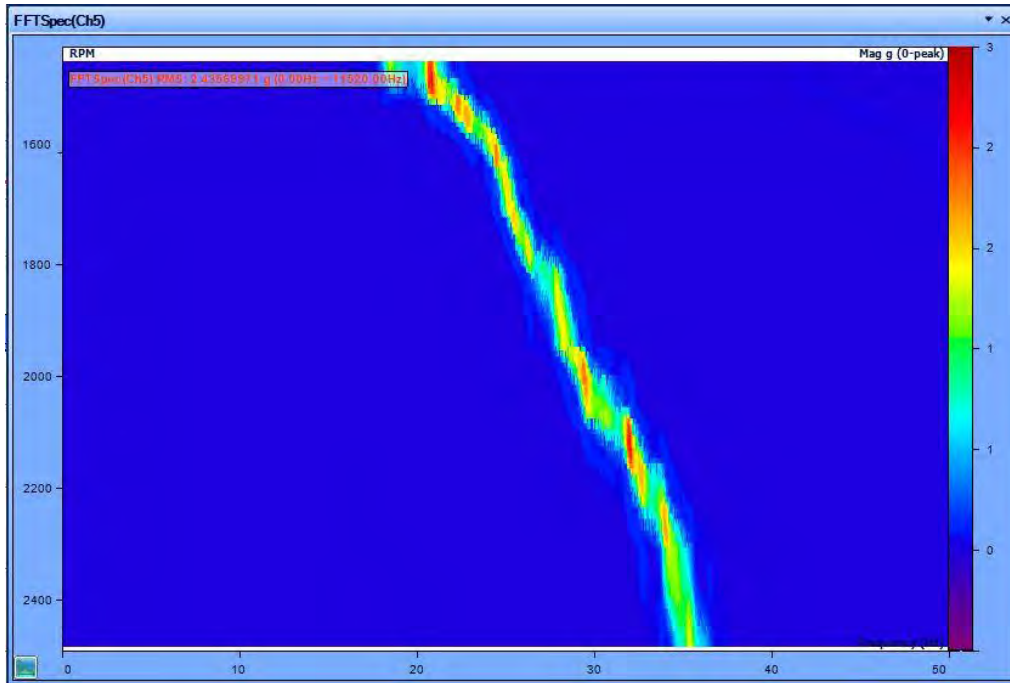**Figure 216: Typical 3D waterfall display**

**Figure 217: Typical 3D Color Map display**

The above figure shows a typical 3D Spectrogram and a typical 3D Waterfall plot.

The Z axis properties can me modified by clicking on the Z-axis line of the chart which pops up a Z axis setting window.
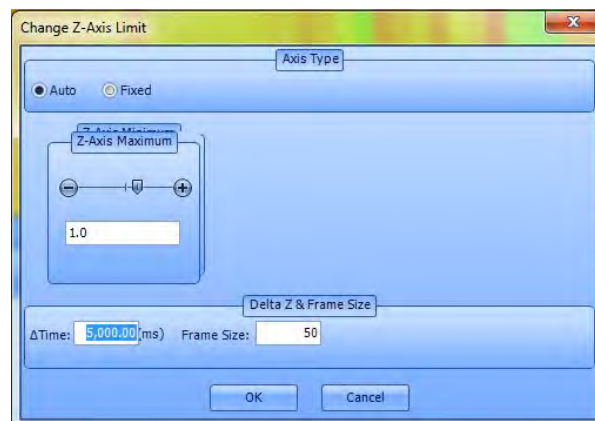


**Figure 218: Z Axis Settings for 3D displays**

The **Delta time** which defines the spacing between two consecutive data frames on the Z axis can be modified. The **Frame Size** gives the maximum number of Z axis points that must be displayed. For e.g. a frame size of 50 can store up to 50 block **signal's d**ata and display it to the user.

# Real Time Digital Filter

Real Time Digital Filters can be used to filter a measured signal in real time. Filter characteristics can be defined by the user to meet the requirements of a specific application. Real-time digital filters are applied in the data conditioning phase. The filters are designed with a graphic design tool and then uploaded to the front-end for real-time calculation. The graphic design tool defines the filter performance vertical axis with a dB scale. The horizontal axis is defined as relative frequency.

For example, a user might want to look at the energy distribution for a specific band of frequencies over time instead of for the entire frequency spectrum. This can be done by creating a band-pass filter and then applying an RMS estimator to the output of the filter.

The figure below shows a graphical representation of the process used to define a real time filter in the EDM software. The icon on the left, CH1 represents the native measured time stream. It is connected to an IIR Filter which computes a signal named iirfilter (ch1) which is connected to an RMS estimator. The output of the RMS estimator is a signal named rms(iirfilter(ch1)).



**Figure 170. Example of real time digital filter application.**

Another example: Perhaps a user wishes to look at the energy in bands from 100 Hz to 200 Hz and from 1000 Hz to 2000 Hz. This can be done by deriving two output streams from the native channel 1 and then applying the band-pass filter to each path as shown in Figure 171.
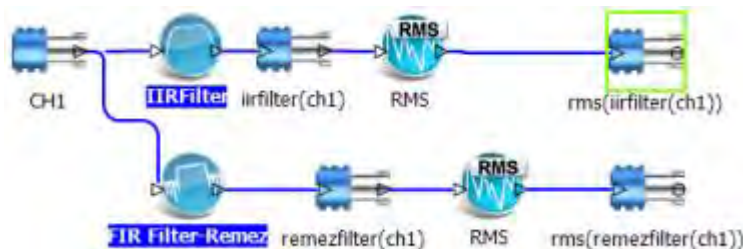


**Figure 171. A Digital Real Time Filter with two output streams.**

In another example, you might want to sample a signal at a high rate to capture high frequency events but may also wish to sample the same channel at a lower rate to see lower frequency events. This can be done by applying a decimation filter to the native time stream. The native channel time stream is split into two streams so the signal from the same channel is recorded at both high and lower sampling rates.

**Figure 172. Example computing high and low sampling rate with a decimation filter.**

The Real Time Digital Filters option includes three types of digital filters: Finite Impulse Response (FIR), Infinite Impulse Response (IIR) and decimation filters. For the FIR and IIR filters you can specify: low-pass, high-pass, band-pass or band-stop filters with several different methods.

This chapter first explains some filter design theory and then introduces filter operations within the EDM and the Spider hardware.

The goal of filter design is to calculate a series of filter coefficients based on user specified criteria. The criteria are often described by following variables:

**Number of filter coefficients**: this is also known as the order of the filter. The filter order defines how many coefficients are required to define the filter. A lower order filter consists has fewer coefficients. A low order filter responds faster than a higher order filter so there are fewer time lags between the input and output of the filter.

**Cutoff frequencies**: For low-pass or high-pass filters, only one cutoff frequency is needed. Band-pass or band-stop filters require two cutoff frequencies to fully define the filter shape. Figure 173 shows a typical band-pass filter design with the two cutoff frequencies set to approximately 0.1 and 0.2 Hz.

**Stop-Band Attenuation**: This specification defines how much of the input signal is cut out of the output at the rejected frequencies. In theory, the higher the attenuation the better the filter. The stop-band attenuation is greater than 40 dB as seen from the highest side lobe just below 0.25 Hz.

**Pass-Band Ripple**: Ripple is an unavoidable characteristic if a digital filter. It refers to the fluctuation in the filter shape outside the transition frequencies. If a very flat filter is required then it can be specified by choosing a very low ripple. In Figure 173, the ripple is seen in the stop band but no ripple is evident in the pass-band. Ideally the pass-band should be very flat and some ripple is tolerable in the stop-band.

**Width of transition bands**: This refers to the filter shape between a band-pass and a stop-band region. Ideally this transition band should be very small. However, a very narrow transitional band requires a higher order filter which affects the filter response time and can also affect ripple. The transition bands are between 0.05 to 0.1 and 0.2 to 0.25.
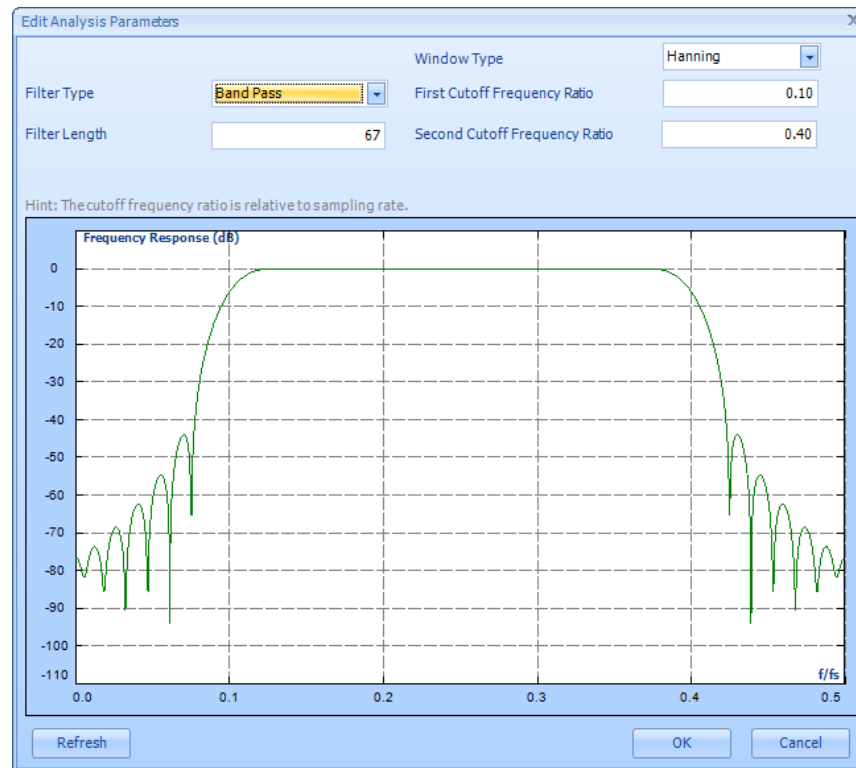
**Figure 173. Filter design shows cutoff frequencies, ripple, band stop attenuation.**

In most cases filter design includes making tradeoffs between minimizing the filter order, ripple, transition band-width, and response time. Not all can be satisfied at the same time. Filter design can be an iterative process and experience is helpful.

## FIR Real Time Digital Filters

Finite Impulse Response (FIR) filters have an impulse response that lasts for a finite duration of time. Infinite Impulse Response(IIR) filters have an impulse **response that is infinite in duration. The FIR filter's finite response is due to a lack** of feedback paths. FIR filters offer several advantages over IIR filters including:

- A completely constant group delay throughout the frequency spectrum. Group delay refers to the time delay between when a signal goes into the filter and when it comes out. Constant group delay means that an input signal will come out of the filter with all parts delayed by the same amount and with no distortion.
- Complete stability at all frequencies regardless of the size of the filter.

FIR filters also have some disadvantages:

- The frequency response is not as easily defined as it is with IIR filters
- The number of coefficients required to meet a frequency specification may be far larger than that required for IIR filters.

A digital filter can be understood by considering the equation which defines how the input signal is related to the output signal:

$$y[n] = b_0 x[n] + b_1 x[n-1] + \cdots + b_N x[n-N]$$

Where $x[n]$ is the current input signal sample, $x[n-1]$ is the previous signal sample and $x[n-N]$ is the last sample in the series. The series multiplies the most recent $N+1$ samples with the associated $N+1$ filter coefficients. $y[n]$ is the current output signal and $b_i$ are the filter coefficients. The number $N$ is known as the filter order; an $N^{th}$-order filter has $(N + 1)$ terms on the right-hand side. $N+1$ filter coefficients are **also referred to as "taps".**

This equation illustrates why a higher order filter has a slower response time. It takes more samples and therefore more time for an event to work its way through the series until the output is no longer affected by the event. A lower order filter has fewer coefficients and therefore a faster response time.

The previous equation can also be expressed as a convolution of the filter coefficients and the input signal, specifically:

$$y[n] = \sum_{i=0}^{N} b_i x[n-i]$$

The Impulse Response of the filter shows how historical data affects the current filtered value. The longer the impulse response, the more the older data will affect the current filtered value. To find the impulse response we set

$$x[n] = \delta[n]$$

Where $\delta[n]$ is the Kronecker delta impulse. The equation below shows that the impulse response for an FIR filter is simply the set of coefficients $b_n$, as follows

$$h[n] = \sum_{i=0}^{N} b_i \delta[n-i] = b_n \, for \, n = 0 \, to N$$

FIR filters are stablebecause the output is a sum of a finite number of finite multiples of the input values that can be no greater than $\sum_{n=0}^{N} |b_n|$ times the largest value appearing in the input.

### Data Windows FIR Filters

In the academic world, hundreds of methods are available to design FIR filters to meet various criteria. EDM includes the most popular filter design methods: Data Window and Remez. Both methods are discussed below.

The Data Window FIR Filter Design method is the easiest to understand. The name "Window" comes from the fact that these filters are created by scaling a

sinc(SIN(X)/X) function with a window such as a Hanning, Flat Top, etc. to produce the desired frequency effect.
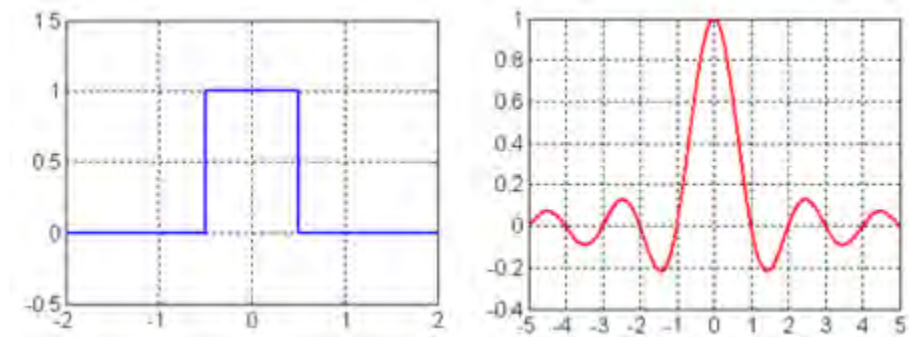


**Figure 174Sinc function is the Fourier transform of a square shape.**

A data window FIR filter is generated by starting with an ideal "brick-wall" shaped filter; that is a filter with vertical edges or zero transition band widthas shown on the left in Figure 174. The brick-wall filter is specified by its cutoff frequencies and it has band-pass amplitude of 1 and stop band amplitude of zero. The problem with the ideal brick-wall filter is that the time response oscillates forever and it requires an infinite number of filter coefficients.

This ideal filter can be modified by applying a data window to force the time response to decay in a finite amount of time. Of course this degrades the ideal shape of the brick-wall filter. It introduces ripple, increases the transition band width and decreases the stop band attenuation but it allows the filter to be defined by a finite number of filter coefficients. Filter performance can be modified by using different data windowing functions that offer tradeoffs between filter order and response time. The user must choose these settings during the filter design.

Figures below show a comparison of various data window choices for the same filter settings. In all cases the low and high cutoff frequencies are 0.1 and 0.2 relative to the sampling frequency. The number of filter taps is 67.
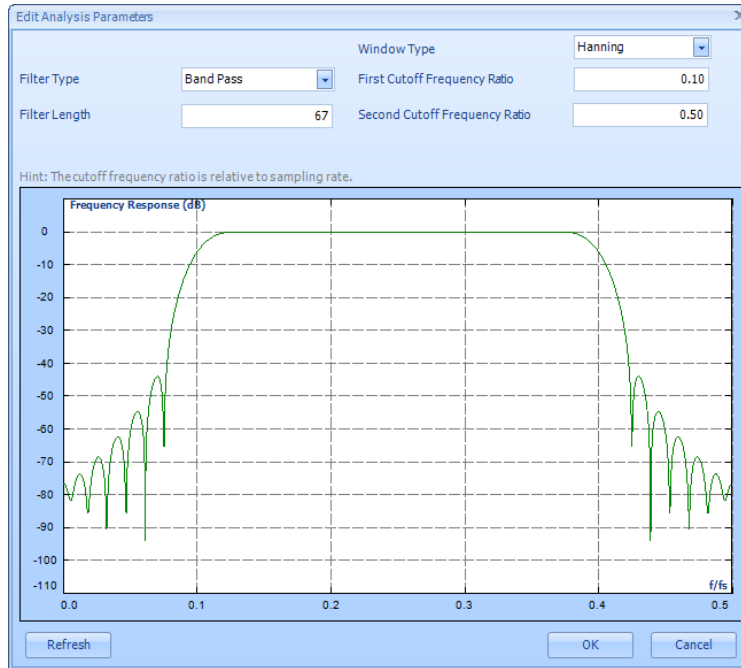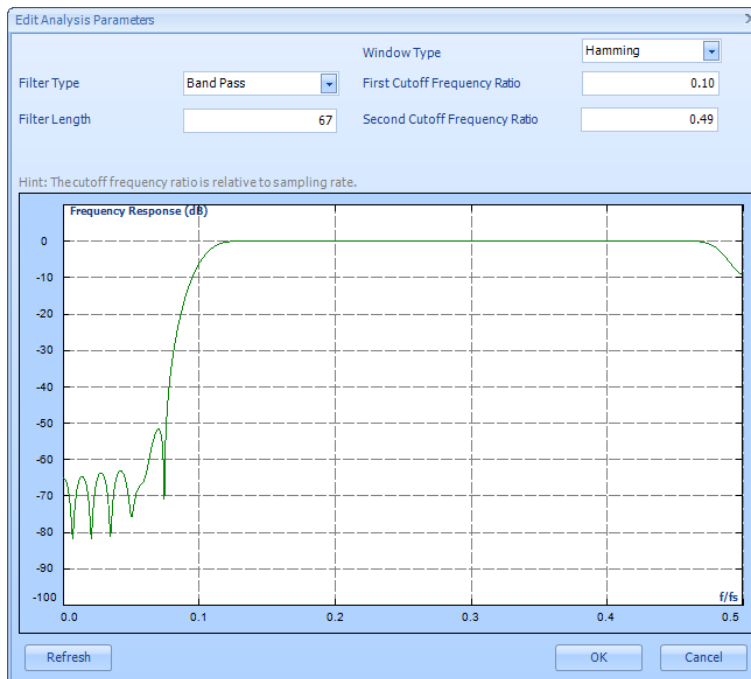
**Figure 175: The Hanning window**
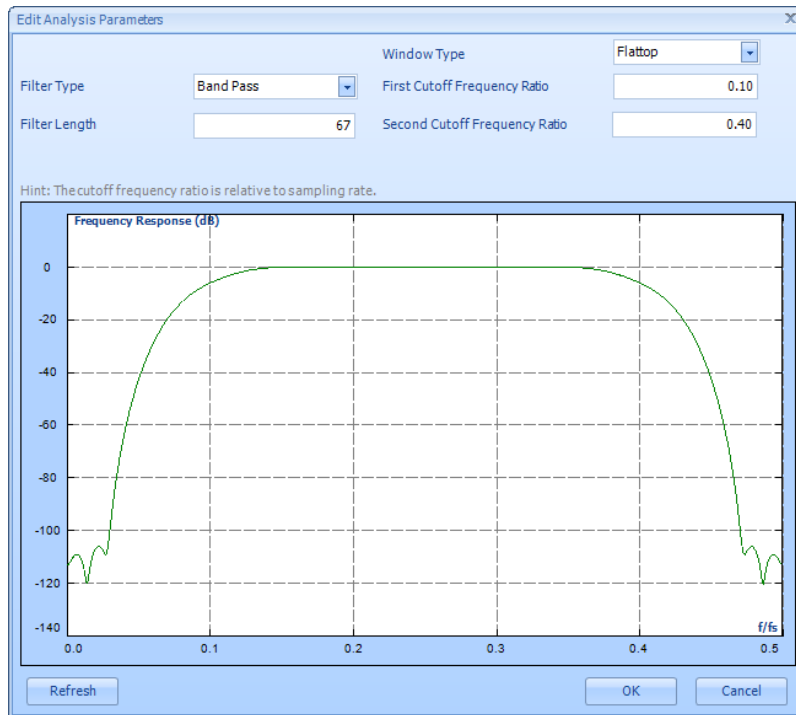


**Figure 176: The Hamming window**

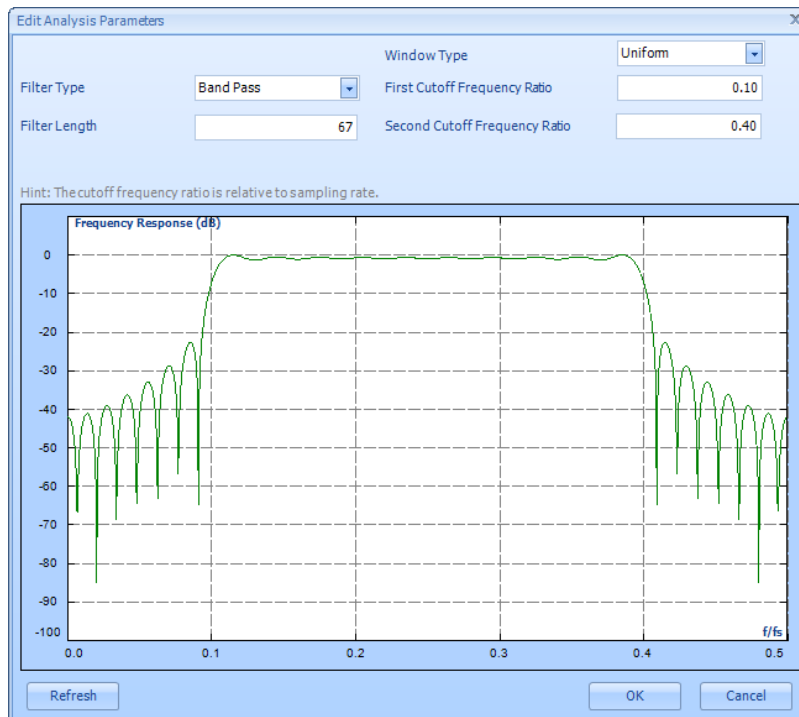**Figure 177: The Flattop window**



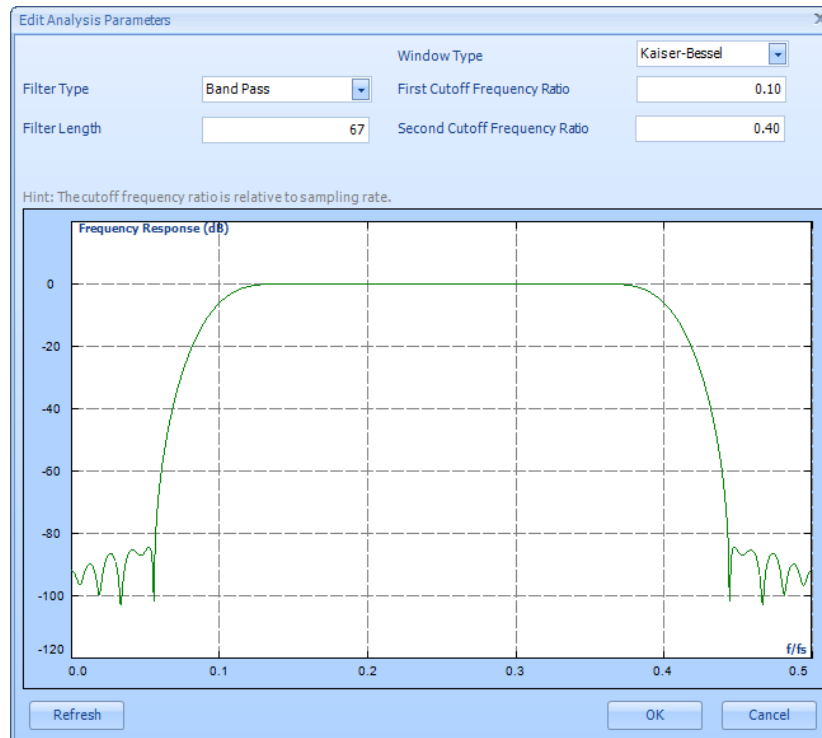**Figure 178: The Uniform window**
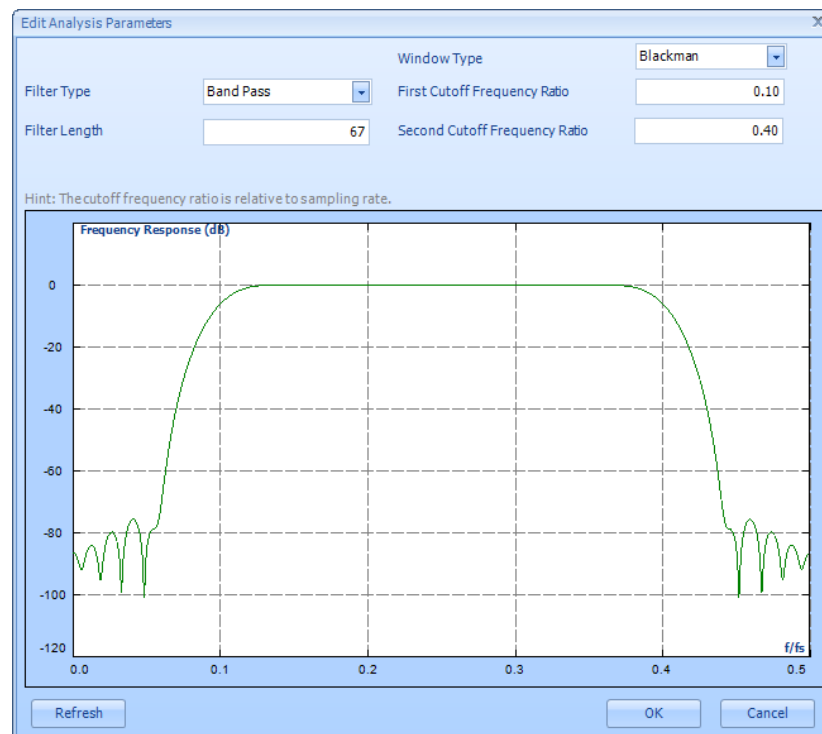
**Figure 179: The Kaiser Bessel window**



**Figure 180: The Blackman window**

As shown in the pictures, different windows produce different filter performance, i.e., different attenuation of the main lobe and side lobes. The best data window is the one that best suits your specific application.

## Remez Filters

The Remez Filter is a different method for designing an FIR filter. It is more computationally intensive than the data window method. A Remez filter is generated with iterative error-reducing algorithms designed to reduce the pass-band error. In addition to allowing stop-band ratio and frequency definition, the Remez filter also allows the "Ripple Ratio" to be defined as a user specified parameter.

The figure shows an example of a filter design using the Remez method in the EDM software. The low and high cutoff frequencies are 0.1 and 0.2 relative to the sampling frequency. The number of filter taps is 67.
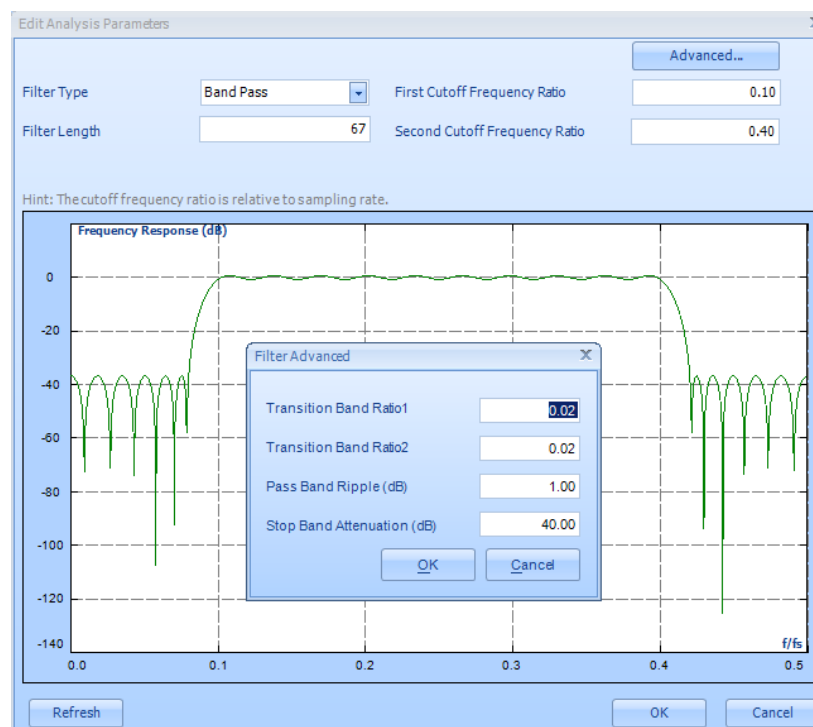


**Figure 181. Remez FIR Filter design dialog.**

The software is intelligent enough to automatically calculate the total FIR filter length (number of taps) based on these criteria. For example if the user asks for very high attention, very small ripple or very sharp transition band, the filter length will go very high. The user must make tradeoffs between these parameters so that appropriate filter length can be generated and used.

## IIR Real Time Digital Filters

**Infinite impulse response (IIR)**filters have an impulse response that decays very slowly and theoretically lasts forever. This is due to the fact that the filter input includes the measured signal and also the filter output creating a feedback path which results in the infinite impulse duration. This is in contrast to finite impulse response filters (FIR) which have fixed-duration impulse responses.

The design procedure for IIR filters is somewhat more complicated than FIR filter design because there is no direct design method like the data window method for FIR filters. IIR filters are typically designed by starting with an ideal analog filter in terms of the frequency response characteristics such as the Chebyshev, Butterworth, or Bessel filter. Then the analog filter is converted into a digital filter using a method known as the Bilinear transformation or the impulse invariance method.

An IIR digital filter can be understood by considering the equation that defines how the input signal is related to the output signal:

$$y[n] = b_0 x[n] + b_1 x[n-1] + \cdots + b_p x[n-P] - a_1 y[n-1] - \cdots - a_q y[n-Q]$$

Where P is the feed-forward filter order, $b_i$ are the feed-forward filter coefficients, Q is the feedback filter order, $a_i$ are the feedback filter coefficients, x[n] is the input signal and y[n] is the output signal.

The previous equation can also be expressed as a convolution of the filter coefficients and the input signal.

$$y[n] = \sum_{i=0}^{P} b_i x[n-i] - \sum_{j=0}^{Q} a_j y[n-j]$$

Which, when rearranged, becomes:

$$\sum_{j=0}^{Q} a_j y[n-j] = \sum_{i=0}^{P} b_i x[n-i] \; if \, weleta_0 = 1$$

To find the transfer function of the filter, we first take the Z-transform of each side of the above equation, where we use the time-shift property to obtain:

$$\sum_{j=0}^{Q} a_j z^{-j} Y(z) = \sum_{i=0}^{P} b_i z^{-i} X(z)$$

We define the transfer function to be:

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{i=0}^{P} b_i z^{-i}}{\sum_{j=0}^{Q} a_j z^{-j}}$$

The transfer function gives the frequency response that relates the input to the output in terms of magnitude and phase.

Various analog filter types can be used as the basis for the IIR filter. The Butterworth Filter results in the flattest pass-band and contains a moderate group delay. Below are examples of Butterworth low-pass and band-pass filters.
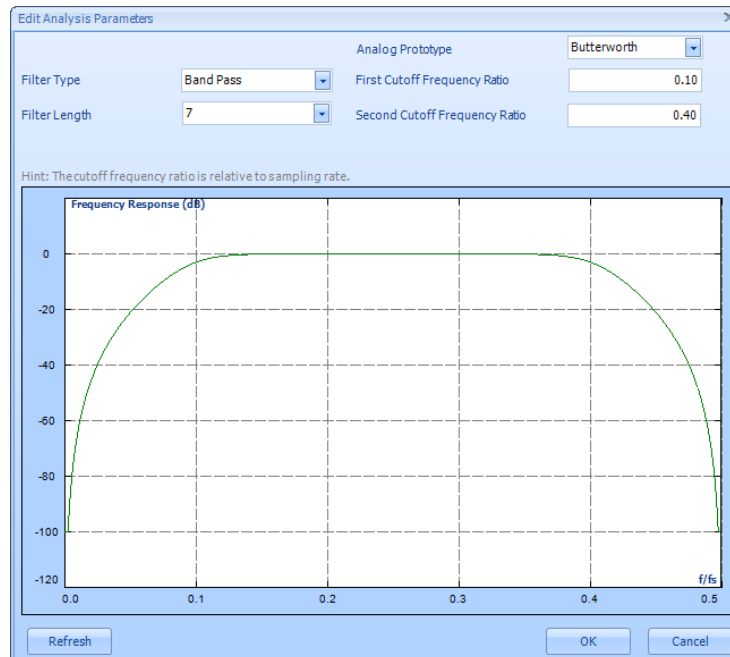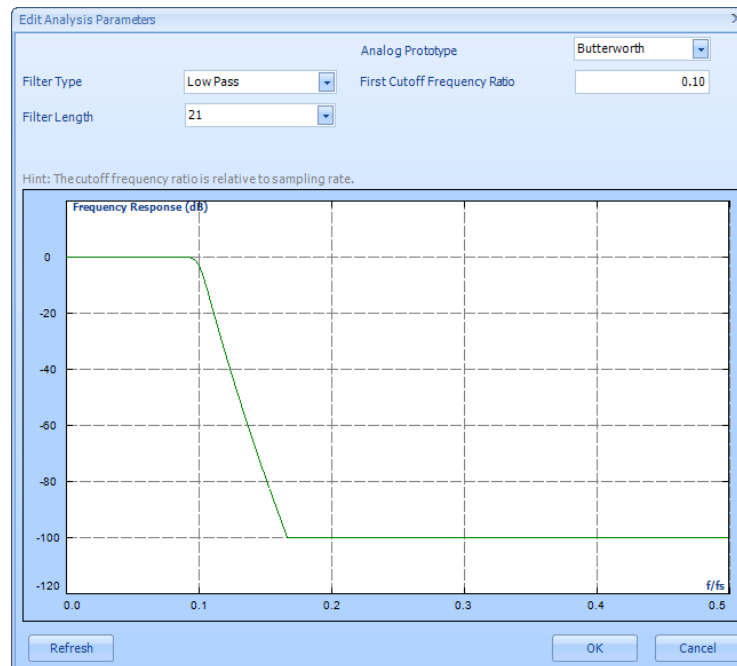


**Figure 182. Butterworth band-pass filter.**

**Figure 183. Butterworth low-pass filter.**

The Chebyshev Type I Filter results in the sharpest pass-band cut off and contains the largest group delay. The most notable feature of this filter is the significant ripple in the pass-band magnitude. A standard Chebyshev Type I Filter's pass-band attenuation is defined to be the same value as the pass-band ripple amplitude. Below are examples of Chebyshev Type I band-pass and high-pass filters.
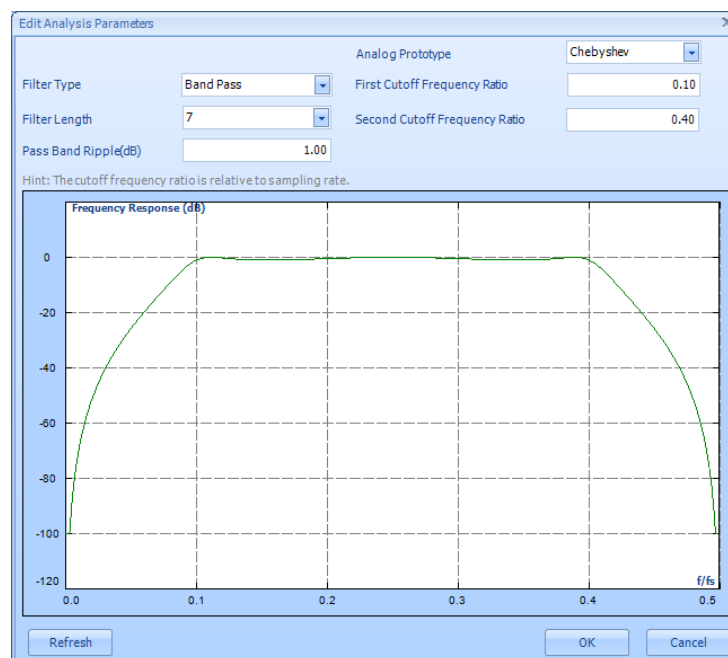


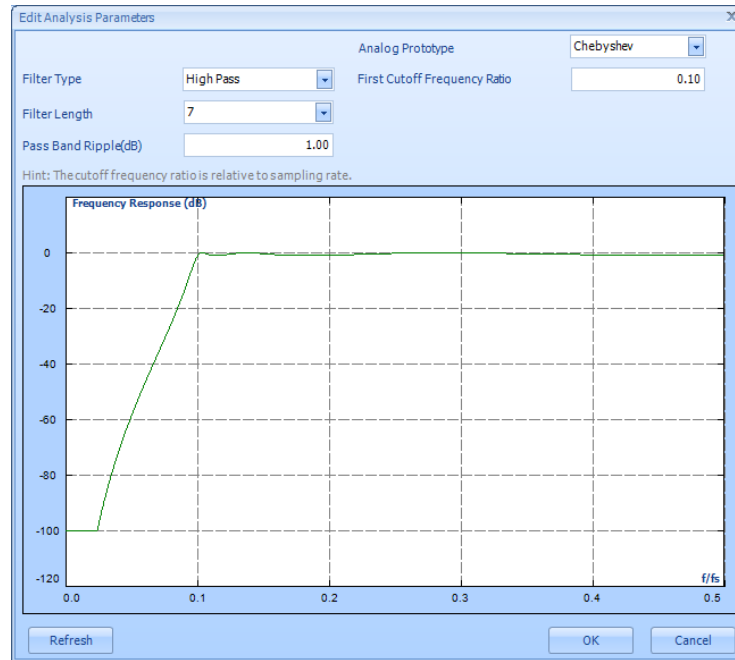**Figure 184. Chebyshev type I band pass filter.**

**Figure 185. Chebyshev type I high pass filter.**

The Elliptic Filter contains a Chebyshev Type I style equiripple pass band, an equipped stop band, a sharp cutoff, high group delay, and the greatest possible stop band attenuation. Below are examples of 7th order Elliptic low-pass, band-stop filters.
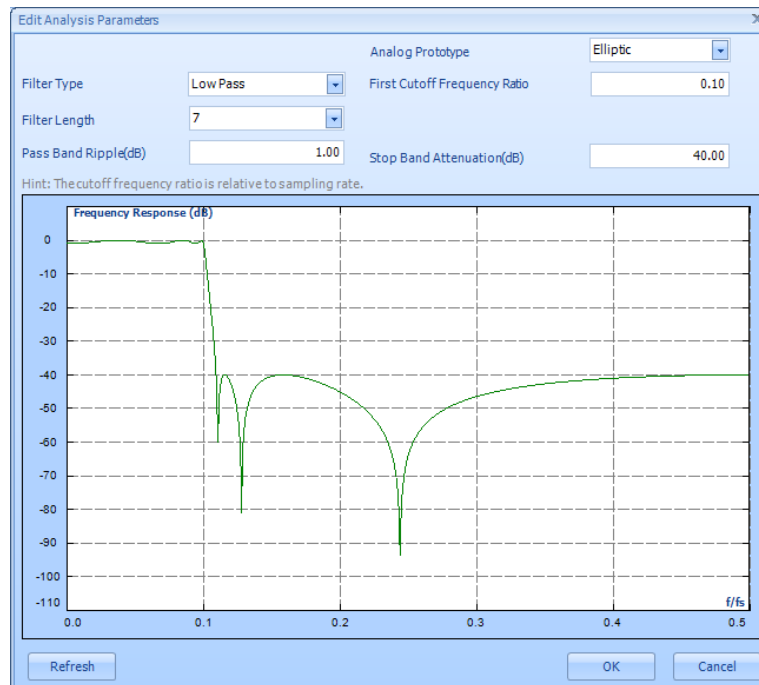


