Phase Measurements on Burst Waveforms

APPLICATION BRIEF
LAB-WM779

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Summary

Performing measurements on burst waveforms is an application that shows the depth of LeCroy Oscilloscopes capabilities.

Figure 1 shows a typical burst waveform where it is desired to make a phase measurement between channel 2 and channel 3 using a LeCroy WavePro 715 Zi 1.5 GHz oscilloscope. The channel 2 and 3 signals could represent the input and output of an amplifier or other transmission device. The waveform consists of a150 MHz carrier amplitude modulated by a 1 kHz rectangular pulse with a 25% duty cycle. Figure 1 shows both channel 2 and 3 along with zoom expansions of both channels. The zoom traces Z2 and Z3 show the 150 MHz sinusoidal carrier.

In order to assure stable acquisition of the carrier the trigger has been set up to be an edge qualified trigger. The qualifier or ‘A’ event is the modulating signal source, in this case the 1 kHz pulse, applied to the scopes ‘Aux In’ connecter. External trigger is selected as the ‘A’ event source. The trigger source or ‘B’ event is channel 2.

Figure 1 **-** *The signals on which we will measure the phase difference consist of a 150 MHz carrier amplitude modulated by a 1 kHz rectangular pulse. The trigger dialog box shows the setup for an edge qualified trigger with a holdoff by 15,000 carrier cycles after the beginning of the burst.*

Since there may be some settling issues near the beginning and end of the burst it is desired to delay the trigger point well into the burst. This is accomplished by selecting holdoff by events. In Figure 1, the “When ‘B’ Occurs” section of the trigger dialog box shows the setup for a delay by 15,000 cycles of the carrier.

Note also, that the Sin(x)/x interpolation has been turned on in both input channels. This action up-samples the data by a factor of 10:1 and helps improve the phase measurement. Vertical amplitude scales are set to use as much of the scopes 8 vertical divisions as possible. This uses the full dynamic range of the scope channel, increasing the channel’s signal to noise ratio. This will also minimize uncertainty in the phase measurement.

The phase measurement has been turned on looking at the zoom traces as their source. Note that the standard deviation, abbreviated as ‘sdev’, is about 0.6°. The range (max-min) of the phase measurement is 3.4° which is larger than the desired 1°. This uncertainty is mostly due to vertical noise on the signal which is varying the measurement threshold crossing. We can minimize this by filtering the signals or averaging.

Let’s change the setup to improve measurement accuracy and decrease measurement processing time.

While we could work with the data shown below we really don’t need 20 Mpoints worth of data to make the phase measurements in the middle of the burst. We can decrease the horizontal scale factor and ac quire a small number of cycles near the trigger point. We also do not need the zoom traces to do this. In Figure 2 the setup has been changed to look at a group of 14 cycles spanning the trigger point.

Figure 2 *- Changing the scope acquisition setup to improve measurement accuracy and measurement throughput.*

The phase measurement source is now channels 2 and 3 directly rather than through the zoom traces. The 'A' in the channel trace annotation boxes indicates that averaging has been turned on. In this case 256 acquisitions are averaged before the measurement is made. Note that the standard deviation of the measurement is only 0.025° and that the range of the measurement is 0.9°. This is a major improvement in the measurement accuracy. The cost for this is increased time to acquire the data for each measurement. For a Gaussian distribution the standard deviation should decrease by the square root of the number of averages.

Figure 3 shows the use of a histogram and trend of the phase parameter. These help analyze the distribution of measured values and the variation in the parameter value over multiple measurements. The trend shows each measured value of phase.

If the data is not repetitive or if the averaging time is an issue then an alternative method would be to use the narrow band phase parameter (nbph). Narrow band phase, shown in Figure 4, provides a measurement of the phase at a specific frequency for a waveform. As described in the oscilloscope user's manual: "The nbph is the phase of the Discrete Fourier Transform (DFT) computed on a waveform at a specific frequency. The result is the phase of the corresponding frequency sine wave component of the waveform at the first data point between the parameter cursors. The nbph parameter calculates one bin of a DFT centered at the frequency provided.

Figure 3 *- Using the histogram and trending functions to analyze phase parameter variations*

The bin width is 0.105% of the frequency selected if the waveform trace displayed by the oscilloscope is 960 x (1/frequency) or more in length (i.e., the trace equal to or longer than 960 cycles of a waveform at the selected frequency). Otherwise, the bin width is: 100/integer[(trace length)/(1/frequency)] % where integer[ ] designates discarding any fractional portions in the result. Thus, if the waveform trace is 48.5 times longer than 1/frequency, the bin width will be: 100/48 = 2.1% of the selected frequency."

This means that the measurement uncertainty decreases with an increasing number of cycles included within the measurement window. This is because the measurement bandwidth decreases with an increasing number of cycles up to a maximum of 960 cycles. After that it remains constant. Reducing the measurement bandwidth decreases noise and thereby improves the signal to noise ratio.

