Filter Measurements Script Notes

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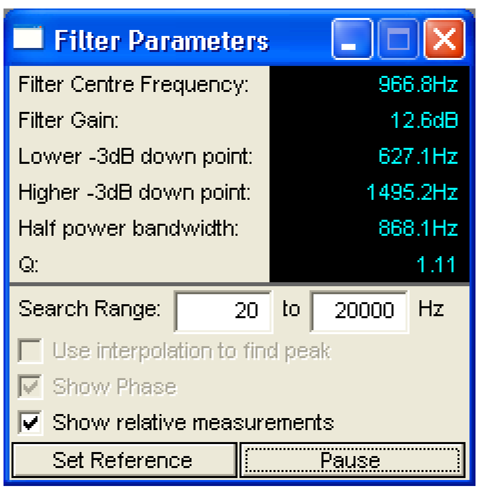
Introduction

These are the notes to accompany dScope automation script “Filter Measurements.dss” and its associated configuration which use a “bin centres” test signal to rapidly measure relative frequency response and phase and calculate a range of filter parameters.

Background

The script uses the dScope’s FFT trace and scripting capabilities, together with a “bin centres” waveform to measure the frequency response of a system relative to a set reference. The idea is that you measure the frequency response of an equaliser with the filters out of circuit (or set to their flat position) and set this as the reference position. Measuring relative to this reference gives a flat line at 0dBr if the frequency response remains the same. You can then change the position of any of the EQ controls and see the effect that it has on the frequency response in real time with high resolution. The script finds the peak bin (positive or negative) within a search range of frequencies. It then measures its gain and finds the points 3dB down from this (using linear interpolation), in order to display the half power bandwidth and calculate the Q of the filter. The interface is shown below.



In addition to the frequency response derived parameters, the script also can plot phase.

Requirements

The script has been developed and tested on dScope version 1.41. This version will not run on dScope Analogue (dScope Series IIIA) hardware as it requires the event manager. It is analogue to analogue only.

Installation

The installation requires two files:

- “Filter Measurements.dss” – the measurement script
- “Filter Measurements.dsc” – the configuration

The script should be copied to the dScope Scripts\Automation folder. This is typically:

C:\Program Files\Prism Sound\dScope Series III\Scripts\Automation

The configuration should be copied to the to the Configurations folder. This is typically

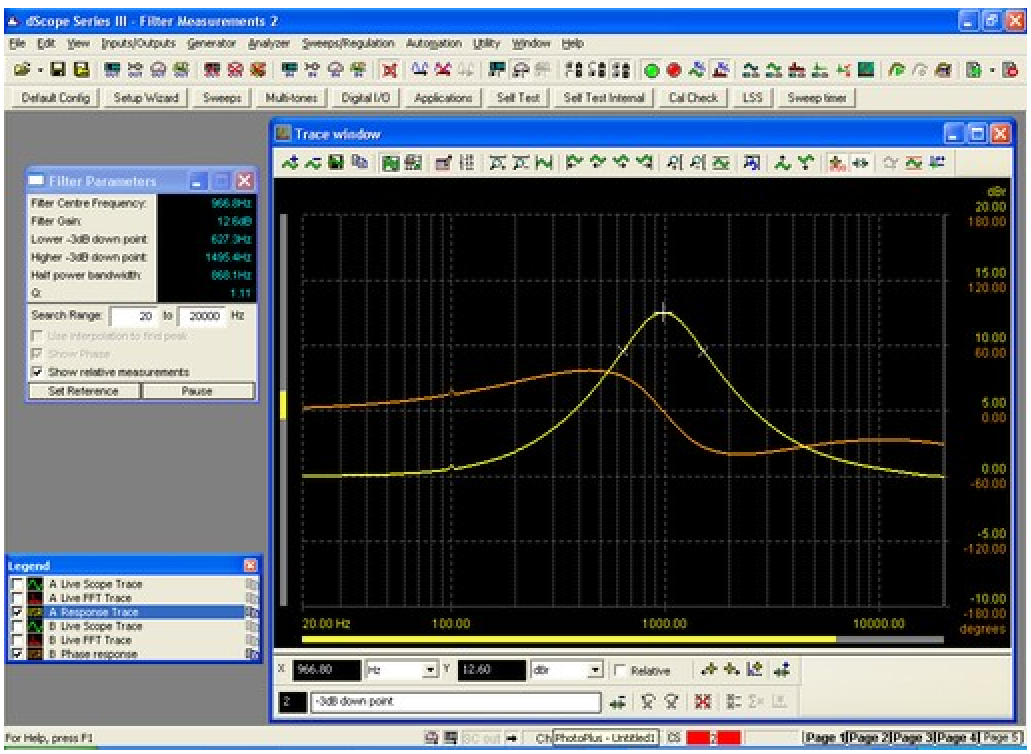
C:\Program Files\Prism Sound\dScope Series III\Configurations

There should be no further configuration required.

Running the Script

Running the script consists of using the “run script” option in the dScope “Automation” menu, or using the “Run script” toolbar icon and selecting the “Filter Measurement” script from the file browser that appears. The script loads the configuration automatically.