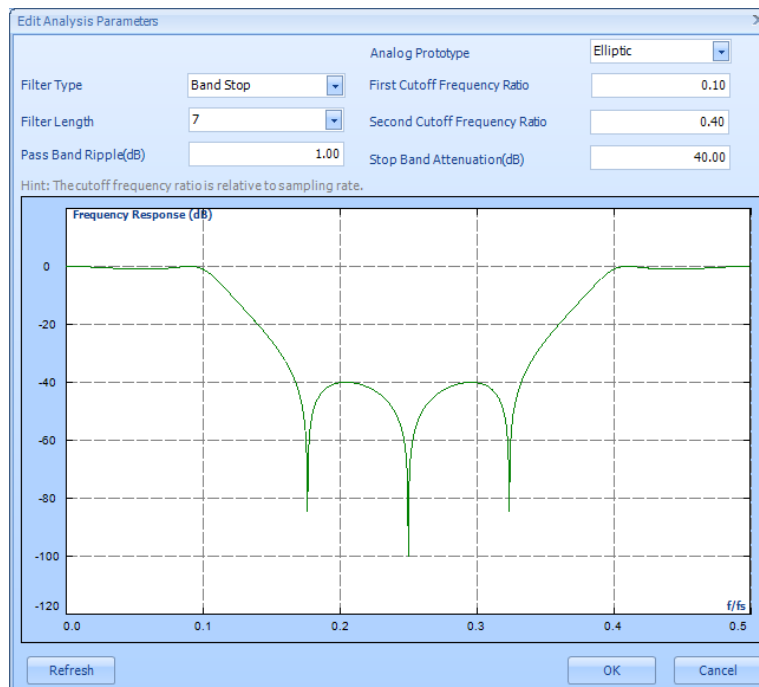**Figure 186. Elliptical low-pass filter.**

**Figure 187. Elliptical band stop filter.**

## Applying Filters

When creating a new FFT test, check the FLT box to enable Filters parameters. When the FLT box is checked, the real time digital filter will be applied to all available input channels.
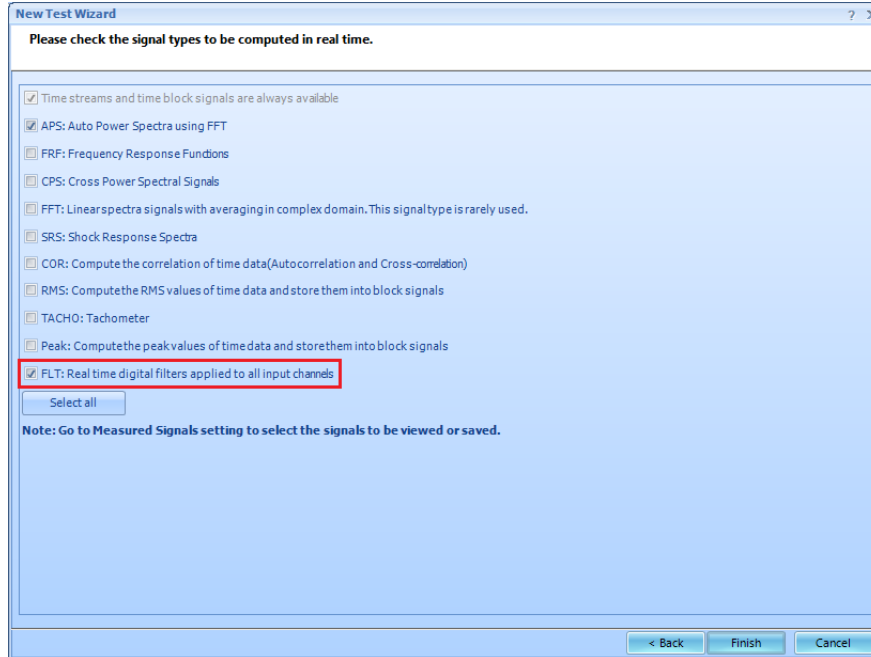
**Figure 188. Enabling Filters in the New Test Wizard**

Go to **Setup->Measured Signals**. The last column is filter selections. There are FIR(Window), FIR(Remez), and IIR filters. Only one type of filter can be applied at a time. In the same test, different channels can have different types of filters. Filters are only applicable to time streams.
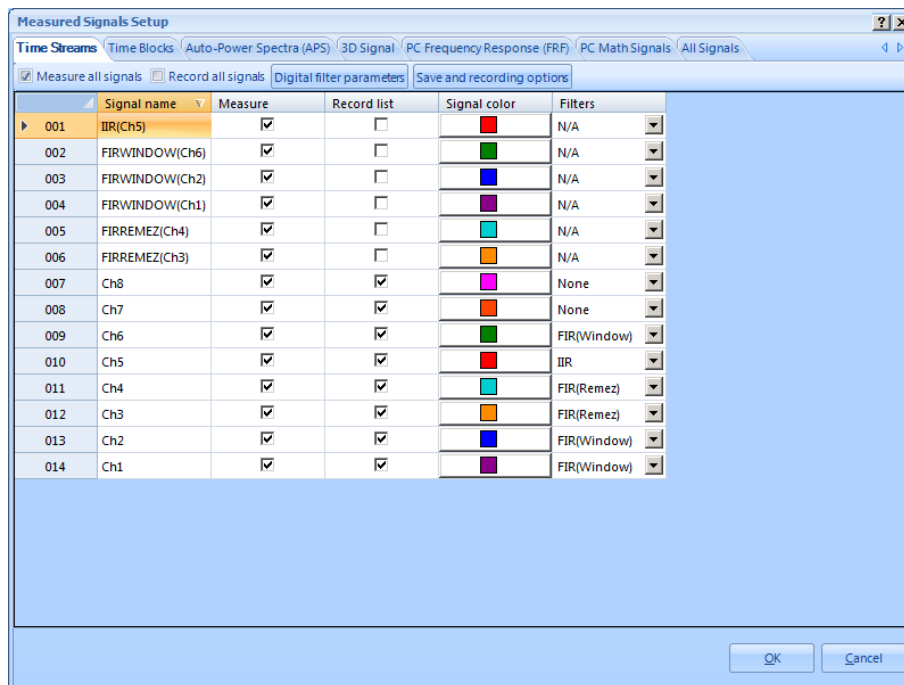


**Figure 189. Measured Signal Setup – Filters**

It is important to keep in mind that the cutoff frequencies are relative to the sampling rate, when the sampling rate changes, the cutoff frequencies in absolute Hz will be changed. For example, when the sampling rate is 1000 Hz, a 0.1 cutoff frequency means 100 Hz. If the sampling rate is changed to 102.4 kHz, the cutoff frequency will be moved to 1.024 kHz.

# Automated Alarm Limit Test

The Automated Alarm Limit test function allows the Spider front-end to conduct automated limit checking for time or frequency signals. The function is supported in both PC-tethered mode and Black Box mode.

The Spider compares the limits to the live measured signal in real-time, after every single frame of measurement. If the limits are exceeded, the Spider takes the appropriate actions based on the user setup.

Limiting signals are created and edited using EDM on the host PC. There are four elements in a limiting test: the signals being tested, upper or lower limits applied, testing schedule and testing log. In most cases it will be easy to generate automated alarm responses when the limits are exceeded. Alarm responses include sending email notifications, beeping, screen flashing and controlling the current test.

In every type of test, limits can be bound to time stream signals, block signals and spectrum signals. Users can define a high limit and a low limit. When a live signal exceed a limit, a predefined event will be triggered as an alarm. Each limit line can have up to 64 segments and there can be a maximum of 64 limit signals.

A **testing schedule** is used to automatically control the limit checking test. The testing schedule defines various operations to automate the process. For example the testing schedule can tell the instrument when the limit checking will be turned on, when it will be turned off and for how long the test will be conducted.

To record the events of the test, a Testing Log and a summary report are needed. The Testing Log records the important events in chronological order, including

whether the limits have been exceeded. The Summary Report provides the status of the limiting checks since the beginning of the test.

When the limit signal is exceeded, a user defined limit alarm event will be triggered. These can include audible beeps, signal saves, send email messages etc.

To summarize: An automated limit checking test requires the following building blocks:

- At least one test signal
- At least one limit signal applied to the measured signals
- A testing schedule
- A testing log and summary report
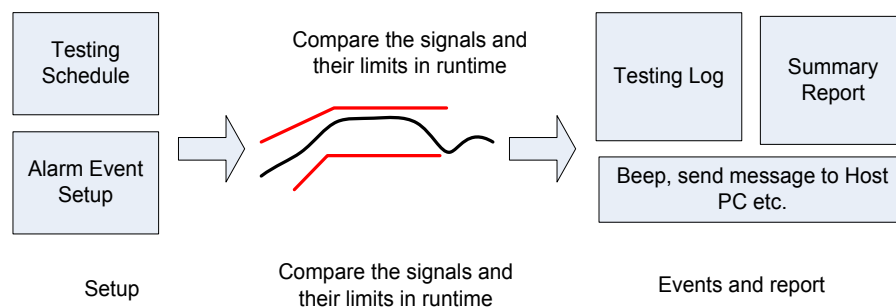- A setup for the limit alarm events



**Figure 190. An Illustration of the Automatic Testing Process**

## Apply Alarm Limits on EDM

Limiting and alarm function only works with the master module in a high-channel count system. This limitation doesn't affect other modules measuring signals. In an FFT test, right-click the signal name and then click **Apply Alarm Limits** to setup limits parameters. Users can also decide here if the limit lines will be displayed with the signals.
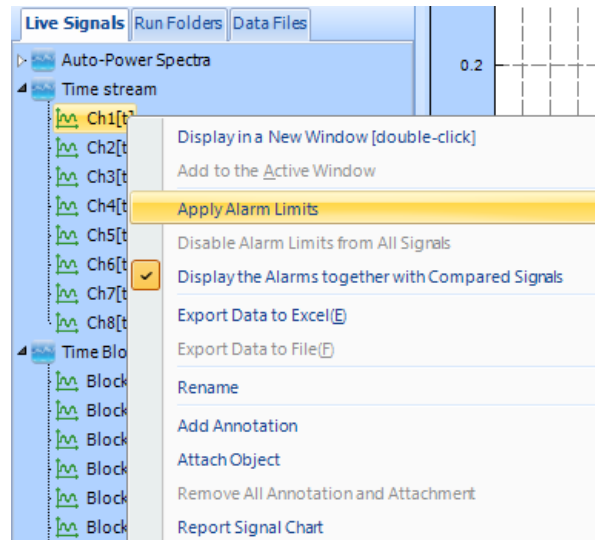
**Figure 191. Apply Alarm Limits**

On the alarm limits list, click **Add Limit** to add a new limit to the list.
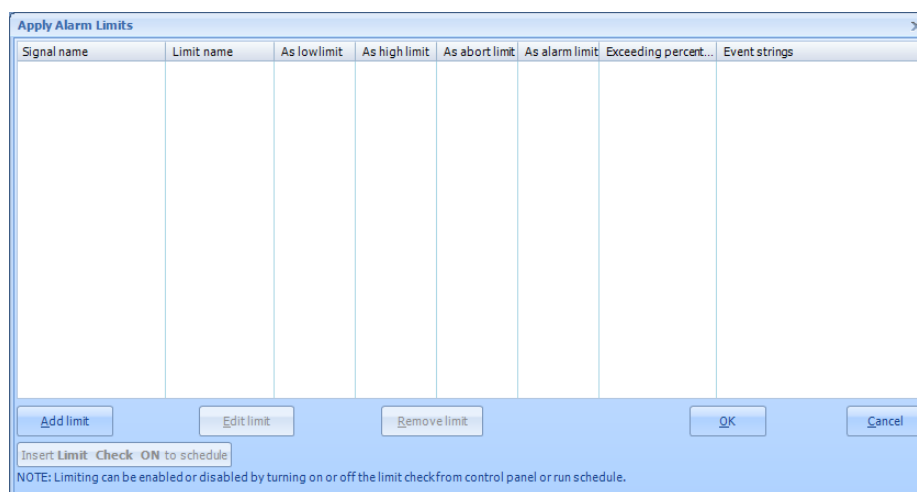


**Figure 192. Add Limit**

Check the signals you want to add limits to. Press OK to return to the **Apply AlarmLimits** main page. Then press **Edit Limit** to define the amplitude of the limit lines. Remember that the limit line can have as many as 64 segments. By using **Add Point/Remove Point**, the number of segments can be adjusted.
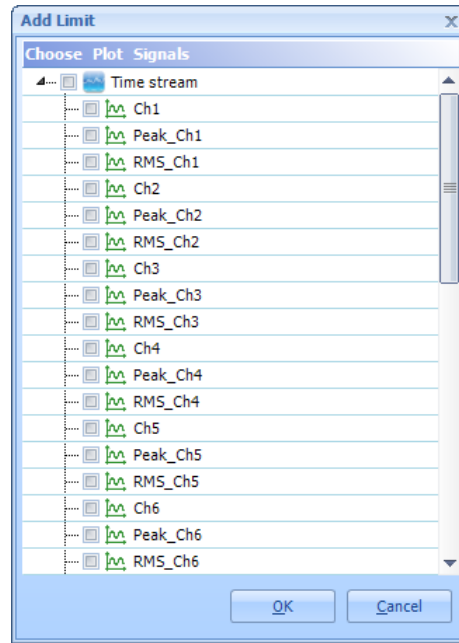
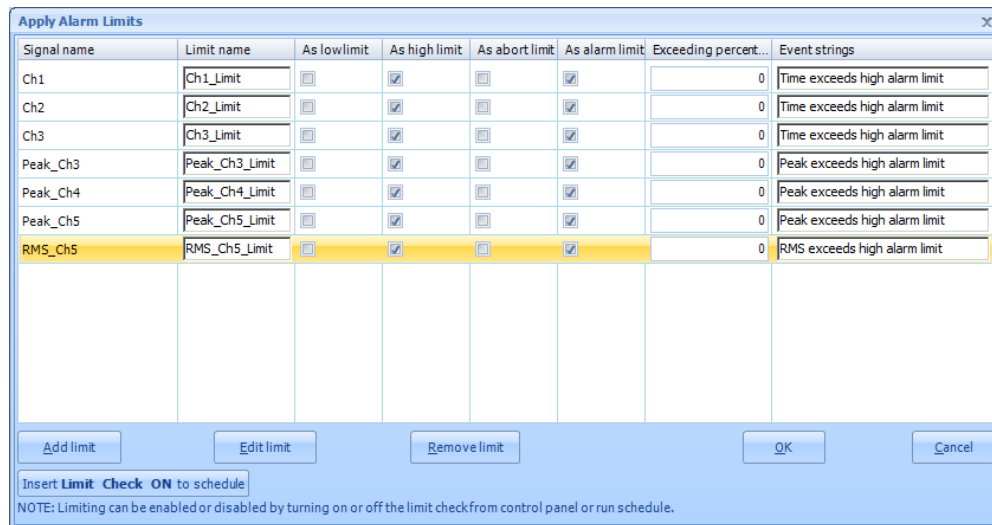**Figure 193. Add Limit Signal List**



**Figure 194. Add Limit Signal List**

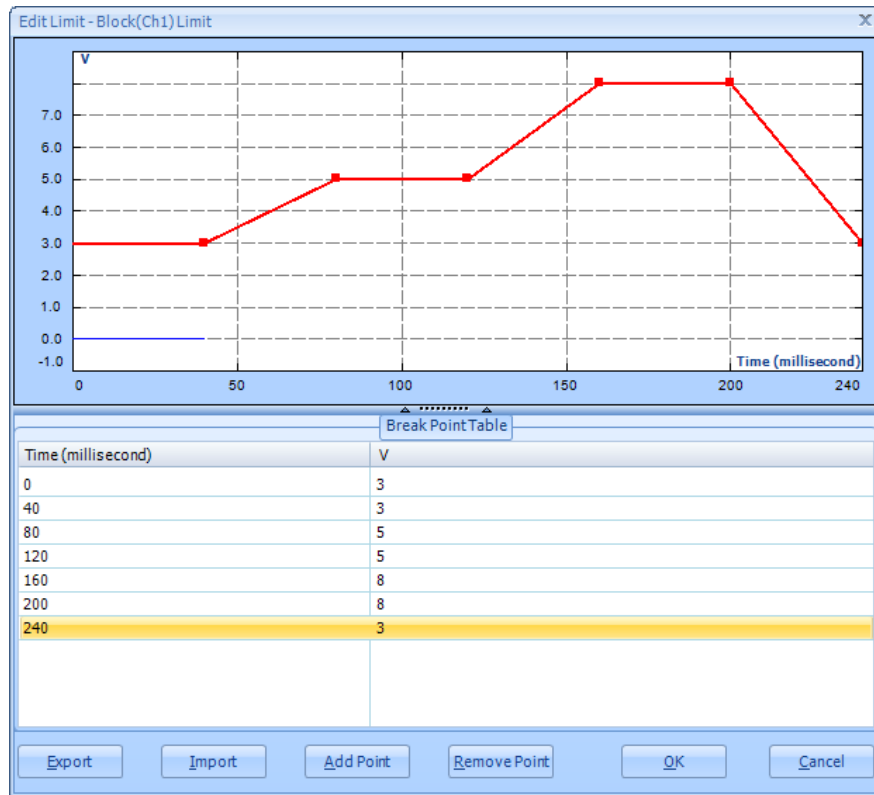In the signal preview window, the solid red line is the limit and the blue line represents the live signal.
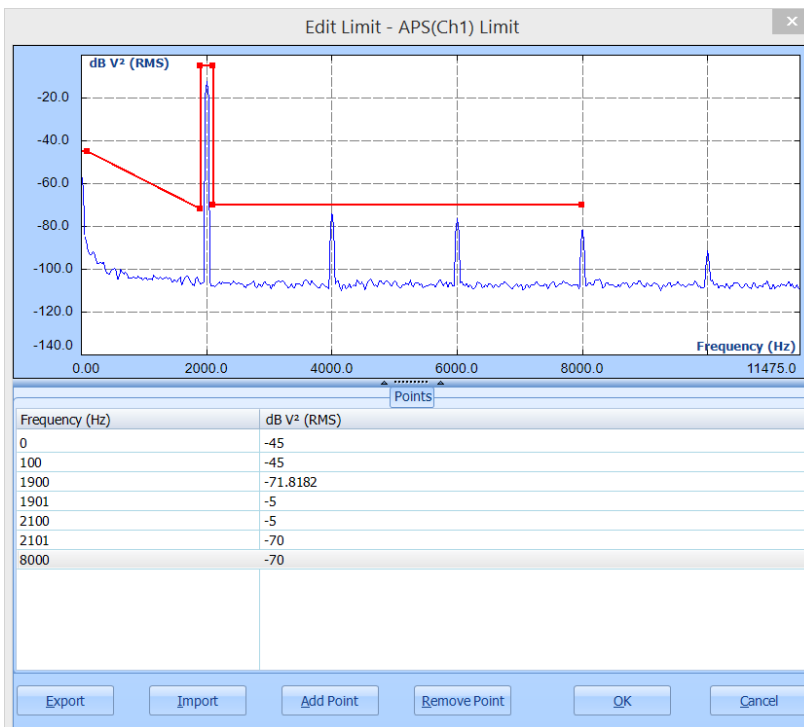
**Figure 195. Edit Limit for a time signal**



**Figure 196. Edit limit for a spectrum signal**

Limit configurations can be saved as data files. Press **Export** to save the current limit to a data file. Press **Import** to load a data file to use as a limit. The **Import/Export** function can save a great deal of time when similar units will be used for different tests.

## Customize Event Action Strings and Its Application in Limit Checking

The user can customize a string to identify an event that corresponds to a specific limit check. These strings will be shown on the Runlog display window or report.
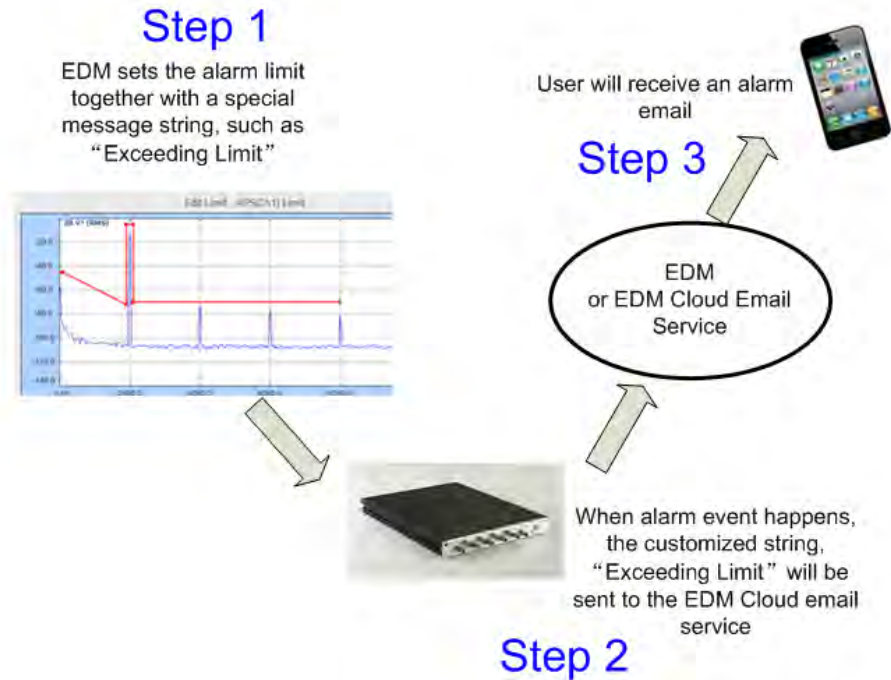


The customized strings will be passed from EDM to the Spider devices during the test initialization phase. The Spider devices will send the strings back when certain events occur.
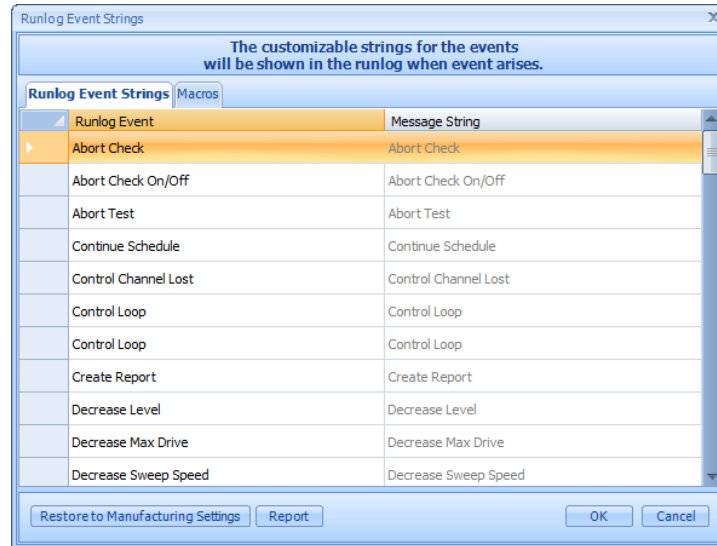
**Figure 197. Runlog Event Strings**

Users can set custom message strings to be logged by the Runlog when a limit is exceeded; these strings can be defined through the edit box. For instance, the user can set messages such as ***Ch1 Aborted*** or ***Sensor 2 Alarm Exceeded*** for their respective events.
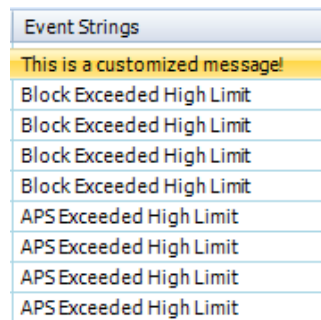


**Figure 198. An Example of Event Strings**

## Limit Related Settings in Run Schedule and Event Action Rules

Most limit function applications rely on the Run Schedule and the Event Action Rules. Here we will only deal with the limit settings, information on the other topics can be found elsewhere in this manual. Multiple events can be triggered when a limit is exceeded by simply adding them to the list of actions.
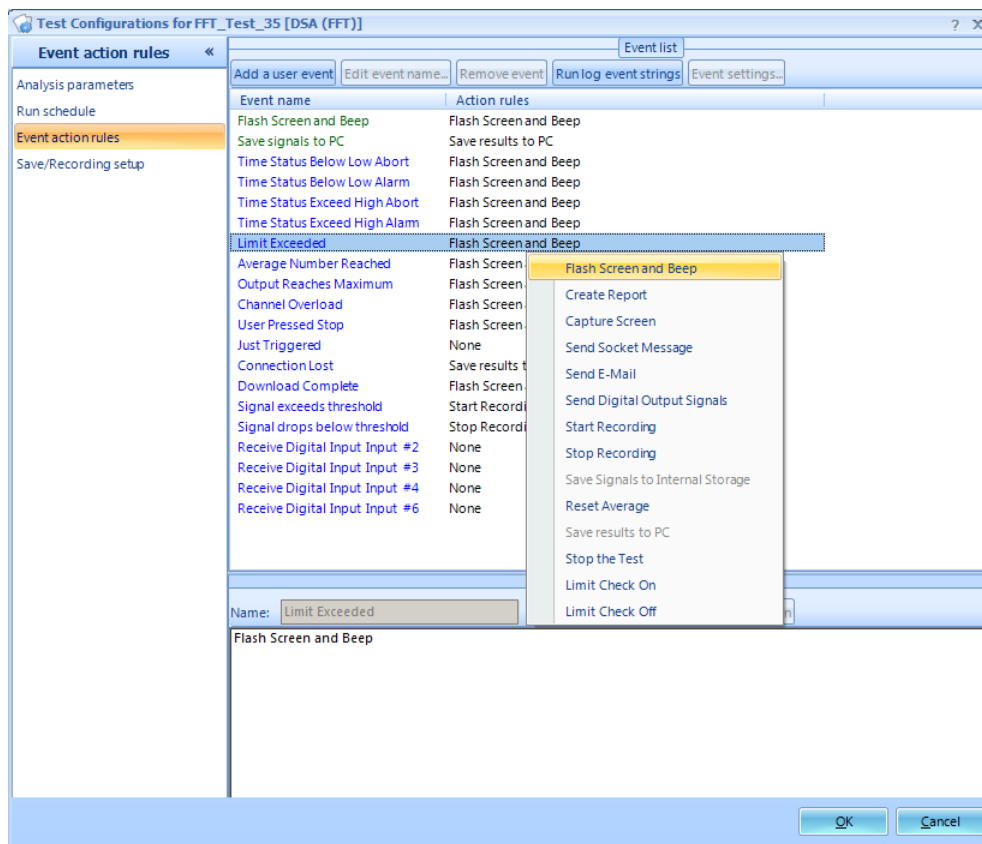


**Figure 200. Limit Exceeded Events**

In the black-box mode, A Limit Check On event must be inserted into the schedule to enable the limit. After the test is uploaded to the front-end there is no way to enable the limit.
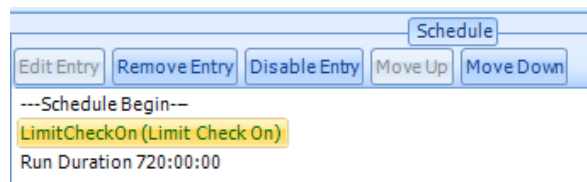


A limit can be removed from a signal by right clicking it and selecting the option to remove it. Note that active limits may not be displayed if the display option is not checked.

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Here is an example of an exceeded limit triggering a flashing screen and a beep. (Note the lower right-hand corner.)



The software is designed with extreme flexibility so that various "actions" can be taken besides flashing the screen or beeping. Sending Socket message is a very powerful tool to communicate with other software applications on the same network. For example a temperature chamber application running on a Linux environment can receives the "Socket Message" from EDM application if a certain vibration limit exceeded.

EDM Cloud is server-based web software that can process the same event action messages described above. Please refer to the manual for EDM Cloud regarding this function.

# Shock Response Spectrum Analysis

A **Shock Response Spectrum** (SRS) is a graphical presentation of a transient acceleration **pulse's potential to damage a structure. It plots the peak acceleration** responses of a bank of single degree-of-freedom (SDOF) spring, mass damper systems all experiencing the same base-excitation as if on a rigid massless base. Each SDOF system has a different natural frequency; they all have the same viscous damping factor. A spectrum results from plotting the peak accelerations (vertically) against the natural frequencies (horizontally).An SRS is generated from a shock waveform using the following process:

- Specify a damping ratio for the SRS (5% is most common)
- Use a digital filter to model an SDOF of frequency, $f_n$ **and damping $\xi$.**
- Apply the transient as an input and calculate the response acceleration waveform.
- Retain the peak positive and negative responses occurring during the **pulse's duration and afterward.**
- Select one of these extreme values and plot it as the spectrum amplitude at $f_n$.
- Repeat these steps for each (logarithmically spaced) $f_n$ desired.

The resulting plot of peak acceleration vs. spring-mass-damper system natural frequency is called a Shock Response Spectrum, or SRS.
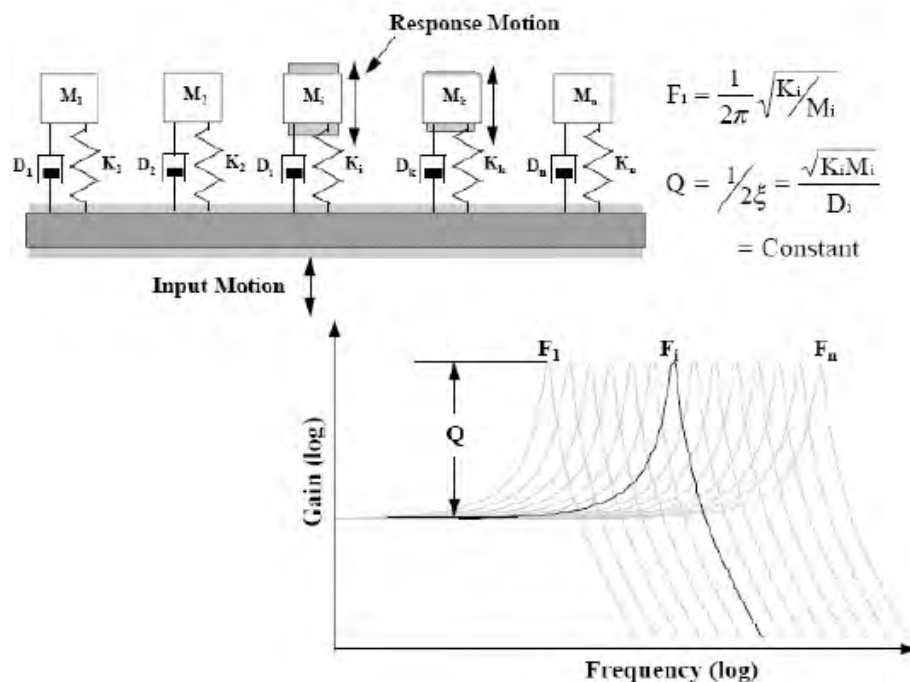


**Figure 201. Illustration of a multi-degree of freedom system model used to compute SRS.**

An SDOF mechanical system consists of the following components:

- Mass, M
- Spring, K
- Damper, C

The natural frequency, $F_n$, and the critical damping factor, $\xi$, characterize a SDOF system, where:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$

$$\xi = \frac{c}{2\sqrt{KM}}$$

For a light damping ratio where $\xi$ is less than or equal to 0.05, the peak value of the frequency response occurs in the immediate vicinity of $f_n$ and is given by the following equation, where Q is the quality factor:

$$Q = \frac{1}{2\xi}$$

Any transient waveform can be presented as an SRS, but the relationship is not unique; many different transient waveforms can produce the same SRS. The SRS does not contain all of the information about the transient waveform from which it was created because it only tracks the peak instantaneous accelerations.

Different damping ratios produce different SRSs for the same shock waveform. Zero damping will produce a maximum response while high damping will produce a flatter SRS. The damping ratio is related to the "quality factor", Q, which can also be thought of as transmissibility in the case of sinusoidal vibration. A damping ratio of 5% ($\xi$=0.05) results in a Q of 10. An SRS plot is incomplete if it doesn't specify the document the damping factor (or Q).

## Frequency Spacing of SRS Bins

An SRS consists of multiple bins distributed evenly in the logarithmic frequency scale. The frequency distribution can be defined by two numbers: a reference frequency and the desired fractional octave spacing, such as 1/1, 1/3 or 1/6. (An octave is a doubling of frequency.)  For example, frequencies of 250 Hz and 500 Hz are one octave apart, as are frequencies of 1 kHz and 2 kHz.
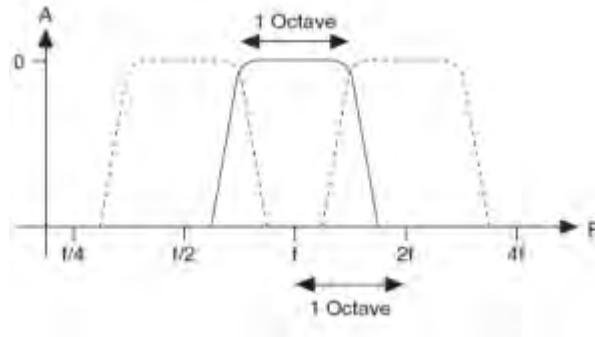
**Figure 202. Full octave filter shape.**

The proportional bandwidth display is very useful for analyzing a variety of natural systems such as the human response to noise and vibration. Many mechanical systems exhibit behavior that is best characterized by proportional bandwidth analysis.

To gain finer frequency resolution, the frequency range can be divided into proportional spacings that are a fraction of an octave. For example, with 1/3 octave spacing, there are 3 SDOF filters per octave. In general, for 1/N fraction octave, there are N band pass filters per octave such that:

$$f_{cj+1} = f_{cj} * 2^{1/N}$$

Where 1/N is called the *fractional octave number* and the *reference frequency* is simply the lowest desired frequency, $f_{c1}$. With the reference frequency and fractional octave number established, the frequency distribution over the whole frequency range is determined.

## Measured Signals in SRS

The measurement quantities available to the Spider SRS test are: time stream of each channel (raw data), block captured time signals and three SRSs of each channel.
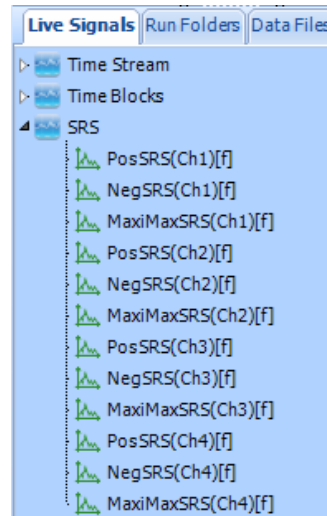
**Figure 203. Measurement Quantities in SRS**

**Time streams**: this is the same as any other applications on the Spider. Time streams are always available for viewing and recording. It is a very useful tool for observing if the input signals are in the valid range or not. The recorded sine wave can also be used for further post-processing.

**Block time signals**: These are the block captured signals that are used for SRS analysis. Acquisition Mode will control how the block time signals are acquired.

**SRS**: Shock Response Spectra will be calculated for each block of time signals. The engineering units of the spectrum are determined by the sensor units specified for the input channel. The spectra are often denoted as three types: Maximum Positive spectrum; Maximum Negative spectrum and Maximum-Maximum spectrum.

**Maximum Positive Spectrum**: This is the largest positive response due to the transient input, without reference to the duration of the input.

**Maximum Negative Spectrum**: This is the largest negative response due to the transient input, without reference to the duration of the input.

**Maximax Spectrum**: this is the envelope of the absolute values of the positive and negative spectra. It is the most often used SRS data type. The log-log Maximax is the universally accepted format for SRS presentation.

## SRS Analysis Parameters and Synthesis Parameters

All of the SRS analysis test parameters can be found in **Test Config->Analysis Parameters**. FFT analysis parameters are defined in the same way as other FFT tests. SRS parameters include:
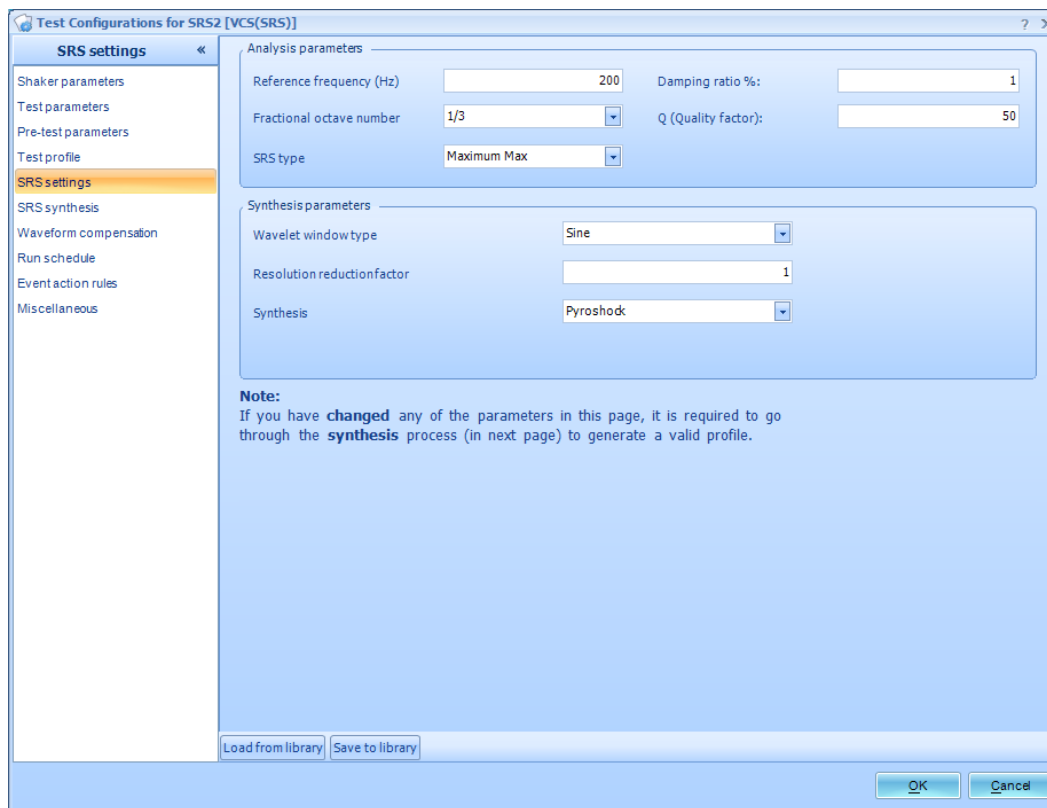
**Figure 204: SRS Analysis Parameters and Synthesis Parameters**

**Reference Frequency**: defines the reference frequency of the SRS spectrum.

**SRS Type includes** the Maximum Max, the Positive Max, and the Negative Max.

**Fractional Octave Number** is chosen from 1/1, 1/3, 1/6, 1/12, 1/24, 1/48.

**Low Frequency**: defines the lowest frequency boundary of the SRS spectrum.

**High Frequency**: defines the highest frequency boundary of the SRS spectrum.

**Damping Ratio (%)**: defines the damping ratio as a percentage.

**Q (Quality Factor)** is a dimensionless parameter that describes how under-damped an oscillator or resonator is, or equivalently, characterizes a resonator's bandwidth relative to its center frequency.

**Wavelet Window Type** is the windowing function available from Sine, Hann, Exponential, and Rectangular.

**Synthesis** has four available synthesis including Pyroshock, Minimum Acceleration, User Defined Duration, and Mil-Std810-F Standard.

