Errata

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HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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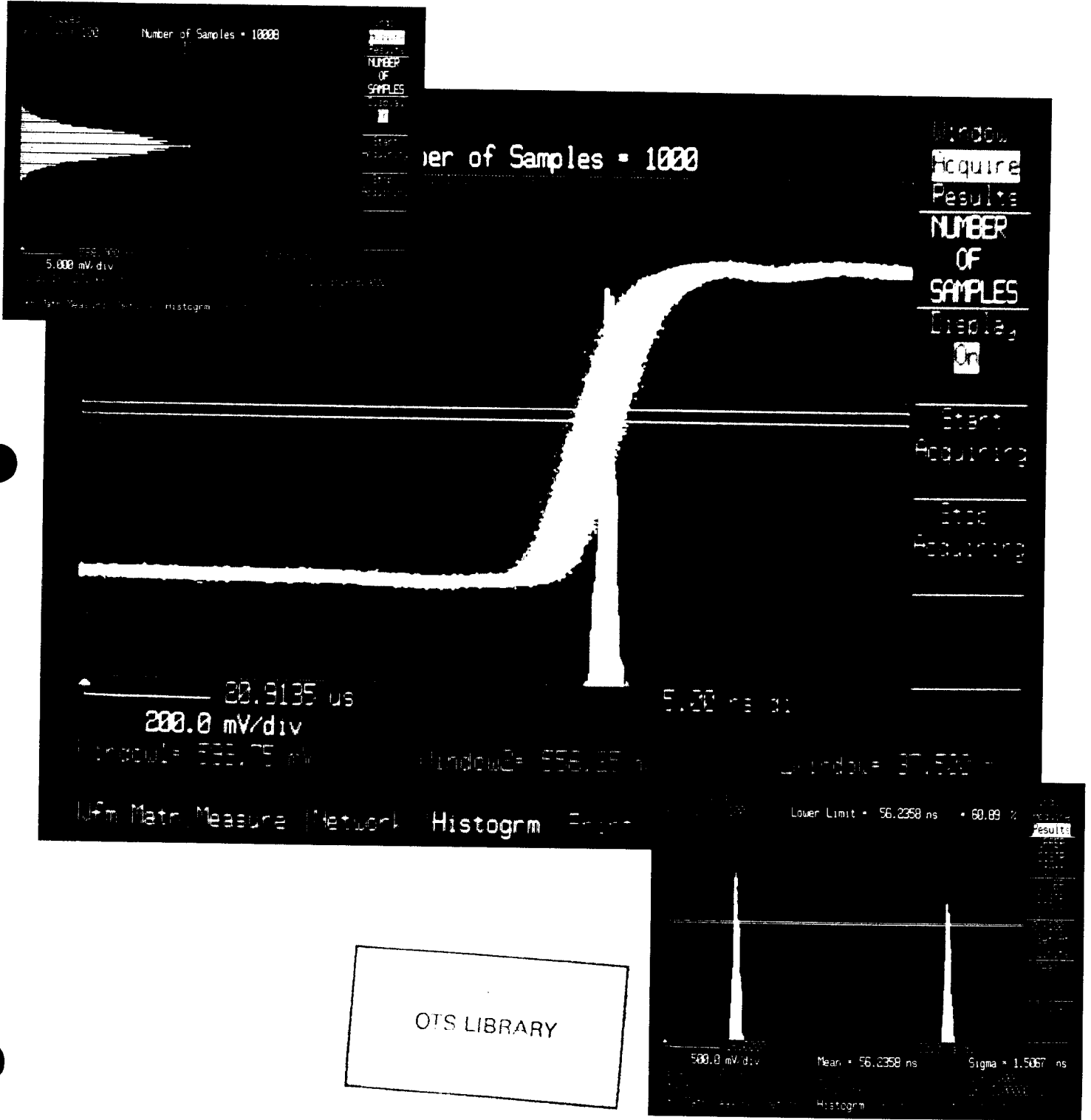
Agilent Technologies

Histograms and Statistical Analysis of Signals
For Use With HP 54120T: Digitizing Oscilloscope

(hp) **HEWLETT PACKARD**

BDVM

Product Note 54120-1

I. Introduction

The HP 54120T digitizing oscilloscope features a histogram function that allows the user to quantify measurements via statistics. As a result, signal characteristics may be measured in ways previously impossible. Two of the most common applications arc measuring jitter and noise on a signal. With the advent of infinite persistence in conjunction with the histogram function, traditional eye diagrams may be quantified like never before. Related statistical information will be covered, followed by 54120T sampling and histograms. Next, time and voltage histogram analysis will be examined along with eye diagram analysis.

II. Basics of Statistics

The HP 54120T digitizing oscilloscope provides two valuable pieces of statistical information with push-button ease: the sample mean and standard deviation.

The sample mean, denoted $\overline{X}$, is the most common way of measuring the center of a set of data. The mean is defined by:

> *Equation 1.* $\quad \overline{x} = \left(^1/n\right) \sum\limits_{i=1}^{n} x\, i$
>
> where: n = number of samples
>
> $\qquad$ x = value of each sample

Example 1. Sample Mean

Determine the sample mean of the random sample whose observations are: $-1, 1, 0, -1.5, 0, 1.5$.

$$\overline{x} = {}^1/_6 \left(-1 + 1 + 0 - 1.5 + 0 + 1.5\right) = 0.0$$

It should be noted that X is an unbiased estimator of the true mean of the the population, μ (mu). Therefore, the sample mean approaches the true mean for a large sample number, n.

The sample standard deviation, denoted S, is a measure of the extent to which the data points deviate from the mean. It is essentially the square root of the average squared deviations from the mean.

> *Equation 2.*
>
> $$S = \sqrt{\left(^1/_{n-1}\right) \sum\limits_{i=1}^{n} \left(x\, i - \overline{x}\right)^2}$$

Example 2. Sample Standard Deviation

Using the sample data as in EXAMPLE 1, determine the standard deviation.

$$S = \sqrt{{}^1/_5 \left[\left(-1\right)^2 + \left(1\right)^2 + \left(0\right)^2 + \left(-1.5\right)^2 + \left(0\right)^2 + \left(1.5\right)^2\right]}$$

$$= \sqrt{{}^1/_5 \left(6.5\right)} = 1.14018$$

S is a biased estimator of the true standard deviation, Σ (sigma) of the entire population. However, for a large sample, S is commonly used to estimate sigma.

