Using ALICE XY display and The Lissajous Pattern

All periodic signals can be described in terms of amplitude and phase. We all learn that in basic circuit theory classes. You surely have needed to calculate a signal's phase change when it passes through a circuit. Fortunately, you can measure phase on the lab bench with oscilloscope hardware such as the ADALM1000 and its accompanying ALICE 1.3 desktop software using several methods.

By way of a little background reminder, phase difference, or phase angle, is the difference in phase between the same points, say a zero crossing, in two different waveforms with the same frequency. A common example is the phase difference between the input signal and output signal after it passes through a circuit, cable, or PC board trace. A waveform with a leading phase has a specific point occurring earlier in time than the same point on the other signal. That would be the case of when a signal passes through, a capacitor: the current in the capacitor will lead the voltage across the capacitor by 90°. Conversely, a waveform with lagging phase has a specific point occurring later in time than the other paired signal waveform. Two signals are in opposition if they are 180° out of phase. Signals that differ in phase by ±90° are in phase quadrature (one quarter of 360°).

The time (phase) relationship between two sine waves can of course be measured from a time domain plot such as figure 1. The Time measurement capabilities of ALICE can display the relative phase between channel A and channel B in degrees and/or the time delay between A and B. The software scans the waveforms looking for the time points where they cross their average value (zero crossing with DC offset removed). It then uses those time points to report frequency, period, phase, delay, duty-cycle etc. Noise and jitter will introduce errors in the results.
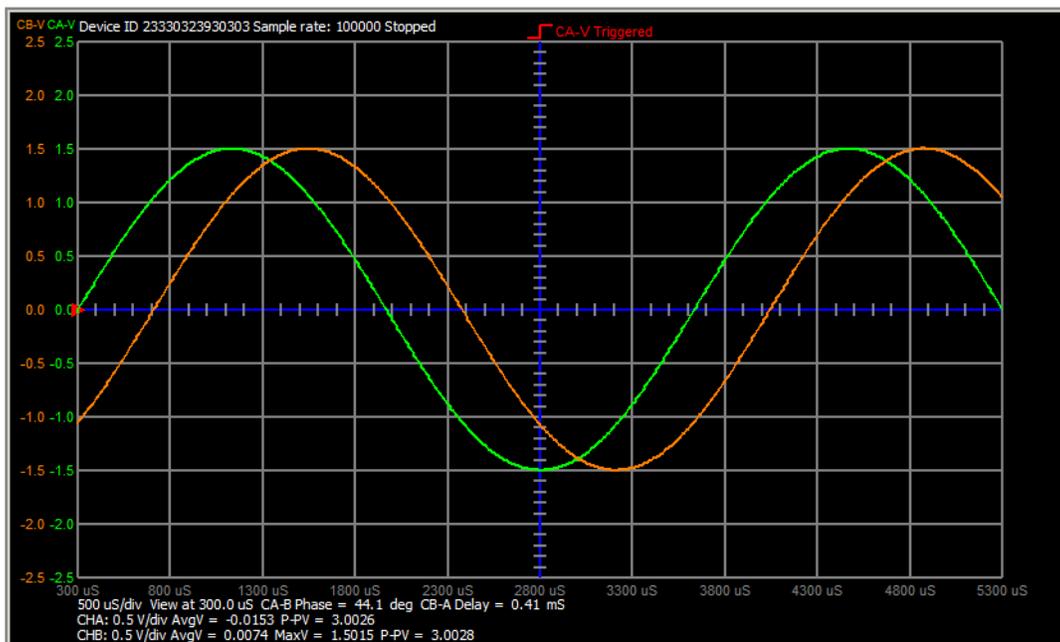

