Measuring Crystal and Narrow-Band Filter Response

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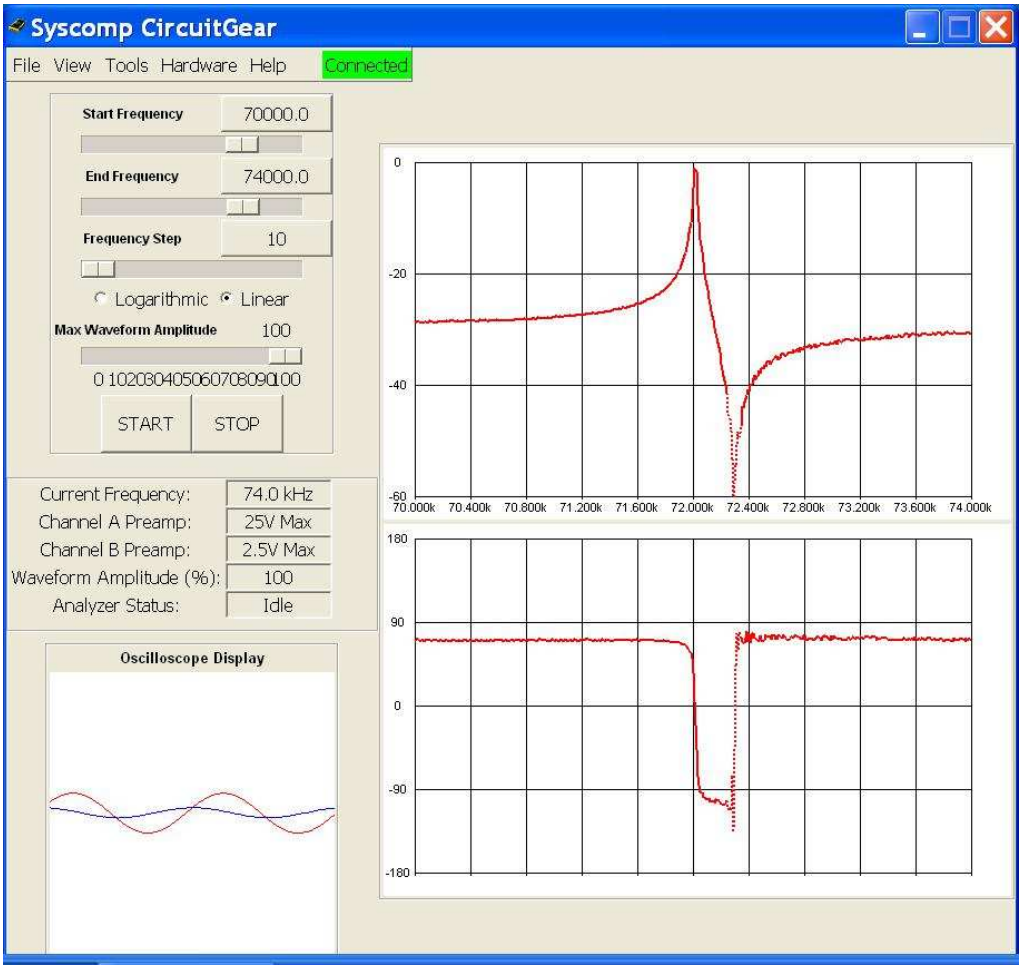


Introduction

It is often useful in RF design applications to measure the amplitude and phase response of a crystal or narrow-band filter. The cover page of this note shows an example: the magnitude and phase of the impedance of a piezoelectric crystal.