# Sweep Sine FRF

## Introduction

Sweep Sine FRF is a shaker diagnosis tool that allows the user to manually control the sine tone and drive voltage. It also has a built-in close loop control so that it can be used as a very simple sine controller.
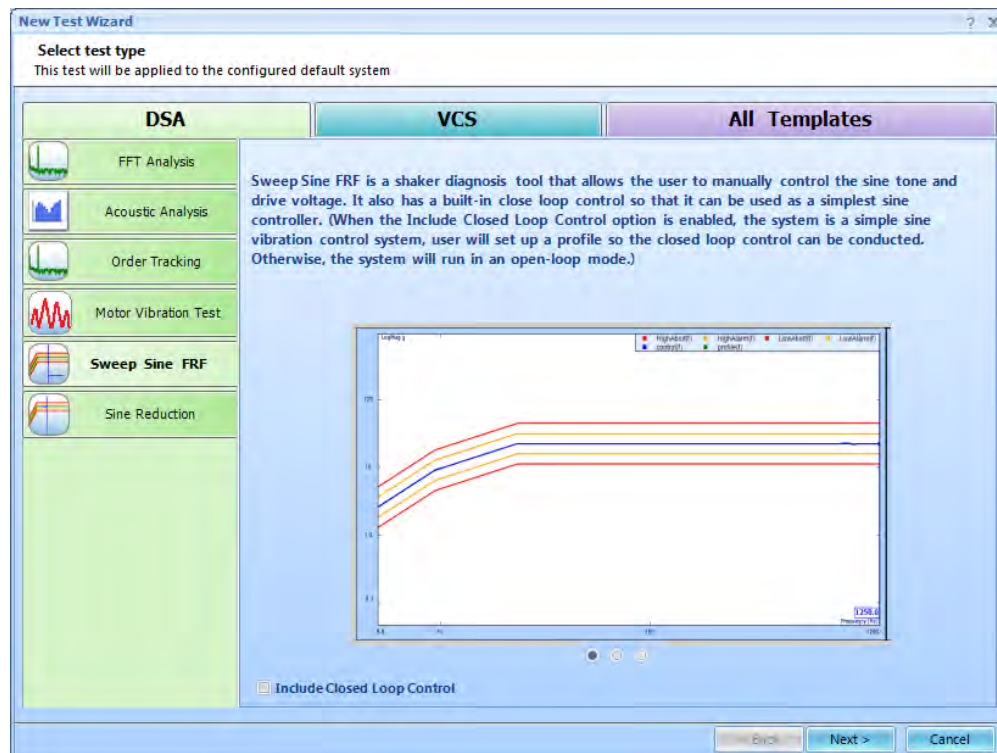


**Figure 205. New Test Wizard**

When the New Test is called, if the **Include Closed Loop Control** checkbox is checked, then the test will ask you to set up the profile so the closed loop control can be conducted. With closed loop enabled, the system is actually a simple sine vibration control system. If this box is not checked, the system will run in the open-loop mode.

The Sweep Sine FRF test allows the output sine wave to be manually controlled by the user. The controllable parameters include frequency, amplitude, sweep rate, frequency limits and direction. When being manually controlled, the sine output is not under closed-loop control as it is during a regular swept-sine test. Closed-loop control can also be turned on to function as a simple sine controller.

The sweep parameters are set under the control panel. This replaces the run schedule used in the regular Sine mode.

**Figure 206. Sweep Sine FRF Control**

The **Drive Mode** switches between Freq. Scanning mode, which outputs a sine sweep, and the Fixed Freq. mode, which outputs a fixed frequency.
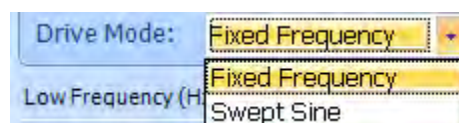


**Figure 207. Drive Mode**

The **Close Loop** button turns on closed-loop control. The output drive level will be adjusted so that the input control signal matches the profile. The profile is set under the Profile and Schedule section of the Test Configuration window, just like the normal Sine test.

To enable the close-loop test in Sine Oscillator, check the box, ***Include* Closed Loop Control,** below when a new test is created:

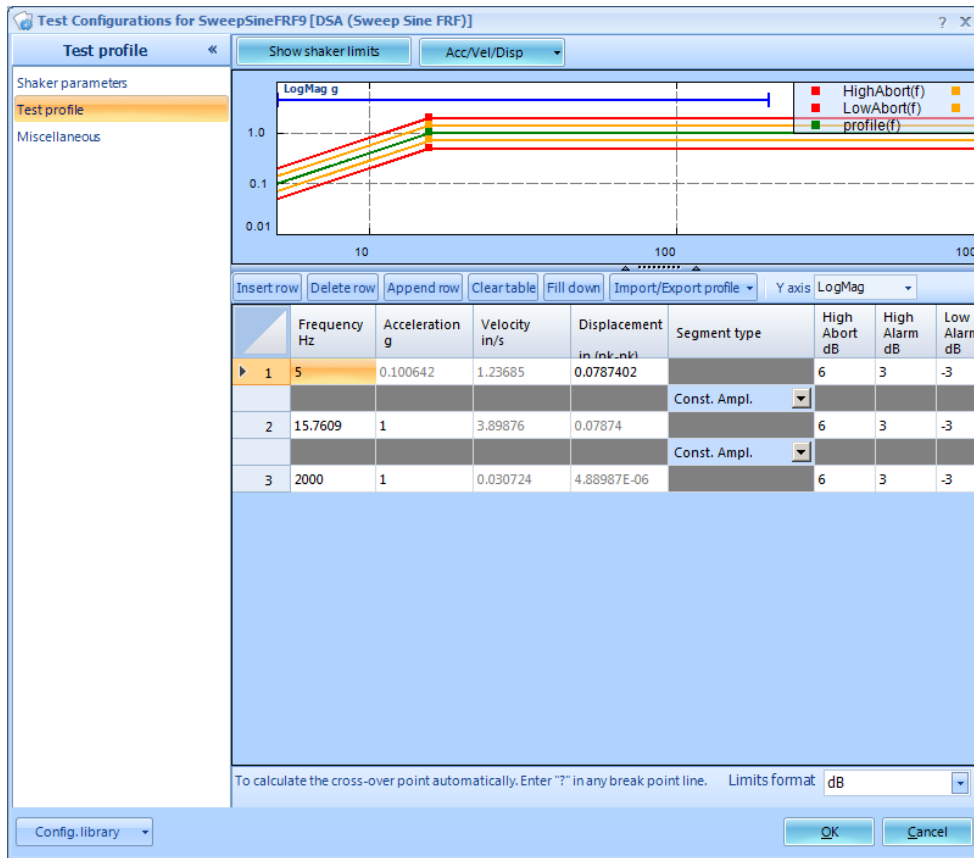In Closed-Loop control, a testing profile must be defined:

**Figure 208. Test profile**

When in closed-loop control mode, pressing **Open Loop** will revert back to the manual control mode.

## General Operation

### Set and Change the Drive Voltage

People use the Sine Oscillator function to test their shaker's performance. Most often, the user wants to set a specific drive voltage at a certain frequency. To set the initial drive voltage, you can use the Set button on the control panel, or use F11/F12 key on the keyboard, or click on the small buttons with numbers as shown below:
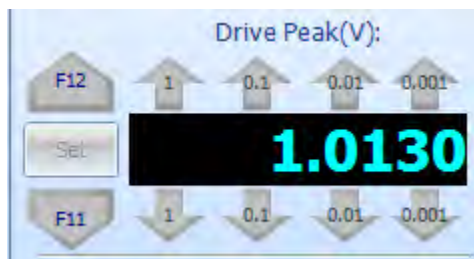


The system will ramp up or down to the target voltage instead of creating a sharp step. Therefore, it will take some time to settle the drive voltage.
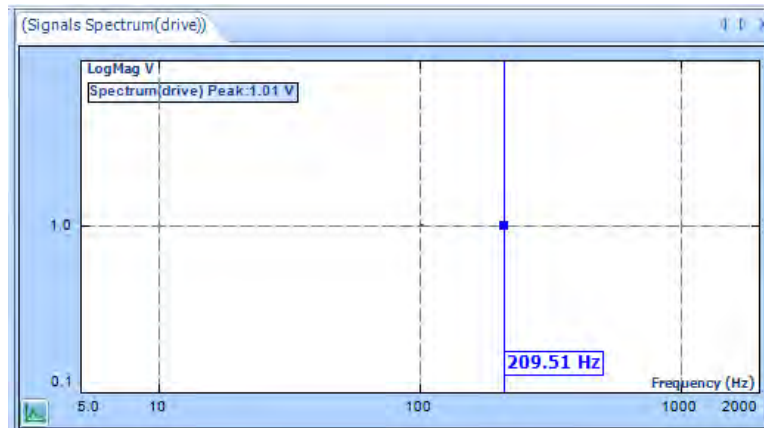
The Drive plot displays the amplitude and frequency of the current drive output.

The following plot shows the increase in the control signal measured from a shaker while the drive voltage is gradually increased by pressing the F12 button.
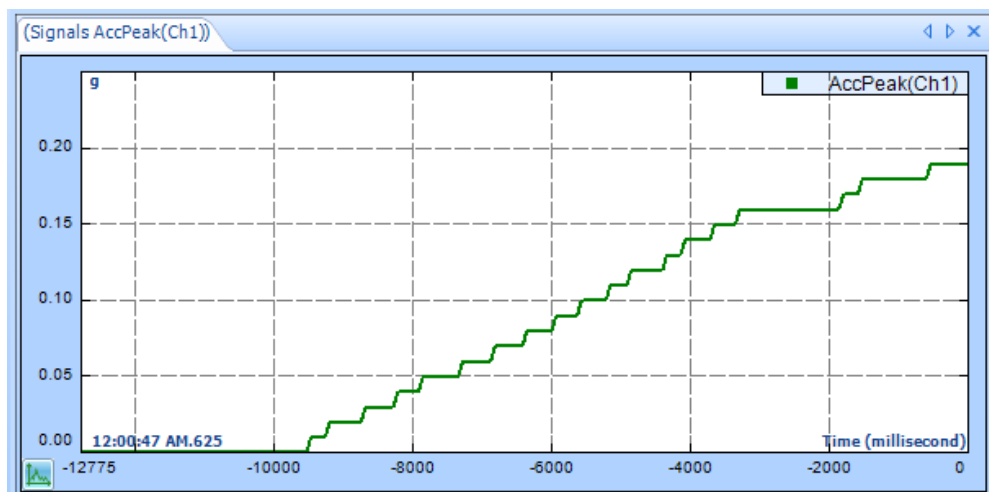


### Set and Change the Frequency



To change the frequency of drive signal, click the Set button in the control panel, or click on the small buttons with numbers, or use keyboard keys F10/F9.

When frequency is changed, the drive will immediately jump to the target frequency without ramping down the signal.

The signal **Frequency_His(t)** is the time trace of the frequency. The picture below shows the frequency trace when the user pressed the 10Hz up and down buttons.
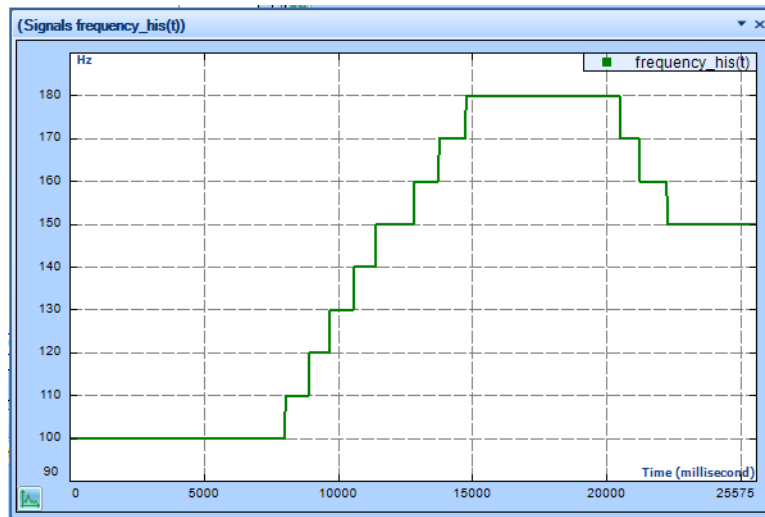


The picture below shows a sine wave that was sweeping up and then down and then placed on-hold.
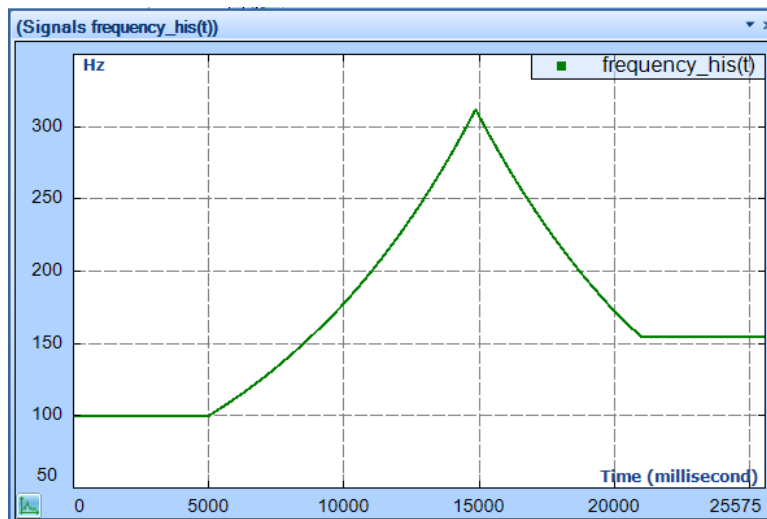


## Calculate the Total Harmonic Distortion

To calculate the Total Harmonic Distortion (THD), press the Calculate THD button on the control panel while in the Fixed Frequency testing mode.

The THD Display can be found by right clicking on the time stream signal:
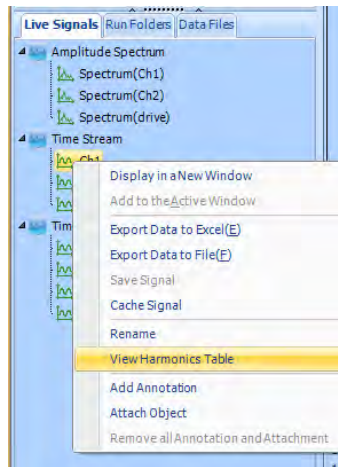
Here is a typical THD display:
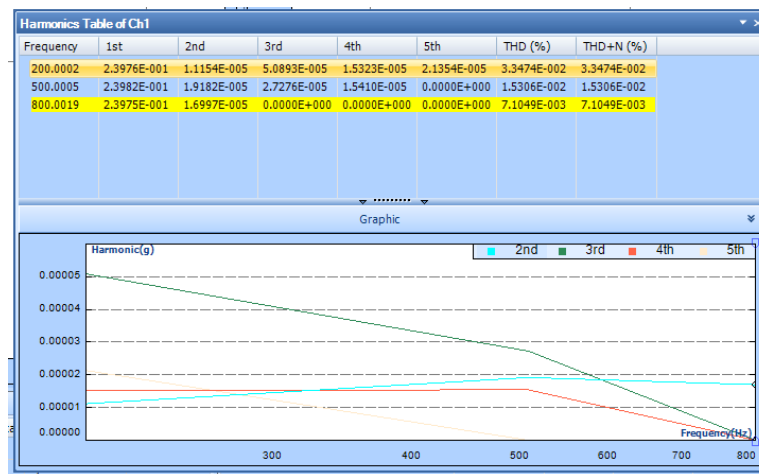


## Make it Sweep

Instead of running in the fixed frequency mode, the sine output can sweep. In Sweep Sine FRF, set the Drive Mode to Swept Sine:
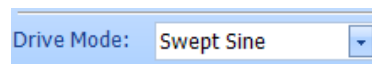


Then make sure the sweeping parameters are set up correctly on the second tab of Control Panel:

| Low Frequency (Hz) | 5 |
| High Frequency (Hz) | 2000 |
| Start Frequency (Hz) | 100 |
| Sweep Type | Logarithmic |
| Sweep Time (Min) | 8.64 |
| Sweep Speed Unit | Oct/Min |
| Sweep Speed (Oct/Min) | 1 |
| Sweep # | 2 |
| Initial Direction | Up |
| Initial Drive (V) | 0.01 |
| Drive Limit (V) | 2 |
| Signal Plot Points | 2048 |
| Measurement Strategy | Proportional |
| Band Width (%) | 25 |
| Calculate Swept THD | OFF |

Control  **Operations**  Cursor

Pressing the Sweep button on the Control Panel will make the output sweep.
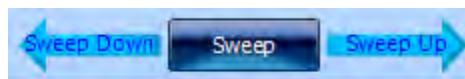


## Display the Acceleration, Velocity or Displacement of the Spectrum
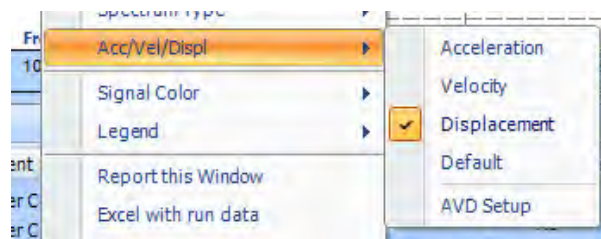


As in any controlled Sine test, you can display the spectrum value in velocity or displacement as well as acceleration. To make the change, simply right click on the signal plot and select the appropriate quantity.

# Sine Reduction

## Introduction

Sine Reduction allows you to "slave" a digital signal analyzer (DSA) to a vibration control system (VCS) to gain more processing channels for a swept sine test. The Sine Reduction software runs on the DSA; no changes to the VCS are required. The **two instruments are synchronized by the controller's COLA (constant outpu**t level amplitude) signal. The COLA is a constant voltage sine wave that tracks the Drive signal in frequency during a Sine test.

## A Typical Test

**Here's a typical test system using Sine Reduction. The Spider**-81 VCS provides eight channels of input. By connecting its Output 2 (the COLA) to the Channel 1 input of a Spider-80X DSA module running Sine Reduction, the combined VCS system provides 15 input channels all running the same tracking filters in perfect synchronization.
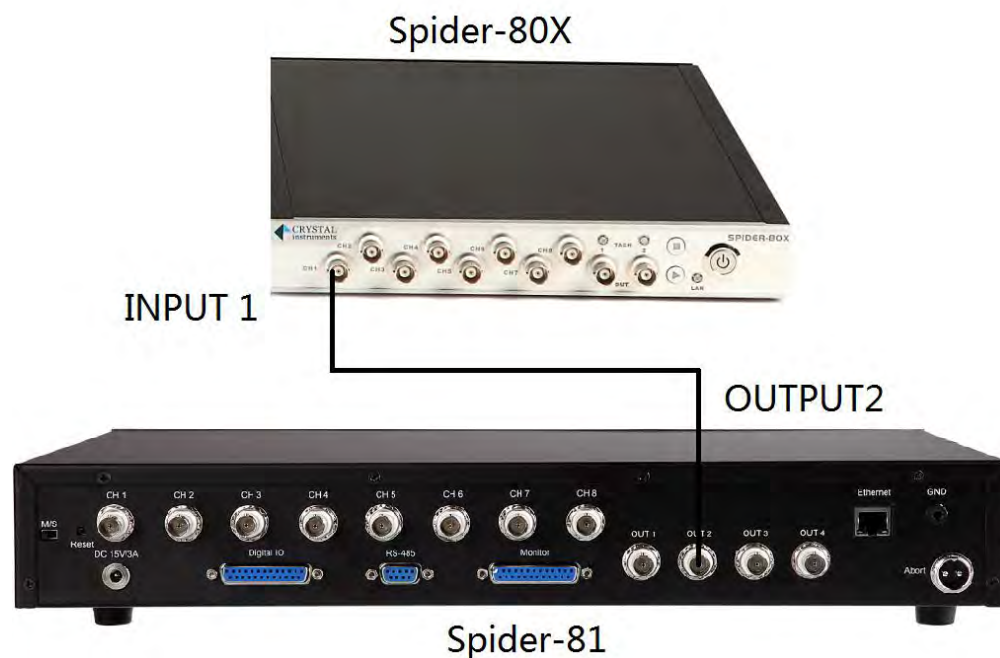


**Figure 209. An Example of Connection**

## Configuration on EDM

To configure the COLA output channel on a Spider controller, Go **to Config.->Miscellaneous->Second Output** tab and set it to **COLA Type 1: Constant Amplitude Sine**; and set the amplitude to**1V**.

If you are using another make of controller, please make sure its COLA channel is set to sweep at the Drive frequency with fixed amplitude.
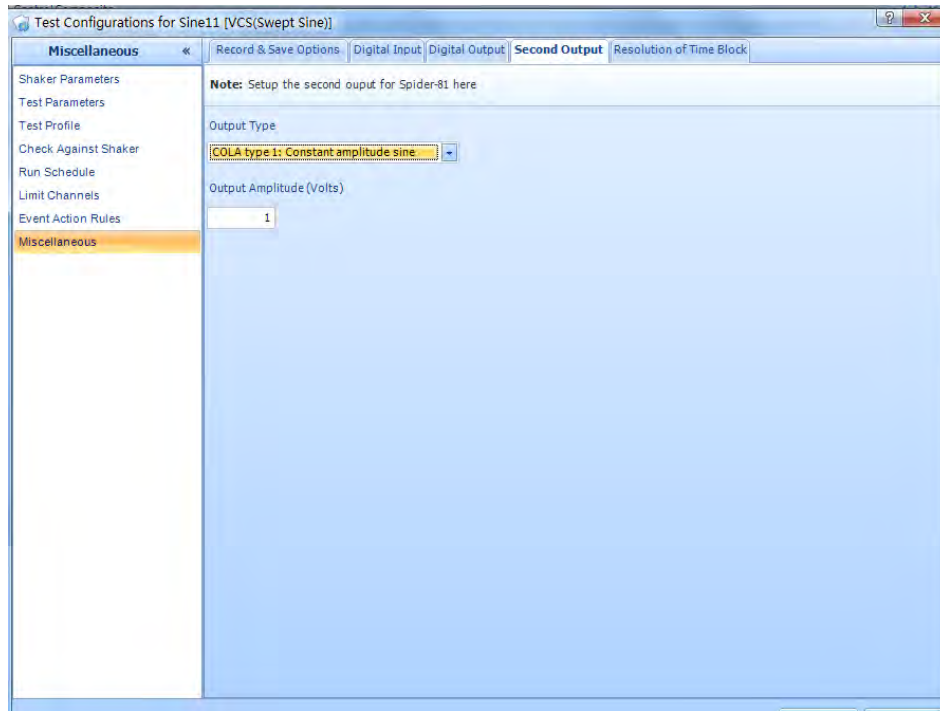
**Figure 201: Setting the COLA signal parameters on the Spider-81 VCS**

To set up the Sine Reduction on the analyzer side, first create a sample test using EDM. A sine reduction test can be created from the New Test tab or the option of the New Test Wizard.
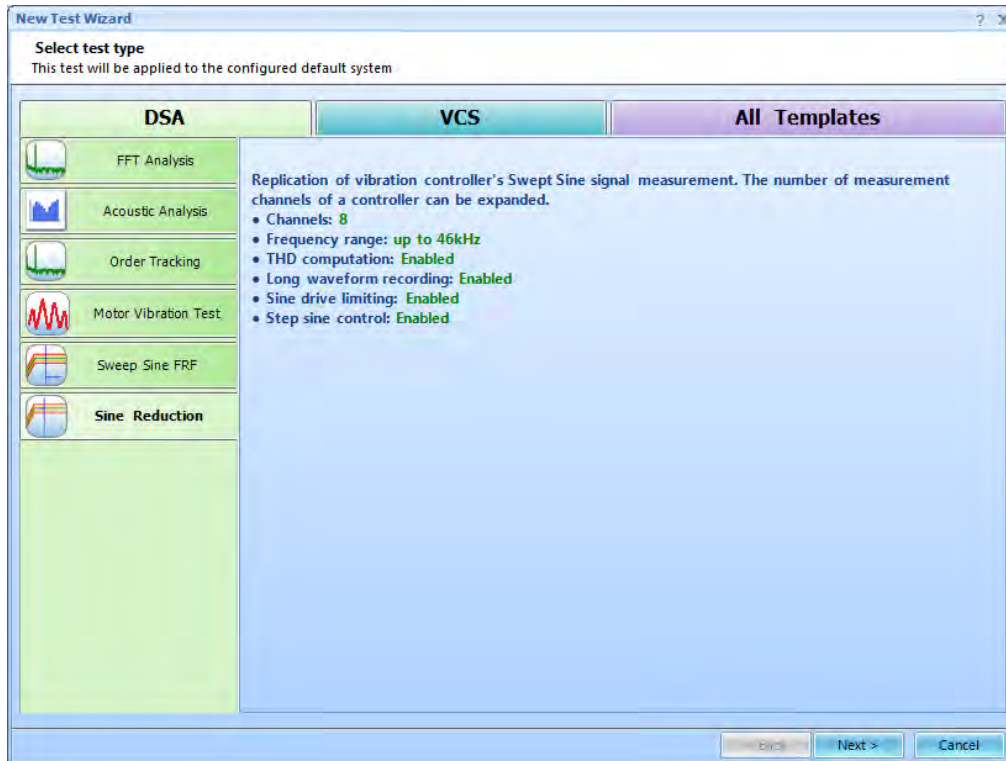
**Figure 202. Create a Sine Reduction test on the Spider-80X DSA**

Go to **Input Channels** table to set the channel 1 **Channel Type** to **COLA**. Each Sine Reduction test has only one COLA channel. In this example, the first is used, but any one of the inputs may be as the COLA input channel.
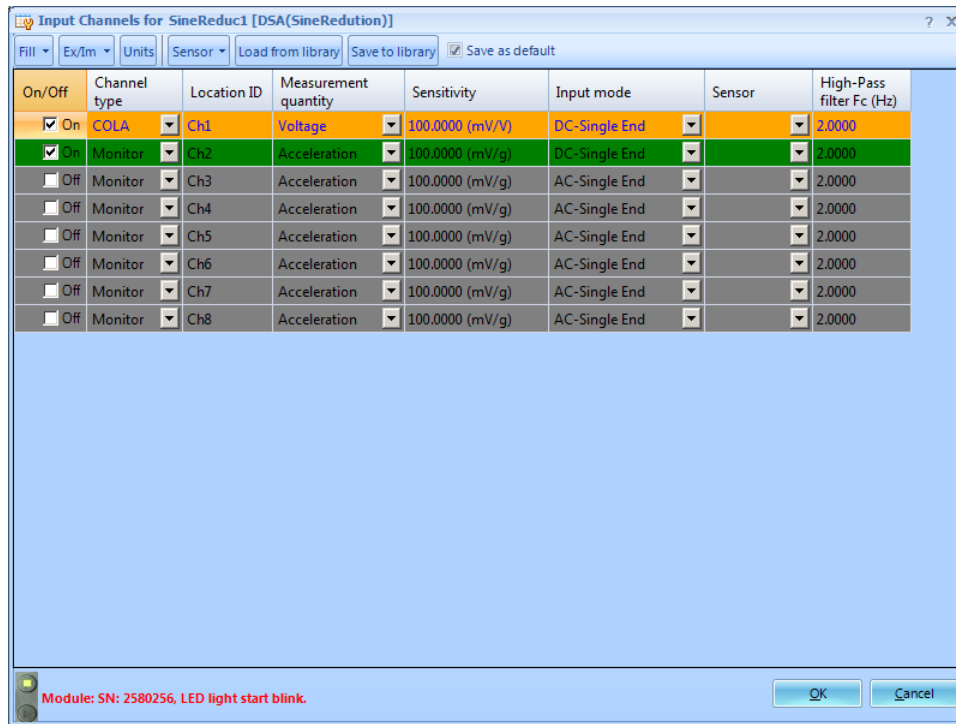
**Figure 210. Channel Table Setting for Sine Reduction Test**

Sine Reduction parameters can be found in the **Test Parameters** tab under Test **Configuration**. All parameters should match those set on the sine controller. The COLA Amplitude is determined by the COLA output value of the controller. The **Low Frequency** and **High Frequency** parameters must match the test profile of the sine controller.
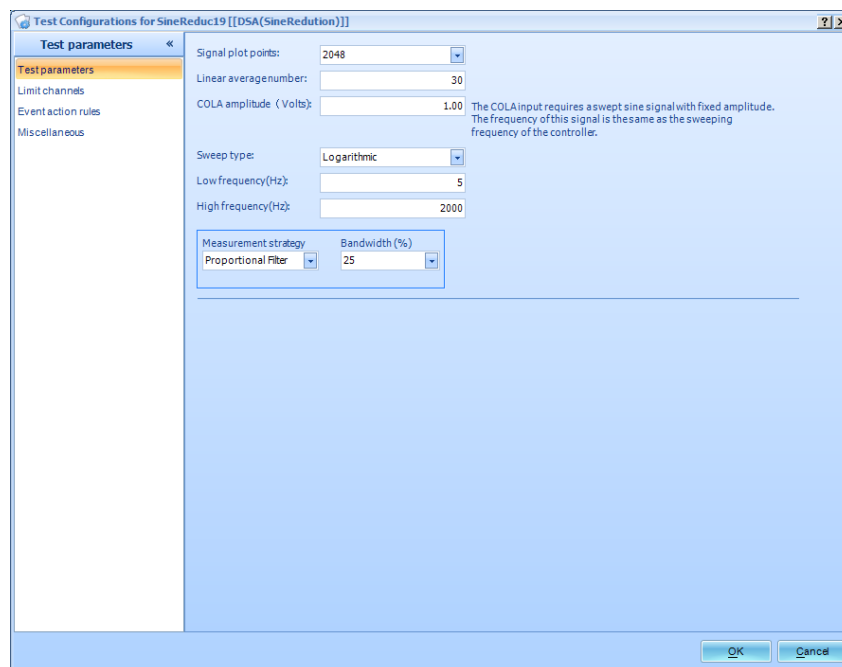


**Figure 211. Sine Reduction Parameters**

When all Sine Reduction parameters are properly set, press the **Run** button to start the Sine Reduction test. The sine controller can be started before or after starting this DSA test.



**Figure 212. A Typical Sine Reduction Test**

In a Sine Reduction test, the user can easily set up FRF, Transmissibility and other measurements identically to the way they are set up on the VCS.

# EDM Keyboard Shortcuts

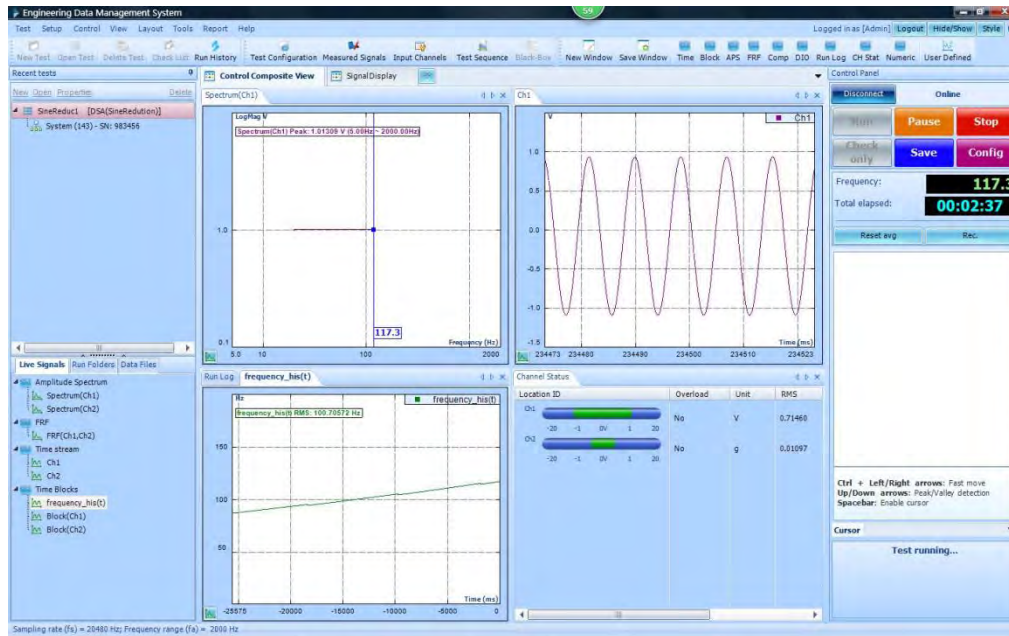| Command | Keys | Description |
| --- | --- | --- |
| Help | F1 | Open a Help file |
| Run, Start | F2 | Start the test or measurement |
| Pause, Hold | F3 | Pause or hold the test |
| Continue | F4 | Continue the test |
| Stop | F5 | Stop the test |
| Record | F6 | Record the time stream |
| Save Sigs | F7 | Save signals in the list |
| New Test | Ctrl-N | Create a new test |
| Find Test | Ctrl-F | Find test (open find test tab) |
| Copy image | Ctrl-C | Copy an image of the active window to the clipboard |
| Add Annotation | Ctrl-A | Add annotation to the active window if there is no cursor. Add annotation to the cursor location if there is a cursor. |
| Save Window Signal | Ctrl-S | Save the signals in the active window |
| Cache Signal | Ctrl-K | Cache signals in the active window. If there are many signals in the active window, cache all of them. The cached signals will be listed in the cached pane (in the lower left corner). |
| Test Config | Ctrl-T | Configure current test |
| Global Setting | Ctrl-G | Access Global settings |
| New window | Ctrl-W | Open an overlaid new empty window |
| Auto/Fix all | Ctrl-Q | Toggle Auto scale and fix scale for all windows |
| Un-Zoom | Ctrl-Z | Zoom back to the previous scaling range for the active window |
| Scroll plots(left, right) | Left and right keys | Move the plot scales to the left or right for about 1/20 of the active window |
| Scroll plots(up, down) | Up and down keys | Move the plot scales to the top or bottom for about 1/20 of the active window |
| Cursor on/off | Spacebar | Enable or disable the cursor on the active window |
| Time Stream | Ctrl+1 | |
| Time Blocks | Ctrl+2 | |
| Spectrum | Ctrl+3 | |
| Frequency Response Function | Ctrl+4 | |
| Composite | Ctrl+5 | |
| Digital I/O | Ctrl+6 | |
| Channel Status | Ctrl+7 | |
| Customize | Ctrl+Shift+I | |
| Save Active Window as... | Ctrl+Shift+S | |
| Connect | Ctrl+Shift+C | |
| Disconnect | Ctrl+Shift+D | |

# Installing the Engineering Data Management Software (EDM)

To install the desktop software on your PC, insert the included CD-ROM into your CD drive. If the Welcome Screen does not automatically open, you can run the Setup.exe file on the root level of the CD.



**Figure 213: Welcome Screen for EDM Installation CD.**

EDM requires MSSQL server 2008 R2 version or later.

## Microsoft SQL Database Server Installation

EDM requires an SQL database server. Currently, EDM software supports Microsoft SQL Server 2008 R2 and MySQL 5.0.67. If neither of the SQL database managers is installed, the EDM installer will prompt the user to install MSSQL before installing EDM. If MSSQL is already installed, the installation of database software will be skipped and the existing database software will be used with EDM. If MySQL is detected, a selection can be made to install and use MSSQL or to continue using MySQL.

The flow chart below illustrates the steps of EDM and database server setup.
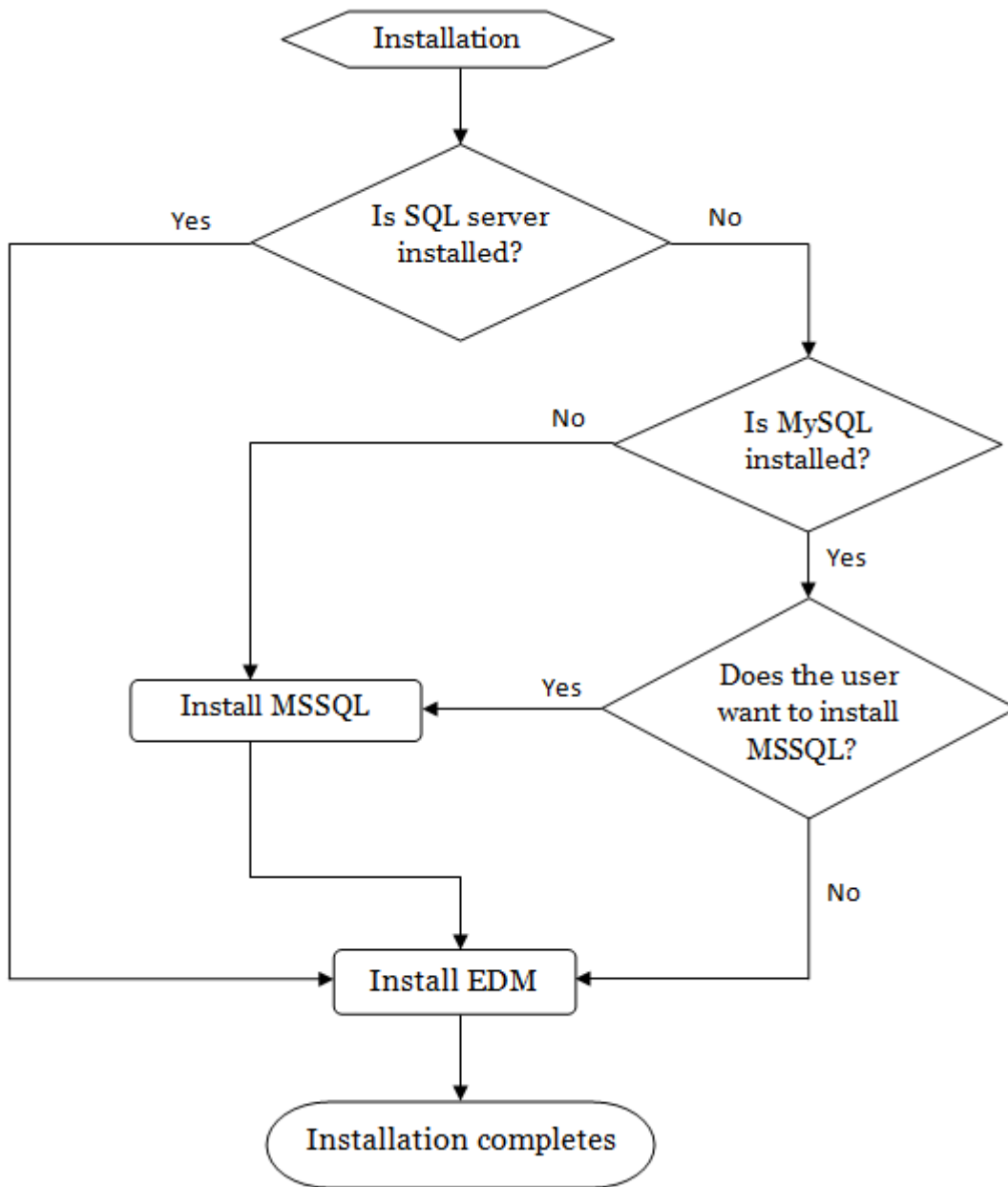
**Figure 214: SQL Server Installation Flow Chart**
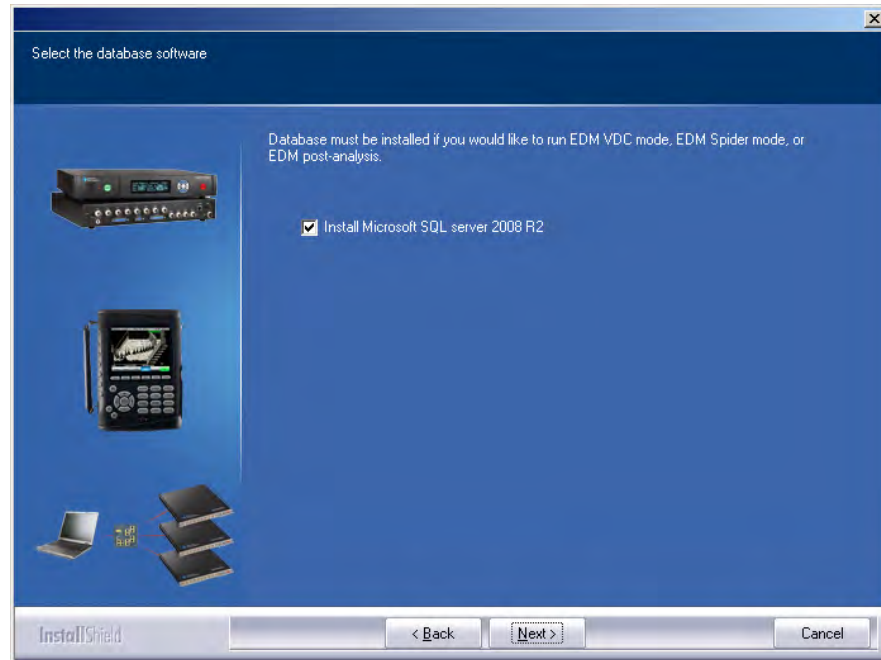
**Figure 215: SQL Server Installation Wizard**

The following instructions describe how to install the MSSQL Server Software. MSSQL is separate software licensed for use with EDM. It is used to manage the database that stores route and measurement data.