Another value of concern is the root-mean-square (rms). The equation for the rms value is given below:

> *Equation 3.*
>
> $$RMS = \sqrt{\left(^1/_n\right) \sum\limits_{i=1}^{n} x\, i^2}$$

Example 3. RMS Value

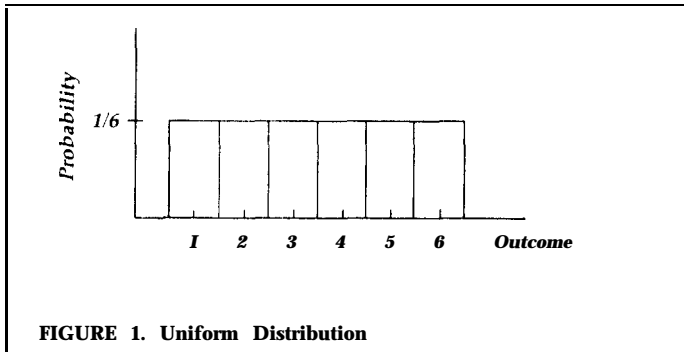Using the same data as in EXAMPLES 1 and 2, determine the rms value.

$$RMS = \sqrt{{}^1/_6 \left[\left(-1\right)^2 + \left(1\right)^2 + \left(0\right)^2 + \left(-1.5\right)^2 + \left(0\right)^2 + \left(1.5\right)^2\right]}$$

$$\sqrt{{}^1/_6 \left(6.5\right)} = 1.04083$$

It should be noted that the rms value is virtually identical to the formula for the standard deviation with a mean of 0, as in this example. With a mean of 0, the rms value and sigma will approach each other as the sample number increases. The rms value for a normal distribution, to be discussed later, is one sigma.
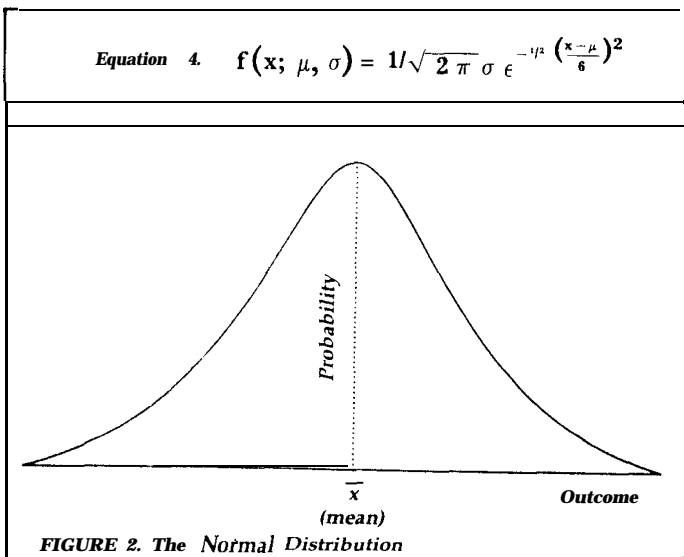
Distributions

Data may take on one of many probability density functions, or distributions. Some of the most common distributions will be discussed.
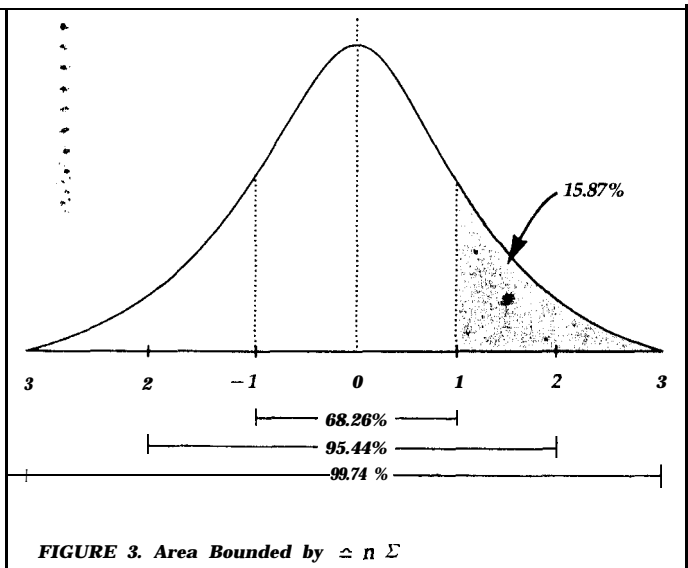
The uniform distribution assumes all its values, or possible outcomes, have an equal probability of occuring, such as rolling a die as shown below:

FIGURE 1. Uniform Distribution

The normal distribution, the bell-shaped curve, and the Gaussian distribution all (describe the distribution in FIGURE 2. Gauss derived the equation for this distribution while studying errors in repeated measurements of the same quantity (See Equation 4.). The distribution is symmetric about the mean and the shape of the distribution is a function of the standard deviation.

$$\text{Equation 4.} \quad f\left(x; \mu, \sigma\right) = 1/\sqrt{2\pi}\,\sigma\,\epsilon^{-1/2\left(\frac{x-\mu}{6}\right)^2}$$

FIGURE 2. The Normal Distribution

In a normal distribution, the area under the curve to the right of the positive one standard deviation (sigma) point is 15.87% of the total area under the curve. Therefore the area under the curve bounded by the one standard deviation points is 68.26% of the total. Similarly, the area bounded by the two and three standard deviation points is 95.44% and 99.74%, respectively.

15.87%

68.26%
95.44%
99.74 %

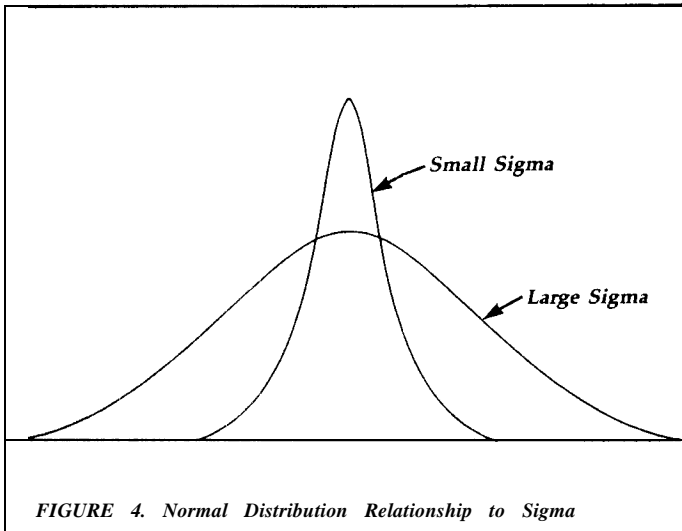FIGURE 3. Area Bounded by $\simeq$ n Σ

In a similar fashion, Table 1 was constructed, giving the percentage of the area bounded by standard deviations on each side of the mean.