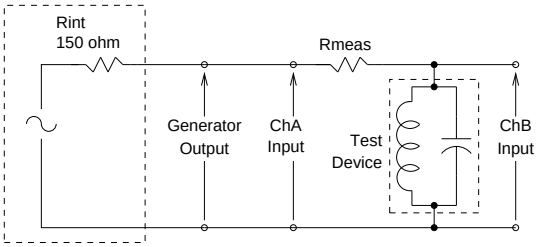


Figure 1: Connections: Two-terminal Network

A modern DDS (direct digital synthesis) waveform generator can be programmed to a very precise frequency, and swept over a narrow range of frequencies. The Syscomp CircuitGear CGR-101 and CircuitGear Mini use this capability of the internal waveform generator, with the oscilloscope hardware and VNA (vector network analysise) software to plot the response of narrow band components such as crystals and IF filters.

In this application note we show the control settings of the VNA display and some examples of measurements.

Other applications of the VNA are shown in references [1], [2].

Two-Terminal Device

Figure 1 shows the connection diagram for plotting the impedance of a two-terminal device, such as a crystal. Resistor $R_{measure}$ is typically chosen to be 10 times the maximum expected impedance of the device, so that the device is current-driven and the voltage across it is directly proportional to the impedance. If that value is impractically large, you can use a lower value of resistance and then calculate the correction factor for maximum impedance.

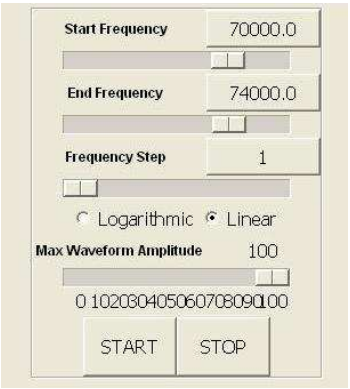


Figure 2: Narrowband Controls

Figure 2 shows the relevant controls of the VNA. Set the `Start Frequency`, `Stop Frequency` and `Frequency Step` to the desired range of frequencies. Small steps result in a long sweep time. Large steps may result in the loss of detail of the curve. In all cases, one can click on the slider label and enter a value from the computer keyboard.

Amplitude setting of the generator is also adjustable. As shown in figure 2, it's usually set to `Maximum` (about 3 volts peak), unless that overloads the device under test. A small auxilary display window shows the actual waveforms, in order to monitor for distortion. The VNA software uses a correlation process, so it can recover small, noisy signals. The available dynamic range is about 60db. If the result is below a threshold, the software throws up a warning and stops the sweep. This can be an issue when sweeping a filter with wide dynamic range and steep skirts. The solution is to start and end the sweep on the skirts of the filter.

Four Terminal Device

Figure 3 shows the connections for measuring the gain and phase of a four-terminal device. The device under test in this case is shown as a transformer with a tuned secondary, but other devices are of course possible.

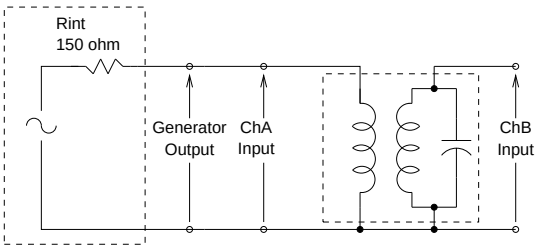
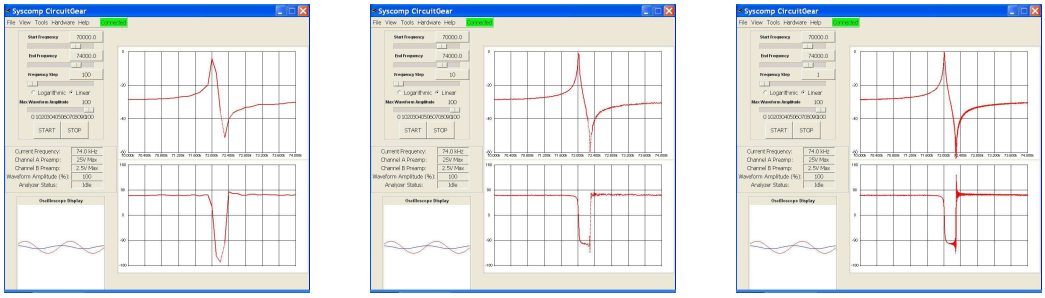


Figure 3: Connections, Four Terminal Network

Here are some examples, kindly provided by Gerard Mindel.