In order to use nbph to measure phase difference we measure the parameter for both channel 2 and channel 3. Using parameter math we compute the difference as shown in the readout field for parameter, P7. Note that the mean phase difference is 3.14° with a standard deviation of 0.081°. At the same time the standard phase measurement parameter, without averaging, shows a standard deviation of 0.5°.

Histograms of both the phase parameter, trace F1, and nbph parameter, trace F3, are shown in Figure 4. The nbph histogram has a narrower distribution confirming the differences in the standard deviations. Basically, this means that the nbph measurement, under these conditions, has much less uncertainty.

Figure 4 *- Setup for the narrow band phase (nbph) parameter*

You can also compare the range of the parameter variation, this is the peak to peak variation. Note that the nbph measurement only has a range (parameter P10) of 0.54°, certainly well within the 1 ° accuracy limit we discussed earlier.

Whichever method you chose, use the parameter statistics to understand the uncertainty in the measurement.

The final topic is that of the track function. Track, like trend, produces a waveform based on a series of measured parameter values. Unlike a trend which shows one point per measurement, track shows the parameter values versus time. An example can be seen in Figure 5.

Here we have captured the entire burst. The phase parameter, gated from 28% to 80% of the acquisition is plotted as a track function in trace F2. This is a plot of phase versus time during the burst. Trace F3 is a zoom of the track showing the phase variation during the start of the burst. The track function provides a phase profile over the duration of the burst.

In summary we have discussed two different methods of measuring phase difference, the phase parameter and the narrow band phase. Narrow band phase generally produces results with less uncertainty. The factors affecting the uncertainty in each measurement were examined. We have also looked at using parameter statistics and parameter track, trend, and histograms to help analyze the measured data. In each instance we have shown methods which can measure phase with accuracies within 1 °.

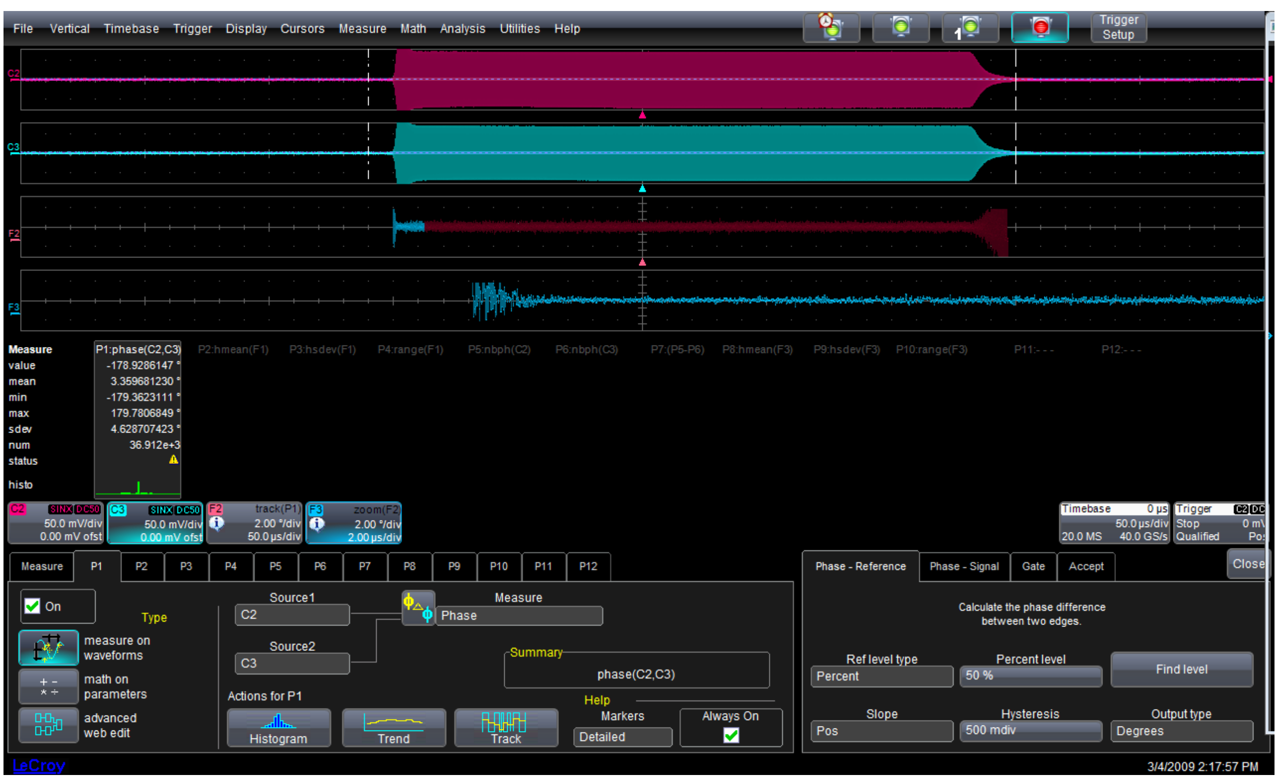

***Figure 5** – Using the track function of the phase parameter to show a phase profile versus time*