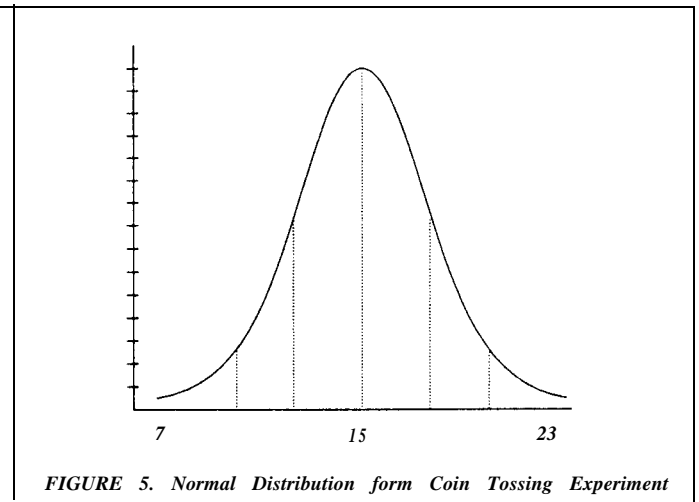TABLE 1. Standard Deviation and % Area

Range (standard deviations)	Area (%)
-0.5 to 0.5	38.30
-1.0 to 1.0	68.26
-1.5 to 1.5	86.64
-2.0 to 2.0	95.44
-2.5 to 2.5	98.76
-3.0 to 3.0	99.74
-3.5 to 3.5	99.99

FIGURE 4 illustrates that the larger the standard deviation, the more spread out the data.

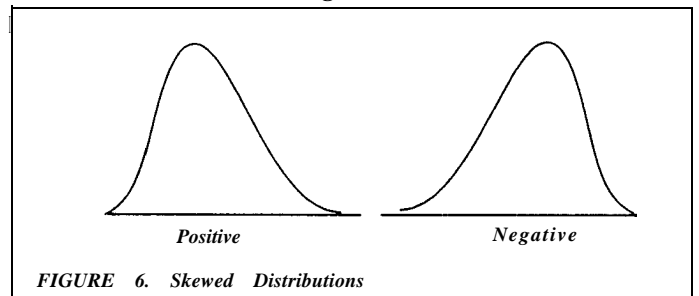FIGURE 4. Normal Distribution Relationship to Sigma

Example 4. Normal Distribution

Suppose a fair coin was tossed 30 times in each of 1000 trials. The number of heads was counted.

TABLE 2. Coin Tossing Experiment

Number of Heads per Trial	Frequency
6	1
7	2
8	4
Y	12
10	27
11	57
12	80
13	111
14	134
15	145
16	134
17	111
18	80
19	56
20	27
21	12
22	4
23	2
24	1

CALCULATIONS:

1. $\bar{X} = 1/n \sum_{i=1}^{n} Xi = \dfrac{(6 \times 1) + (7 \times 2) + (8 \times 4) + ... + (24 \times 1)}{1000}$

$= \dfrac{14997}{1000} = 14.997$

2. $S = \sqrt{1/n-1 \sum_{i=1}^{n} (X_i - \bar{X})^2} = \sqrt{\dfrac{11999 \ 1/6\cdot14.997 \ + 2 \ 7\cdot14.997}{4(8-14.997) \ + ...1(24-14.997)}}$

$= 2.7268$

The distribution is normal with a mean of 14.997, as expected The standard deviaton Σ (sigma) is 2.7268. Therefore, approximately 99.74% of the time the outcome should be plus or minus three sigma of the mean. In other words, 99.74% of the time the outcome should be between 7 and 23 heads. The trials with outcomes outside of these extremes have a probability of only 0.26% (see figure 5).

7   15   23

FIGURE 5. Normal Distribution form Coin Tossing Experiment

If the mean is not centered at the peak value, the distribution is asymmetrical and said to be skewed. A positively-skewed distribution has a long "tail" on its right side, while a negatively-skewed distribution has a long "tail" on its left side as shown below: (see figure 6).

Positive   Negative

FIGURE 6. Skewed Distributions

For a positively-skewed distribution, the mean is to the right of the peak value and the mean is to the left of the peak value for a negatively-skewed distribution. The standard deviations of skewed distributions tend to be large because of the long tail. Sigma is greatly affected by low probability points because the deviations from the mean are squared. Commonly in statistical analysis a skewed distribution indicates that there is some degree of bias in the data. In other words, the distribution may be truncated at at one end or there may be a problem with the process being sampled or the sampling method.

Derivation of the Histogram

The histogram is a graphical method of displaying data derived from a frequency table. Data may be expressed in a frequency table by counting the number of times an observation occurs in certain intervals.

Example 5. Frequency Table

Assume the HP 54120T oscilloscope has acquired the following voltage data (table 3). Table 4 is a frequency table formed from the following data with 0.5-mV intervals:

TABLE 3. Sample Data for EXAMPLE 5

Trial	Voltage (mV)	Trial	Voltage (mV)
1	3.41	16	3.51
2	3.33	17	2.93
3	3.59	18	3.42
4	2.96	19	4.68
5	2.91	20	3.05
6	3.20	21	2.70
7	4.13	22	3.36
8	2.98	23	4.27
9	3.05	24	3.52
10	3.64	25	3.33
11	3.36	26	2.89
12	2.49	27	3.50
13	1.71	28	3.53
14	3.53	29	2.41
15	3.35	30	3.57

The number of samples in each interval are tallied, counted, and displayed in Table 4.