When the script interface first appears, you will find that the “set reference” button is disabled. This is because there is not data yet. First click “Run” and wait until you have a settled plot. Initially this is showing the response of the signal on channel A relative to the generator signal and will include any gain in the system. If the gain through the device is more than 20dB or less than -20dB you may not see anything on the trace window initially. Once you have clicked “Set reference” you will be seeing a plot of the device relative to itself and you should have a flat yellow line at zero dBr. You can then change the filter settings and you will see the effect of the filter in the trace as below:



The Search Range

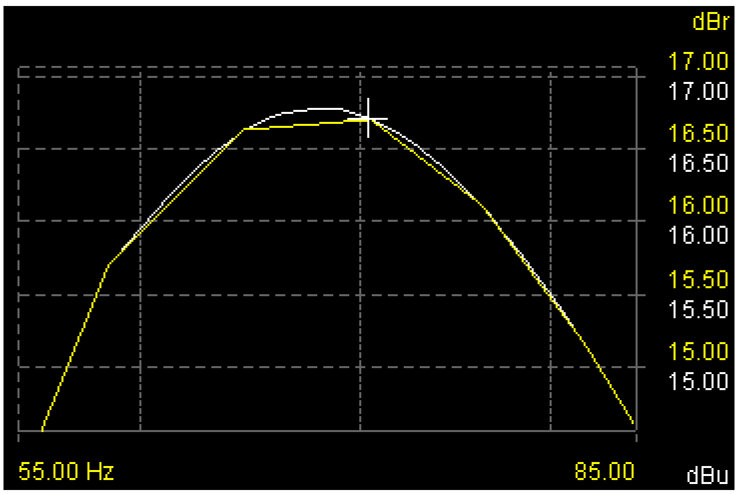
If there are multiple peaks on the plot, you can isolate one for measurement using the “search range” edit boxes. Note that if the 3dB down points are not within this range, the readings will be shown in red and the half-power bandwidth and Q readings will be wrong.

The Phase Plot

If the phase trace is also on, you should also see an orange line for the phase plot. The has the same relativity as the main trace.

Use Interpolation to find peak

If the “Use Interpolation to find peak” box is checked, you may see a white line (sometimes very small) at the peak of where the trace thinks the filter centre frequency is. This gets turned off if the script thinks that the peak is too near the end of the trace for there to be enough points to interpolate. Normally the script just looks for the highest point in the trace in the search range set on the form, and reports this as the filter centre frequency. If the “Use Interpolation to find peak” box is checked it takes two points either side of this peak and uses a cubic spline interpolation routine to infer what the shape of the curve would most likely be between these points. It plots this in white using 40 points. It's most use where there are only a few frequency points between the 3dB down-points of the filter such as shown below



In this case, the marked peak point in the yellow trace is at 70.3Hz, but the interpolated trace (in white) has a peak at 67.7Hz.

Show Relative Measurements check-box and the Set Reference button

When the script first starts up, it is showing the level of the output of the EUT relative to the generator. When you click “Set Reference” it takes the current reading and sets it as a reference reading and begins to display readings relative to this. At this point the “Show Relative Measurements” button gets checked, but you can un-check it to see the level relative to the generator again. The setting of the reference applies to both the magnitude and phase plots.

Connections

Connect your EUT between the analogue output and analogue input on channel A of the dScope Series III. This is a single channel test. Settings for the output level and for the analogue outputs and inputs are on page 2 of the configuration.

Setting Levels

You can set the level of the test signal on page 2 of the configuration. Note that the level is the level of *each bin-centred tone* which is why the value is so small. Changing the number of samples in the generator wave-table will therefore have a direct effect on the level of the signal. This is measured in RMS and Peak dBu on page 2 of the configuration. You can change the units of these Readings if you prefer not to use dBu. When setting levels with bin-centred signals, you are aiming for a smooth flat line – if you see regular deformation and raggedness of the line that is the same every time the trace refreshes, this is distortion. If you see irregular raggedness that changes every time the trace refreshes, this is noise.

Because of the wave-table and buffer based nature of this test, the dScope's auto-ranging is turned off and the script manages the levels itself. This is particularly difficult to achieve in an FFT based script and it is sometimes quite slow to react so large changes in level from a filter may take a few buffer captures to settle and you may see the trace offset by multiples of 2dB while the gain ranging settles. When the level into the dScope increases, you may also hear the dScope gain ranging relays clattering and see over-range warnings. The script will be watching for these and should range up, but it may take it a few seconds.

Other Parameters you can change

Because the script is depending on some settings in the configuration in order to be able to make its measurements, there are many parameters you cannot change without causing problems for the script. Page 2 of the configuration contains dialogues to allow you to change a variety of parameters, but not even all these are OK to change. In general, avoid changing anything that isn't set on page 2 of the configuration. Of the parameters on page 2 the following are OK to change:

Signal Generator Dialogue

- Amplitude
- Samples
    - WARNING: this will change the level of the test! More samples = louder. 3dB increase in level per doubling of sample points.
    - Changing this will cause the script to change the FFT buffer size to keep the two in sync.
- Pink response
    - Because the measurement is relative to generator, changing this should make no difference to the flatness of the curve, but may make the signal to noise ratio poorer at high frequencies. This might help if making acoustic measurements. Note that the system must be linear time-invariant (LTI).
- Phases

Analogue Outputs

- You can change anything here (except the mutes!).

