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# UNDERSTANDING HISTOGRAMS (WR_XI NOTE 2)

Histograms are a very powerful tool for understanding random events like noise and jitter. LeCroy's WaveRunner Xi oscilloscopes include histograms of parameters as a standard feature, bringing this valuable tool to more scope users. Histograms represent large amounts of data in a very compact graphical format. Figure 1 shows a histogram of the parameter frequency. The histogram is formed by taking the range of frequency values from the highest to the lowest and dividing it up into equal width bins. Then the number of measured values that fall within each of these bins is used as the vertical magnitude of the histogram. Since the histogram usually is used to characterize random events a whole series of histogram specific measurement parameters have been developed to describe the data shown in the histogram.

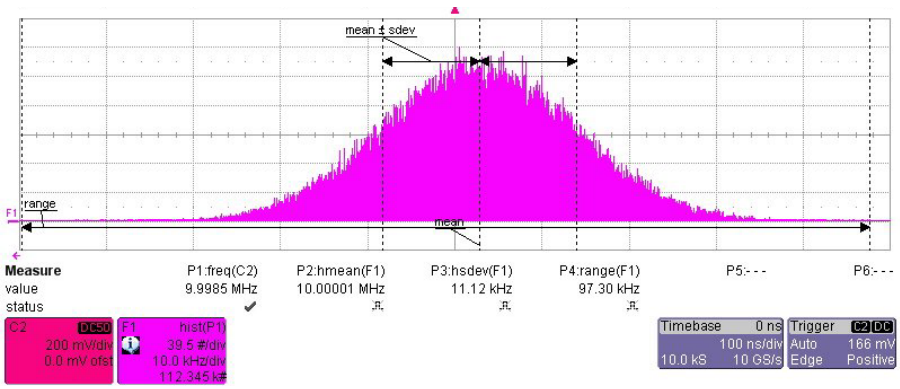


**Figure 1: A histogram of the frequency parameter showing a Gaussian or Normal distribution characterized by histogram parameters.**

The key histogram parameters are mean, standard deviation, range, and total population. These statistics are included in the standard scope configuration as part of the parameter readout. The mean or expected value is the average of all the values measured. It represents the best estimate of the measured value and as the vertical line marked "Mean" in Figure 1.

The standard deviation is a measurement of the distribution of the data about the mean value. Sixty-eight percent of all the measured values fall within ± one standard deviation from the mean value. This is shown as the data between the lines marked "mean ± sdev" in Figure 1. For a signal with zero mean the standard deviation is equivalent to the root mean square (rms) value of the measured parameter.

The range, as indicated by the horizontal line beneath the histogram in Figure 1, is the difference between the highest and lowest value in the histogram. The physical interpretation of range is as the peak-to-peak value of the binned parameter being histogrammed. For random processes the range is unbounded so any attempts to compare range figures should take into account the number of measurements included in the histogram, which is the total population..

The total population is the total number of measurements included in the histogram. It can be found in the trace descriptor box for the histogram in Figure 1 where it is the bottom number in the list. In this example measurement, the total population is 112,345 measured values of the frequency parameter.

In Figure 1, notice in addition to the frequency parameter, P1, three other parameters: Hmean, Hsdev, and Hrange. These are three of the histogram parameters included in the optional WRXi-STAT Advanced Statistics option. This option increases the total population limit in a histogram from the standard 1000 values to 2 billion values and adds 18 specialized histogram related parameters. A summary of the optional parameters is given in Table 1.

As an example of how these specialized parameters may be used, consider the example in Figure 2. The histogram of frequency in this figure is derived from a frequency modulated signal. The peak-to-peak frequency deviation

is the difference between the two peaks, which can be read directly by the histogram amplitude (hist ampl) parameter. While the histogram top and histogram base read the absolute frequency values of the maximum and minimum frequency excursion.

It is also possible to use cursors to interpret some histogram characteristics like top, base, and range. Other histogram characteristics such as mean and standard deviation require the use of the histogram parameters.

So as you can see histograms convey a lot of information in a very compact format that can be measured and analyzed using the specialized histogram parameters to extract information. These are certainly things that you will want to consider for your next oscilloscope.

**Table 1. The Optional Histogram Parameters**

| | |
|---|---|
| hist ampl -- | histogram amplitude between two largest peaks |
| hist base -- | histogram base or leftmost of two largest peaks |
| hist max -- | value of the highest (right-most) populated bin in a histogram |
| hist mean -- | average or mean value of data in the histogram |
| hist median -- | value of the x-axis of a histogram that divides the population into two equal halves |
| hist min -- | value of the lowest (left-most) populated bin in a histogram |
| hist rms -- | rms value of data in histogram |
| hist sdev -- | standard deviation of values in a histogram |
| hist top -- | histogram top or rightmost of two largest peaks |
| max populate -- | population of most populated bin in histogram |
| mode -- | data value of most populated bin in histogram |
| percentile -- | data value in histogram for which specified `x'% of population is smaller |
| peaks -- | number of peaks in histogram |
| pop @ x -- | population of bin for specified horizontal coordinate |
| range -- | difference between highest and lowest data values |
| total pop -- | total population in histogram |
| x at peak -- | x-axis position of specified largest peak |

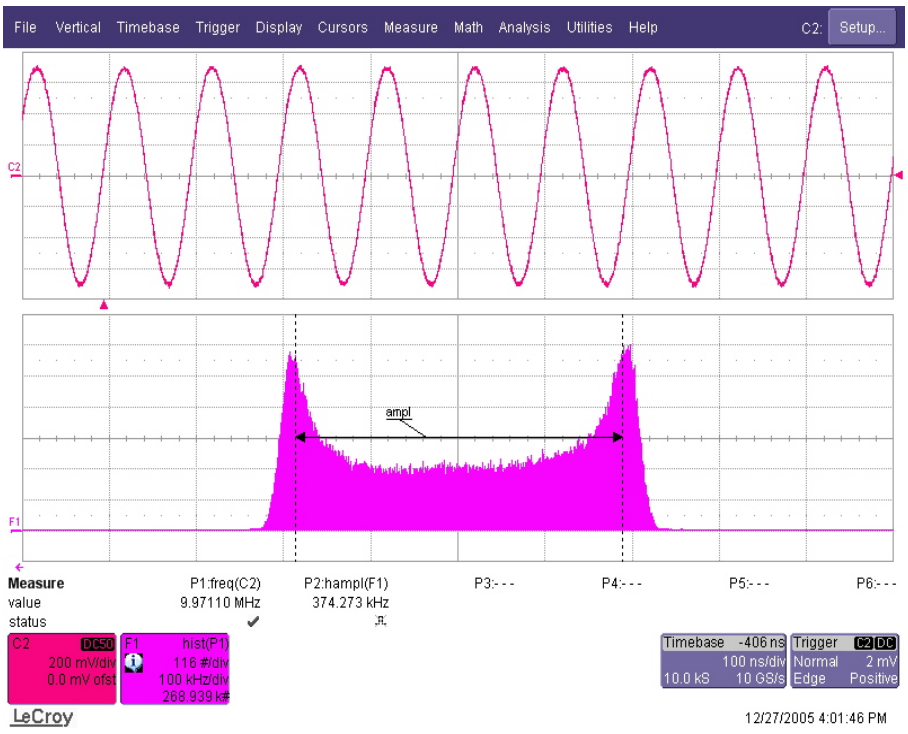


**Figure 2: An example of using the histogram parameters to read the peak-to-peak frequency deviation in an FM signal, using histogram amplitude**