TABLE 4. Frequency Table

Voltage Interval	Tally	Frequency
1.50-1.99	1	1
2.00-2.49	11	2
2.50-2.99	1111111	7
3.00-3.49	1111111111	10
3.50-3.99	1111111	7
4.00-4.49	11	2
4.50-4.99	1	1

mean = 3.2770 mV   sigma = 0.5637 mV

Example 6. Derivation of Histogram From Frequency Table

FIGURE 7 is a histogram of the frequency table. The frequency table is easily converted into a histogram, centering each bar at the mean value of each interval (i.e. 1.75 mV is the center of the 1.50-1.99 interval).
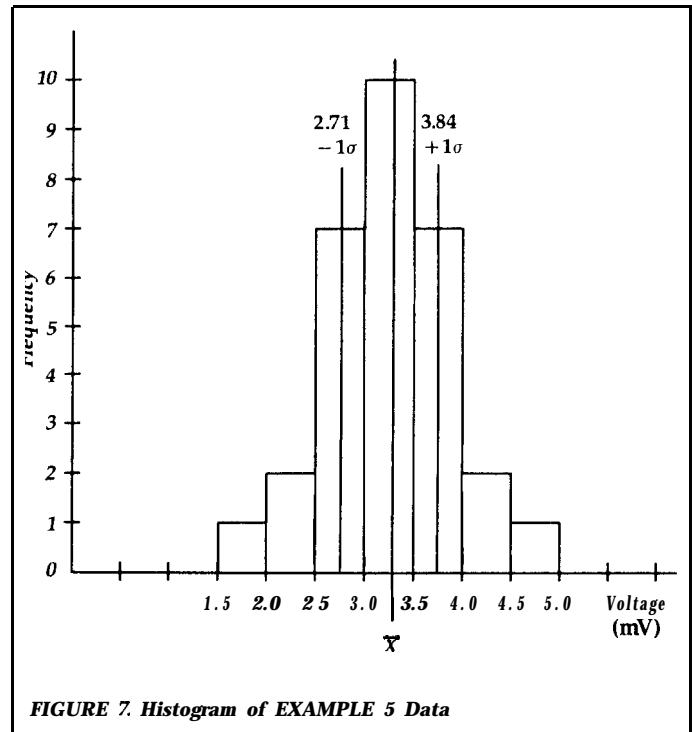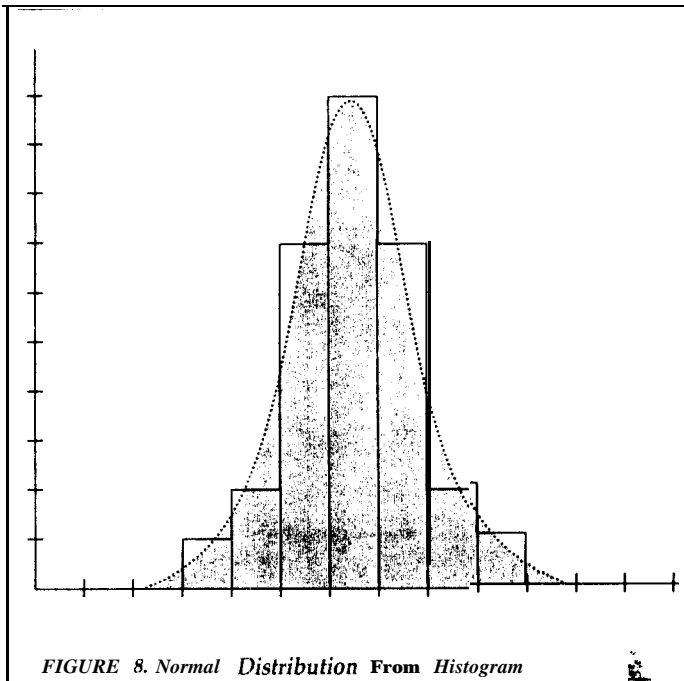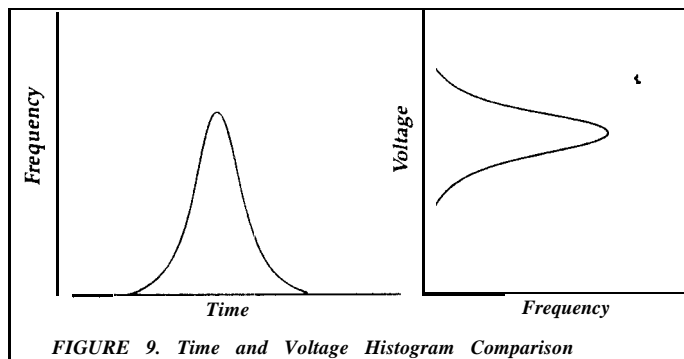

FIGURE 7. Histogram of EXAMPLE 5 Data

As the histogram is broken up into more and more intervals or "buckets", the histogram takes the form of a smooth continuous function. At this point conclusions may be drawn about the distribution. For instance, the distribution may be uniform, skewed, or perhaps normal as in this example. The mean and sigma are also calculated using Equations 1 and 2. Assuming a normal distribution, 68.26% of the data falls within plus or minus one sigma (0.5637 mV) of the mean (3.2770 mV).

FIGURE 8. Normal *Distribution* From *Histogram*

III. HP 541201' Histograms

The HP 54120T digitizing oscilloscope offers two kinds of histograms: time and voltage. The histograms are configured by counting the frequency of "hits" in small voltage or time intervals or "buckets." This is similar to the way the frequency table and histogram were constructed earlier.

FIGURE 9. *Time and Voltage Histogram Comparison*

Histograms may be produced by analysis of data in either the voltage or time axis of the oscilloscope. The data for the histogram is gathered from a window defined by the user. (see figure 10). A voltage histogram will be produced from data that is gathered from a specified time interval. A time histogram will be produced from data that is gathered from a specified voltage range.
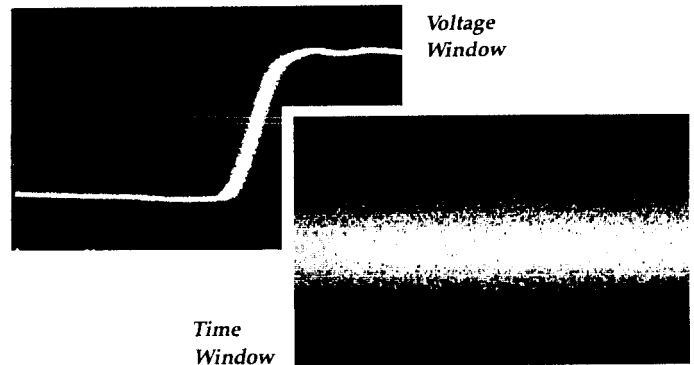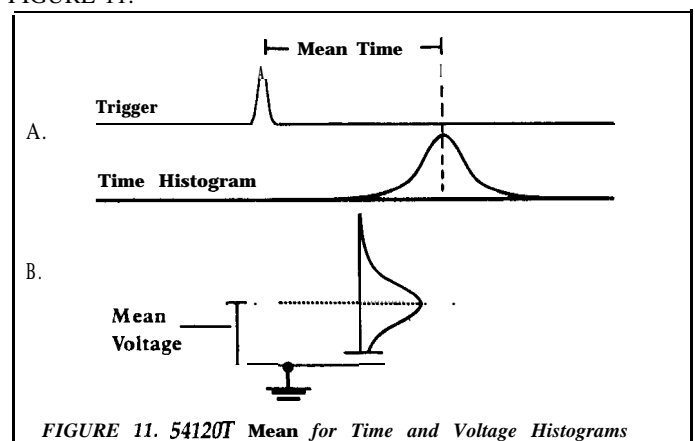