Figure 1 Time plot of two sine waves

Old timers who started out their careers using an analog oscilloscope probably remember using the Lissajous pattern to measure the phase difference of two sine waves. It can be measured by cross plotting the two sine waveforms on the X-Y display in ALICE as shown in Figure 2. In this figure, the waveform on channel A provides the horizontal or X displacement. Channel B provides the vertical or Y deflection. The Lissajous pattern indicates the phase difference by the shape of the X-Y plot. A straight line indicates a 0° or 180° phase difference. The angle of the line depends on the difference in amplitude between the two signals, a line at 45° to the horizontal means the amplitudes are equal. While a circle indicates a 90° difference. It will only be a true circle if the amplitudes are equal. Phase

differences between 0° and 90° appear as tilted ellipses and phase is determined by measuring the maximum vertical deflection (Y_{max}) and the vertical deflection at zero horizontal deflection ($Y_{x=0}$). In Figure 2, cursors mark these two locations on the X-Y plot. Note that this is only valid if the X-Y plot is centered on 0,0. Any DC offset in the two waveforms must be removed first.
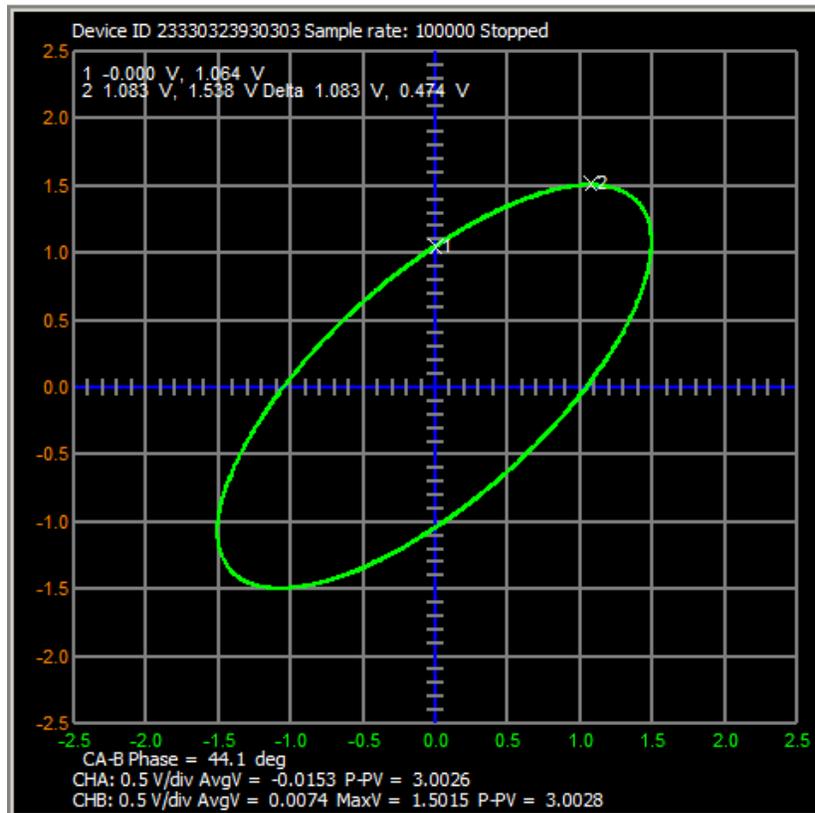

Figure 2 Using the XY display lets you measure the phase difference between two sine waves.

Marker readouts in upper left of the plot show the required values for computing the phase difference.

$\Phi2 - \Phi1 = \pm \sin^{-1} (Y_{x=0}/Y_{max})$ for when the top of the ellipse is located in quadrant 1

$\Phi2 - \Phi1 = \pm 180-\sin^{-1} (Y_{x=0}/Y_{max})$ for when the top of the ellipse is located in quadrant 2

The sign of the phase difference is determined by inspecting the channel time traces.

In the figure 2 example, the Y_{max} value is 1.538, $Y_{x=0}$ is 1.064, and the top of the ellipse is in Q1:

$\Phi2 - \Phi1 = \pm \sin^{-1} (1.064/1.538) = \pm \sin^{-1} (0.692) = 44°$

The accuracy of this method is dependent on the placement of the cursors but it produces reasonable results with certain artistic panache.

Hardware like the ADALM1000 and ALICE desktop software offer multiple techniques to measure phase. Direct measurement in the time domain supports both static and dynamic measurements of phase. Frequency domain based calculation provides somewhat more accurate results for static phase measurements but requires you to take the difference of the FFT phase data at the fundamental frequency. This can be done using the Spectrum Analyzer tool in ALICE.