Analogue Inputs

- Sample Rate
    - Changing this forces the script to re-calculate all the traces and may take a moment
- Input Impedance
- Auto-ranging step size
    - Although the script manages the auto-ranging (and will override the “auto” and “tied” settings) you can set the step size to make it less sensitive to changes in level – using a larger step size will give the inputs more headroom before they need to auto-range up.

FFT Parameters

- Number of points
    - WARNING: Changing this will cause the script to change the size of the generator wave-table – this will have implications for the audio level of the test! More points = louder.
- Averaging: you can use all the averaging features. Some will cause the measurement to stop when the FFT trigger turns off. This is by design.

Appendix

How it works

This section describes in some detail the process the script uses to get the information. It is not absolutely essential to read this section, but it will help to understand the limitations of the technique and understand the implications of the settings on the interface and will enable you to get the most out of it.

The basic principle is that the dScope is measuring a signal that has passed through the EUT on channel A of the analyzer and a signal that has come directly from channel A of the generator on channel B. Initially we are displaying the EUT signal relative to the generator signal in dBr. When we set the reference, we take this trace and set it as the reference and proceed to measure in dBr relative to the reference. The same applies to the phase measurement.

Bin Centres test signal

The measurement of the frequency response is done using a special form of multi-tone that has equal amplitude tones at every FFT bin centre frequency. When viewed on a synchronous system, the FFT of this signal can be performed without an FFT window and the resulting frequency domain trace is the frequency response. This can be done very fast with thousands of frequency points with high precision. This is roughly equivalent to making a measurement with a perfect white noise signal and infinite averaging, although typically no averaging is required as long as the signal dominates the noise. Distortion shows up in the trace as jaggedness that remains steady, unlike noise that is variable. Averaging will reduce the effects of noise, but have little or no effect on the distortion jaggedness.

Peak Detection

Peak detection is done by searching between the frequency points set in the interface for the highest and lowest points of the trace. Whichever has the greater magnitude is determined to be the peak and is marked with the cursor. When not measuring relative to a reference, any gain in the system can throw this out considerably. By setting a frequency range over which we are looking for the peak we are able to isolate one peak from others in the same response.

Interpolation

To assist in finding the peak more accurately, particularly when the spacing of the FFT bins is fairly sparse compared to the shape of the curve (eg, small FFT's and/or high sample rates at low frequencies) a cubic spline interpolation routine can be used.

When the “Use interpolation to find peak” check-box is checked, the script will attempt to find the peak from an interpolation routine, however, this is not possible if the peak lies within 3 FFT points of the start or finish of the frequency range as the interpolation routine needs the two points either side of the detected highest bin in order to calculate the best fit line. In this case the warning “(Range!)” will appear next to the check-box, the interpolated trace will be turned off and the reading will revert to the peak FFT bin reading.

Although the interpolated trace is shown on the trace window, the cursor remains on the FFT trace and shows the position of the peak FFT bin, and not the interpolated peak.

Although the interpolated trace is shown plotted with 40 data points, the peak frequency and gain as displayed in the scripted interface are found by a binary search routine working with the interpolation equation directly and not with the plotted trace points. There may not be a trace point corresponding exactly to this value, even on the interpolated trace.

-3dB point determination

In order to determine the 3dB down points, the script reads through the points to the left and right of the peak until the reading exceeds 3dB difference from the level at the peak (either the interpolated peak or the FFT peak point if interpolation is not enabled) . Marks are placed on the trace at these points. The script then does a simple linear interpolation between this point and the previous point (closer to the peak) to resolve the -3dB frequency more accurately. This is particularly important at lower frequencies and on filters with higher Q. Note that the frequency reported is the interpolated value and not the frequency at the Mark on the trace which is the next available point on trace beyond 3dB.

Auto-ranging

Because the dScope auto-ranges fast enough that it can change several times within the period of a bin-centres wave-table it has difficulty with wave-tables with variations in level over the period of the buffer. This is particularly true with filters and larger FFT size Newman phase bin-centred signals. To get round this a scripted auto-ranging solution is used here. This periodically checks the level of samples in the sample buffer on both channels and fixes the gain ranges based on these data. It uses the auto-ranging step size from the dScope to determine how much headroom to leave. This works particularly well with larger FFT sizes and when the level of the signal decreases.

If the level of the signal increases, the dScope's own auto-ranging will be over-ridden and buffer data will not be captured. The script therefore has no data to work with and must detect the auto-ranging being over-ridden and adjust the range used upwards. It doesn't know the extent to which the gain ranging is being over-ridden (this is not available from the automation interface) and must just step the gain up until a buffer is captured. This doesn't happen fast enough to prevent the relays clattering but it should eventually adjust itself and is better than the auto-ranging getting into a cycle where it ranges multiple times per wave-table. This causes and every buffer capture to be rejected because it contains gain range changes, locking up the dScope FFT process and requires the gain range to be fixed manually.