FIGURE 10. *Voltage and Time Window Comparison*

HP 54120T Mean and Sigma

The HP 54120T calculates the mean and sigma automatically. It does not rely on the assumption that the data is of a particular distribution to determine the sample mean or standard deviation (sigma). The microprocessor-controlled acquisition allows the oscilloscope to store and display every data point. Therefore, the sample mean and standard deviation are easily computed by the microprocessor using Equations 1 and 2, respectively.

The mean for time histograms is the time from the trigger point to the sample average. The mean for voltage histograms is the average voltage with respect to ground reference. See FIGURE 11.

FIGURE 11. 54120T **Mean** *for Time and Voltage Histograms*

Histogram measurements require a three-step process. This process is controlled by the uppermost key in the histogram menu. The first step is to select the part of the waveform to be analyzed in the WINDOW menu. The second step is to gather the data for the histogram in the ACQUIRE menu. The final step of the process is the calculation of the mean and sigma in the RESULTS menu. The step-by-step procedures for making time and voltage histograms are outlined in Section 3 of the Getting Started Guide for the HP 54120T Digitizing Oscilloscope.

HP 54120T Sample Number, Repeatability, and Window Size Comparisons

The HP 54120T digitizing oscilloscope allows the user to produce histograms, specifing the number of samples (between 100 and 655,000,000) to be taken. The sampling rate is dependent on the trigger repetition rate, the time base range, and the width of the window (the larger the window, the faster the sampling rate). A typical sampling rate is 4,500 samples per second. There is a tradeoff between the time it takes to sample (acquisition time) and the accuracy of the histogram. If the sampling is taking too long, the user may STOP the sampling and a histogram will be produced based on the samples acquired.

Example 7. Relationship Between Sample Number, Acquisition Time, and Results

To illustrate the relationship between the number of samples, the acquisition time, and the results, a signal was sampled with the same time window. The number of samples was the only variable.

From FIGURE 12 it is apparent that the distribution becomes smoother and fills in with an increase in the number of samples. It should also be noted that the mean and the standard deviation varied very little as the sample number varied from 100 to 1,000,000. The acquisition time was proportional to the number of samples taken. Again, the accuracy is proportional to the number of samples.

Making statistical measurements such as NOISE or JITTER analysis by use of an analog oscilloscope has produced unsatisfactory results. The analog oscilloscope's data gathering ability is a function of intensity and focus settings, as well as CRT writing rate. These variables make comparisons of test results very difficult if not impossible. This is not the case for the HP 54120T because this digitizing oscilloscope stores all the data for analysis. Repeatability of measurements makes comparisons and analysis an easy process. This is shown in figures 12 and 13.
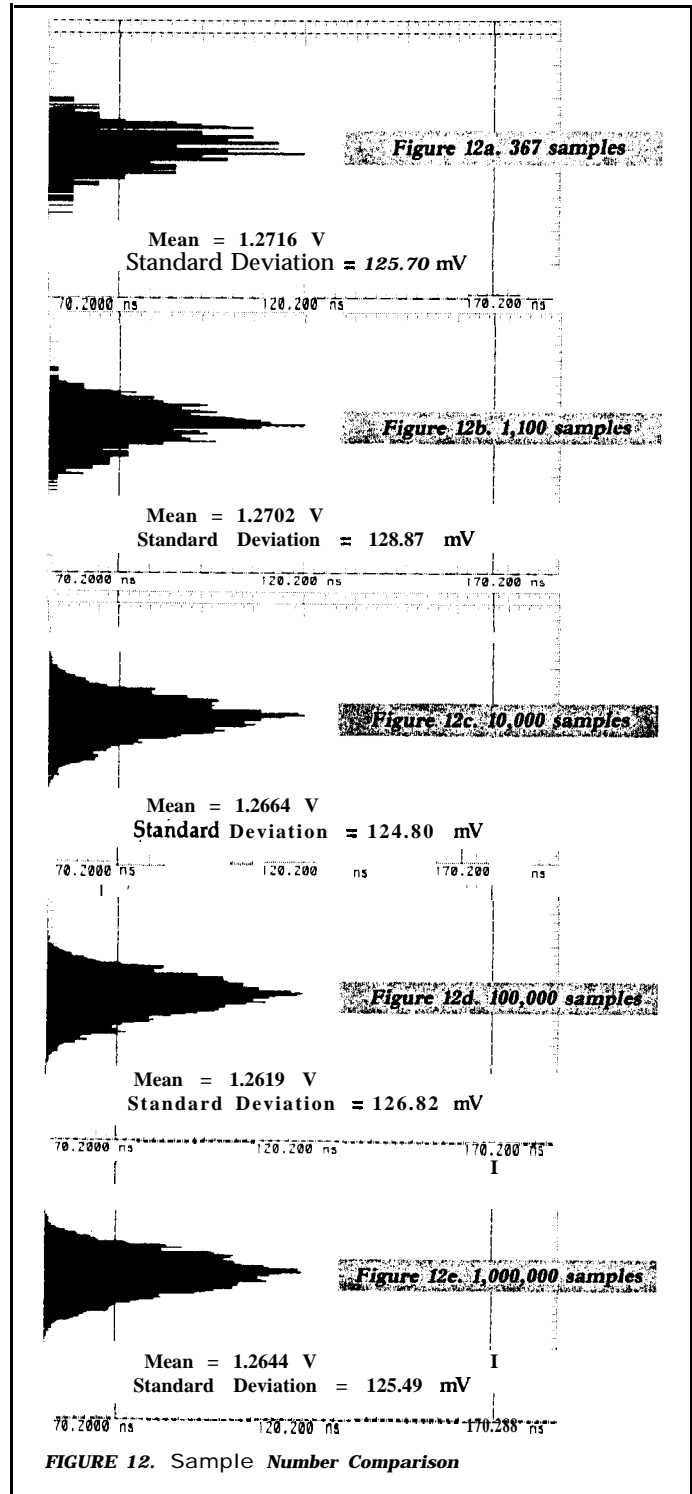

