How to Verify Time-Domain Signal Harmonics and Transfer into Frequency-Domain

Learning the basics of periodic waveforms like the sine wave can provide extremely powerful tools that can be used to explain and understand more complicated waveforms. From previous articles, we focus on a single sine waveform Now, let's take a look at a few other waveforms.

Here in Figure 1, we are sourcing a 5V sine wave into an oscilloscope:

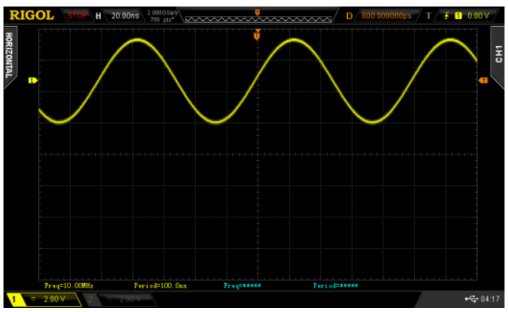

Figure 1: An Oscilloscope displaying a sine wave with a frequency of 10MHz.

You can see that the frequency is 10MHz.

Now, let's source a 20MHz sine wave at the same time and compare the two. So, we have a 10MHz sine wave and a 20MHz sine wave. (Figure 2)

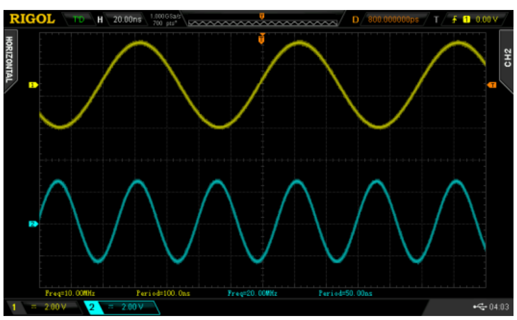

Figure 2: An Oscilloscope displaying a sine wave with a frequency of 10MHz (yellow) and another sine wave with a frequency of 20MHz (light blue).

What happens when we add them together?
The waveform changes. (Figure 3)

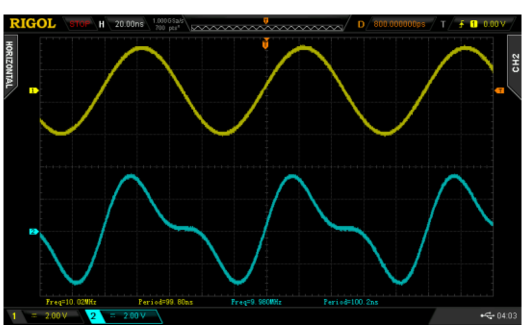

Figure 3: An Oscilloscope displaying a sine wave with a frequency of 10MHz (yellow) and a wave that is the addition of a 10MHz and a 20MHz sine wave (blue).

This is known as the superposition principle. You can add sine waves together and the resultant wave can have a drastically different shape than the original waveforms. To put it another way, any waveform can be constructed by the addition of simple sine waves.

Now, let’s discuss some basic terms. The fundamental frequency of the new waveform is the lowest repeated frequency. In this case, the fundamental frequency of the waveform is 10MHz.

The second harmonic is a waveform with a frequency that is twice the fundamental. In this case, the second harmonic is 20MHz (2*10MHz). You can continue on in this way to create any waveform.

Let's take a look at a special case. If you continue to add odd harmonics (1, 3, 5, 7, 9, etc..), you will build a square wave.

In Figure 4, there is a waveform that was built using odd harmonics:

Note that the waveform is starting to look more "square". But, the frequency of the main shape is still at 10MHz.

What would these waveforms look like in the frequency domain?

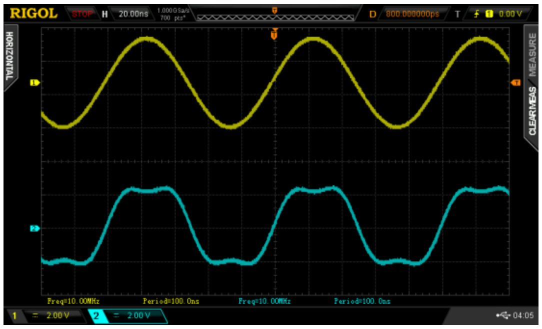

Figure 4: An Oscilloscope display showing a sine wave with a frequency of 10MHz (yellow) and a square waveform with a frequency of 10MHz (light blue).:

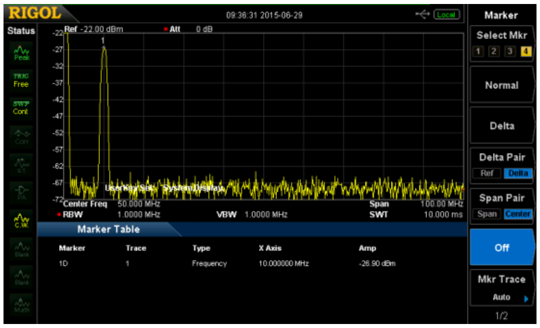

Figure 5: A 10MHz sine wave displayed on a spectrum analyzer. Note the peak at 10MHz.

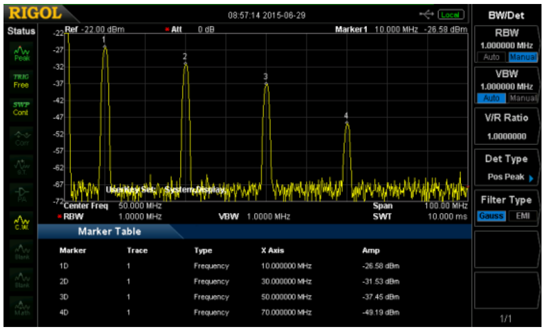

Figure 6: 10MHz square wave displayed on a spectrum analyzer.

A spectrum analyzer is an instrument that displays the amplitude vs. frequency for input signals.

If we source a 10MHz sine wave into a spectrum analyzer, we see a display like figure 5.

Now, let's look at the square waveform on a spectrum analyzer.

You can see the fundamental frequency at 10MHz, the 3rd (3*10MHZ = 30MHz), 5th (5*10MHz = 50MHz), and 7th (7*10MHz = 70MHz) harmonics are also shown on the display.

By visualizing the signal in frequency domain, we can easily see what frequencies we are sourcing as well as the power distribution for each frequency. Spectral analysis is critical in designing and troubleshooting communications circuits, radio/broadcast, transmitters/receivers, as well as Electromagnetic Compliance (EMC) measurements.

In the following chapters, we will explain spectrum analyzer design and techniques for using the instrument properly.

On a historical note, some of the most historically significant contributions to our understanding of waves were made by the French Mathematician Jean-Baptiste Joseph Fourier (21 March 1768 – 16 May 1830).

Fourier was investigating a solution to modeling the transfer of heat across a metal plate. As part of his work, he created a method of adding simple sine waves to create a more complicated waveform. His "Fourier Transform" has been used to solve many complex physical problems in Thermodynamics, Electronics. It also provides a way to convert signals captured in the time domain into the frequency domain.

This concept has had far reaching effects in electronics, communications, and the physical sciences. The superposition principle that we highlighted earlier is based on Fourier's initial research.