The EDM installer will prepare the necessary files for MSSQL Server Installation and will begin installing MSSQL.
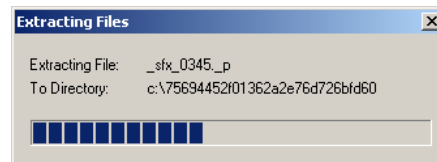


**Figure 216: EDM Extracting MSSQL Installation Files**

The message box and the command line window below indicate that the MSSQL installer has been initialized successfully. Do not close any windows during the setup process.
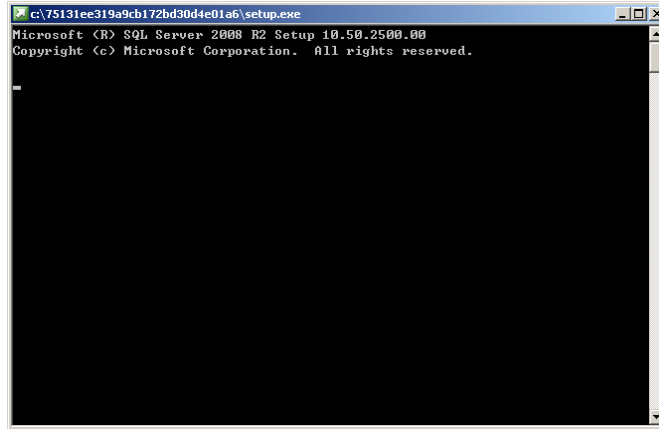
**Figure 217: MSSQL installation initialization**



**Figure 218: MSSQL Installation Wizard Launching**

The Installation Wizard will prepare support files for troubleshooting and Help menus after installation.
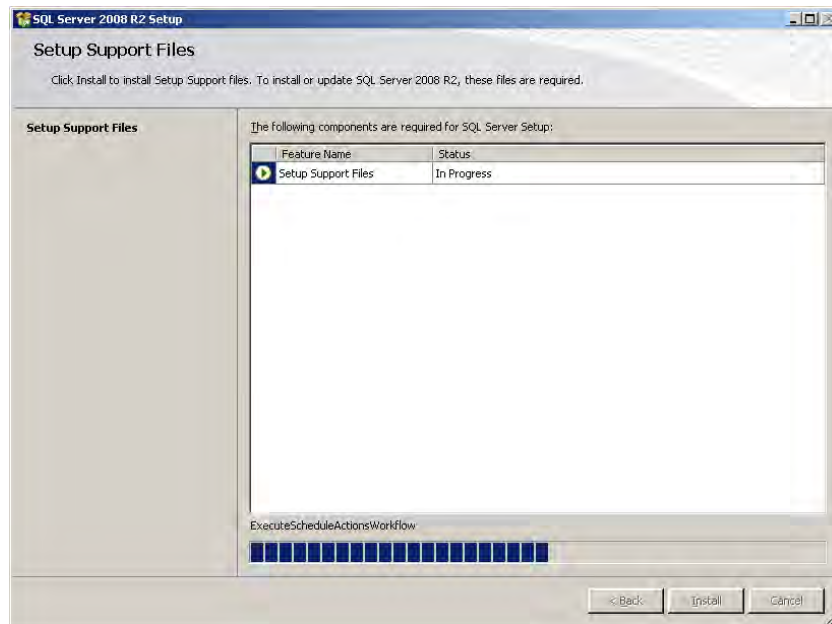


**Figure 219: MSSQL Support Files Setup**

The Wizard is configured to install MSSQL with default options that ensure it works with EDM. There are no settings that need to be specified by the user.
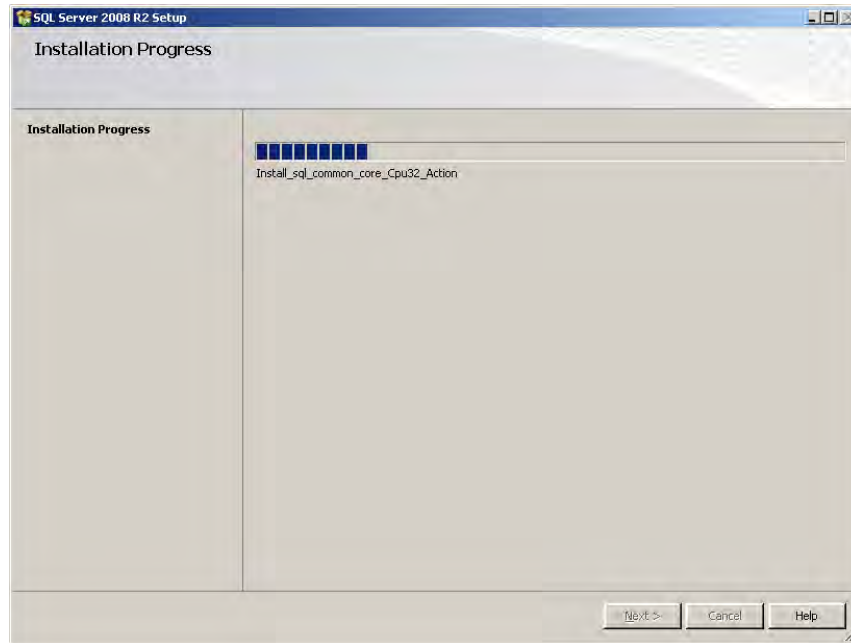
**Figure 220: MSSQL Installation in Progress**

When the database server is successfully installed the EDM installation will begin. The following section discusses the installation procedure for EDM.

> **Note**: Having a computer and a user account with the same name can cause login errors. If problems are encountered logging into MSSQL, verify that the computer name does not match any user account. To check the computer name: right-click on My Computer and select Properties. The computer name will be on the first page. To check the user name: right-click on My Computer and select Manage. Expand Local Users and Groups and click on Users to see all user accounts.
>
> Windows Installer 4.5 is a prerequisite for MSSQL installation. The system must be rebooted after Windows Installer 4.5 is installed.
>
> Folder may not have the advanced options of encryption or compression enabled.
>
> When EDM fails to connect to the MSSQL server database, deleting "EDM.database.dll.config" might solve the problem.

EDM versions newer than Version 3.1.5.1 use MSSQL instead of MySQL. However, newer EDM versions are still backward compatible with MySQL for users upgrading from older versions (Version 3.1.5.1 or older).

This means that users who are familiar with MySQL can keep using the MySQL database. Switching to Microsoft SQL Server is not mandatory. The MySQL installer is not available in versions higher than 3.1.5.1.

## EDM Software Installation Wizard

The EDM installer will launch immediately after completing the installation of the MSSQL database management software. To install the Engineering Data Management (EDM) software without installing an SQL server, click *Install EDM Software (version X.X.X.X)* from the EDM Installation screen to launch the Installation Wizard.

> **Important**: SQL database software is necessary for EDM to operate. The supported database managers are MSSQL (recommended and installed by default) and MySQL. If MySQL is preferred or currently used for EDM database management, refer to Appendix 3.



**Figure 221: EDM Installation Wizard**

Click *Next* to begin the installation process.

Review and accept the license agreement and click *Next*.

**Figure 222: EDM License Agreement Acceptance Page**

To install EDM a valid license key is required. If the default location does not contain your license key, browse for the correct folder. Once the license key has been specified, press *Next*.



**Figure 223: License Key Directory Page**

The **Software Renew Period** is the time period during which the software can be upgraded. The **Software Activation Period** is the time period during which the software is operational and can be used.

### Where is My License Key?

There are two ways to obtain your EDM software License Key.

When you received your Spider module from Crystal Instruments, you should have received an automated email message with shipping information, your EDM license key file, and your product serial number. The license key file is a file that contains the extension .LIC.

If you have not received this email message, or do not have your license key, you will need to obtain the license key file from the Crystal Instruments support website: http://www.go-ci.com/support.asp. If you do not have a password, call Crystal Instruments tech support and they will send it to you. (Your login username is the product serial number).

> It is a good idea to store the License Key, the serial number of your instruments, and your password somewhere secure where you can always find them. You will need this information to log onto the CI Technical Support Site for assistance and updates. If they are lost, please call CI Technical Support at (408) 986-8880.

Continue the installation process after obtaining the License Key files. Select the features to be installed.
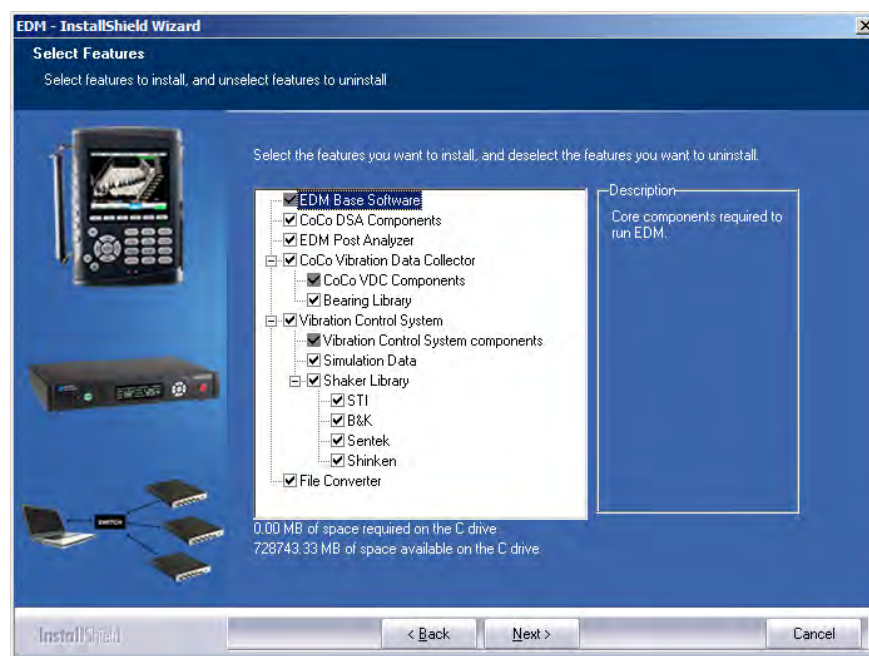
Specify the installation directory and press **Next**. The default directory is C:\Program Files\Crystal Instruments\EDM.
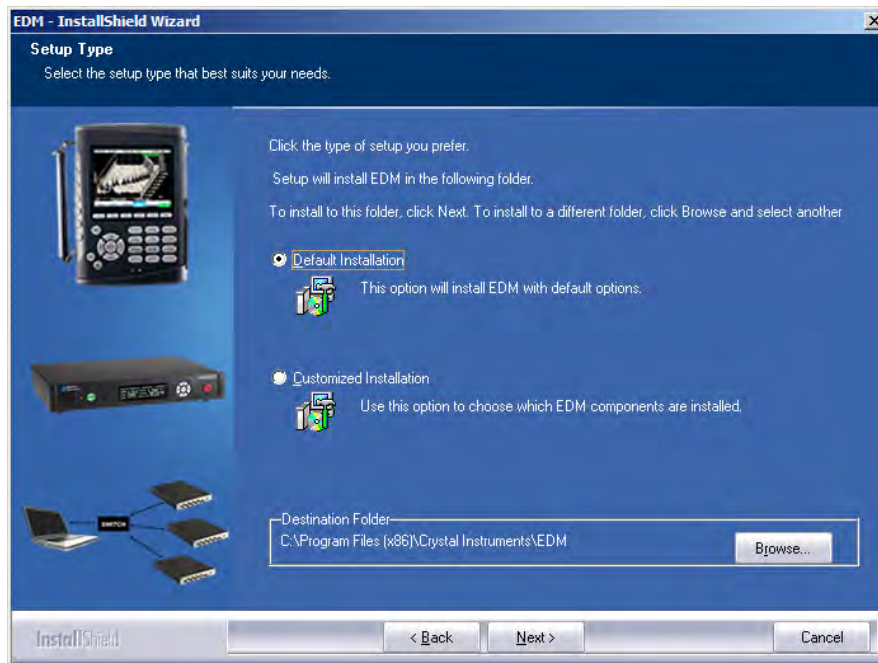


**Figure 224: Installation Directory Page**

If desired, specify a preferred location for Data Files, CSA Projects, Arbitrary Signal files, and Limit Collection files. Press **Next** to continue.



**Figure 225: EDM Default Save Location Page**

Specify the Start Menu folder name and press *Next*.
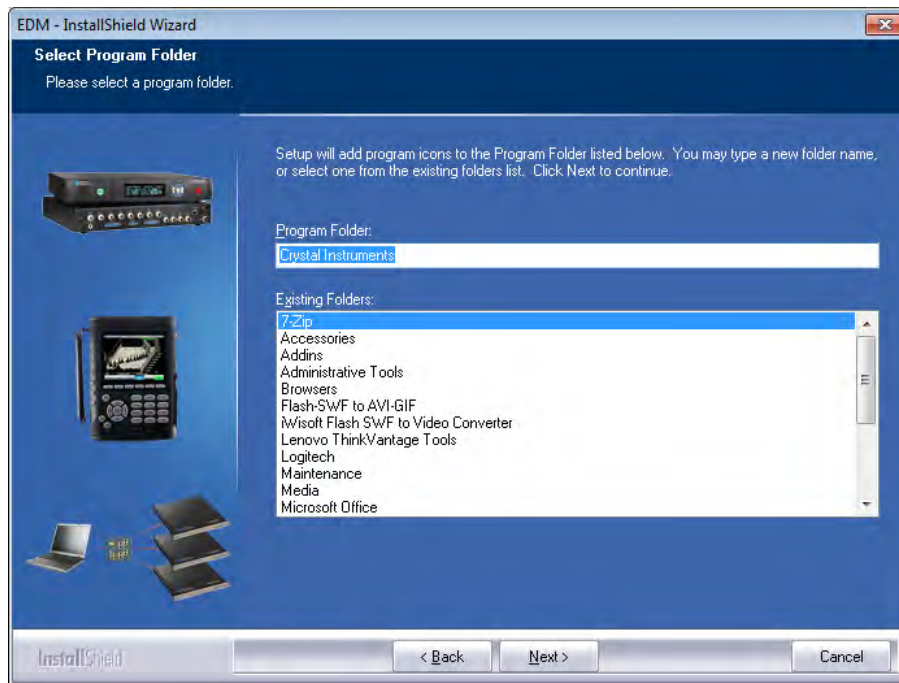


**Figure 226: Programs Folder Title Page**

Select your preferences for Shortcuts, Default Units, Default Language, Paper Size, and Multiple Module support. These settings can be changed later in the EDM Settings menu. Press *Next*.
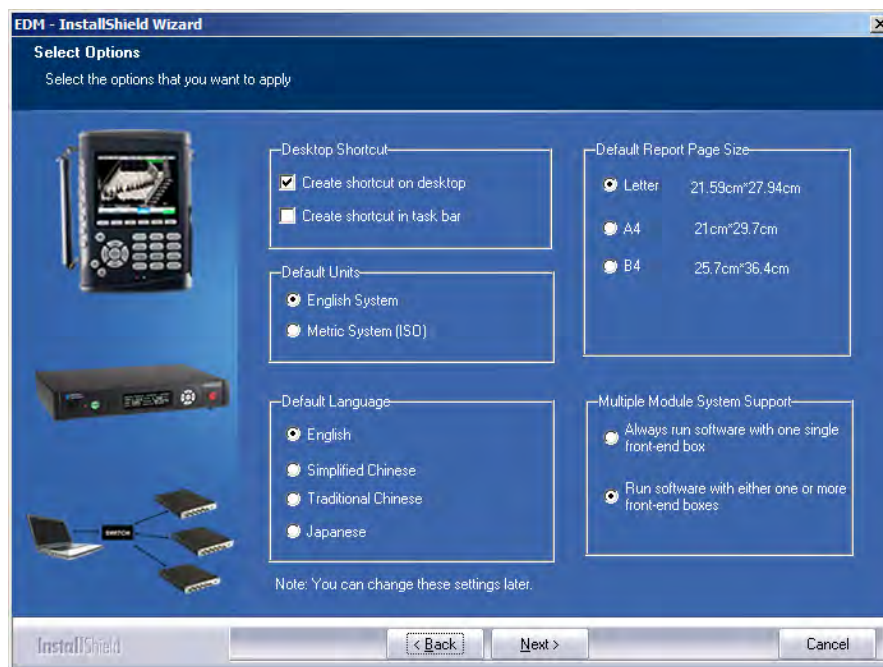


**Figure 227: EDM Default Settings**

Review the installation settings. Click **Back** if changes are necessary. Click **Next** if all settings are correct. The Installation Wizard will then set up EDM according to the settings you have chosen.
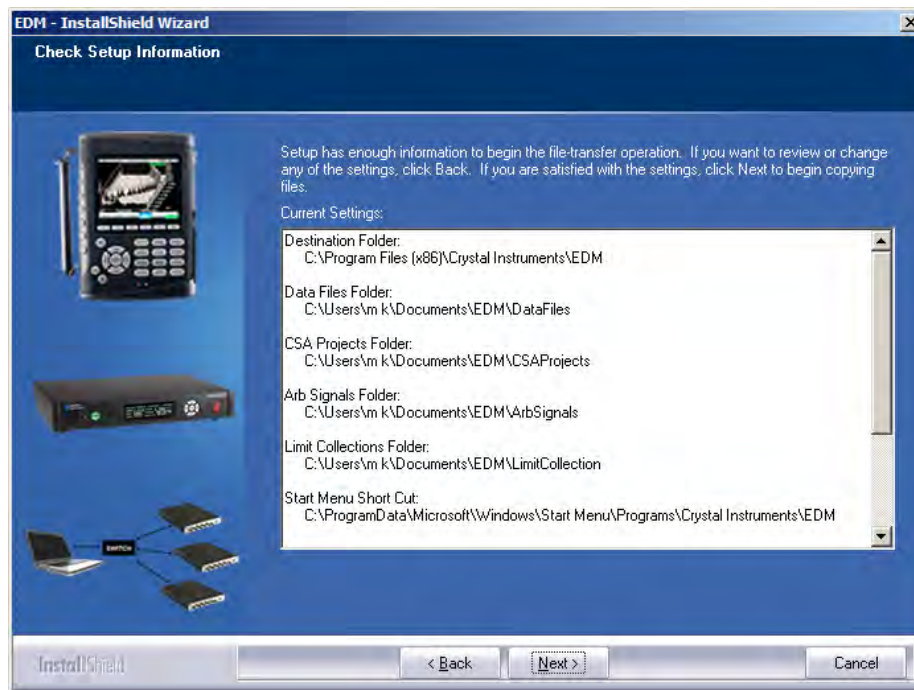


**Figure 228: Installation Summary Page**

Click **Finish** to exit the EDM installer.



**Figure 229: Completed Installation Page**

# Using EDM App

The EDM App for iPad is a software program designed for vibration control and real time data processing on the iPadmanufactured by Apple Inc..It supports FFT, Random,Swept Sine, and Shockvibration control tests that are uploaded by the EDM PC software. The EDM App for iPad also createstests directly on the iPad.

The Spider-20/20E only support DSA function mentioned below, and all VCS related functions will be available on other Spider platforms.

The user can adopt one of the following two scenarios to run a test on the Spider hardware platform:

**Normal Configurable Mode:**The EDM App for iPad can create and edit its own tests and run those tests on Spider front-ends. In this process the EDM PC software is not required. The tests created and run by the iPad have reduced functions compared to the EDM PC version.

**Black Box Mode:**The VCS and DSA tests can be uploaded via EDM PC software. The test typesinclude*FFT DSA,Random, Sine-on-Random, Random-on-Random, Swept Sine, Resonance Search and Dwell.*Afterthe PC is disconnected from the Spider, the Spider can run in Black Box mode. While running in Black Box mode, the EDMApp for iPad can access tests on the Spider, view signals, and control tests. In this case the test setup such as profile or channel table cannot be changed by the iPad app.The control options in the app include reset average, next entry button, level adjustments,anON/OFF switch for abort checks, a closed loop and schedule timer apart from Run, Pause, and Stop buttons.

The benefit of running theiPad in Black Box mode is that the test can be any configuration as long as the EDM VCS (PC version) supports it. For example, tests as complex as RSTD or Sine-on-Random are all be supported. Up to 8 input channels are supported. The drawback of this approach is that the EDM App for iPad will not be able to edit or change any parameter settings.

Through a direct wireless connection between your iPad and any Spider units on the wireless network, the EDM App for iPad allows engineers to monitor and control test settings and measurements, flip through existing measurement setups and past measurements runs, or create new test configurations from scratch. A wide range of display types and layouts offers online data viewing and real time interaction.

Using the iPad brings additional freedom to test engineers, making it possible to control any shaker table in the lab on or near the test object while walking around freely during a test, or monitoring signals on the iPad in real time.

The EDM App for iPad is the only software required to run the Spider hardware. Screen shots together with testing status are emailed as testing report to the recipients with one command.

The EDM App for iPad software only runs one Spider front-end at a time. From the EDM App, the user can select one of the Spider front-ends detected through its wireless network. TheiPad can be disconnected or reconnected to any valid front-end.

Each Spider front-end has its own access control passwordto prevent unauthorized access on the wireless network.

English, Japanese and Simplified Chinese are available. The language can be switchedthrough the iPad language environment without reinstalling the software.

All types of Spider platforms are supported by this iPad application.

**Spider-80X**
**High Performance Dynamic Signal Analyzer**

**Spider-DAQ**
**Data Acquisition System**

**Spider-81**
**High End Vibration Controller**

**Spider-81B**
**Compact Vibration Controller**

**Spider-20**
**Wireless Dynanmic Signals Analyzer**

**Spider-81C**
**Wireless Vibration Controller**

**Figure 230. All supported Spider's**

The new design of hardware and software completely eliminates the reliability issue caused by a PC in the real-time control and data acquisition application.

It is ideal for production tests or long duration tests. It is ideal for data acquisition applications that run without people in attendance.
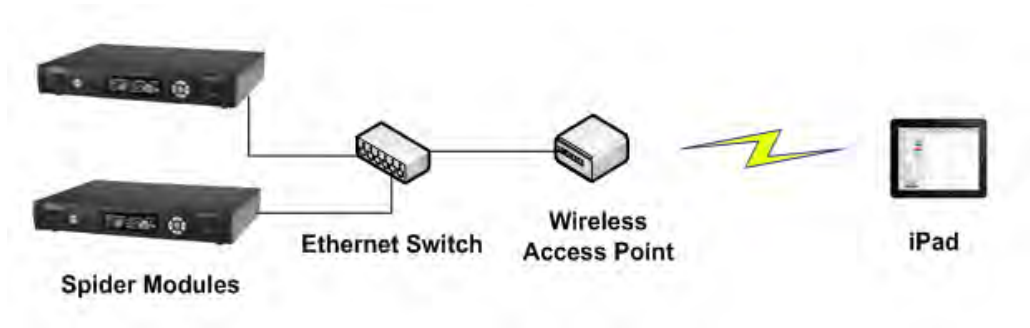
**Figure 231. Connection topology**

Hardware devices connected to the local area network will be identified by the IP addresses.

For Spider-81C or Spider-20 which has a built-in Wifi router,  the iPad will be directly communicate with these front end devices without going through external router.
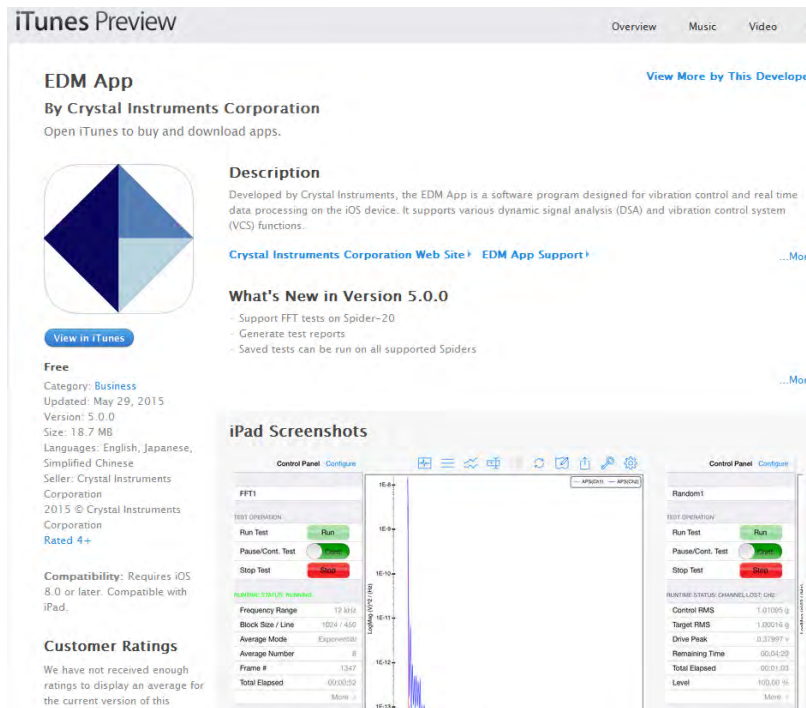


**Figure 232. iPad connects to Spider-20 through wireless**

# Installing the iPad Software

The EDM apps can be downloaded from the Apple Store at the following address

https://itunes.apple.com/en/app/wireless-edm/id496468252



**Figure 233. EDM App in App Store**

The EDM iPad App is available on the Apple App Store that is included on all iPads. It is easiest to find the app by searching "Crystal Instruments".
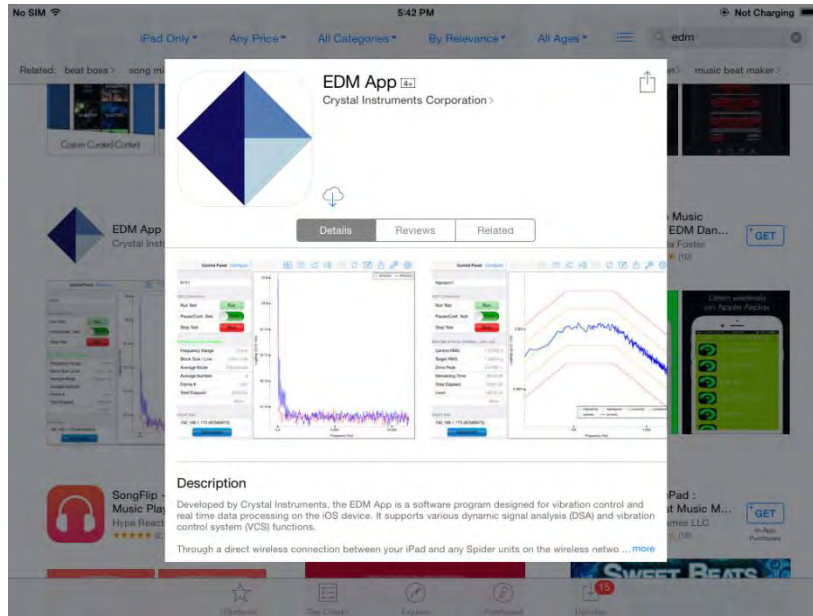
**Figure 234. Download EDM App from App Store on the iPad**

# Control the Spider from the iPad

## Network Connection

In order to connect, the iPad on its wireless connection must be on the same network as the Spider on its wireless/wired connection.

Spider-20 and Spider-81C are equipped with built-in wireless connection. Because they are wireless device themselves, the App on the iPad can establish a point-to-point wireless connection with Spider-20 and Spider-81C. No external routers are required in this connection.

Following are the factory settings of Spider-20 and Spider-81C.

WI-FI ID: Spider_SERIAL_No

WI-FI Password:  [BLANK]

DHCP Gateway: 192.168.1.10

Subnet Mask: 255.255.255.0

DHCP Server: Enabled

For the wired Spider device such as Spider-80X, Spider-81, and Spider-81B, the best way to do this is to use a wireless access point connected directly to the Spider. The iPad then connects to it through Wi-Fi. If the access point has a DHCP server, it should be enabled so that all devices automatically get a configured IP address.

On the iPad, the wireless setting is configured under Settings->Wi-Fi. If the Spider or the wireless router has DHCP server enabled, user should use DHCP IP address **on the iPad. If the Spider or the wireless router doesn't ha**ve DHCP server enabled, use can either enable it or use static IP address on the iPad.

When iPad has the Wi-Fi enabled, the list of available network will be shown with **SSID. Tap the wireless Spider's SSID or the wireless router with wired Spider** connected, the connection between the iPad and the Spider will be automatically established.

Unless very necessary, DHCP address is highly recommended to avoid encountering network issue.

## License Key

The iPad must load a license key corresponding to the serial number of the Spider in order to connect to it. License Keys are loaded either directly from the Crystal Instruments servers or from local disks. While loading license keys, the iPad must have internet access and the user must have the account password associated with **the Spider's serial number.**

License keys are managed through the License Key Management window. All the loaded license keys are listed here, and a new key can be loaded by entering the serial number and password and pressing Add License Key.

For the system with more than one license key, only one license key can be set as active. Only the device associated with the active license key can be controlled by iPad. To select the active license key, tap on the serial number in the list and then tap on *Set as Active License* .
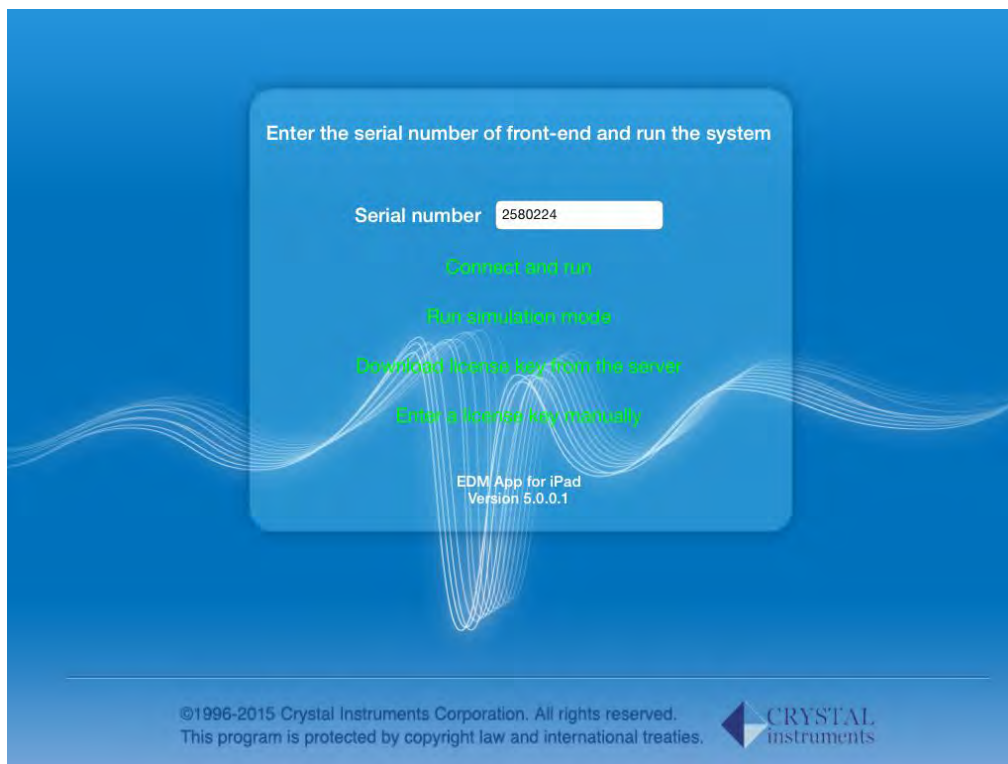


**Figure 235: Start Page**
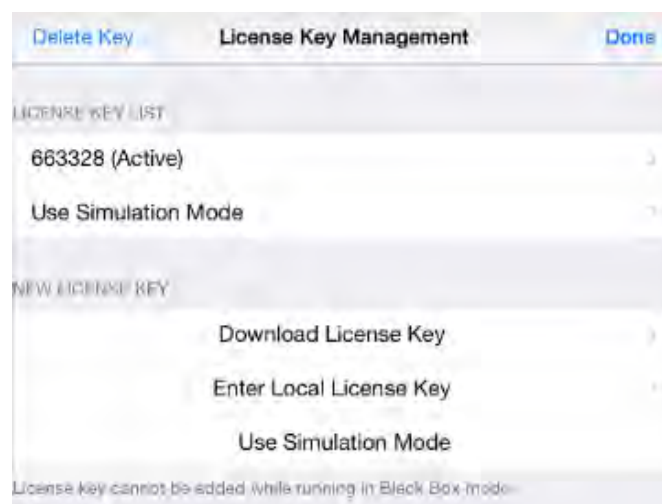
**Figure 236: License Key Management**
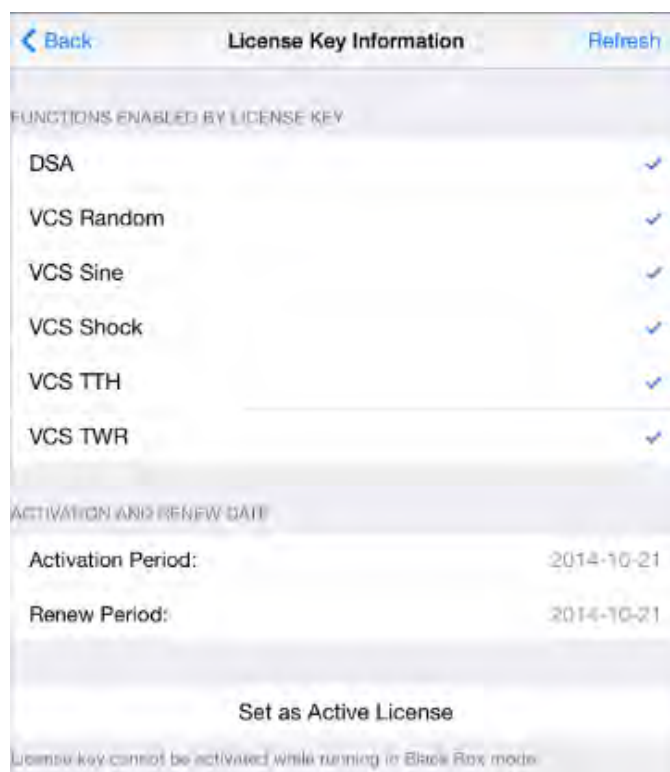


**Figure 237:License Key Information**

## Simulation Mode

The EDM App includes a Simulation Mode that allows the features to be demonstrated without connecting to an actual front-end device. Just tap Use Simulation Mode to enter simulation mode as shown in License Key Management page, or tap Run Simulation Mode as shown in Start Page. Add a license key with **the Serial Number and Password both set to '000000'. Make sure this license is set** on active. When a test is run with this license, demo data will be displayed in the plot area.

## Front-End Detection

Once the iPad and Spider are powered on and connected to the same network, the iPad will automatically detect the Spider. Press the front-end selection button to open a list of all detected modules. *Front-End detected and connectable* are modules that are ready to be connected to from the iPad. *Front-End already connected by other EDM* shows detected modules that are connected to other devices (like EDM on a computer). They must be disconnected first before the iPad can connect to them.

**Figure 238. Detected devices**

After selecting the Front-End module in the detected list, the selection will be shown on the control panel. When a device is selected, click the **Connect** button to connect to the device.

If the device the iPad is trying to connect to is already running in Black-Box mode, a warning will be displayed as shown. This warning will appear if the Start button on the front of the Spider is pressed before connecting from the iPad, or, if a test is started from the iPad, the iPad is disconnected, and then later reconnected while that test is still running.
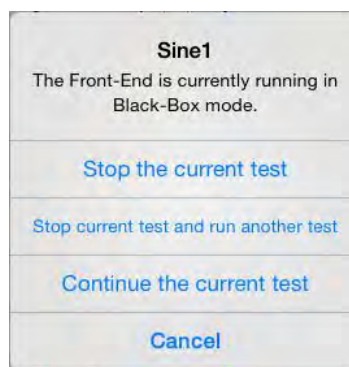


**Figure 239. Test status and operations**

## Create A New Test

If there are existed tests uploaded to the Spider from black-box mode, the list of tests will be displayed in the test list. Users just need to select a test to run. For those tests uploaded from black-box mode, the details are illustrated in Black-box Mode chapter.
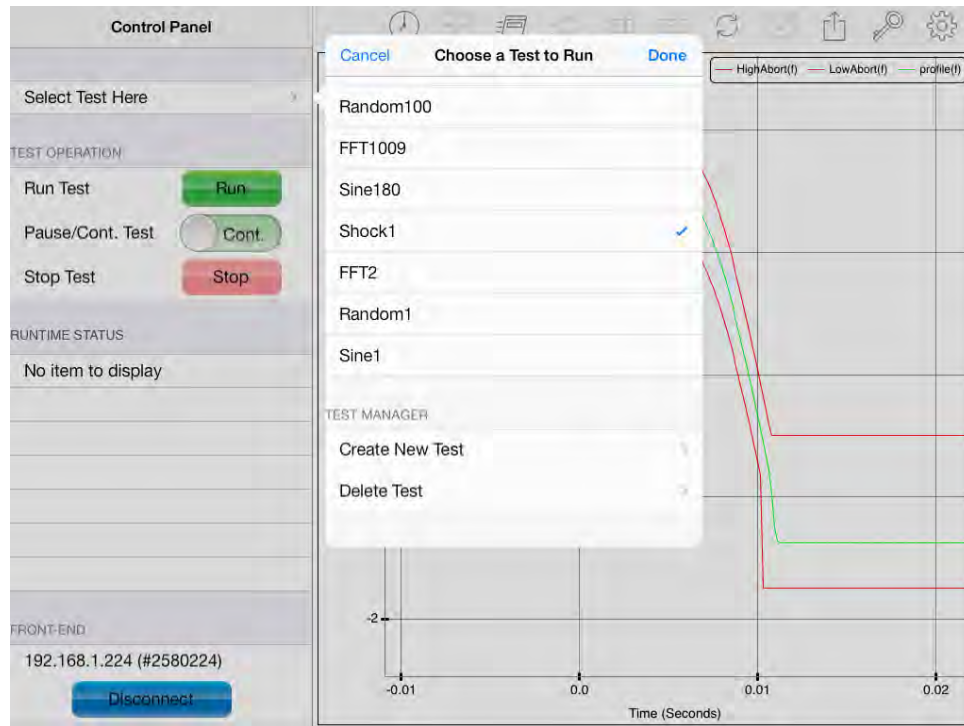
**Figure 240. Create a test from iPad**

Tap the Create New Test button to create a new test; select the test type from FFT Analysis, Random, Swept Sine, and Classic Shock; tap the test name to rename it.

Test can also be deleted by tapping the Delete Test button.

## Input Channels

Tap the Configure button at the top of the Control Panel to configure the channel table.