Figure 12a. 367 samples

Mean = 1.2716 V
Standard Deviation = 125.70 mV

Figure 12b. 1,100 samples

Mean = 1.2702 V
Standard Deviation = 128.87 mV

Figure 12c. 10,000 samples

Mean = 1.2664 V
Standard Deviation = 124.80 mV

Figure 12d. 100,000 samples

Mean = 1.2619 V
Standard Deviation = 126.82 mV

Figure 12e. 1,000,000 samples

Mean = 1.2644 V
Standard Deviation = 125.49 mV

FIGURE 12. Sample *Number Comparison*

Example 8. Repeatability

Using the same configuration as in EXAMPLE 7, the sample number is kept constant (100,000 samples) and the repeatability is examined.
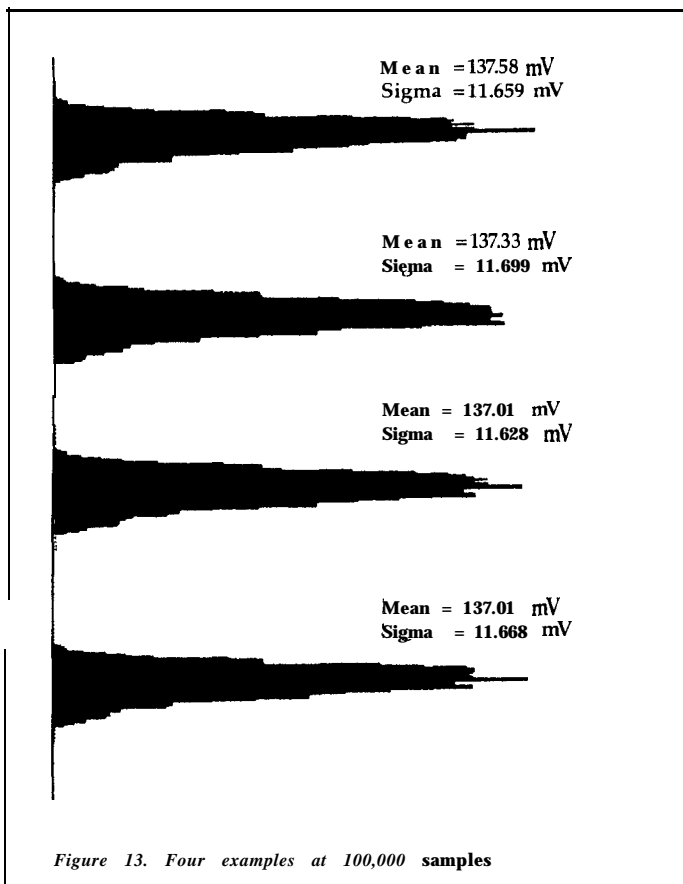
Mean = 137.58 mV
Sigma = 11.659 mV

Mean = 137.33 mV
Sigma = 11.699 mV

Mean = 137.01 mV
Sigma = 11.628 mV

Mean = 137.01 mV
Sigma = 11.668 mV

Figure 13. Four examples at 100,000 samples

From FIGURE 13 it is apparent that the histograms have the same general shape. Also, the means and sigmas deviated very litte from one another. From trial to trial it is evident that the results are repeatable to a great extent.

One of the first steps in producing a histogram is setting the 'WINDOW MARKERS to determine the window size and position. Many times it is advantageous to have as narrow a window as possible (i.e. jitter measurements). It should be understood that when producing a time histogram, the acquisition time is a function of the window size. A smaller window takes more time to acquire the number of samples specified, because only the data points that fall in the window are counted. For example a window of zero height would never gather a data point. Relationship between window size and ACQ time for time histograms is shown in example 9.

Example 9. Window Size and Acquisition Time

The data in TABLE 5 was acquired using a step generator with 10,000 samples being taken to illustrate the relationship between window size and acquisition time.

TABLE 5. Voltage Window Size and Acquisition Time

Trial	Window Size (mV)	Window As A Percent Of Full Screen	Acquisition Time (sec)
1	500.0	25.000	5
2	250.0	12.500	9
3	125.0	6.250	12
4	62.5	3.125	20

The repetitive sampling assures that the data will be acquired with a minimum number of triggers. As a result, voltage histograms are typically formed in a matter of seconds. A time window is still required because the user is interested in looking at the voltage distribution over a certain finite time window. TABLE 6 was also created with 10,000 samples.

TABLE 6. Time Window Size and Acquisition Time

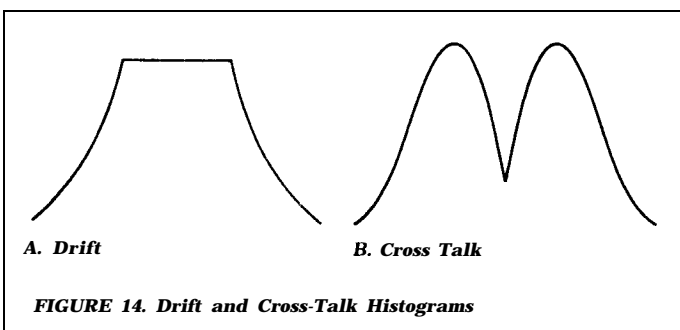| Trial	Window Size (ns)	Window As A Percent Of Full Screen	Acquisition Time (sec)
1	50.00	25.000	3
2	25.00	12.500	3
3	12.50	6.250	3
4	6.25	3.125	3

IV. 54120T Time Histogram Measurements

Measuring jitter is the most common application of time histograms. Analog scopes have 5 major problems in accurately displaying jitter. First, with analog scopes jitter measurements are subjective with respect to the observer. Second, the apparent jitter is dependent on the intensity and focus adjustments of the scope. Third, low probability jitter is not displayed, consequently, those infrequent traces that do not occur often enough to keep the CRT's phosphor excited go unseen. This means worst-case noise and jitter may not be observed. Fourth, the problem of ramp linearity in analog scopes further makes the measurements less accurate. Fifth, time base jitter in the analog oscilloscope contributes a significant portion to the measured jitter.