1. The cover image of this application note is the amplitude and phase response of a MURATA CFS455J Ceramic Filter, typically used in the IF filter of an AM radio.

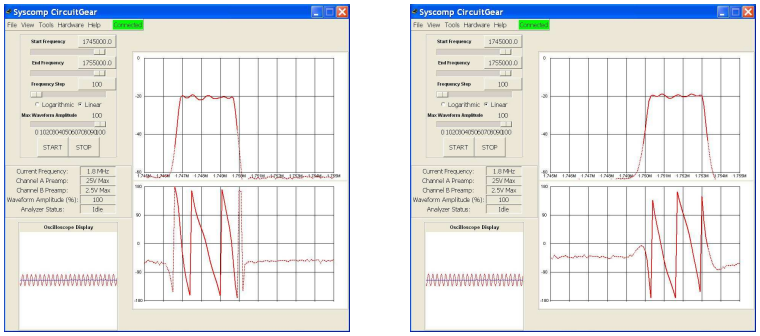
2. Impedance Curves for a 72KHz Crystal, at various sweep rates. Notice the loss of detail at higher sweep rates.



(a) 100Hz Steps (b) 10Hz Steps (c) 1Hz Steps

Figure 4: 72kHz Crystal Impedance

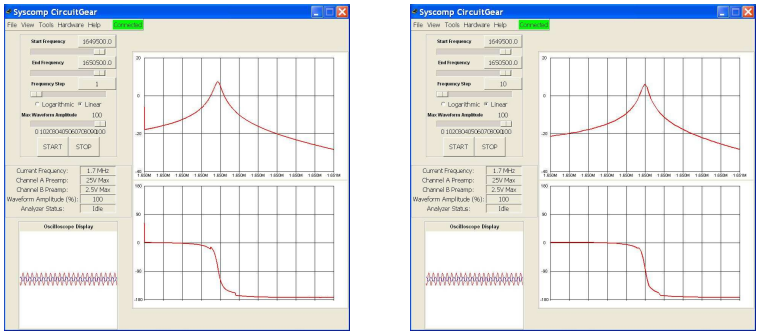
3. Frequency response of a 3kHz single-sideband filter.



(a) Lower Sideband Filter (b) Upper Sideband Filter

Figure 5: Sideband Filter

4. Effect of a trim capacitor on filter response.



(a) Without Trim Cap (b) With Trim Cap

Figure 6: Effect of Trim Capacitor

In figure 3, the network under test is shown connected directly to the generator and oscilloscope. It may be necessary, depending on the device under test, to add matching resistors: one in series with the input, and another as a load across the output. Keep in mind the internal resistance of the generator, 150Ω, which adds to the series input resistance.

Both the CircuitGear CGR-101 and CircuitGear Mini CGM-101 are equipped with a vector network analyser. The CircuitGear has a maximum generator and oscilloscope frequency of 2MHz. The Mini maximum frequency is a decade lower, 200kHz. Consequently, the CircuitGear is most appropriate for measurement of these RF filters and crystals. Either instrument is suitable for audio measurement and other low frequency measurements, such as the stability margin of a feedback system.

For the measurement of higher frequency devices, it would be necessary to translate the generator output up to the test frequency. The output of the device under test must then be translated back down to the generator frequency. This could be accomplished by the same *translation oscillator* and two frequency mixers.

Acknowledgement

Special thanks to Gerard Mindel, who provided the measurements shown in this note, and a number of suggestions related to the operation of the VNA.

References

[1] Measuring Frequency Response and Impedance of Guitar Pickups
`http://www.syscompdesign.com/assets/Images/AppNotes/guitar-pickups.pdf`

[2] *Audio Measurements with a Network Analyser*
`http://www.syscompdesign.com/assets/Images/AppNotes/audio-exercises.pdf`