In FFT test, the Input Channels setup include the following items.

**Figure 241. Input channels for FFT test**

**Sensitivity** sets the proportionality factor for the measurement (millivolts per engineering unit) given as a parameter of the sensor.

**Input mode** is the electrical interface mode of the sensor. The available options are DC-Differential, DC-Single End, AC-Differential, AC-Single End, and IEPE.

**High-Pass Filter Fc (Hz)** sets the digital high-pass filter frequency, used to block spurious low frequency and DC signals. To measure very low frequency or DC signals set this value to zero and use the DC-SE or the DC-DI input mode.

In VCS test, the Input Channels setup includes all items which are available in DSA and the **Channel Type** which could be the control channel or the monitor channel.

**Figure 242. Input channels for VCS test**

## Pre-test Status

Some types of test begin with a pre-test. When a pre-test is running, the Pause/Cont. button will be not available until the pre-test is done.



**Figure 243. Control panel of a random test**

## Advanced Control Items

The control menu contains manual control options specific to the type of test being run. For example, there are items to increase or decrease the current test level and to run in open-loop.
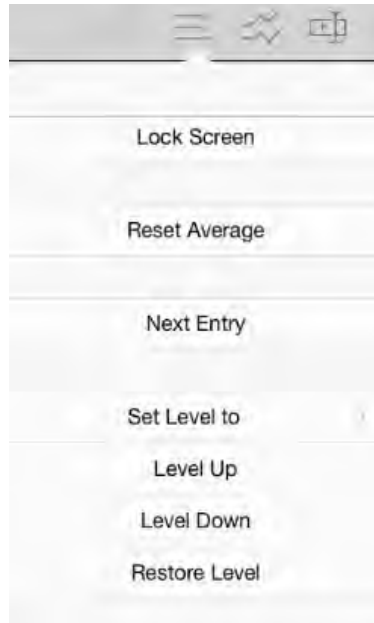


**Figure 244. VCS control buttons**

## Viewing Data

Use the Signals button to choose which signals to display. By default in VCS tests, the Control Composite view is displayed. This shows the control signal, test profile, and alarm and abort lines. All other live signals from the test are also available for display. Signals with the same type and unit can be simultaneously selected and displayed.



**Figure 245. Menu bar**
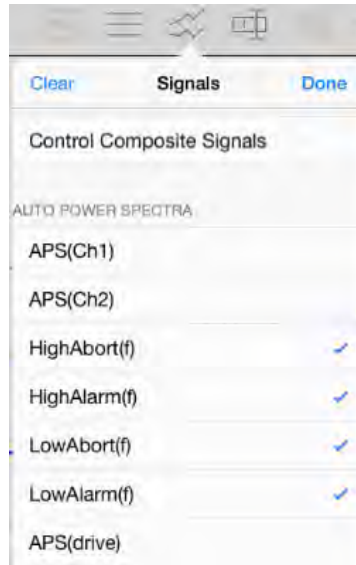
**Figure 246. Signal display setup**

The color of the signal lines can be changed.
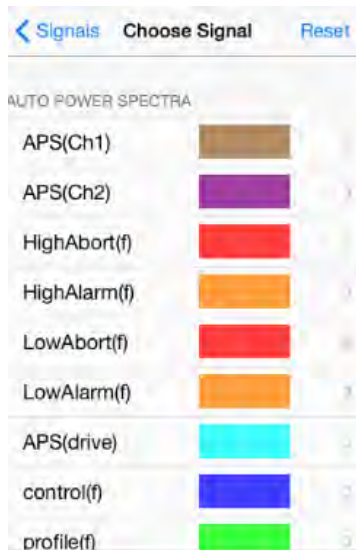


**Figure 247. Signal color setup**

A cursor can be added by pressing the add cursor button. Move the cursor by dragging it across the screen.
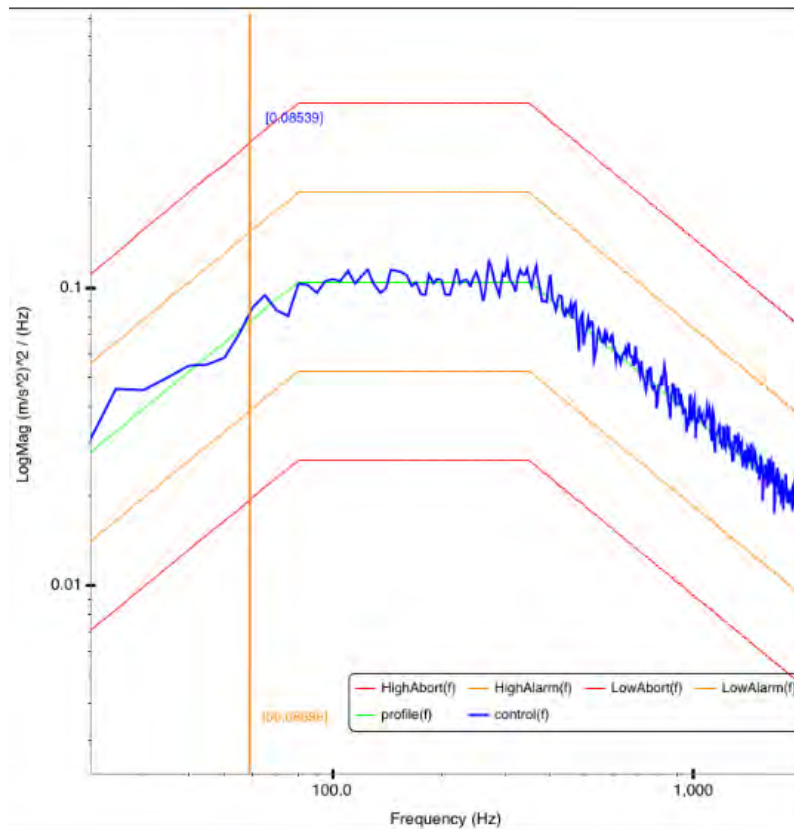
**Figure 248. Moving the legend in the composite window**

The legend can be moved by tapping and dragging it to anywhere on the screen.
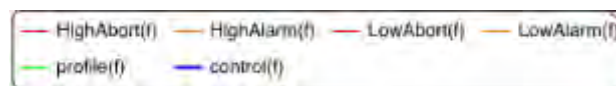


**Figure 249. Lengend**

The auto-zoom button will zoom out the display to show the best view of the displayed signal. The display can also be manually zoomed by using two fingers pinching to zoom in, and the opposite movement to zoom out. Use one finger to move around the display area.

Axis and signal unit options can be changed in the display format menu. The horizontal can be viewed with a linear or log scale. The vertical axis can be viewed with a linear, log, or dB scale. For frequency signals, the units can be changed under Spectrum Type.
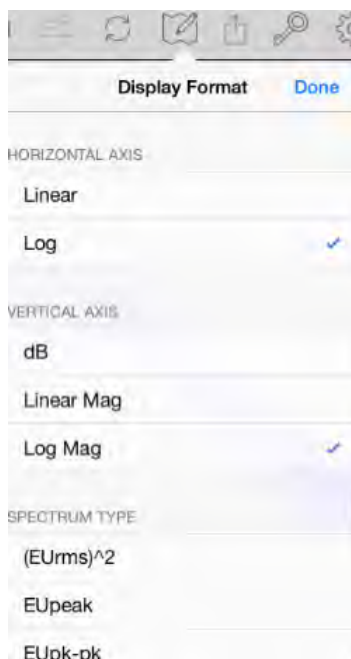
**Figure 250. Signal display setup**

## Sharing Data

The share menu is used to export the current signal view.
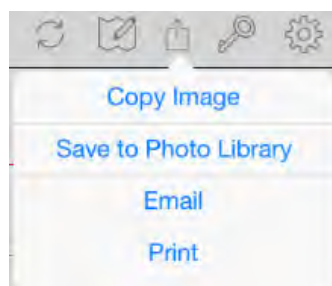


**Figure 251. Data sharing menu**

**Copy Image** will save a snapshot of the display to the clipboard.

**Save to Photo Library** will save the image to the Photo Library on the iPad.

**Email** will open the Mail App with the image attached.

**Print** will print the image using an AirPrint compatible printer (consult the Apple documentation on using printers with the iPad).

## Generate Report, Save Test, and Save Signal

The Data Management menu contains features of generating report, saving tests, and saving signals. Tap Generate report button to create a report in PDF format containing all testparameters, input channels status, run schedule, test profile,

shaker parameters, and hardware information.Tap Save test button to save current test. Tap Save signals to save checked signals which are defined under the Signals menu.
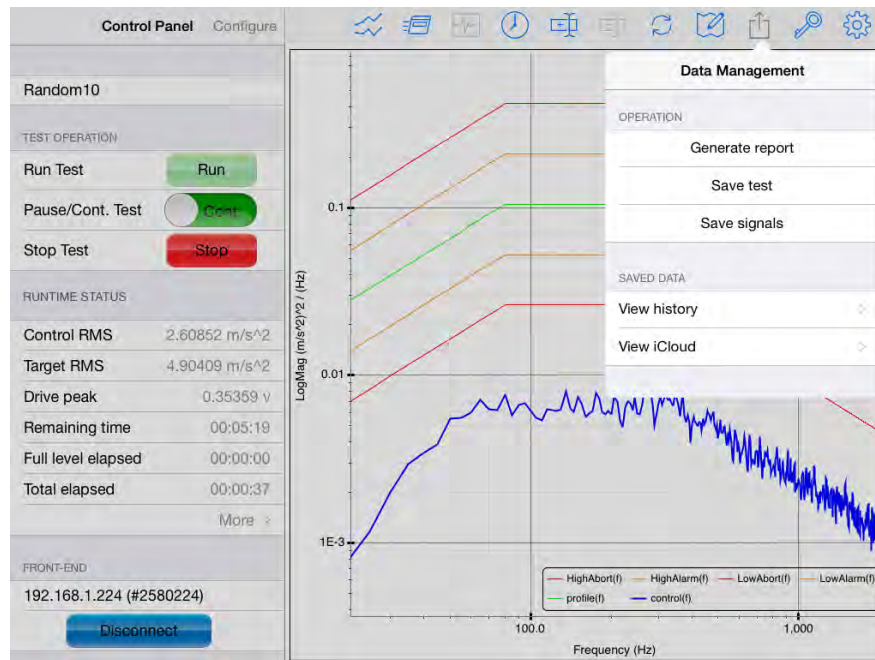


**Figure 252. Data management setup**

Here is an example of a test report in PDF format. User can swipe up to view more parameters in this report.
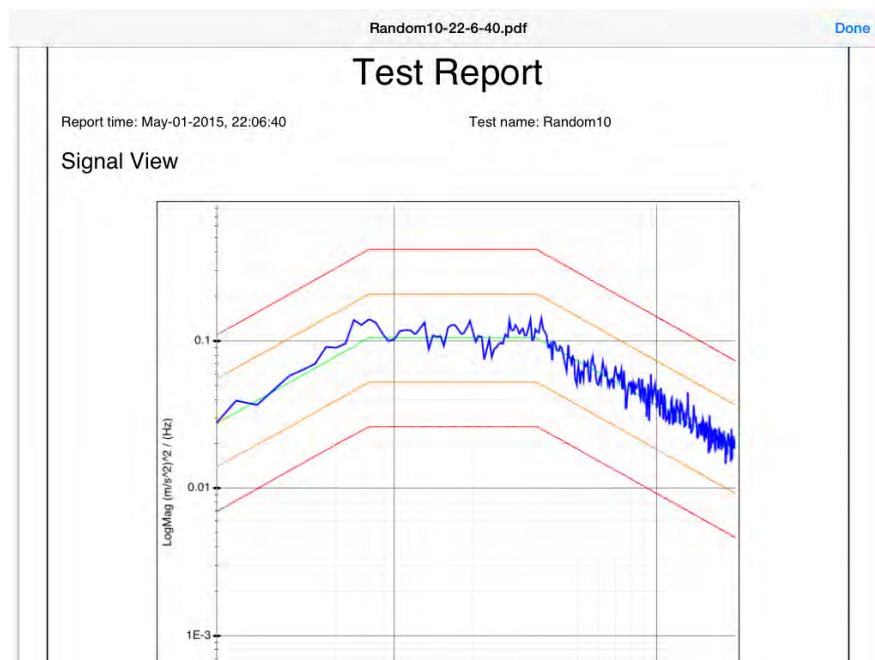


**Figure 253. Sample test report in PDF format**

The report can be saved to iCloud or iPad in PDF format. Or it can be used for an instant overview and be discarded.
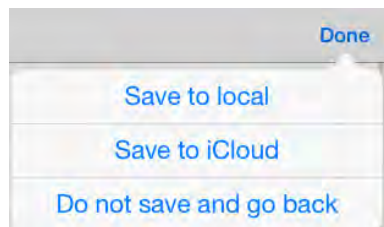


**Figure 254. Save functions**

To open the saved report, tap the View history or View iCloud button to select the PDF file with a check mark.



**Figure 255. Save and view**

**Figure 256. Sample of saved files**

Tap the Operation button to view, email, print, save to the other location, and delete the select PDF files.
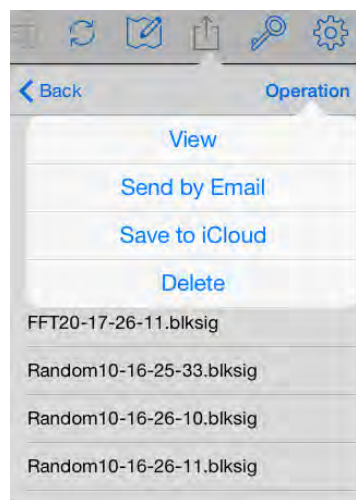


**Figure 257. View, send, and delete functions**

All saved test and signals files can be open by other iPad device, and the PDF files can be viewed on both iPad and other compatible device such as PC.

## Settings

The **Settings** tab includes **Engineering Unit**, **Plot Setting**, and **Email Settings**.

**Figure 258. Settings page**

Engineering Unit Setting



**Figure 259. Changing engineering units**

## Update Firmware Version

Firmware refers to the DSP software resident on the Spider hardware. The firmware is stored on the flash memory on board. It can be updated by using either the EDM App software running on iOS, or the EDM PC software.

The Update Firmware function can be found under ConfigureTest. By tapping the Update Firmware button, the current firmware version and the latest available firmware version will be display. When the current version is older than the available latest version, tap Download & Update to update the firmware to the latest version. It is highly recommended to always to the latest firmware to run a test.



**Figure 260. Update firmware page**

# Real-Time FFT Analysis

FFT analysis is conducted in the DSA real-time operation mode. These applications involve Digital Signal Processing calculations such as the Auto-Power Spectrum, Cross Power Spectrum, and Fourier Transform etc. for input channel signals.

## Dynamic Signal Analyzer Basics

This section will give an overview of the theory behind the functions performed in the FFT analysis mode of the Spider module. For more detailed information on this topic please **refer to "Dynamic Signal Analyzer Basics" published by Crystal** Instruments.

The Fourier Transform is one of the most fundamental and popular methods of signal analysis. It transforms an infinite time waveform into its frequency components. These frequencies may then be analyzed or further manipulated to calculate phase or transfer functions. Because the Fourier Transform involves an infinite sum the signal must be broken into finite blocks of N samples. Each block is then transformed using the Discrete Fourier Transform (DFT) However, computing DFT is computationally intensive and so a more efficient algorithm called Fast Fourier Transform (FFT) was developed.

Some applications of the FFT are listed below:

### Power Spectrum

The magnitude of the frequency components of signals are collectively called the amplitude spectrum. In many applications, the quantity of interest is the power or the rate of energy transfer that is proportional to the squared magnitude of the frequency components. The average squared magnitudes of all of the DFT frequency lines are collectively referred to as the Power Spectrum, $G_{xx}$. The averaging process is more properly termed an ensemble average, wherein the squared amplitude from N signal blocks at a each measured frequency, f, are averaged together. Letting an asterisk (*) denote conjugation of a complex number, **the "power" averaging process is defined by:**

$$G_{xx}(f) = |X(f)|^2 = \frac{1}{N}\sum_{k=1}^{N} X_k(f)X_k^*(f)$$

### Cross Spectrum

The Cross Spectrum characterizes the relationship between two spectra. For two signals $x$ and $y$, with frequency components X(f) and Y(f) it is defined as:

$$G_{xy}(f) = \frac{1}{N}\sum_{k=1}^{N} Y_k(f)X_k^*(f)$$

The Cross Spectrum reflect the correlation between the two signals. While the Power Spectrum is real-valued, the Cross Spectrum is complex. This means that it also describes the phase relationship between the two signals.

## Frequency Response Function

An important application of Dynamic Signal Analysis is characterizing the input-output behavior of physical systems. In linear systems, the output can be predicted from a known input if the Frequency Response Function (FRF) of the system is known. The Frequency Response Function, H(f), relates the Fourier Transform of the input X(f) to the Fourier Transform of the output Y(f) by the simple equation:

$$Y(f) = H_{xy}(f)X(f)$$

Multiplying both sides of this equation by the conjugate of the input spectrum and ensemble averaging explains the importance of the power and cross power spectra as they allow H(f) to be measured and calculated.

$$\frac{1}{N}\sum_{k=1}^{N}Y_k(f)X_k^*(f) = G_{xy}(f) = H_{xy}(f)\frac{1}{N}\sum_{k=1}^{N}X_k(f)X_k^*(f) = H_{xy}(f)G_{xx}(f)$$

That is:

$$H_{xy}(f) = \frac{G_{xy}(f)}{G_{xx}(f)}$$

The fact that Y(f) is dependent on the input X(f) is what makes the system linear. When measuring the input-output behavior of a system, there is always noise present that obscures the output. An important measure is how much of the output is actually caused by the input *and a linear process*. This is indicated by another important real-valued spectrum called the (ordinary) Coherence Function. This coherence function is also defined in terms of the cross spectrum and the power spectra. Specifically:

$$\gamma_{xy}^2(f) = \frac{G_{xy}(f)G_{xy}^*(f)}{G_{xx}(f)G_{yy}(f)}$$

Note that the coherence can also be stated as the product of an FRF with its inverse function. That is, if $H_{xy}$ measures a process going from input, x, to output, y, $H_{yx}$ characterizes the same process, but treats y as the input and x as the output.

$$\gamma_{xy}^2(f) = H_{xy}(f)\frac{G_{xy}^*}{G_{yy}} = H_{xy}(f)H_{yx}(f)$$

This product definition indicates the coherence represents an "energy round trip" or a reflection through the process. We apply $G_{xx}$ to $H_{xy}$ and get $G_{xy}$ at the output. Then we conjugate $G_{xy}$ (to flip it or reflect $x(t)$ in time) and pass it through $H_{yx}$. In a perfect world, this would result in exactly $G_{xx}$ as the output of $H_{yx}$.

If the system is linear and none of our measurements are contaminated by noise, the trip is perfect and we get back everything we put in. That is, the coherence will be exactly 1.0. If the system is non-linear or if extraneous noise has been interjected, the round-trip will be less efficient and the coherence will be less than one (but never more).

Thus, the coherence is always between 0 and 1. A coherence of 1.0 means the output is perfectly explained by the input (i.e. the system is linear). A coherence of 0 means the output and input are unrelated. Values in-between state the fraction of measured output power explained by the measured input power and a linear process. Experienced analysts always use the coherence measurement to quantify the quality of an FRF measurement at every frequency.

## Shock Response Spectrum

The Shock Response Spectrum (SRS) is an entirely different type of spectral measurement. It is used access the damage potential of a transient event such as a package drop or an earthquake. The SRS was first proposed by Dr. Maurice Biot in 1932. The SRS is not the spectrum of the pulse. (The FFT provides this.) The SRS is not a linear operator as the FFT is. That is, an SRS does not uniquely define a single waveform. Many very different transient time-histories can produce the same SRS.

What the Shock Response Spectrum is, is the representative response of a class of simple structures to the given transient acceleration time-history. This response is provided by simulating a group of spring-mass-damper systems sitting on a common rigid base that is forced to move with the measured acceleration of the subject shock pulse. Each single degree-of-freedom (SDOF) spring-mass-damper has a different natural frequency; they all have the same damping factor. The spectrum is formed by plotting the extreme motion (acceleration) experienced by each mass against its resonance frequency.

The frequency spacing of the resonance frequencies is logarithmic, much like the 1/3 octave filters used in acoustical analysis. That is, it is a type of proportional bandwidth analysis where the half-power bandwidth of each SDOF system increases in proportion to its resonance frequency. The resolution of an SRS is defined by the number of simulated SDOFs included in the desired analysis span. The percent damping of all the SDOFs is selectable (although most tests specify 5% damping).

The extreme motion of each mathematically simulated SDOF mass is monitored by several peak detectors. The extreme positive and negative accelerations are retained *during the duration of the input pulse* and *after it*. Maximum and minimum values captured during the pulse's duration are termed *Primary* extremes. Those found

after the pulse has returned to zero are termed **Residual** extremes. Specific tests will prescribe whether positive, negative or extreme absolute values captured should be displayed. They will further specify Primary, Residual or combined (maxi-max) data be plotted.

## FFT Test Parameters

In the Test Configuration window, the Test Parameters section has settings for the main analysis parameters of the FFT test.
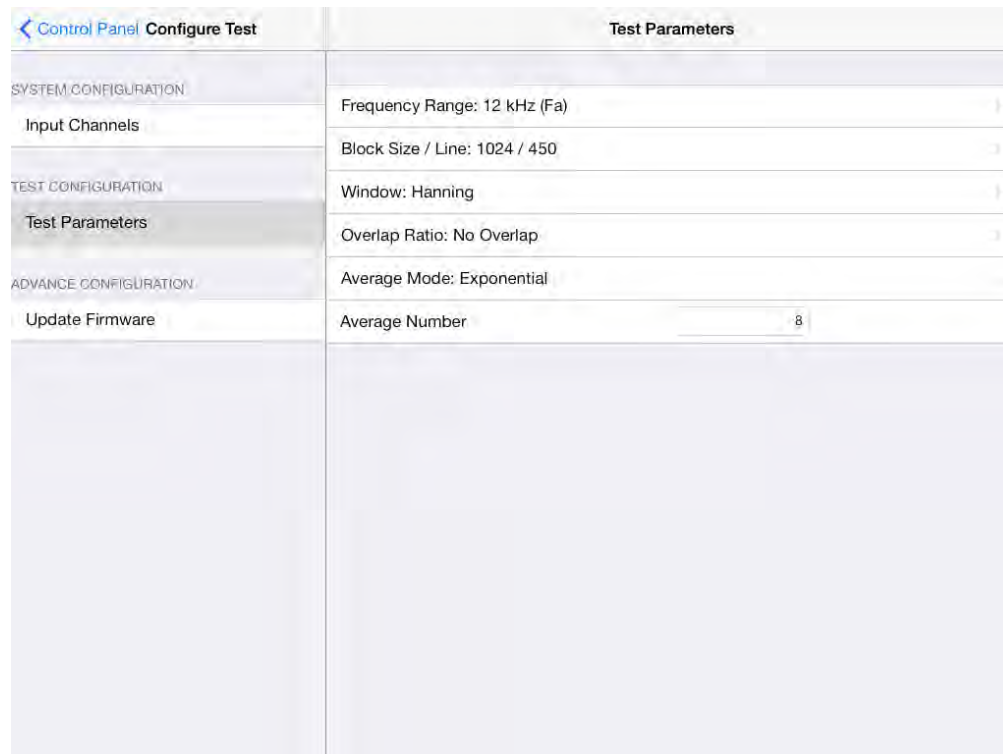


**Figure 261. Test parameters of a FFT test**

**Frequency Range** is defined as the maximum frequency range for the FFT analysis. Frequency range determines the sampling rate required.

**Block Size/ Line** are the number of samples in each time blocks and the number of (un-aliased) spectral lines in each resulting spectrum.  Increasing the block size increases the resolution of the frequency transform and allows lower frequencies to be detected but it also increases the calculation time and slows down response. The ratio between Lines and Block Size is determined by the characteristics of A/D converter and its anti-aliasing filter. In general, this ratio is about 0.46, meaning that 1024 samples in the waveform will produce about 0.46 * 1024 = 471 lines in the spectrum.

**Window** lets the user choose the window to be applied during FFT operation. Windowing functions can help reduce leakage and increase the precision of the

frequency measurement. In general select None for triggered transients, Hanning for general continuous signals and Flat Top when studying tonal data (such as a rotating machine) and needing extreme accuracy of spectral peaks. Detailed descriptions about window types and average modes can be found in the DSA Basics document.

**Overlap Ratio** sets the proportion of the samples in a time block that are overlapped (redundant with samples in a prior block) when calculating the FFT of (un-triggered) continuous signals. Higher overlap ratios result in faster variance reduction per unit time producing smoother data but they increase the processing requirements. The Overlap Ratio options are: no overlap, 25%, 50%, 75% and As High As Possible. For most applications employing a symmetrically tapered window function (such as Hanning), an overlap of 50% proves optimal.

**Average Mode** gives options such as Exponential, Linear, and Peak Hold as the methods used to average the signal spectrum.

**AverageNumber** is the number of blocks that are averaged for the signal spectrum. Increasing the average number will reduce the variance of the signal spectrum.

## Measured Signals in FFT

Tap the Signal button to display measured signals in the sine test.
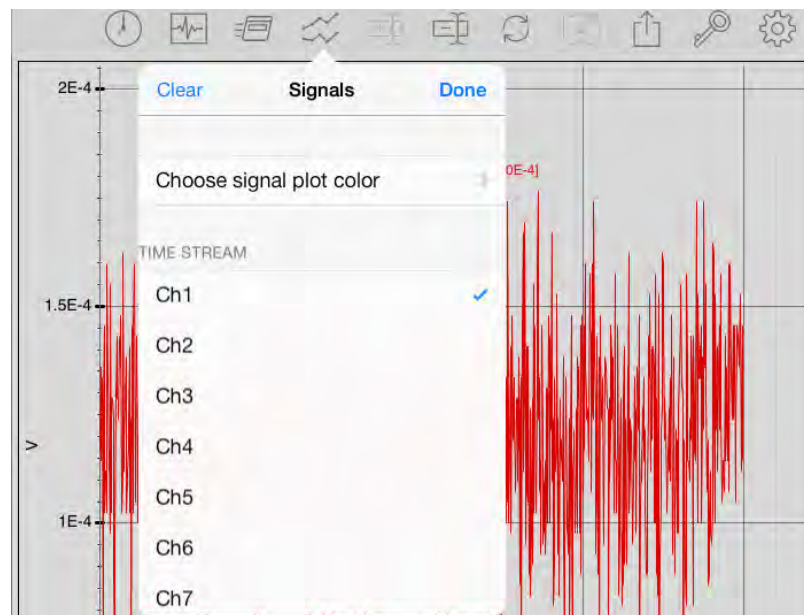


**Figure 262. Measured signals setup**

**Ch1~Ch8** are the native time streams of the input channels.

**Block(Ch1)~Block(Ch8)** are the block signals of the input channels.

**APS(Ch1)~APS(Ch8)** isthe auto power spectra signalsof the input channels.

## Run the Test

When a test is created or selected, tap the green Run button the start running the test; tap Stop button to stop running the test; tap Pause/Cont. button to pause/continue the test.
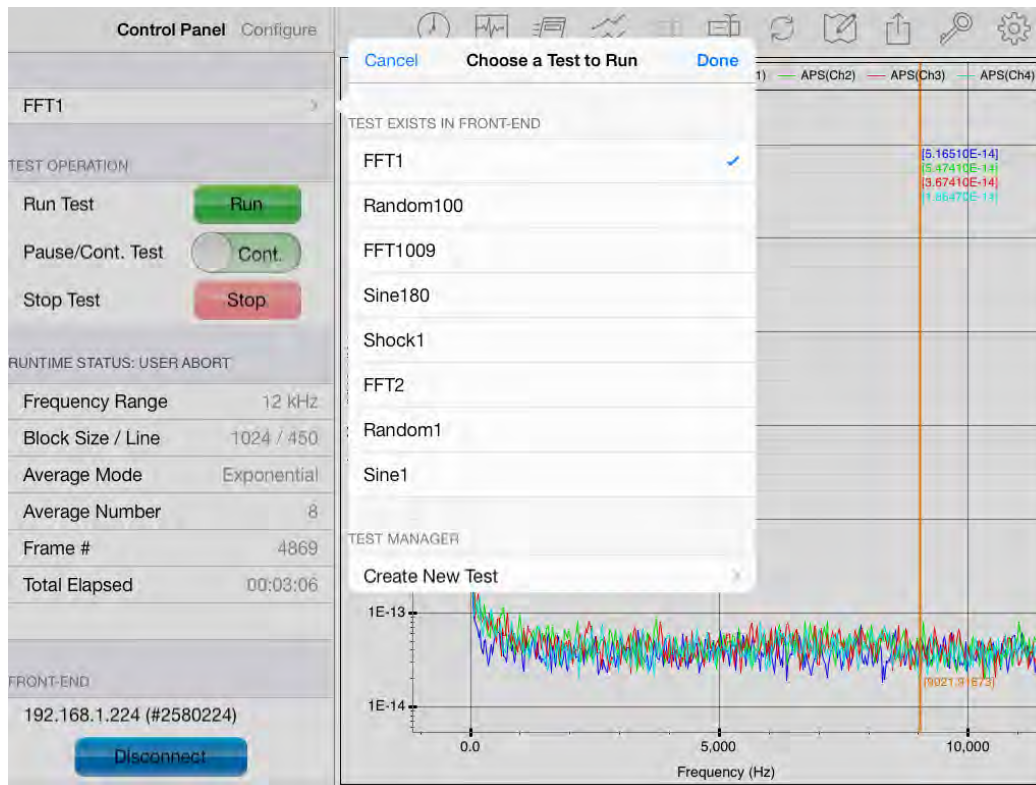


**Figure 263. Choose a test to run**

The Control Panel is used to start, stop, or pause the test, and shows status information like test level and elapsed time. The three function buttons in the Test Operation aear are always available for each type of the test.
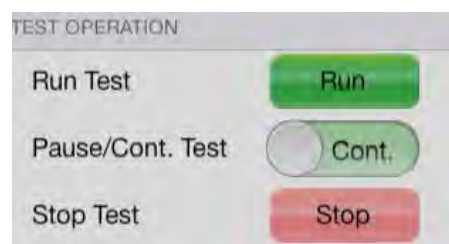


**Figure 264. Test operations**

However the Runtime Status varies among each type of the test. Tap the More> to display the completed list of status parameters for the FFT test.Test state information is displayed in the following fields:
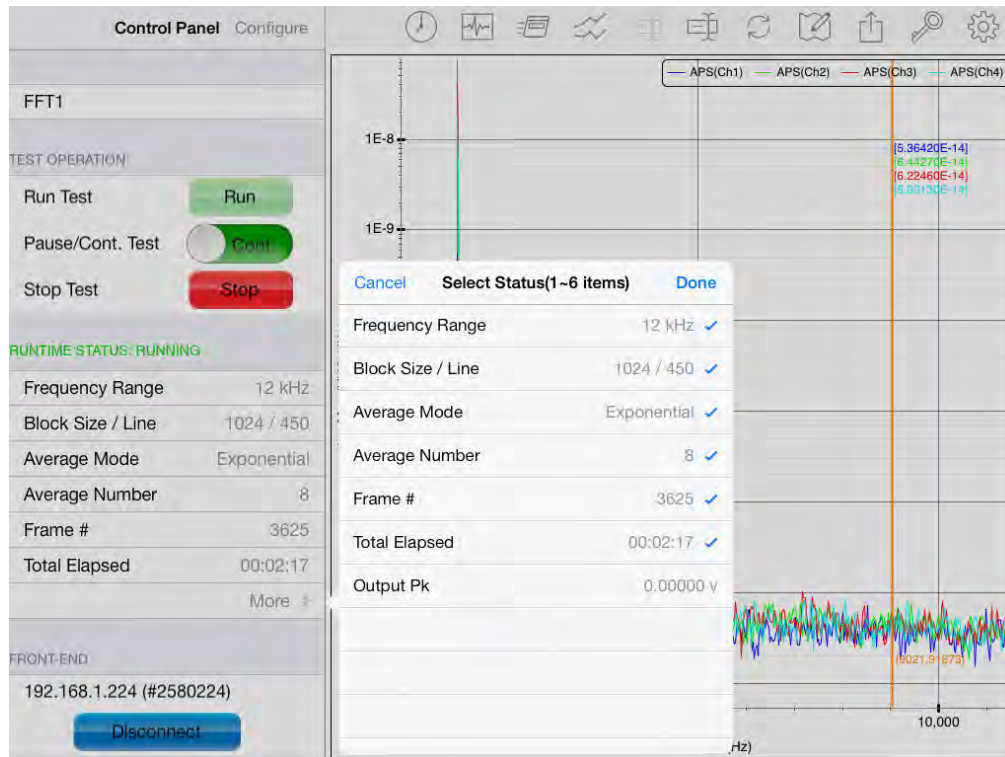
**Figure 265. Choose status displayed**

**Frequency Range** is defined as the maximum frequency range for the FFT analysis. Frequency range determines the sampling rate required.

**Block Size/ Lines** are the size of the time blocks, in number of samples, which the FFT algorithm transforms to the number of Lines in the frequency domain. Lines are the useful number of spectral lines. Increasing the block size increases the resolution of the frequency transform, and allows lower frequencies to be detected, but increases the calculation time and slows down response.

The ratio between Lines and Block Size is determined by the characteristics of A/D converter and anti-aliasing filter. In general, the ratio is about 0.46. It means that given an FFT transform size of 1024, the useful frequency lines is about 0.46 * 1024 = 471.

Sampling Rate Format is just a display preference for sampling rate and allowed frequency range for user.

**Average Mode** gives options such as Exponential, linear and peak hold as the methods used to average the signal spectrum.

**AverageNumber** is the number of blocks that are averaged for the signal spectrum. Increasing the average number will reduce the variance of the signal spectrum.

**Frame #** is the total number of frame elapsed.

**Total Elapsed** is the time elapsed since the test was started.

**Output Peak** is not controlled by the test. Users can configure the output channels manually.

# Random Control Tests

In a random control test, the shaker is driven by a wide band random signal. Feedback control adjusts this drive signal to generate a response that conforms to a specified test profile. The control algorithm calculates the inverse transfer function between the output drive and the input control channels, which is the composite of the amplifier, shaker, and UUT response. The product of the inverse transfer function and the response profile then gives the output drive spectrum. A phase randomizer and inverse FFT then generate the random drive output time stream.

The test profile is set under the Broadband Profile and Line Limits section of the Test Configuration window. The input channels used for control are selected in the Input Channels settings, and the other channels may be used to monitor responses of other parts of the test unit. If more than one channel is selected as a control channel, the channels will be combined, in an average, maximum, or minimum strategy, to form a composite control signal. The FFT of this signal is the *control(f)* signal. The controller monitors the deviation of *control(f)* from the target profile and updates the output drive signal in real-time.

## The Random Control Process

Random excitation is often used to simulate real world vibration. The purpose of the random vibration control system is to generate a true random drive signal such that, when the signal is applied via an amplifier/shaker to the device under test, the resulting shaker output spectrum will match the user-specified test profile. This reference profile is defined in the frequency domain in units of *(Acceleration)²/Hz*. This signal is to be applied to the UUT for a specified amount of time to verify the device's ability to function in its service environment.

If the series of components being controlled (i.e., the amplifier, shaker, and testing structure) is assumed to be an integrated linear system, then it can be described by a system transfer function H(f) in frequency domain. The frequency spectra of the control and drive signals, Y(f) and X(f), can be linked together by H(f) as:

$$Y(f) = H(f)\ X(f)$$

Or

$$X(f) = H(f)^{-1}\ Y(f)$$

where H(f)$^{-1}$ is called the *inverse transfer function*.

If a flat spectrum drive signal excites a shaker/test-article system, the resulting acceleration response spectrum will not be flat. The armature resonances and the dynamics of the test-article react on the system to produce peaks (resonances) and valleys (anti-resonances) in the resultant spectrum.

To apply a specified spectrum to the test article, the drive spectrum must be altered to correct for the dynamics of the shaker/load combination. This process is **generally referred to as "Equalization". The inverse transfer function is calculated** continuously while the test is running to monitor any change in the system characteristics. Corrections are applied in real-time.

Given a desired spectrum R(f) (reference spectrum, or profile), the required value for the drive can be calculated as:

$$X(f) = H(f)^{-1} R(f)$$

where X(f) is the spectrum of the required drive signal.

Once the drive spectrum X(f) is known, there are several ways to generate a random output signal in the time domain. This signal must have the following properties:

- A spectral shape defined by *X(f).*
- Free of discontinuities
- A Gaussian amplitude distribution

The algorithm involves these steps:

1. Digitize the input signals and transform them into frequency domain using the FFT process.
2. Estimate the inverse system transfer function between the averaged input and output via cross-spectral method.
3. Generate a reference spectrum with random phase.
4. Multiply the reference spectrum by the inverse transfer function, and apply an Inverse FFT to the result to generate the output-time waveform.
5. Output the time waveform through a D/A converter.