The HP 54120T avoids these problems by storing and displaying every data point acquired. In addition, the HI? 54120T digitizing oscilloscope has very little internal jitter (< 5 ps $+ 5E^{-5}$ x delay setting rms), making it ideal for this type of measurement. However, when measuring time distributions at the picosecond level be aware of the internal jitter. The data is quantified using the MEAN and SIGMA keys. The histogram display allows for further interpretation of the data. to see the "unseen."
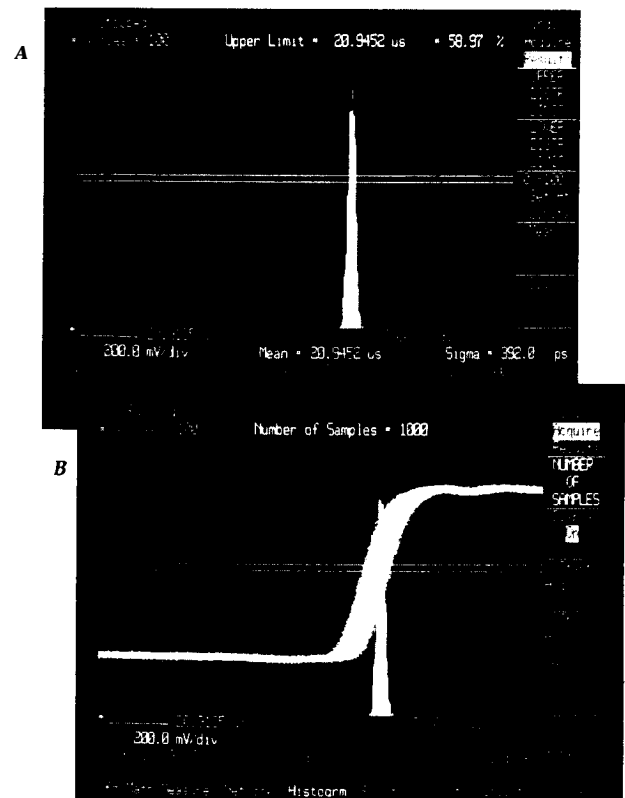
At a glance, the distribution may be characterized as normal or not. If it is symmetrical about the mean and it has tails, it is most likely a fairly normal distribution. Further, by pushing the SIGMA key, the area betwen the one sigma markers should be around 68%. This is an easy test.

If the waveform appears to drift in one direction as it is being formed, then the histogram will be fairly uniform. A bimodal histogram, one with two distinct peaks, might be the result of cross-talk; or, it may be an indication of a non-random source of error in the system under test (see figure 14).

A. Drift   B. Cross Talk

FIGURE 14. Drift and Cross-Talk Histograms

Example 10. Jitter Measurement on a Signal

To determine the jitter of the signal in FIGURE 15A, follow the time histogram procedures outlined in Section 3 of the Getting Started Guide. Specify as narrow a voltage window as possible in the transition region as shown in FIGURE 15A. A narrower window examines a more precise portion of the signal, but it takes longer to accumulate the given number of samples. This removes the transition slope from the measurement. To obtain the most accurate results, expand the timebase as large as possible. In other words, adjust the TIME/DIV so that the peak-to-peak jitter fills at least one major division of the screen.

FIGURE 15. Jitter Distribution

The jitter may be easily quantified. Assuming a normal distribution for interpretation, the 1 sigma points represent 68.26% of the jitter distribution, which corresponds to rms jitter. If the jitter is defined by 3 sigma on either side of the mean or 99.74% of the data (assuming a Gaussian distribution), the jitter is six times the standard deviation. This could be considered peak-to-peak jitter. It is left up to the user to define what is peak-to-peak. Perhaps the user wishes to define peak-to-peak as 99.99% of the data. This is 4 sigma on either side of the mean, therefore multiply sigma by 8 (assuming a Gaussian distribution).

V. 54120T Voltage Histogram Measurements

The most common application of the voltage histogram is the measurement of noise on a signal. The 54120T has a very low "noise floor" ($<$1 mV of internal noise rms in the Persistence Mode), making noise measurements very accurate.

Example 11. Standard Noise Measurement

To determine the noise on a digital signal, specify a time window on a stable portion of the waveform (either a 1 or 0 level) as seen in FIGURE 10. Pick the number of samples from the ACQUIRE menu and START ACQUIRING data.

A voltage histogram is then produced. To view the histogram more clearly, the data points may be erased using the CLEAR DISPLAY key. The average "one" or high voltage level may be obtained by isolating the l's distribution with the UPPER and LOWER DISTR LIMIT keys and pushing the MEAN key. Assuming a normal distribution, 68.26% of the data is plus or minus 1 sigma of the **mean**. The rms noise is simply equal to one sigma, which is given. If the user wants to know the extremes of the distribution, the mean minus three times sigma would give the lowest "one" voltage 99.87% of the time.

FIGURE 16. Voltage Histogram of Noise

VI. Eye Diagrams and the Histogram Function

Another application of the histogram and statistical function involves the analysis of eye patterns. The eye diagram is used to analyze the distortion in digital transmission systems. When serial digital data is displayed on an oscilloscope, triggered by the data clock, an eye pattern is formed. The formation of the eye is simply the superposition of all the 1 and 0 levels, the 0 to 1 transitions, and all the 1 to 0 transitions over one unit interval.

'The wider the eye is open, in general, the lower the bit error in the recovery of data from the signal. Additive Gaussian noise, jitter, and intersymbol interference (ISI) are the three main types of distortion. All three act to close the eye aperture. In particular, in the absence of ISI, timing jitter decreases the eye width and additive Gaussian noise (decreases the eye height. ISI is dispersion in the channel resulting from design imperfections in the time domain response. For high speed systems with large signal-to-noise ratios, ISI is frequently the main source of distortion. However, even if the eye is almost completely closed, this does not absolutely mean that ISI is large. It simply means that worst-case ISI is large.