All these calculations are completed within the period of one time frame to ensure a very fast control loop time.
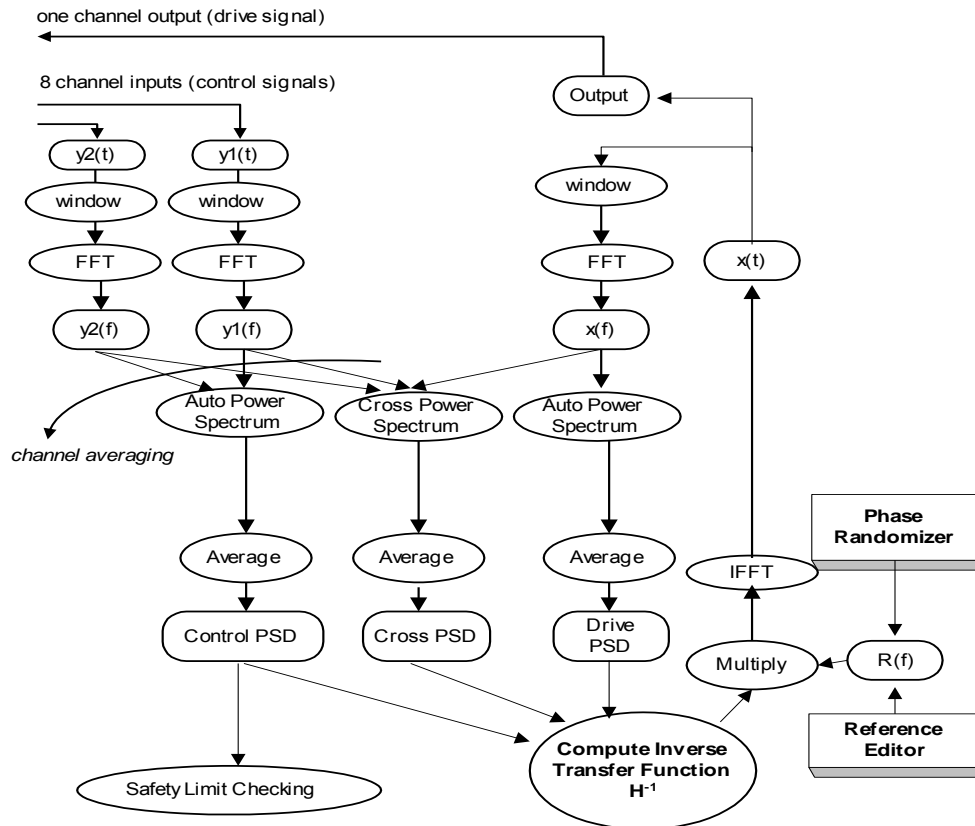
**Figure 266. Random control process flowchart**

## Control Dynamic Range in Random

One of the key requirements for a random controller is to achieve high control dynamic range. Control dynamic range is a measure to compare the highest and lowest spectrum amplitude in the control signal. Spiders can achieve at least 90dB control dynamic range. This can be measured by a modified Chinese testing standard, JJG-948. The JJG-948 only requires a control dynamic range up to 60dB. By modifying the noise floor to lower quantity we can show much higher control dynamic range.
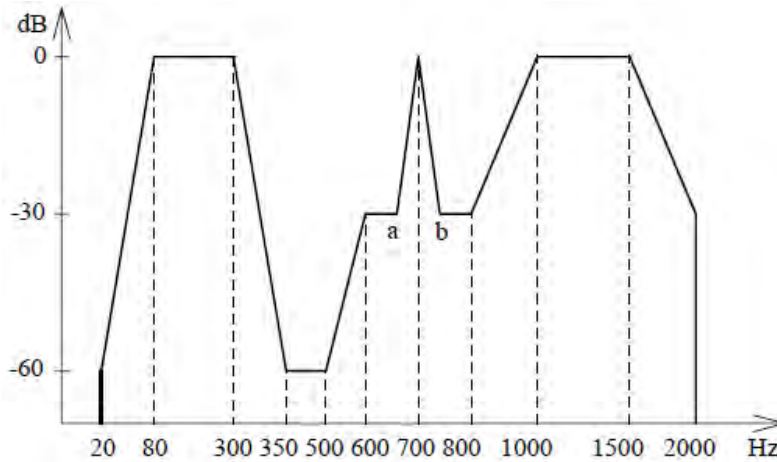
**Figure 267. Control Dynamic Range in Random**
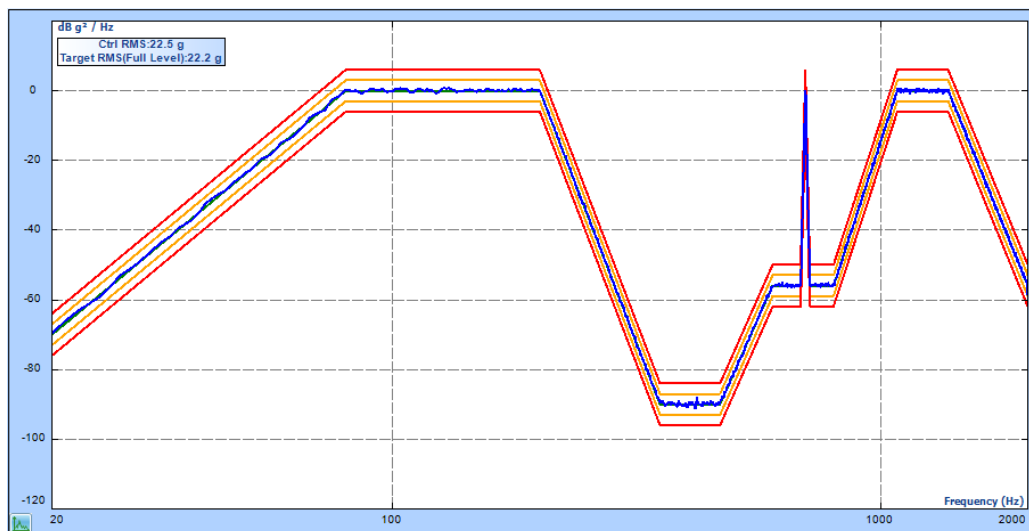


**Figure 268. Control Dynamic Range in Random**

## Safety Features

During the Random test, various safety checks are applied to ensure that the test is being performed as defined, the shaker response remains measureable, and that the drive signal remains within certain limits. There are 5 different types of checks that are performed and an event is triggered if any of the checks fail. The response actions to these events can be customized under the Event-Action Rules. The 5 checks are,

1. The broadband profile line limits
2. Maximum shaker drive voltage limiting
3. Channel overload or loss detection

4. RMS limits
5. Limit channels.

The test profile sets limits for the spectral lines of the control signal. If the control profile falls outside these limits, alarm or abort events will be triggered.

As another safety feature, the hardware detects when input channels are overloaded or lost, which can indicate a sensor fault or an accidental disconnect, and will abort the test.

RMS limits and limit channels are described in their own sections below.

In the event of an accidental network disconnection or power loss, the hardware is able to save test data and state information to non-volatile memory to protect against loss. For a network disconnection, the test can continue to run in Black Box mode or save all data and execute an orderly shutdown.

## RMS Limits

The overall RMS level of the control channel (or control channels) is monitored and an alarm or abort event is triggered if it falls outside of predefined limits. These limits are set under the RMS Limits section of the Test Configuration window.

The table at the top gives the expected RMS and peak values for the current broadband profile, the peak safety limits of the shaker, and the proportion of the profile values to the shaker limits as a percentage. This data comes from the given profile settings and the shaker parameters and cannot be changed here. Just like in setting the broadband profile, EDM has RMS limits for high- and low-alarm and high- and low- abort. These events trigger their associated actions defined in the Event Action Rules. The values are calculated automatically, but can be entered manually as an absolute magnitude or as a percent change relative to the profile RMS.

## Limit Channels

Any input channels can be set as limit channels. These channels are given limiting spectral profiles (separate from the test profile), and if the spectrum of these channels exceeds their profile, an event is triggered. These limit channels can be set as either Aborting or Notching. Abort limit channels will abort the test when the response exceeds the limit. Notch limiting channels will lower the output until the response falls under the limit. These options are set under Test Configuration.
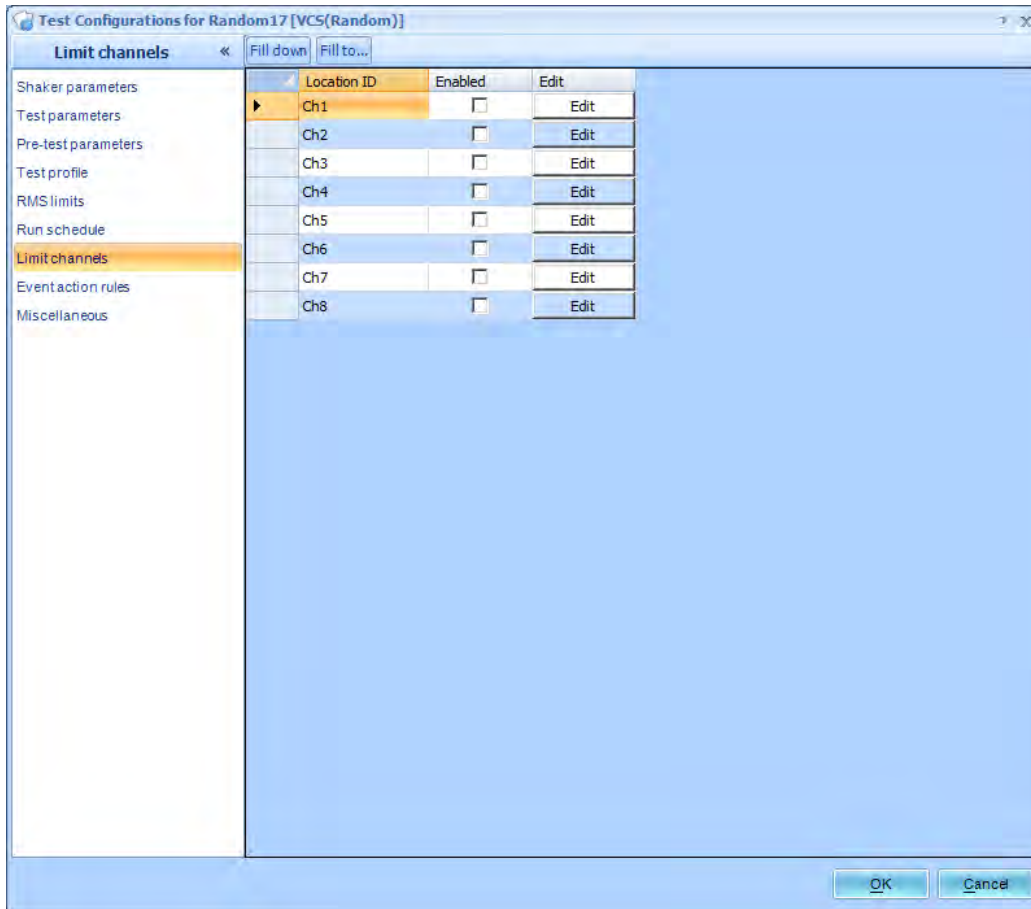
**Figure 269. Limit channel setup on the EDM**

To enable a limiting channel, first enable the channel in the **Test Configuration->Limit Channel tab**, and then click **Edit** to select either **Notching Limit** or **Abort Limit** or **Alarm Limit** in the State column here. Click **Edit** to bring up the limit profile editor. Click **Insert** or **Append** to add lines to the profile.

The picture below shows how the control signal and one of the APS signal will change after notching is applied. The control signal will drop down in the frequency ranges where drive signal is lowered.

**NOTE**: dB value in Limit Profile has the different reference than the dB value in Signal Display.

**Figure 270. Signal change after notching**

## Averaging and DOF

In Random mode, an estimate of the spectral values of the input control signal is generated by averaging the spectral transforms of multiple blocks. These blocks may be overlapped, where a specified proportion of samples are reused in s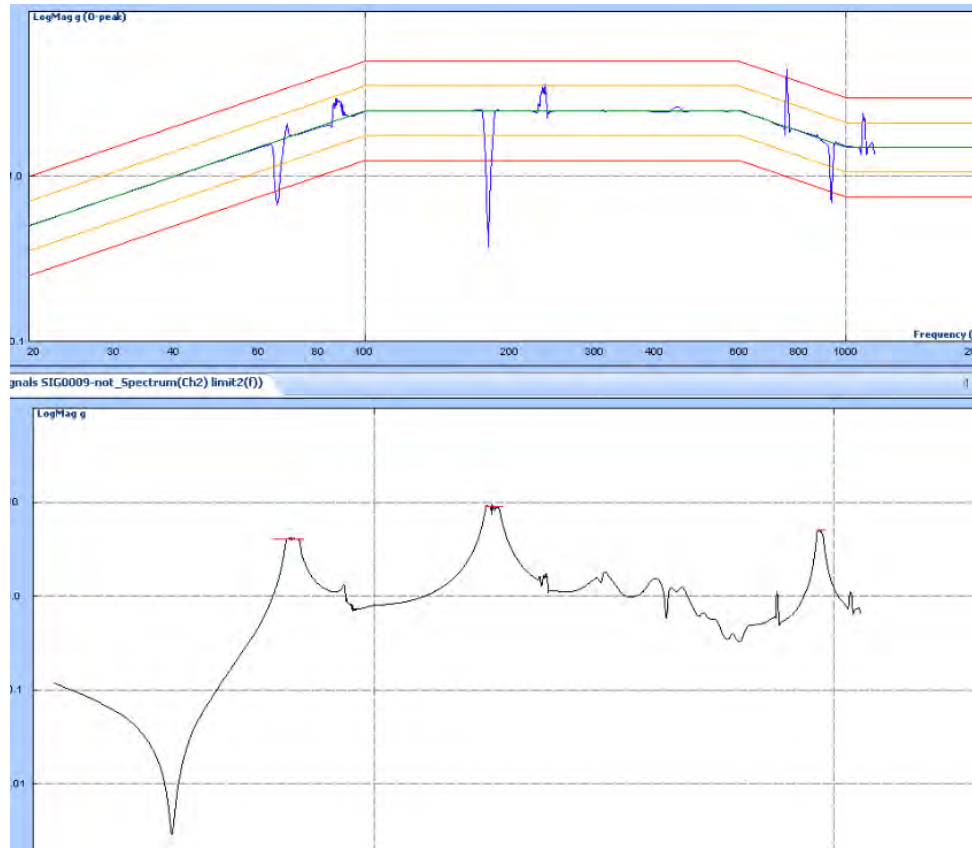ubsequent blocks. A windowing function is applied to these blocks before they are transformed into the spectral domain by the FFT algorithm. A number of these blocks, set by the average number, are averaged together to create the spectral estimate. It is this estimate that the control algorithm uses in its calculation of the system transfer function.

Given a stationary system, it is desirable that this spectral estimate does not vary significantly from the true power spectral density of the underlying Gaussian process. Given an infinite average number, this estimate would indeed converge to the true PSD with zero variance. Unfortunately, such an average number would make the control loop time prohibitively large.

The spectral estimate varies along a chi-squared distribution with a Degrees-of-Freedom parameter given as a function of average number, block size, and window

type. As the DOF increases, the variance of this distribution decreases. The relationship is:

$$DOF = 2\frac{E^2[P(f_n)]}{Var[P(f_n)]}$$

where $P(f_n)$ is the spectral estimate, E[] is the expected value, and Var[] is the variance.

On the basis of control accuracy, it is therefore desirable to increase the DOF as much as possible (by using a large average number). On the basis of response time, however, a large average number is undesirable. There is a tradeoff between accuracy and responsiveness.

Block overlapping can help decrease response time while maintaining a large DOF. Overlapping involves reusing a specified number of samples in subsequent blocks. With no overlapping, DOF is approximately twice the average number. With a non-rectangular window, the DOF will be about 1.3 times the average number with 50% overlap, which will allow a higher DOF value for the same total number of samples. Increasing overlap beyond 50%, however, will not yield any more advantage in reducing the variance. However a higher overlap ratio will still be beneficial to reduce the loop-time of control.

## Random Test Parameters

In the Test Configuration window, the Test Parameters section has settings for the main analysis parameters of the random test.

**Figure 271 .Test parameters for a random test**

**Lines** are the useful number of spectral lines. Increasing the block size increases the resolution of the frequency transform, and allows lower frequencies to be detected, but increases the calculation time and slows down response.

The ratio between Lines and Block Size is determined by the characteristics of A/D converter and anti-aliasing filter. In general, the ratio is about 0.46. It means that given an FFT transform size of 1024, the useful frequency lines is about 0.46 * 1024 = 471.

**Overlap Ratio** sets the proportion of the samples in the time blocks that are overlapped when calculating the FFT. Higher overlap ratios result in faster response time but increase processing requirements. Overlap ratio, average number and DOF are dependent to each other.

Overlap ratio can be chosen from no overlap, 50%, 75% and 87.5%. Overlapping greatly decreases the loop time of the random controller. In older controllers, a 200 line/2000 Hz test can have up to a 100 ms loop time. In the CI controllers, the loop time can be reduced to as little as 12.5 ms at the same line and Frequency Range.

**DOF** is the statistical Degrees of Freedom of the spectral averaging. It is a function of average number, data window and overlap ratio (see above).

**Drive Limit (Volt Pk)** limits the absolute maximum voltage output of the drive signal during the scheduled test. If the drive limit is reached but the control signal still does not reach its target, the system will show a warning sign, Drive Maximized, on the control panel. For safety reasons, the output signal will not exceed the Drive Limit.

**Response Level Goal During Pre-Test** is the expected level reached when the pre-test is finished.

**Sigma Clipping** limits the peaks of the output voltage distribution. Any output level greater than this number times the variance of the output will be clipped. A special algorithm is developed to clip the output signal smoothly so no discontinuity will be output. Clipping produces non-linear effects that can significantly reduce the **system's ability to control sharp resonances. This effect results from energy leaking across the test frequency range from the "square-wave" shape of the clipped peaks.** The apparent noise floor will rise when a sigma- clipping factor of 4 or less is used. In addition, signal energy out of the test bandwidth may be generated causing excitation of out-of-band resonances and poor control of resonances in the control frequency range under some conditions.

> **Tips**: Sigma Clipping applies to the drive channel of a controller. Kurtosis control applies to the input control channel of a controller. Do not get confused between two different goals.
>
> Sigma Clipping is used to try to maximize the shaker rating. If the vibration test is far below the maximum force rating of the shaker system, Sigma-Clipping should not be used. Setting the sigma-clipping value to 5 or more will disable the sigma-clipping.

**Frequency Range (Fa)(Hz)** sets the maximum frequency resolved by the FFT transform by adjusting the sample rate. Selecting **CalculatedBy Profile** will set the sample rate based on the other settings especially the frequency range of profile.

**Delta Frequency (Hz)** is the spacing of the frequency lines in Hertz, and is a function of the block size and sample rate.

## Run Schedule

The Run Schedule allows the test to be run automatically through a preset routine. This schedule can include loops and periods of running the test at a specified level and duration The schedule is activated when the test is started.
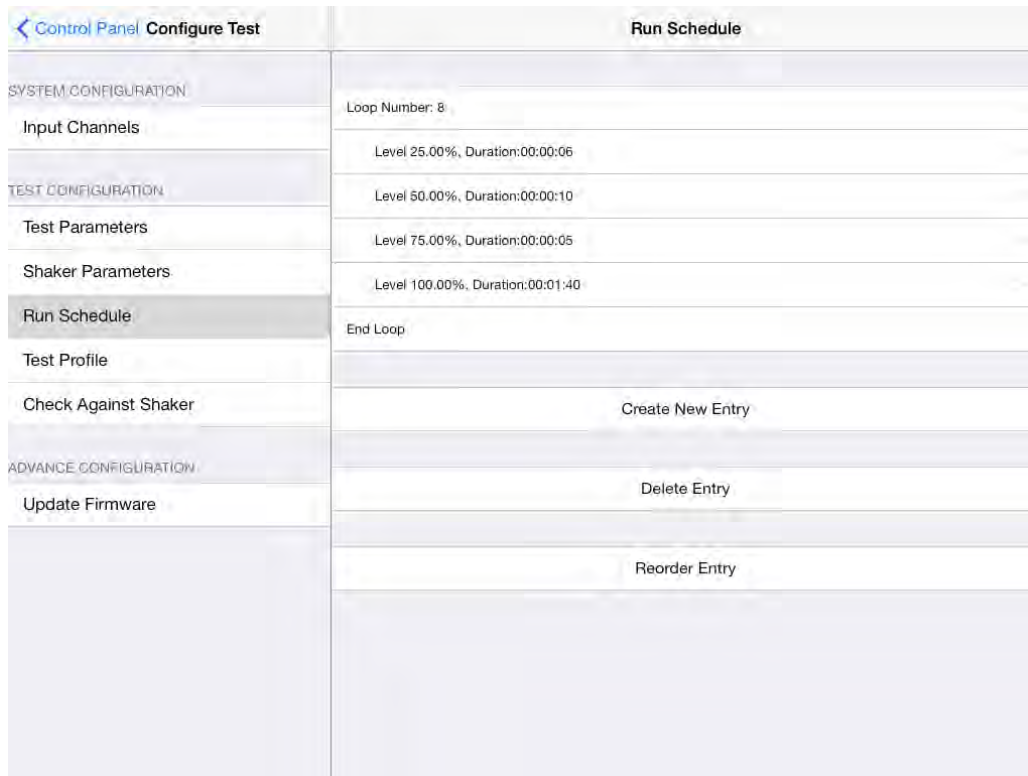
**Figure 272. Sample run schedule of a random test**

Clicking on the right arrow icon of each entry allows users editing this entry. This operation can modify the loop times, level percentage, and time duration.

Create New Entry button is used to insert a new entry to the last place before the End Loop entry.

Delete Entry button shows the deletable entries when it is clicked. The loop entries cannot be deleted. Swipe the entry to the left to display the red Delete button; click the Delete button to remove the entry from the Run Schedule.

Reorder Entry button shows the entried eligible to be reordered when it is clicked. Press and hold the Move icon on the right side of each entry; drag the entry to the desired place to finish reordering the entry.

## Test Profile

The test profile is defined in the **Test Profile** section of the Test Configuration window. The window shows a graphical plot of the profile, in log magnitude versus log frequency axes. The profile is shown as a green line, high and low alarm lines are shown as yellow lines, and high and low abort lines are red lines. Below the graphical plot the profile points are shown in a table form. The profile is defined as a set of breakpoints, with defined frequency and amplitude values, connected by straight lines.
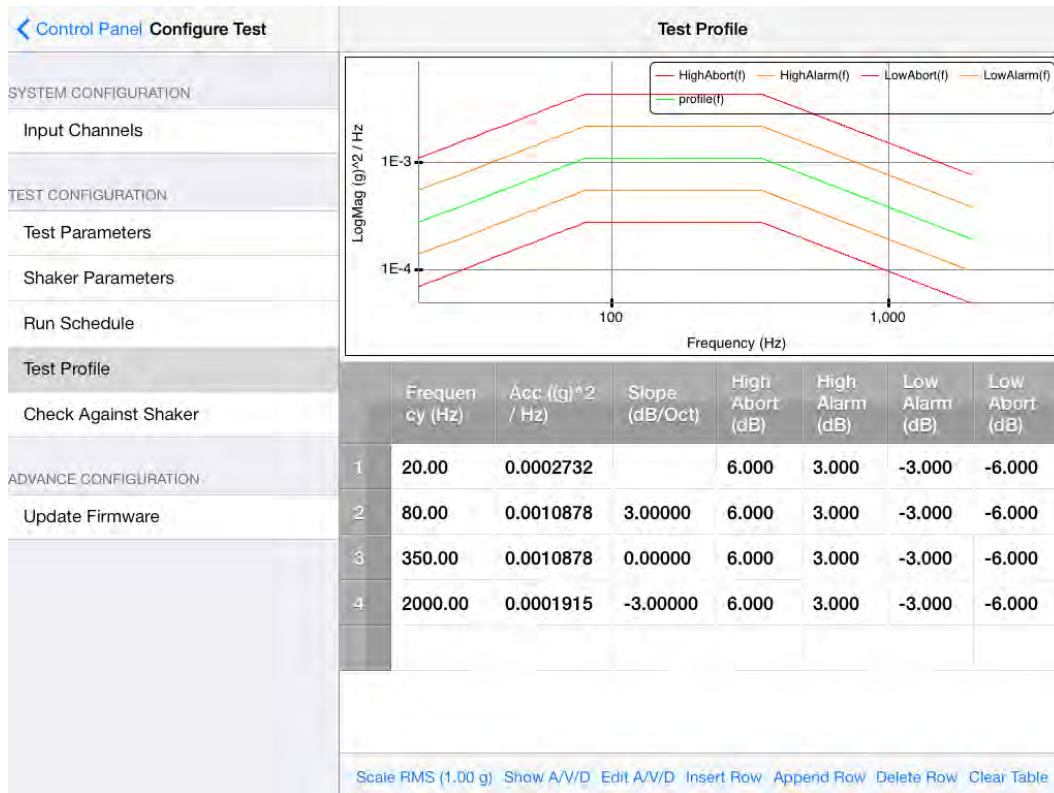
**Figure 273. Random test profile**

The breakpoints can be added and deleted. Each point corresponds with a row on the table below which can be directly edited by entering frequency and magnitude values. The table also gives the slope of the lines between the points (in decibels per octave), and the alarm an abort levels in dB above and below the profile level. The overall RMS level of the profile is shown on the upper left. This overall level can be changed by clicking on **Scale RMS**, which scales the ordinate axis to reach the specified RMS level.

## Measured Signals in Random

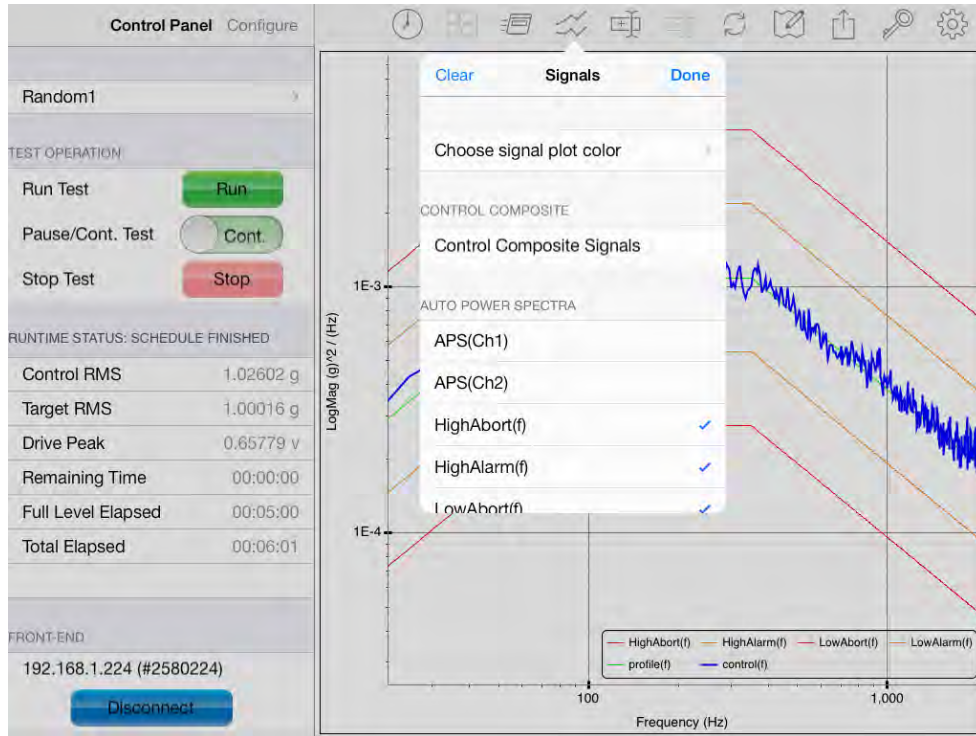Tap the Signal button to display measured signals in the random test.

**Figure 274. Measured signals setup**

**Time Stream** is the native time streams of the input channels labeled as Ch1, Ch2, and drive.

**Time Block** is the block signals of the input channels labeled as Block(Ch1), Block(Ch2), and control_his(t).

**Auto Power Spectra** is the auto power spectra signals of the input channels labeled as APS(Ch1), APS(Ch2), and APS(drive).

**HighAlarm(f), LowAlarm(f), HighAbort(f), and LowAbort(f)** are the limit lines of the profile.

**control_his(t)** is the RMS level history of the control signal.

**control(f)** is the power spectrum of the control signal. If multiple control channels are used, the control(f) signal is either weighted-averaged spectra from all control channels, or the maximum spectrum, on per frequency bin base, among all the control spectra.
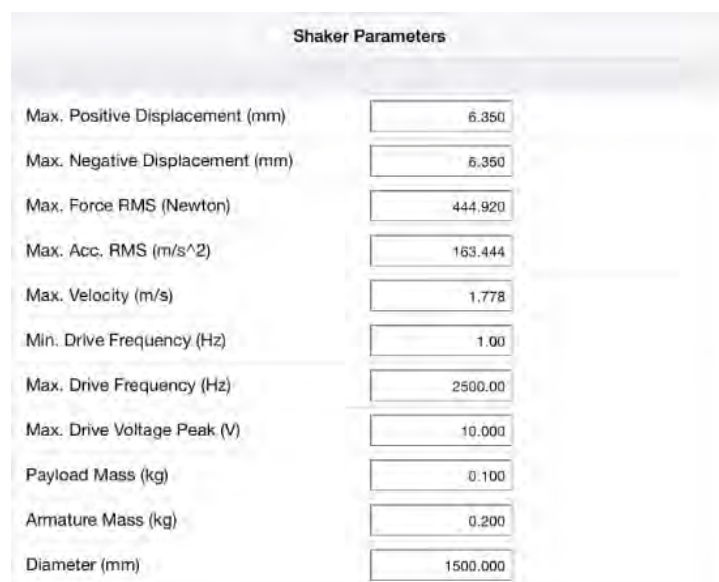
**profile(f)** is the frequency-domain test profile.

**noise(f)** is the power spectrum of the system noise, measured in the first part of the pre-test.

**FRF(Ch2, Ch1)** is the transmissibility signal between two channels. It will be available in both complex and real measurement. Currently Random test has no limitation in the flexibility of FRF channel selection on the PC level.

**H(f)** is the frequency response function between the drive output and the control input signal.

## Shaker Parameters

Click on Parametersto edit the information from the shaker specifications. This is important for the safety of the shaker and testing unit. Once the proper shaker parameters are entered, use the Check Against Shaker feature to confirm the correctness and expectations.



**Figure 275. Shaker parameters setup**

## Check Against Shaker

Check against Shaker shows the peak acceleration, velocity, displacement, and force of the profile and compares the values to the shaker limits.

**Figure 276. Check against shaker page**

## Run the Test

When a test is created or selected, tap the green Run button the start running the test; tap Stop button to stop running the test; tap Pause/Cont. button to pause/continue the test.
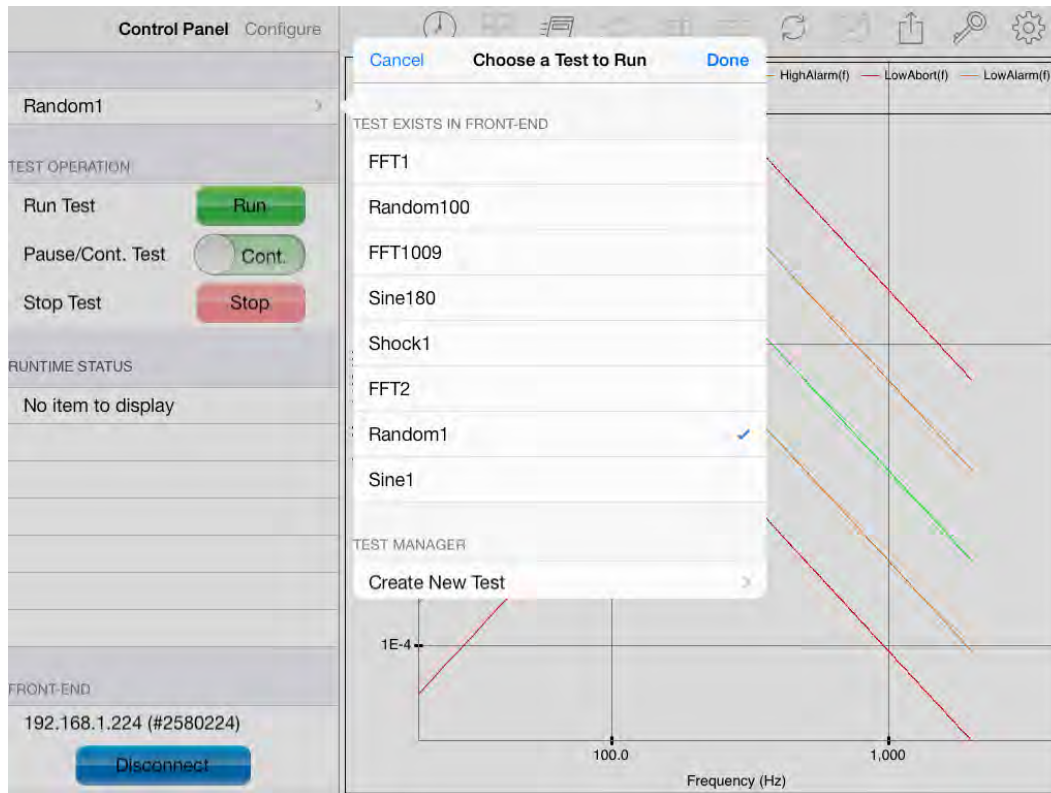
**Figure 277. Choose a test to run**

The Control Panel is used to start, stop, or pause the test, and shows status information like test level and elapsed time. The three function buttons in the Test Operation aear are always available for each type of the test.
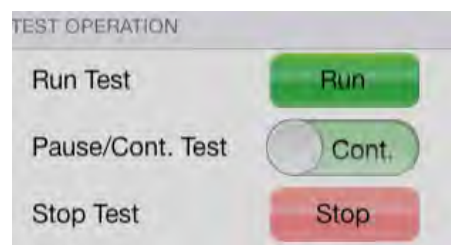


**Figure 278. Test operations**

However the Runtime Status varies among each type of the test. Tap the More> to display the completed list of status parameters for the Random test.Test state information is displayed in the following fields:

**Figure 279. Choose status displayed**

**Ctrl RMS** is the RMS level of the input control signal. It is an overall rating of the control signal.

**Target RMS** is the target RMS level of the current test stage. This is a function of the test profile and the current test level percentage. The output is increased until the Ctrl RMS reaches the Target RMS.

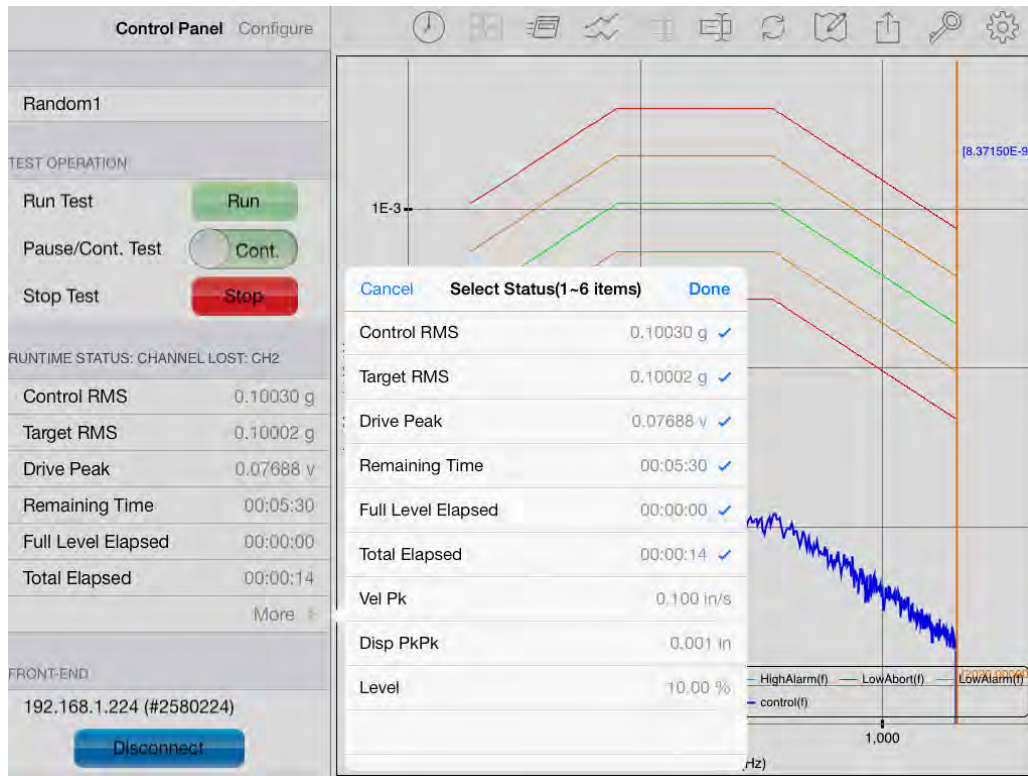**Drive Pk** is the peak voltage of the output drive signal. This is shown graphically in the green bar below, as a proportion of the maximum drive voltage limit (set in Test Parameters).

**Remaining** is the remaining time of the test, according to the run schedule.

**Full Level Elapsed** is the time elapsed running at full (100%) output level.

**Total Elapsed** is the time elapsed since the test was started.

**Vel Pk**: This is the estimated peak velocity of the control channel. If there is more than one control channel, only the velocity peak of the first control channel is displayed. The displacement signal is computed by integrating the acceleration signal. The accuracy of this computation may be very low if the signal contains significant amount of low frequency energy. Therefore this display is only used as a reference.

**Disp PkPk**: This is the estimated peak-peak displacement of the control channel. If there is more than one control channel, only the peak-peak of the first control channel is displayed. The displacement signal is computed by double-integrating the acceleration signal. The accuracy of this computation may be very low if the signal contains significant amount of low frequency energy. Therefore this display is only used as a reference.

**Level** is the current output level, as a percentage of the test profile. This is displayed graphically in the green bar below this field.

# Swept Sine Control Tests

Whereas a Random test generates many frequencies over the band of interest at once, a swept sine control test generates only one frequency, and sweeps this frequency through a pre-set range. Feedback from the control signal is then used to adjust the output amplitude such that the response amplitude of the UUT matches a test profile. The test profile is a graph of amplitude (usually defined as peak acceleration) versus frequency.

RSD, or Resonant Search and Dwell, is an extension of the Swept Sine test.

## The Sine Control Process

The swept sine control process consists of generating a sine wave output to excite the device under test, detectingthe control signal input amplitude, comparing the detected level with the reference amplitude, and updating the drive signal amplitude appropriately.
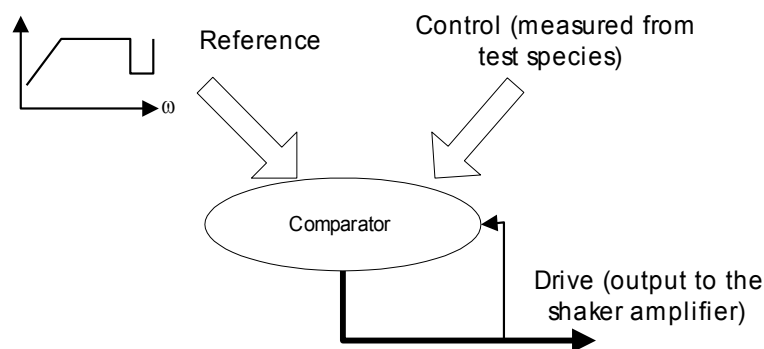


**Figure 280. Sine control process**

To measure the level in the incoming control signal, the detector can use a tracking filter, or can measure the RMS, peak, or mean value of the signal. When using a tracking filter, amplitude and phase data are produced while the other measurement methods only produce amplitude data.

If more than one control channel is used, then the output of each detector is combined in the Channel Averaging Block.
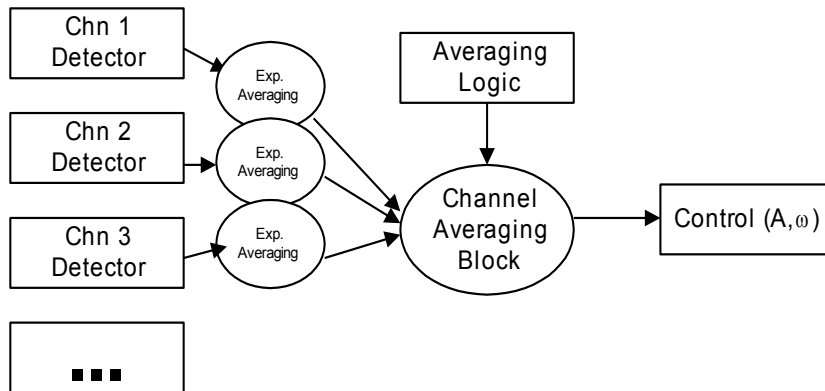
**Figure 281. Control signal calculation flowchart**

Tracking filters greatly reduce the noise and harmonic signals above and below the sine drive frequency. Their center frequency is always tuned to the current drive frequency, allowing all other signals to be rejected from measurement and control. The filter bandwidth can be either fixed or proportional to the current frequency.



A tracking filter with changing bandwidth and center frequency can eliminate the noise outside the band
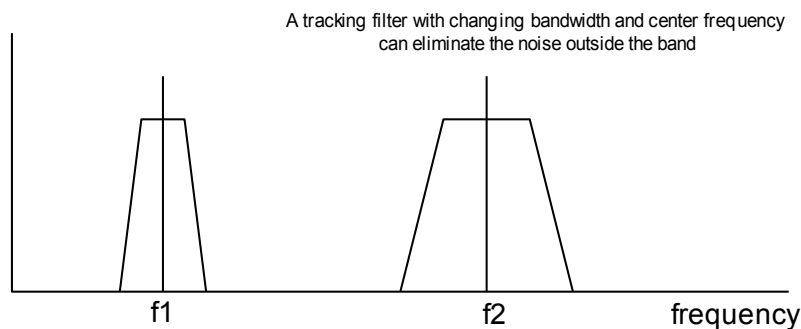
**Figure 282. An example of tracking filters**

The Spider system continually updates the tracking filter coefficients based on the current center frequency and bandwidth. It has a stop band rejection of about −60 dB. The output of the filter is averaged to produce a control amplitude value, which is then used by the comparator to correct the output drive amplitude.
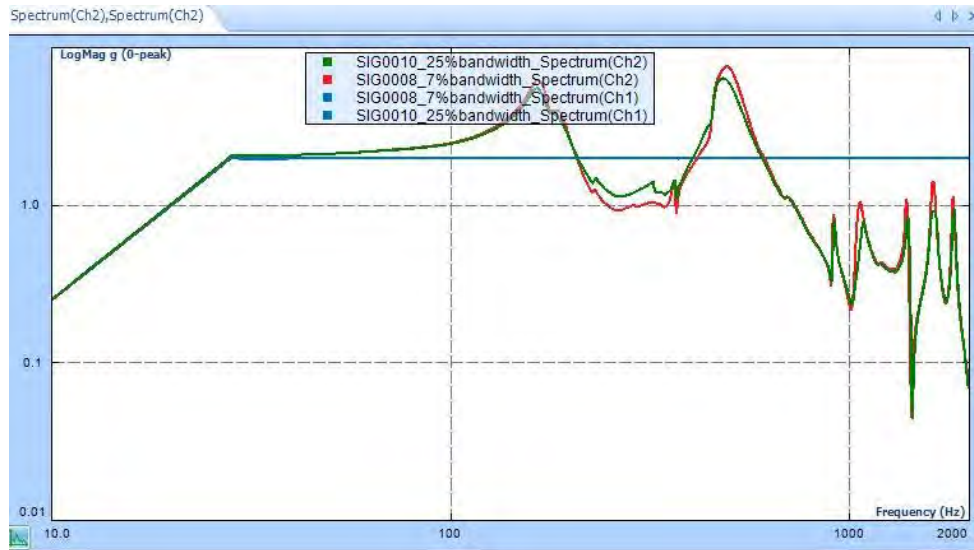
**Figure 283. Tracking filters in EDM**

In general, the narrower the bandwidth of the tracking filter, the sharper the resonance that the control system can calculate. As shown in the picture above, the red line that uses 7% bandwidth can show sharper resonance than the green line which uses the 25% bandwidth. However, the bandwidth of the filter also affects the speed of response time of a control system. The system response time is inversely proportional to the filter bandwidth. Therefore, choosing the right bandwidth of the tracking filters is usually a trial process.



**Figure 284. Tracking filter theory**

The Peak, Mean, and RMS measurement methods analyze the data in blocks, with a length determined by the bandwidth settings:

Block length (second) = 1/bandwidth (Hz)

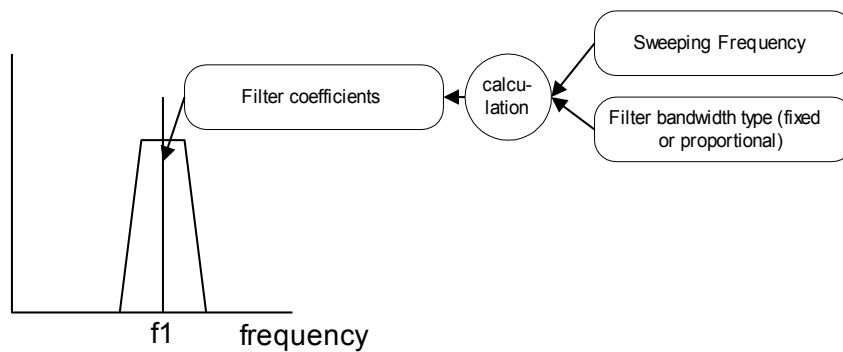Both fixed and proportional bandwidths can be used. The block duration is constant for fixed bandwidth, and changes with the drive frequency when using proportional bandwidth.
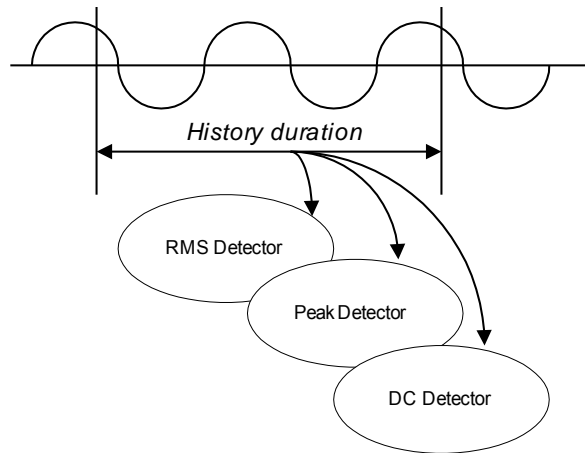


**Figure 285. History duration**

If N is the length of this block, in samples, then the RMS is defined as

$$RMS = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1} x(i)^2}$$

And the Mean is the statistical Mean Absolute Deviation:

$$Mean = \frac{1}{N}\sum_{i=0}^{N-1} ABS(x(i))$$

With RMS, Mean, and Peak measurement strategy, signals at harmonics of the drive frequency can contribute to the final overall measurement result. Therefore, the drive level may be lower than when a tracking filter is used. In other words, when tracking filters are turned on, the UUT might get over-tested; when RMS, Mean and especially Peak are used as measurement strategy, the UUT might get under-tested.

> **Note:** When the input channels are not well calibrated, the DC offset in the input will contribute to the calculation results of Sine amplitude spectrum. This error will eventually be reflected in the control accuracy. This is not a big problem for high frequency (say larger than 10Hz) but for low frequency control, the DC offset will have bad impact. Therefore, the system should be well calibrated before they are used.

## Safety Features

In the Sine mode, there are a number of safety features that help prevent damage to the shaker and related equipment. During a shake test, 5 different types of checks are performed and an event is triggered if any of these checks fail. The response actions to these events can be customized under Event-Action Rules. The 5 checks are 1) the profile line limits, 2) Maximum shaker drive voltage limiting, 3) Channel overload or loss detection,and 4) Limit channels.

The test profile has lower and upper limits for the control channel over the frequency range of the test. If the control signal falls outside these limits, alarm or abort events will be triggered.

The system also detects when input channels are overloaded or lost which can indicate a sensor fault or an accidental disconnect. The test will be aborted if this occurs.

Limit channels are described in the next section.

In the event of an accidental network disconnection or power loss, test data is saved to non-volatile memory to protect against loss. For a network disconnection, the test can either continue running in Black Box mode or save all data or execute an orderly shutdown.

### Limit Channels

Any input channels can be set as limit channels. These channels are given limiting spectral profiles (separate from the test profile), and if the spectrum of these channels exceed their profile and event is triggered. These limit channels can be set as either Aborting or Notching. Abort limit channels will abort the test when the response exceeds the limit. Notch limiting channels will lower the output until the response falls under the limit. These options are set under Input Channel Setup.
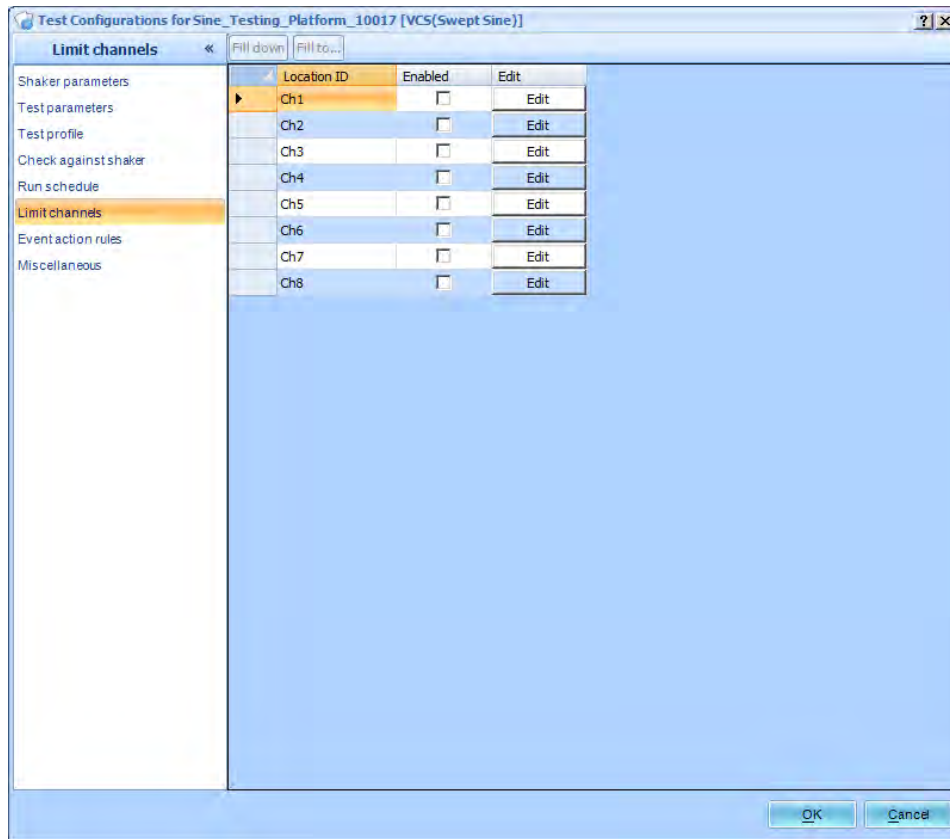
**Figure 286. Limit channels setup on the EDM for a sine test**

To enable a limiting channel, first set the channel type to Limit in the Channel Setup tab, and then select either **Notching Limit** or **Abort Limit** in the State column here. Click **Edit** to bring up the limit profile editor. Click **Insert** or **Append** to add lines to the profile.

## Sine Test Parameters

In sine mode, this section of the Test Configuration window is used to configure settings related to the Sine mode analysis parameters.

**Figure 287. Sine test parameters**

**Maximum Drive (Volts)** is the maximum RMS voltage output for the initial test level.

**Drive Limit (Volt Pk)** limits the absolute maximum voltage output of the drive signal. If the drive limit is reached before the control signal reaches its target, the system will show a Drive Maximized warning. The output signal will not exceed the Drive Limit.

**Sweep Type:** Linear or Logarithmic. When the Sweep Type is Linear, the Sweeping Speed is in the unit of Hz/Min; When the Sweep Type is Logarithmic, the Sweep Speed can be defined in unit of Octave/Min or Decade/Min.

**Measurement Strategy** defines how the sine waves are measured. The selections are: *Proportional Filter*, *Fixed Filter*, *RMS*, *Mean* and *Peak*. In the perfect world when the sine signals have no distortion, all the measurement strategies will generate the same results. When signals are distorted, the controller will generate different drive magnitude by selecting different Measurement Strategy.

## Run Schedule

A sine test is controlled by a run schedule. The schedule contains one or more entries that define test stages. A stage defines the output behavior and timing The Run Schedule sets the sequence of test stages that are activated when the test is run. A test stage is either a sweep entry, a step sine entry, or a fixed dwell entry.
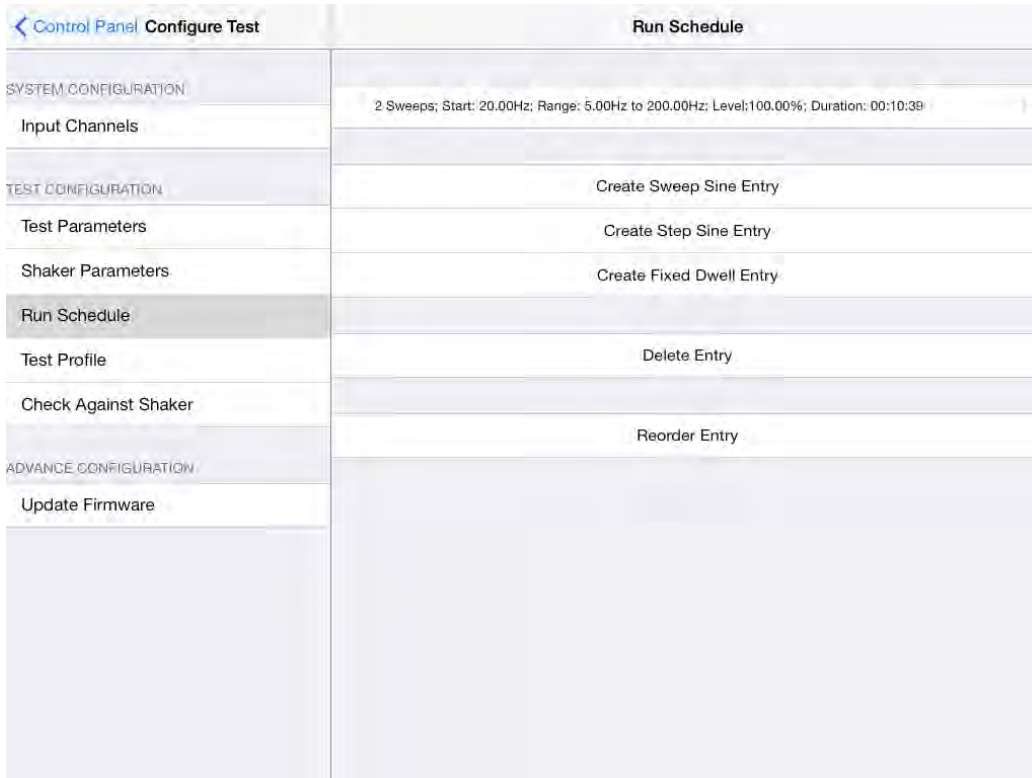
**Figure 288. An example of sine run schedule**

Clicking on the right arrow icon of each entry allows users editing this entry. This operation can modify all the parameters as shown below.

The **sweep entry** sweeps the output between a low frequency and high frequency at a fixed rate or over a fixed period of time. The sweep rate can be logarithmic or linear, depending on the setting under Test Parameters. The **Level** sets the amplitude of the expected control signal, relative to the reference profile, and the **Sweep#** sets the number of times the sweep will be repeated.

**Figure 289. Sweep sine entry parameters setup**

A **step sine entry** steps the output from the low frequency to the high frequency at increments given by **DeltaF(Hz)**. The duration at each step can be either set system-wide, given as a time period, or given as number of cycles.



**Figure 290. Step sine entry parameters setup**

A **fixed dwell entry** holds the output at a fixed frequency for a given duration. There is also an option to dwell at frequencies given in the dwell list.
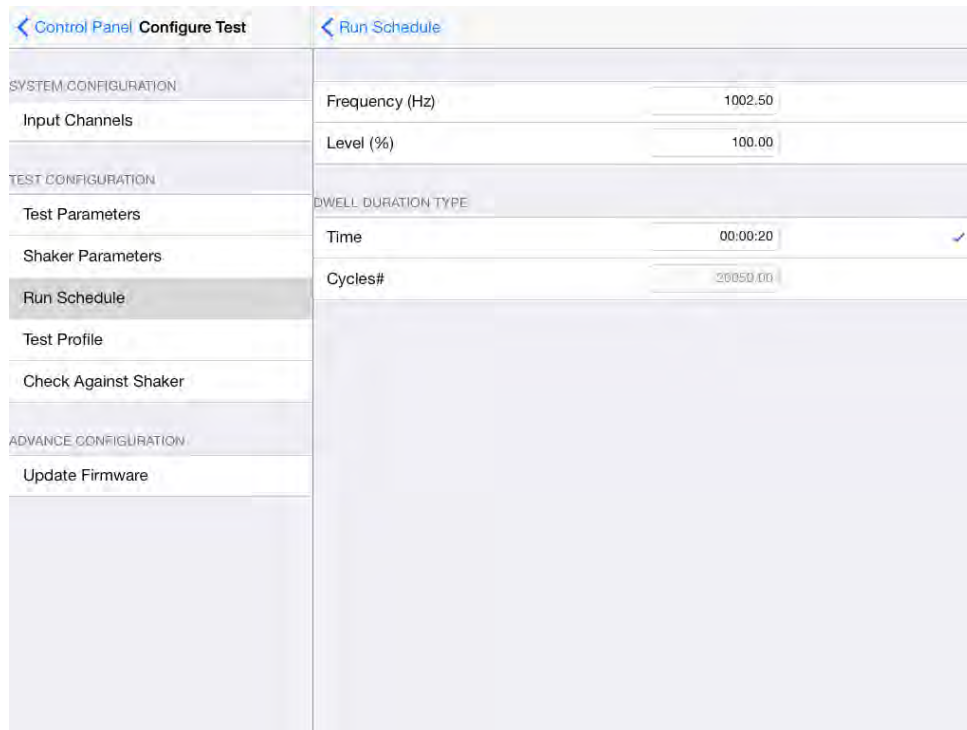


**Figure 291. Fixed dwell entry parameters setup**

Users can create three types of entry by clicking corresponding Create Entry buttons.

Delete Entry button shows the deletable entries when it is clicked. Swipe the entry to the left to display the red Delete button; click the Delete button to remove the entry from the Run Schedule.

Reorder Entry button shows the entried eligible to be reordered when it is clicked. Press and hold the Move icon on the right side of each entry; drag the entry to the desired place to finish reordering the entry.

## Test Profile

The graph below shows the profile shape, along with four other lines: the Low- and High-Alarm Levels and the Low-High- Abort levels. The profile consists of breakpoints at a given frequency and magnitude connected by line segments. The breakpoints can be added, deleted, and manually dragged around the graph. Each point corresponds with a row on the table under the Profile Table tab. This table can be directly edited by entering frequency and magnitude values in the cells. The magnitudes are listed as acceleration, velocity, and displacement.
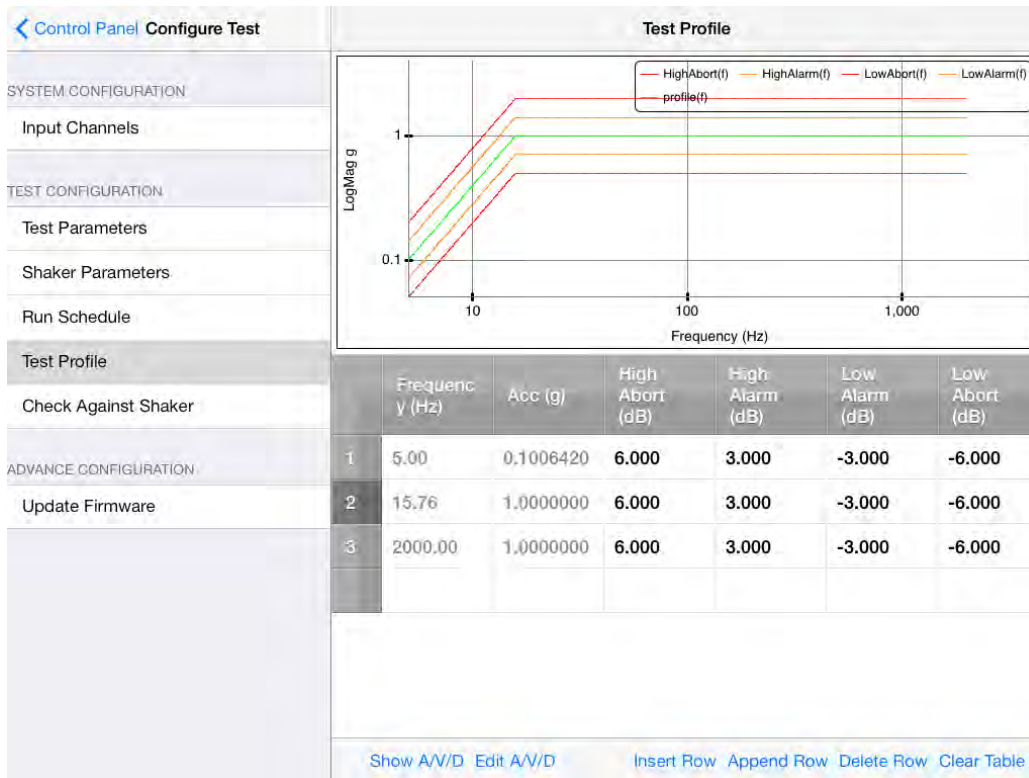
**Figure 292. Sine test profile**

There are three types of segments that can connect the breakpoints: constant amplitude, log-log slope, and linear slope. The segment type can be edited by clicking the Edit A/V/D button at the bottom of the Test Profile page.



**Figure 293. Segment type setup**

During the full test, if the response magnitude falls outside of the Alarm or Abort lines for longer than the Abort Latency value, then an Alarm or Abort event will be triggered.

## Measured Signals in Sine

Tap the Signal button to display measured signals in the sine test.
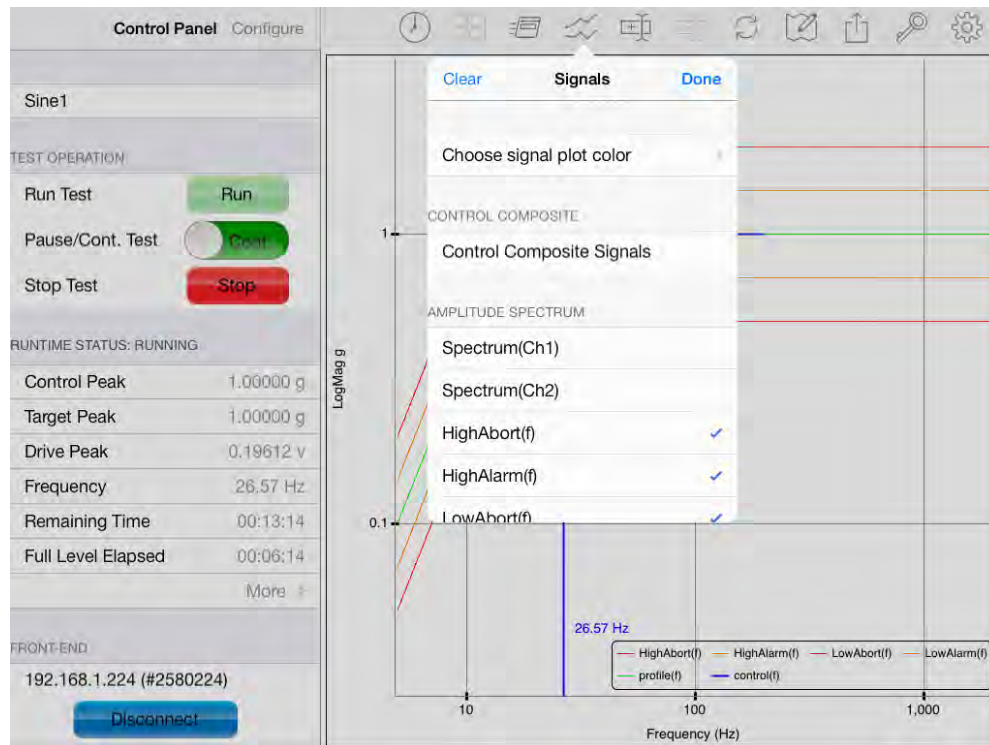
**Figure 294. Measured signals setup**

**Time Stream** is the native time streams of the input channels labeled as Ch1, Ch2, and drive.

**Time Block** isthe block signals of the input channels labeled as Block(Ch1), Block(Ch2), control_his(t), and frequency_his(t).

**Spectrum**is the sine measurement value plotted across the frequency. Usually it is represented in acceleration peak value. The sine measurement is taken at the output of tracking filter. In Sine the *Spectrum* in Sine is not a snapshot of a measurement. It is just the history trace drawn across the whole frequency. The resolution of Spectrum signal has nothing to do with the resolution of frequency change in the control process.Those spectrum signals are labeled as Spectrum(Ch1), Spectrum(Ch2), and Spectrum(drive).

**HighAlarm(f), LowAlarm(f), HighAbort(f), and LowAbort(f)** are the limit lines of the profile.

**control_his(t)**is the RMS level history of the control signal.

**frequency_his(t)** is the time trace of the frequency.

**control(f)** is the power spectrum of the control signal. If multiple control channels are used, the control(f) signal is either weighted-averaged spectra from all control channels, or the maximum spectrum, on per frequency bin base, among all the control spectra.

**profile(f)** is the frequency-domain test profile.

**FRF(Ch2, Ch1)** is the transmissibility signal between two channels. It will be available in both complex and real measurement. Currently Random test has no limitation in the flexibility of FRF channel selection on the PC level.

**H(f)** is the frequency response function between the drive output and the control input signal.

## Shaker Parameters

Click on Parametersto edit the information from the shaker specifications. This is important for the safety of the shaker and testing unit. Once the proper shaker parameters are entered, use the Check Against Shaker feature to confirm the correctness and expectations.



**Shaker Parameters**

| | |
|---|---|
| Max. Positive Displacement (mm) | 6.350 |
| Max. Negative Displacement (mm) | 6.350 |
| Max. Force RMS (Newton) | 444.920 |
| Max. Acc. RMS (m/s^2) | 163.444 |
| Max. Velocity (m/s) | 1.778 |
| Min. Drive Frequency (Hz) | 1.00 |
| Max. Drive Frequency (Hz) | 2500.00 |
| Max. Drive Voltage Peak (V) | 10.000 |
| Payload Mass (kg) | 0.100 |
| Armature Mass (kg) | 0.200 |
| Diameter (mm) | 1500.000 |

**Figure 295. Shaker parameters setup**

## Check Against Shaker

Check against Shaker shows the peak acceleration, velocity, displacement, and force of the profile and compares the values to the shaker limits.

**Figure 296. Check against shaker page**

## Run the Test

When a test is created or selected, tap the green Run button the start running the test; tap Stop button to stop running the test; tap Pause/Cont. button to pause/continue the test.
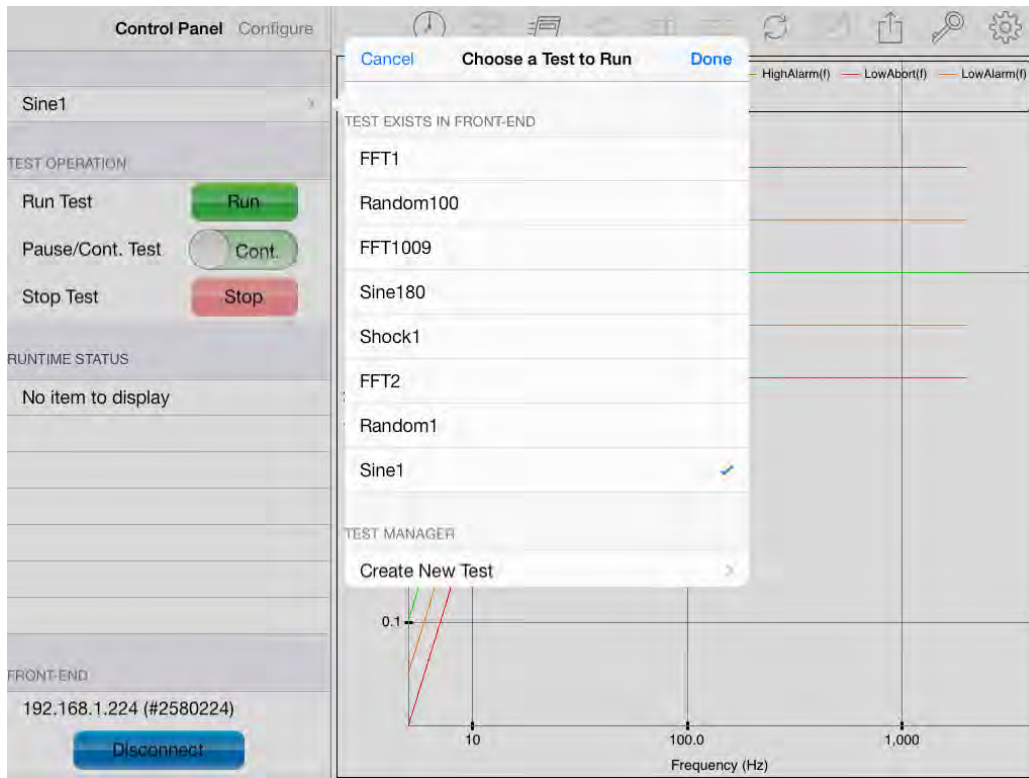
**Figure 297. Choose a test to run**

The Control Panel is used to start, stop, or pause the test, and shows status information like test level and elapsed time. The three function buttons in the Test Operation aear are always available for each type of the test.
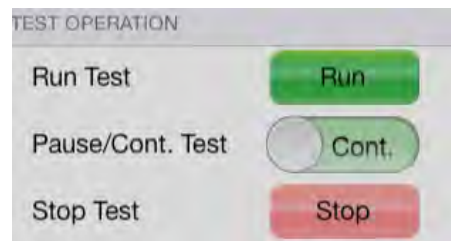


**Figure 298. Test operations**

However the Runtime Status varies among each type of the test. Tap the More> to display the completed list of status parameters for the Sine test. Test state information is displayed in the following fields:
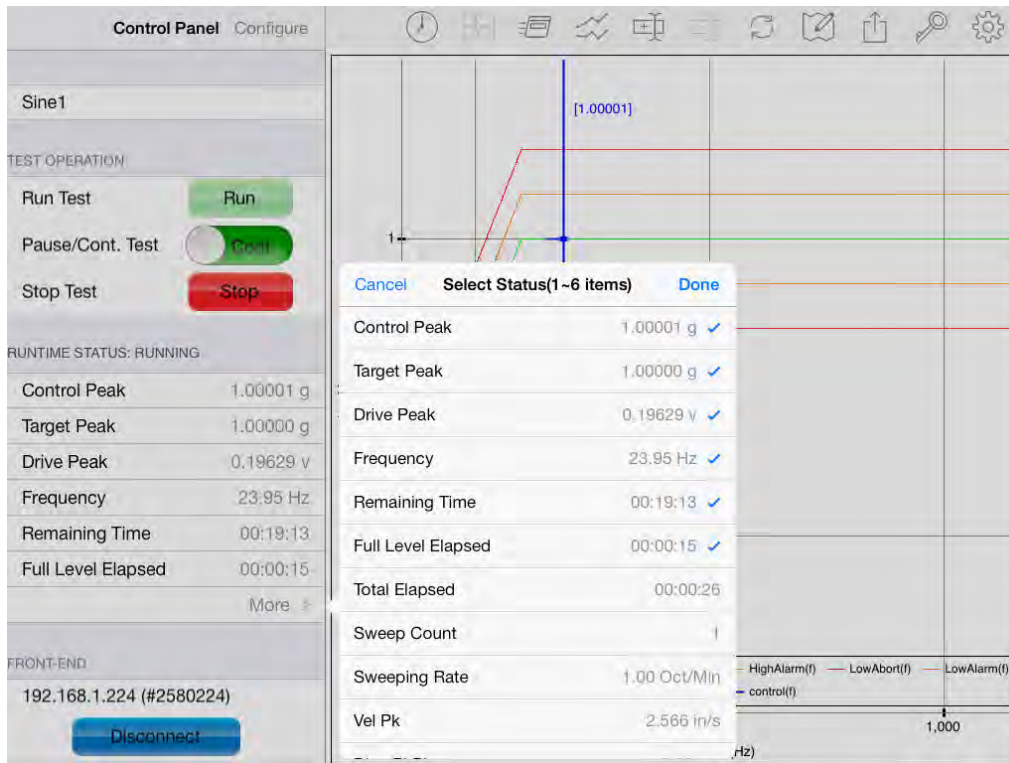
**Figure 299. Choose status displayed**

**Ctrl Peak** is the averaged Peak of the input control signals.

**Target Peak** is the target Peak level of the current test stage. This is a function of the test profile and the current test level percentage. The output is increased until the Ctrl Peak reaches the Target Peak.

**Drive Peak** is the peak voltage of the output drive signal. This is shown graphically in the green bar below, as a proportion of the maximum drive voltage limit (set in Test Parameters).

**Frequency** is the current sweeping frequency.

**RemainingTime** is the remaining time of the test, according to the run schedule.

**Full Level Elapsed** is the time elapsed running at full (100%) output level.

**Total Elapsed** is the time elapsed since the test was started.

**Sweep Count** is the number of sweep count.

**Sweeping Rate** is the speed of sweeping.

**Vel Pk**: This is the estimated peak velocity of the control channel. If there is more than one control channel, only the velocity peak of the first control channel is displayed. The velocity signal is computed by integrating the acceleration signal.

The accuracy of this computation may be very low if the signal contains significant amount of low frequency energy. Therefore this display is only used as a reference.

**Disp PkPk**: This is the estimated peak-peak displacement of the control channel. If there is more than one control channel, only the peak-peak of the first control channel is displayed. The displacement signal is computed by double-integrating the acceleration signal. The accuracy of this computation may be very low if the signal contains significant amount of low frequency energy. Therefore this display is only used as a reference.

**Level** is the current output level, as a percentage of the test profile. This is displayed graphically in the green bar below this field.

# Classic Shock Control Tests

A Shock control test outputs a series of pulses to excite the structure under test. The response is measured at one or more locations on the structure and a spectral analysis is used to determine its response and resonance characteristics. This pulse response is an approximation of the impulse response, which requires a pulse of infinite amplitude. The Fourier transform of the impulse response is the Frequency Response Function (FRF) of the system.

The Shock control process is essentially a time-domain waveform replication process that uses an FFT based algorithm to correct for the test system dynamics. The algorithm is similar to the one used for Random Control. The difference is in how the test profile is defined: in random control, it's defined in the frequency domain; while in shock control, it's defined in the time domain.

It is assumed that the test system is linear, which means that its response to any input can be predicted from its Frequency Response function. In the control process, this FRF is continually estimated and updated, and used to calculate the output drive signal. This output waveform should cause the test system to respond in a way that the control signal matches the test profile.
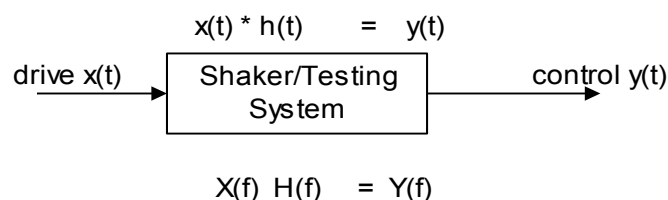
```
           x(t) * h(t)     =   y(t)

drive x(t)   ┌─────────────────┐    control y(t)
   ────────► │  Shaker/Testing │   ────────►
             │     System      │
             └─────────────────┘

           X(f)  H(f)    =  Y(f)
```

**Figure 300. Mathematics of Control System**

The system output $y(t)$ can be calculated as the convolution between the system input, x(t), and the system impulse response, $h(t)$.

$$y(t) = h(t) * x(t)$$

However, convolutions are tricky to calculate, and it may be impossible to fully determine the impulse response. Fortunately, this convolution is equivalent to a multiplication in the frequency domain. The system output $y(t)$ is replaced with the output spectrum $Y(f)$, the input $x(t)$ is replaced with $X(f)$, and the impulse response $h(t)$ is replaced with the frequency response function $H(f)$. Calculating the Fourier transforms $Y(f)$ and $X(f)$ are straightforward, and determining $H(f)$ is much easier than $h(f)$.

The controller calculates the required test system input $x(t)$ by:

$$x(t) = IFFT( X(f) ) = IFFT( R(f)/H(f) )$$

$$= \mathrm{IFFT}(\ \mathrm{FFT}(\ r(t)\ )\ /\ H(f)\ )$$

where $R(f)$ is the test profile in the frequency domain and IFFT is the inverse FFT (an algorithm for the Fourier transform). The test profile is specified by the user as $r(t)$, in the time domain, and is then transformed into $R(f)$ before the test begins.

In the classic shock test, $r(t)$ can be a half-sine, sawtooth, triangle, rectangle, trapezoid, or haver-sine shape.

The target pulse shape can be half-sine, sawtooth, triangle, rectangle, trapezoid, or haver-sine. The pulse itself is always one-sided — its displacement is only in one direction. A series of these pulses would cause an unbounded armature excursion of the shaker in one direction, which is not physically possible. To keep the armature centered, each pulse must have a zero mean displacement. This is done by adding a compensating pre- and post-tail to the pulse.

## Waveform Compensation

At the end of each pulse output, the shaker must return to its rest position. However, the pulse shapes used in the classical shock test are one-sided, meaning that, if used by themselves, they would leave the shaker armature with residual displacement and velocity. A series of these pulses would cause the armature to travel all the way to its stops, and then no more outputs would be possible.

Compensation is the method of "correcting" the control signal so that the ending displacement and velocity is always zero. It involves adding smaller pulses before and after the main pulse.
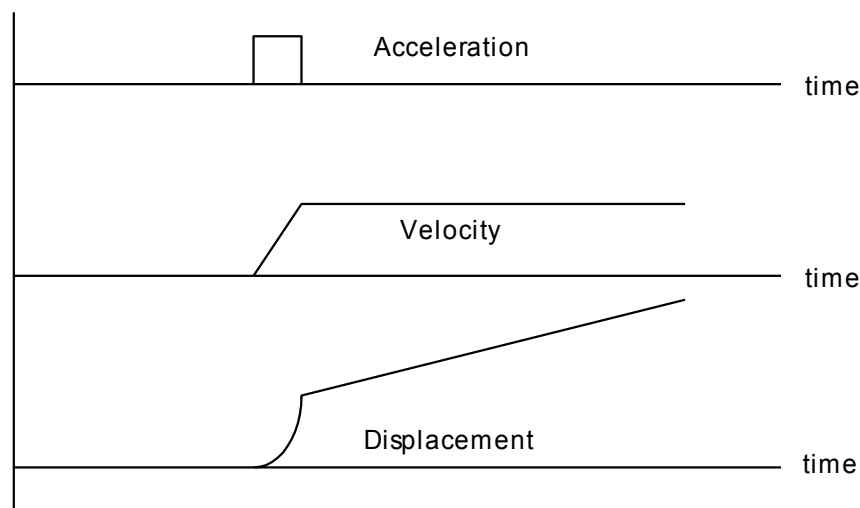


**Figure 301. A Single Square Pulse and Its Effects on Velocity and Displacement over Time**

Given a main pulse shape, there are different algorithms that can be used to generate an optimized waveform. Compensation pulses can be added before or after the main pulse.

The figure below shows a half-sine pulse that has been properly compensated, along with its velocity and displacement profile.
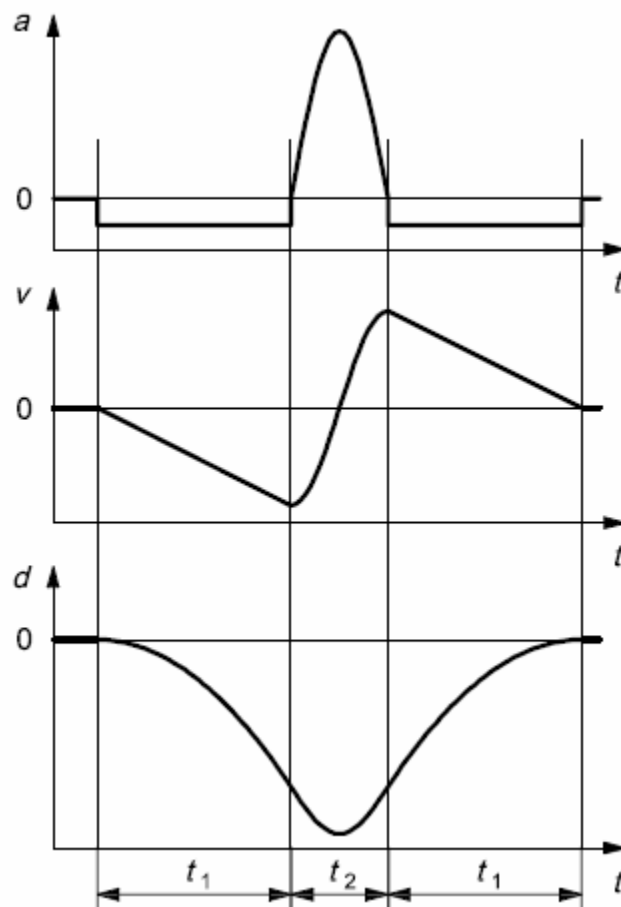


**Figure 302. Shock Pulse Compensation**

When generating the profile waveform, it is important not to exceed the limits of the shaker. These limits include the voltage and current capabilities of the power supply driving the system, and the ability of the system to generate peak acceleration, force, velocity, and displacement levels.

## Safety Features

In sine mode, there are a number of safety features that help prevent damage to the shaker and related equipment. During a shake test, 5 different types of checks are performed and an event is triggered if any of these checks fail. The response actions to these events can be customized under Event-Action Rules. The 3 checks are

1. Maximum shaker drive voltage limiting
2. Channel overload or loss detection
3. Shock abort limits.

The system also detects when input channels are overloaded or lost which can indicate a sensor fault or an accidental disconnect. The test will be aborted if this occurs.

In the event of an accidental network disconnection or power loss, the hardware is able to save test data and state information to non-volatile memory to protect against loss. For a network disconnection, the test can continue to run in Black Box mode or save all data and execute an orderly shutdown.

## Shock Abort Limit

Shock abort limits are similar to the abort lines in the sine and random tests, but are defined in the time domain rather than the frequency domain. If the level of the control signal, within the vicinity of the pulse output, falls outside these limits then an abort event is triggered.
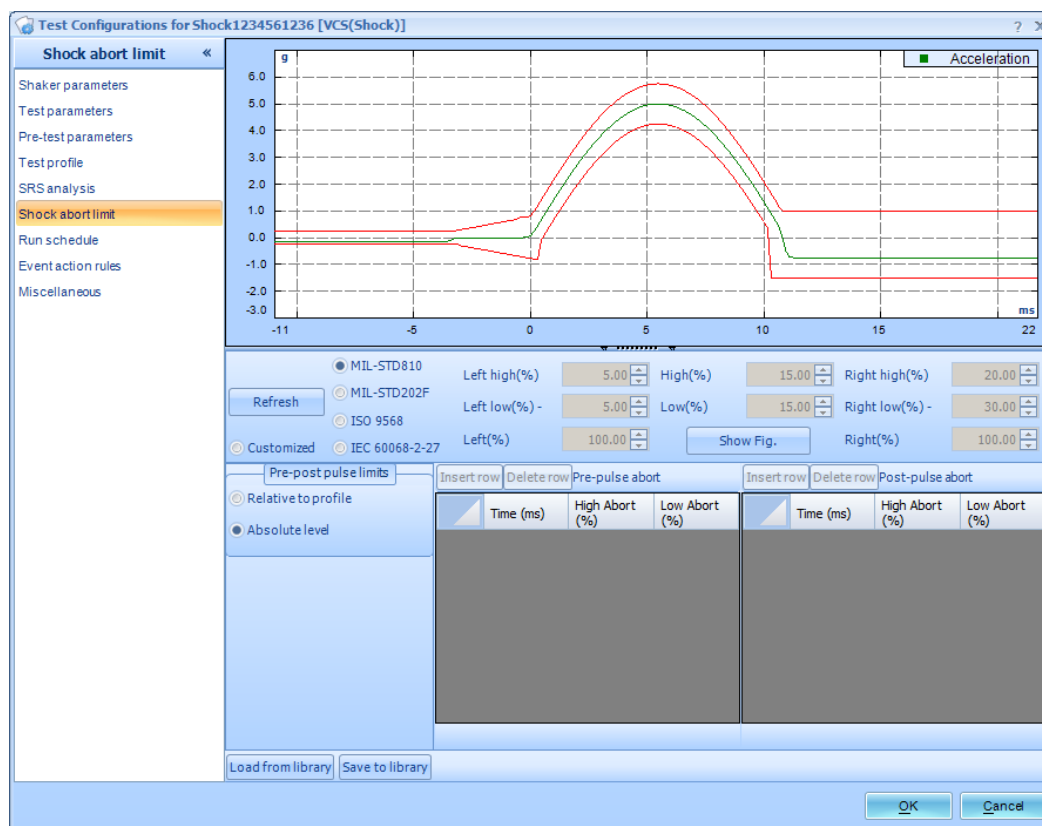


**Figure 303. Shock Abort Limit**

The top of the window shows the pulse acceleration shape as a green line with the beginning of the pulse at time zero. The abort limits are red lines (this is the same graph as shown in the Shock Settings section).

These limits can be set according to three standards: Mil-Std 810, Mil-Std 202F, and the ISO mechanical shock test standard. The text fields show the characteristics of the limits — high and low values as a percentage of the main pulse peak

amplitude for the left tail, main pulse, and right tail; and the time length of the left and right tails as a percentage of pulse width. The figure below shows a graphic definition of these values (this figure can be shown by clicking the button **Show Fig.**).
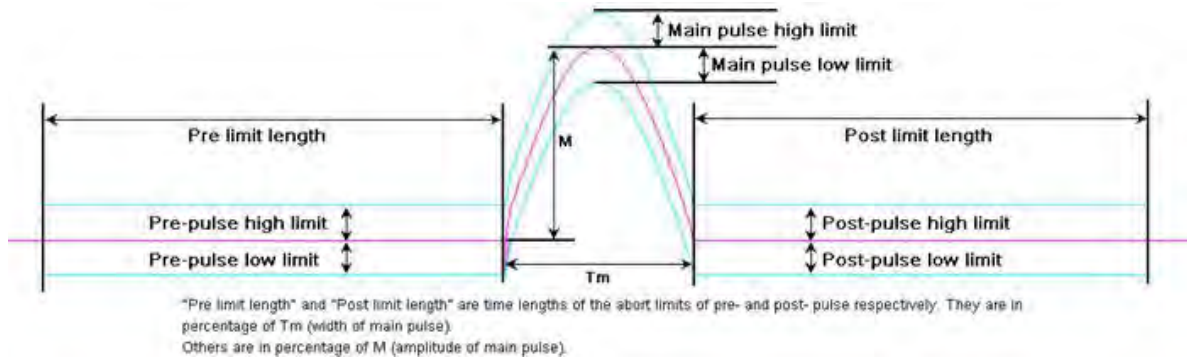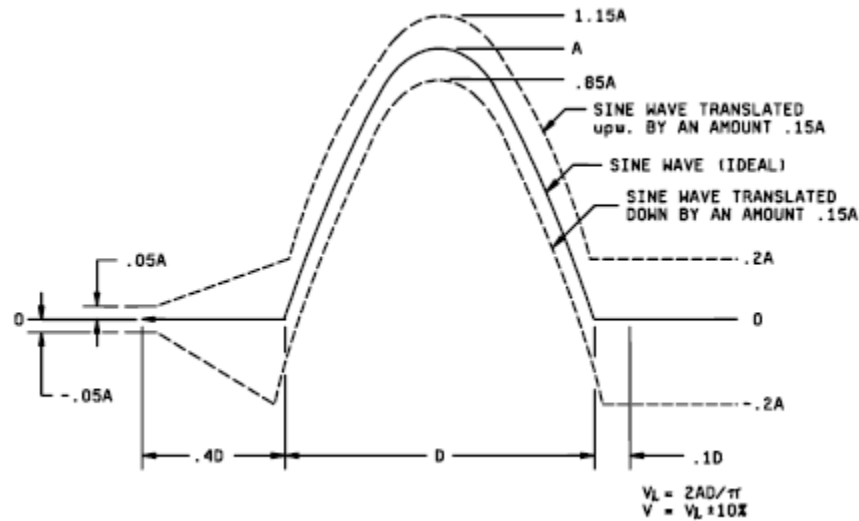


**Figure 304. Shock limit definitions**

There is also an option to set customized limits, with points entered on the table below.

**Draw main pulse** zooms the graph in to show the main pulse outline.

**The figures below show some standard waveform shapes and tolerances.**
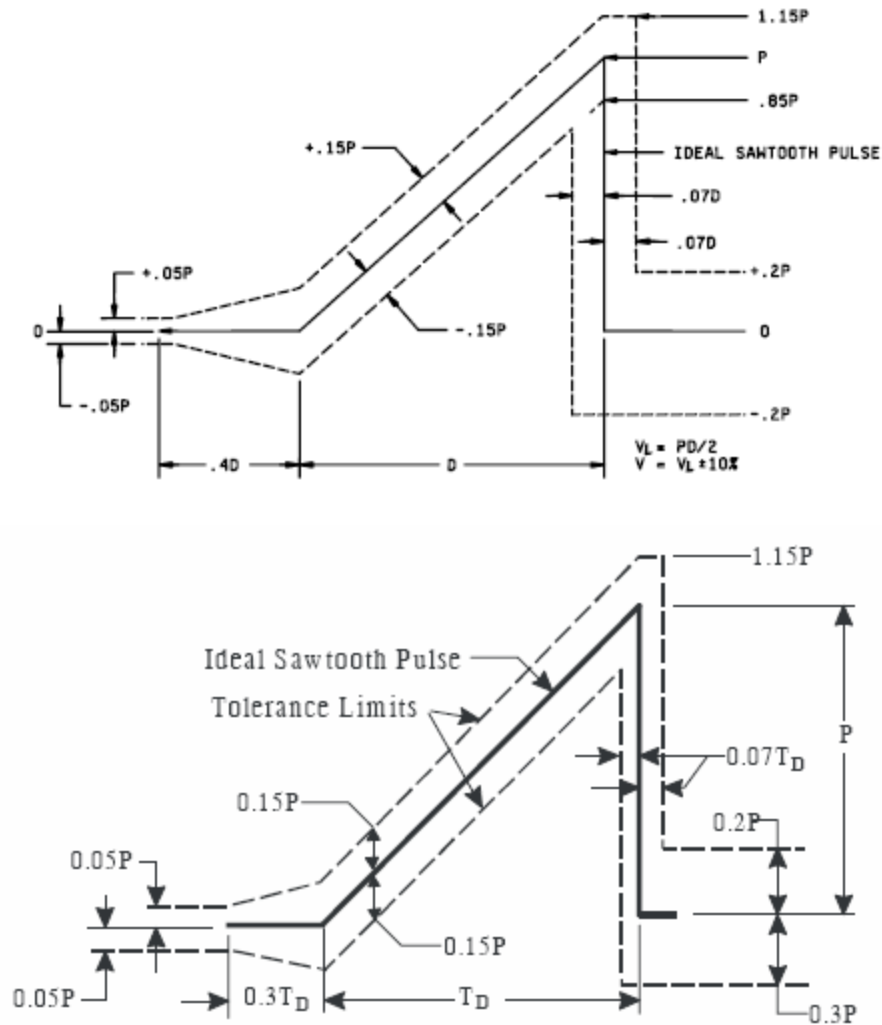
**Figure 305. Standard waveform shapes and tolerances of a shock pulse**

## Shock Test Parameters

In the shock test, this section of the Test Configuration window is used to configure settings related to the shock test parameters. The Block Size, Block T, dT, Sampling **Rate, and Frequency Range are automatically calculated and users' input is not** required.

**Figure 306. Shock test parameters setup**

**Average Number** is the number of blocks that are averaged for the response profile. Higher averages will smooth out the response to any transient events. In general this value should be between 2 and 5.

**Drive Limit (Volt Pk)** limits the absolute maximum voltage output of the drive signal. If the drive limit is reached before the control signal reaches its target, the system will Drive Maximized warning. The output signal will not exceed the Drive Limit.

**Interval Between Pulse** is the number of second between adjacent pulses in time length.

## Run Schedule

When a test is run, it executes the entries in the run schedule. These entries define test stages at certain levels and durations.

**Figure 307. An example of the shock test run schedule**

This schedule can also include loops to repeatedly execute a series of entries. When the test is running, pulses will be continually output at their set interval. The schedule is activated when the test is started.

Clicking on the right arrow icon of each entry allows users editing this entry. This operation can modify the loop times, level percentage, and pulse numbers.

Create New Entry button is used to insert a new entry to the last place before the End Loop entry.

Delete Entry button shows the deletable entries when it is clicked. The loop entries cannot be deleted. Swipe the entry to the left to display the red Delete button; click the Delete button to remove the entry from the Run Schedule.

Reorder Entry button shows the entried eligible to be reordered when it is clicked. Press and hold the Move icon on the right side of each entry; drag the entry to the desired place to finish reordering the entry.

## Test Profile

This is where the pulse shape and time characteristics are set. The graph below shows the pulse shape as a green line. The pulse is set as an acceleration profile, and this shape is integrated to draw the velocity and displacement profiles. The acceleration graph also shows the abort limits as red lines above and below the pulse.
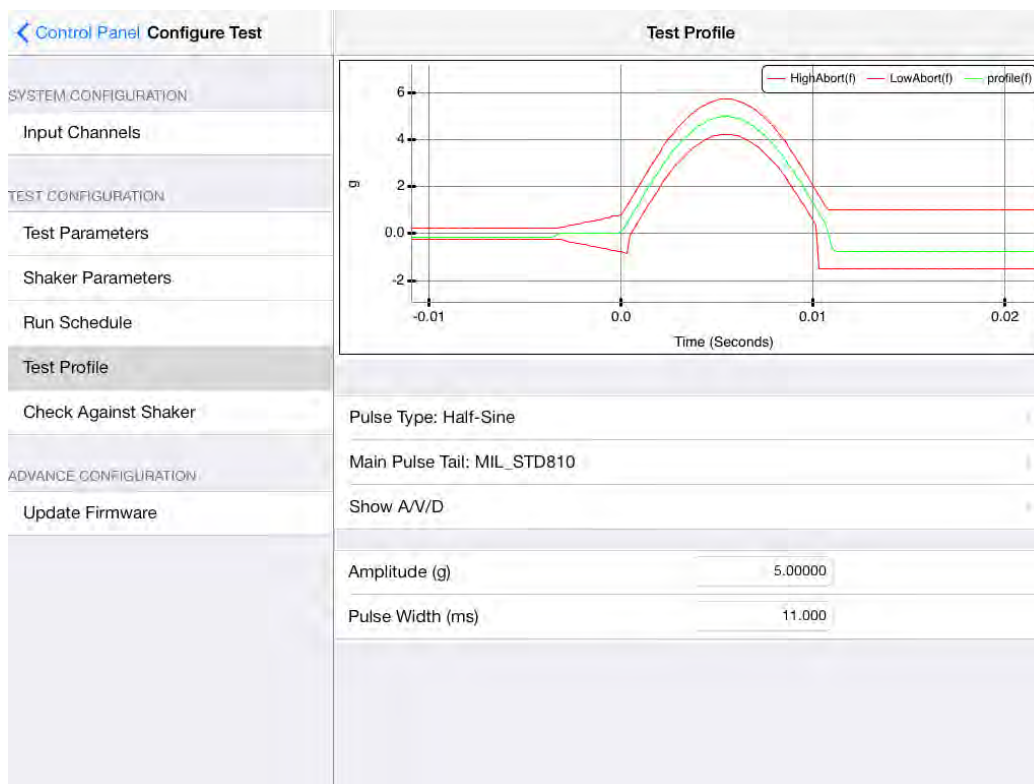
Figure 308. Shock test profile

**Pulse Type** is the shape of the pulse. The options are half-sine, terminal-peak sawtooth, initial-peak sawtooth, triangle, rectangle, trapezoid, and haver-sine. The shapes have different frequency characteristics and are suitable for simulated different impulse conditions. Many testing standards specify the pulse shape to be used.

**Main Pulse Tails** are the compensation tails described below. The time length of the pre- and post-tails can be set according to these four standards: MIL_STD 810, MIL_STD 202F, ISO_Standard, and IEC_60068_2_27.

**Show A/V/D** sets the unit in Acceleration, Velocity, or Displacement.

**Amplitude** sets the peak acceleration value of the pulse.

**Pulse width** sets the width of the pulse in milliseconds. Narrower pulses have greater high-frequency components.

## Measured Signals in Shock

Tap the Signal button to display measured signals in the shock test.
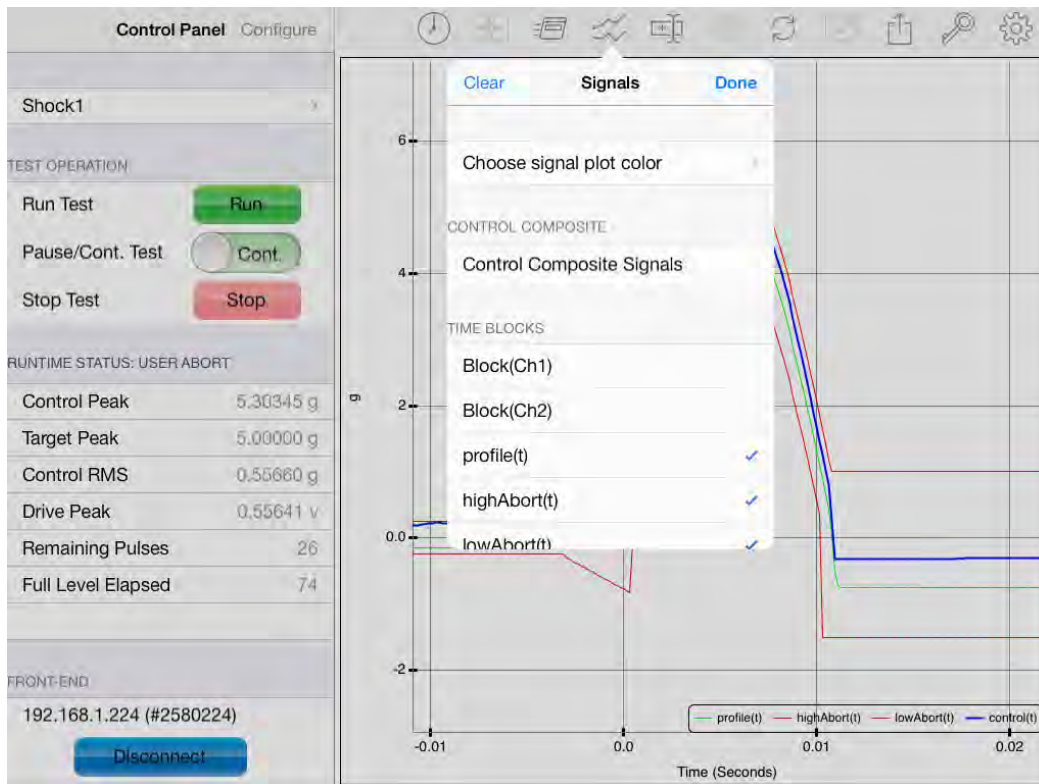
**Figure 309. Measured signal setup**

**Time Stream** is the native time streams of the input channels labeled as Ch1, Ch2, drive(t), profile(stream), and control(stream).

**Time Block** isthe block signals of the input channels labeled as Block(Ch1), Block(Ch2), and Block(drive).

**HighAlarm(t), LowAlarm(t), HighAbort(t), and LowAbort(t)** are the limit lines of the profile.

**drive(t)** is the time stream of the drive signal.

**control(t)**is the control signal time stream.

**control_scroll**is the RMS level history of the control signal.

**error_t** is the error between the actual time domain profile and the time domain control signal of each block.

**noise(t)** is the time domain system noise, measured in the first part of the pre-test.

**profile(f)** is the frequency-domain test profile.

**drive(f)** is thethe frequency domain of the drive signal.

**control(f)** is the power spectrum of the control signal. If multiple control channels are used, the control(f) signal is either weighted-averaged spectra from all control channels, or the maximum spectrum, on per frequency bin base, among all the control spectra.

**hinv(f)** is the frequency response function of the system when inverted pulses are output.

## Shaker Parameters

Click on Parametersto edit the information from the shaker specifications. This is important for the safety of the shaker and testing unit. Once the proper shaker parameters are entered, use the Check Against Shaker feature to confirm the correctness and expectations.

**Shaker Parameters**

| | |
|---|---|
| Max. Positive Displacement (mm) | 6.350 |
| Max. Negative Displacement (mm) | 6.350 |
| Max. Force RMS (Newton) | 444.920 |
| Max. Acc. RMS (m/s^2) | 163.444 |
| Max. Velocity (m/s) | 1.778 |
| Min. Drive Frequency (Hz) | 1.00 |
| Max. Drive Frequency (Hz) | 2500.00 |
| Max. Drive Voltage Peak (V) | 10.000 |
| Payload Mass (kg) | 0.100 |
| Armature Mass (kg) | 0.200 |
| Diameter (mm) | 1500.000 |

**Figure 310. Shaker parameters setup**

## Check Against Shaker

Check against Shaker shows the peak acceleration, velocity, displacement, and force of the profile and compares the values to the shaker limits.

**Figure 311. Check against shaker page**

## Run the Test

When a test is created or selected, tap the green Run button the start running the test; tap Stop button to stop running the test; tap Pause/Cont. button to pause/continue the test.
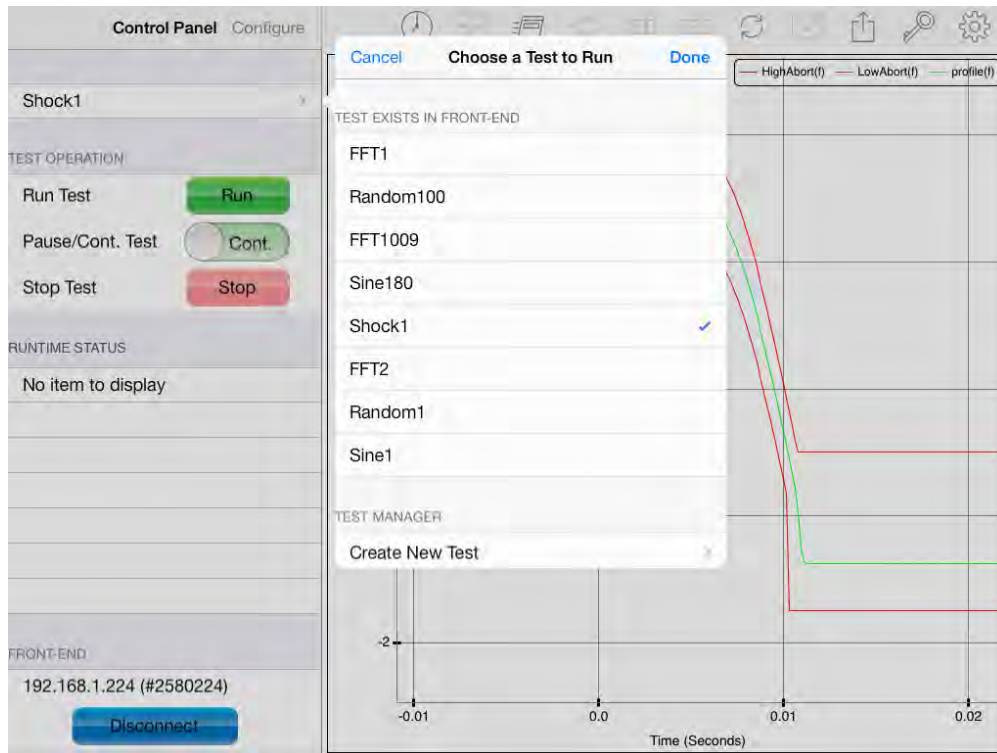
**Figure 312. Choose a test to run**

The Control Panel is used to start, stop, or pause the test, and shows status information like test level and elapsed time. The three function buttons in the Test Operation aear are always available for each type of the test.
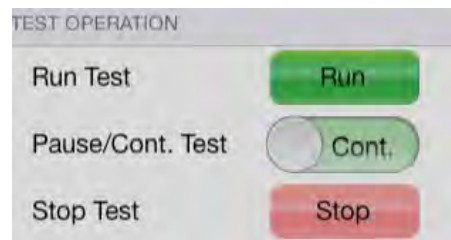


**Figure 313. Test operations**

However the Runtime Status varies among each type of the test. Tap the More> to display the completed list of status parameters for the Shock test. Test state information is displayed in the following fields:
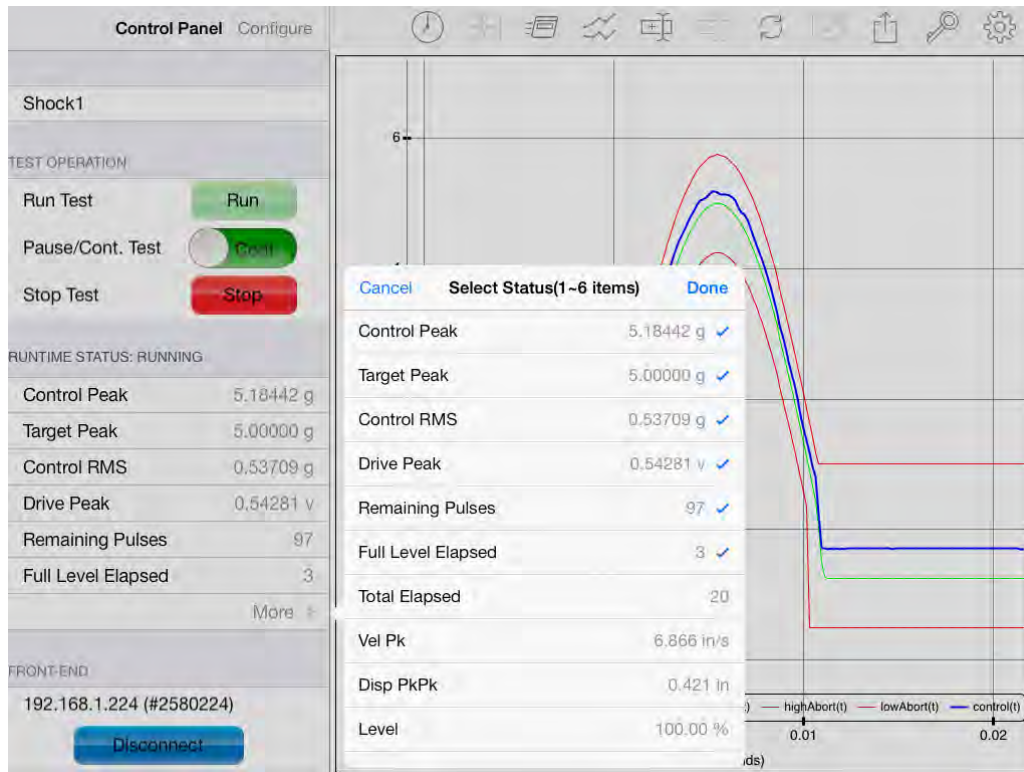
**Figure 314. Choose status displayed**

**Ctrl Peak** is the averaged Peak of the input control signals.

**Target Peak** is the target Peak level of the current test stage. This is a function of the test profile and the current test level percentage. The output is increased until the Ctrl Peak reaches the Target Peak.

**Ctrl RMS** is the RMS level of the input control signal. It is an overall rating of the control signal.

**Drive Pk** is the peak voltage of the output drive signal. This is shown graphically in the green bar below, as a proportion of the maximum drive voltage limit (set in Test Parameters).

**RemainingPulse** is the remaining number of pulse of the test, according to the run schedule.

**Full Level Elapsed** is the time elapsed running at full (100%) output level.

**Total Elapsed** is the time elapsed since the test was started.

**Vel Pk**: This is the estimated peak velocity of the control channel. If there is more than one control channel, only the velocity peak of the first control channel is displayed. The displacement signal is computed by integrating the acceleration signal. The accuracy of this computation may be very low if the signal contains

significant amount of low frequency energy. Therefore this display is only used as a reference.

**Disp PkPk**: This is the estimated peak-peak displacement of the control channel. If there is more than one control channel, only the peak-peak of the first control channel is displayed. The displacement signal is computed by double-integrating the acceleration signal. The accuracy of this computation may be very low if the signal contains significant amount of low frequency energy. Therefore this display is only used as a reference.

**Level** is the current output level, as a percentage of the test profile. This is displayed graphically in the green bar below this field.

# Black-box Mode

## Introduction

The Spider platform from Crystal Instruments operates as a real-time data acquisition and analysis system while connected to a desktop PC. It can also function as a stand-alone data recording system that does not require a separate computer. This second mode is called **Black Box Mode** and it is unique to Crystal Instruments' products. A computer is used to set up test parameters and to download test data after the test has been run. While running, the Spider operates autonomously according to a pre-set run schedule. Only single module systems can run in black box mode.

Running in Black Box mode eliminates the reliability issues caused by PCs in real-time control and data acquisition applications.

Black Box mode is ideal for production tests or long-duration tests. It is ideal for data acquisition applications that run without people in attendance.
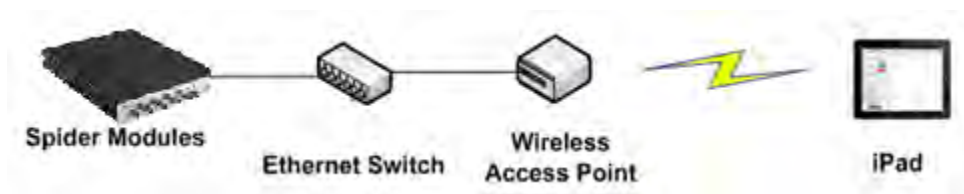


**Figure 315. A typical connection method**

In order to use iPad to control the existing tests on the Spider, those tests must be uploaded from the desktop version of EDM before using iPad to take control. Every time a test is run from the desktop EDM, it is automatically uploaded if the option **"Always overwrite" is checked. The Spider can also store 7 other test configurations,** for a total of 8.

Note: Currently only Random, Sine, Shock, and FFT tests are supported on the iPad.

## Uploading Tests

In order to run a test on the Spider, it must be uploaded from the desktop version of EDM. Every time a test is run from the desktop EDM, it is automatically uploaded if **the option "Always overwrite" is checked. The Spider can also store 7 other test** configurations, for a total of 8.

To see which tests are currently loaded on the Spider, go to the Setup menu in EDM and select **Black Box Setup** (make sure the Spider is turned on and connected first). From this windows, the loaded tests can be deleted or new tests can be uploaded (错误！未找到引用源。).

To upload another test, click on Upload Test. A list of all tests in the current database is shown. Select the test(s) to upload and press Upload (错误！未找到引源。).
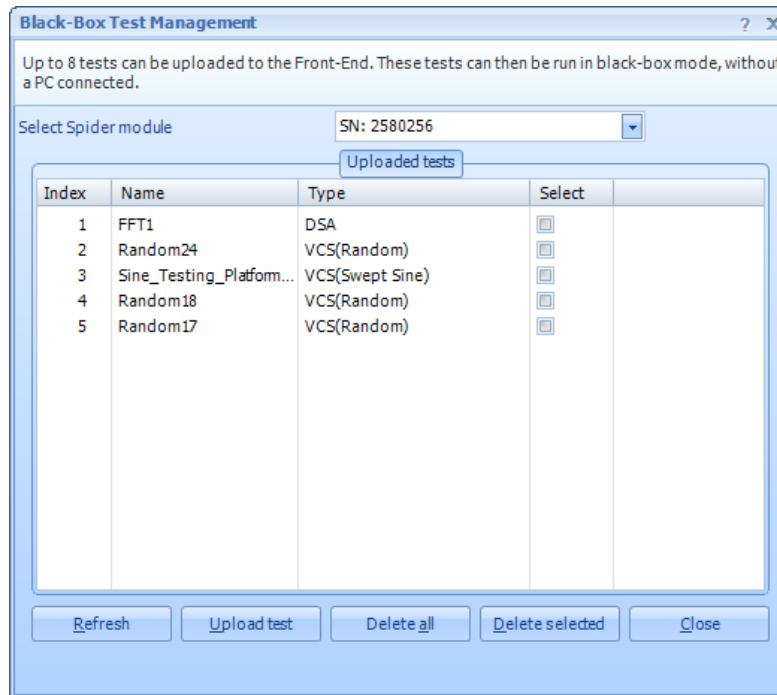


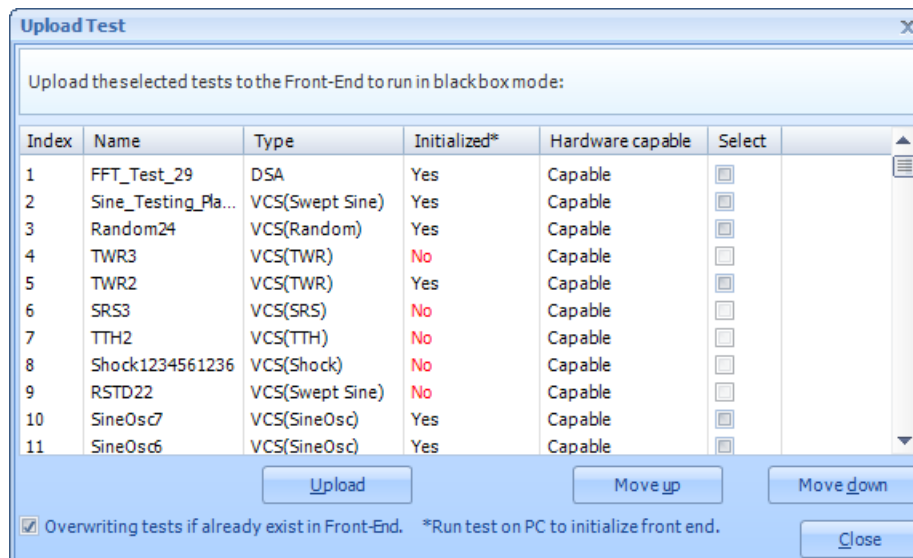**Figure 316. List of black box test and function buttons**



**Figure 317. Choose a test to upload to the Spider**

Now that the tests are uploaded to the Spider, they are ready to be run in Black Box Mode.

To see which tests are currently uploaded on the Spider, go to the Setup menu in EDM and select **Black Box Setup** (make sure the Spider is turned on and connected first). From this window as shown below, the loaded tests can be deleted or new tests can be uploaded.

To upload another test, click on Upload Test. A list of all tests in the current database is shown. Select the test(s) to upload and press Upload.

Now that the tests are uploaded to the Spider, they are ready to be run in Black Box Mode or from the iPad.Open EDM App on the iPad; connect to the front-end; the list of the test which can be run in the black-box mode is shown as below; select the test and go back to control panel to tap Run Test button to start the test in the black-box mode.
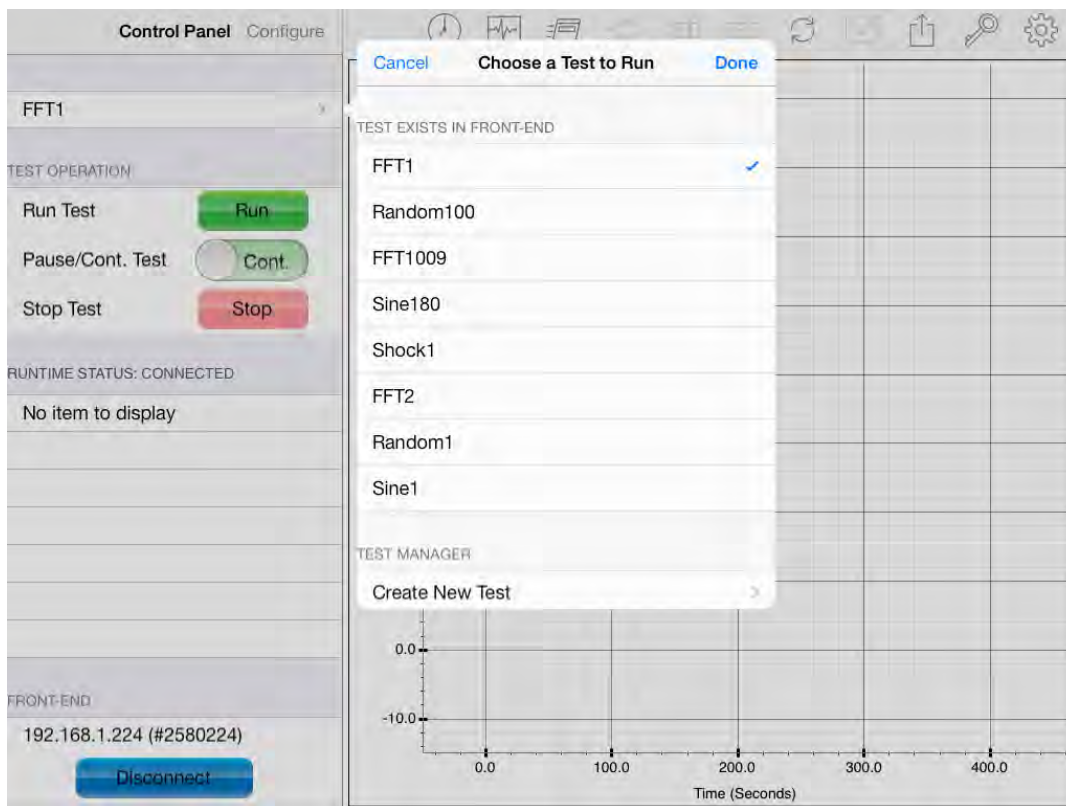


**Figure 318. Choose a test to run**

# Limited Warranty & Limitation of Liability

Each CI product is warranted to be free from defects in material and workmanship under normal use and service. The warranty period is one year for the Spider hardware and its accessories. The warranty period begins on the date of shipment. Parts, product repairs and services are warranted for 90 days. This warranty extends only to the original buyer or end-user customer of a CI authorized reseller, and does not apply to fuses, disposable batteries or to any product which, in CI's opinion, has been misused, altered, neglected or damaged by accident or abnormal conditions of operation or handling. CI warrants that software will operate substantially in accordance with its functional specifications for one year and that it has been properly recorded on non-defective media. CI does not warrant that software will be error free or operate without interruption.

CI authorized resellers shall extend this warranty on new and unused products to end user customers only but have no authority to extend a greater or different warranty on behalf of CI. Warranty support is available if the product is purchased through a CI authorized sales outlet or the Buyer has paid the applicable international price. CI reserves the right to invoice the Buyer for importation costs of repair/replacement parts when product purchased in one country is submitted for repair in another country.

CI's warranty obligation is limited, at CI's option, to refund of the purchase price, free of charge repair, or replacement of a defective product which is returned to a CI authorized service center within the warranty period.

To obtain warranty service, contact your nearest CI authorized service center or send the product, with a description of the difficulty, postage and insurance prepaid (FOB Destination), to the nearest CI authorized service center. CI assumes no risk for damage in transit. Following warranty repair, the product will be returned to Buyer, transportation prepaid (FOB Destination). If CI determines that the failure was caused by misuse, alteration, accident or abnormal condition of operation or handling, CI will provide an estimate of repair costs and obtain authorization before commencing the work. Following repair, the product will be returned to the Buyer transportation prepaid and the Buyer will be billed for the repair and return transportation charges.

**This warranty is the buyer's sole and exclusive remedy and is in lieu of all other warranties, expressed or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose. CI shall not be liable for any special, indirect, incidental or consequential damages or losses, including loss of data, whether arising from breach of warranty or based on contract, tort, reliance or any other theory.**

Since some countries or states do not allow limitation of the term of an implied warranty, or exclusion or limitation of incidental or consequential damages, the

limitations and exclusions of this warranty may not apply to every buyer. If any provision of this Warranty is held invalid or unenforceable by a court of competent jurisdiction, such holding will not affect the validity or enforceability of any other provision.

Hereby, Crystal Instruments, declares that this MINI-DYNAMIC SIGNAL ANALYZER AND DATA RECORDER is In compliance with the essential requirements and other relevant provisions of Directive 1999/5/EC.
The AC plug considered as disconnect device of power supply.

I/P AC 100-300V, 50/60Hz, 1.5A, O/P 15.0V, 4A

Environment friendly disposal

You can help protect the environment!
Please remember to respect the local regulations: hand in the non-working electrical equipments to an appropriate waste disposal

CE0700

FCC Warning:
This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Any Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
-Reorient or relocate the receiving antenna.
-Increase the separation between the equipment and receiver.
-Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
-Consult the dealer or an experienced radio/TV technician for help.
To maintain compliance with FCC's RF exposure guidelines, this equipment should be installed and operated with a minimum distance of 20cm between the radiator and your body.