When all three forms of distortion exist, it is difficult to quantify the individual types of distortion. Figure 17 contains pictures of the individual distortions, as well as a combination of all three.
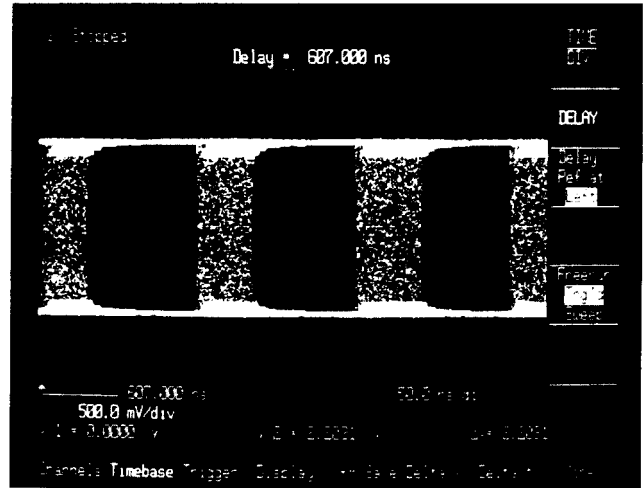

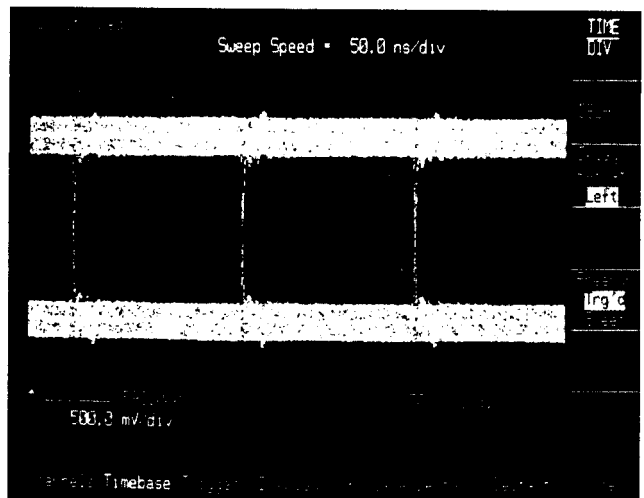*FIGURE 17a. Free of Distortion*

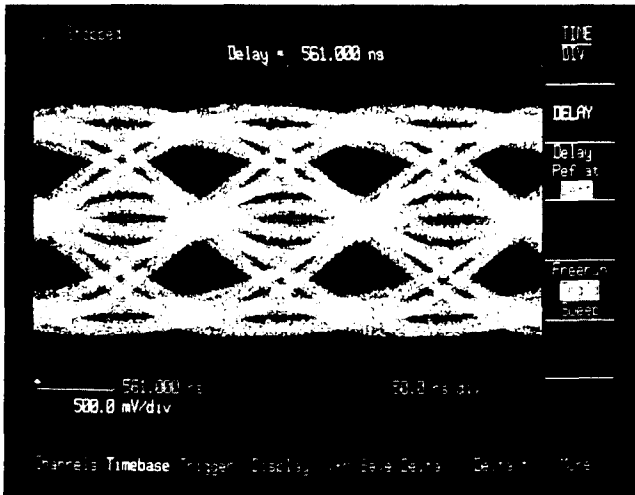*Figure 17b. Jitter*

Figure 17c. Noise
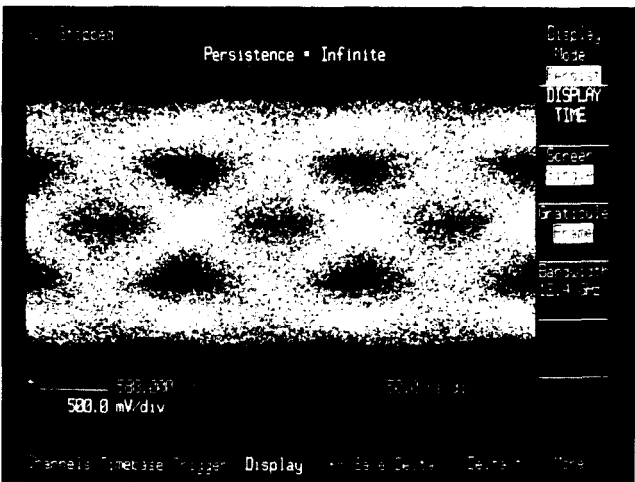
Figure 17d. ISI

Figure 17e. Jitter, Noise & ISI

Figure 18 shows an eye diagram with the distortion and noise and phase margins shown. The noise margin, AV has a corresponding phase margin, AT or vice versa. As seen below, AV is inversely proportional to AT.
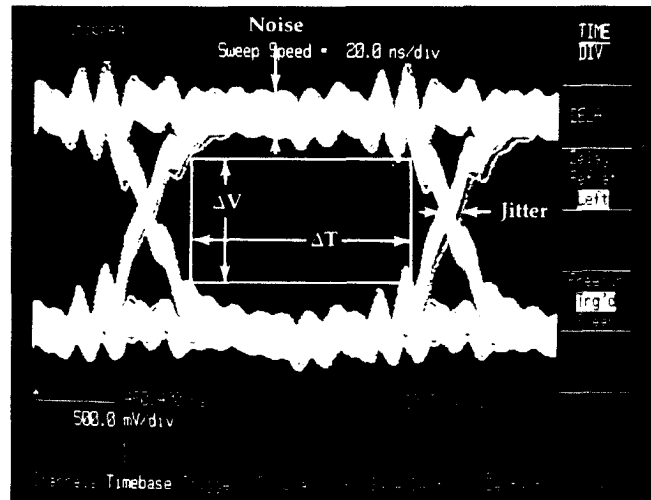

FIGURE 18. Measurements on the Eye

54120T Eye Diagrams

Most digitizing oscilloscopes are unable to successfully display eye diagrams because of their single-value display memories. Despite large quantities of memory, they cannot display more than one voltage at a particular instant of time as is required in the multi-value display of an eye diagram. With selected digitizing scopes, such as the 54120T, worst-case analysis is possible with infinite persistence displays. These displays will display every data point acquired without the drawbacks of analog storage scopes. HP's digital variable persistence allows the user to select how long individual data points remain on screen before being erased. This makes it easy to view eye diagrams that exhibit occasional time shifts or that tends to wander with respect to the clock. Eye diagrams may be printed or plotted directly form the PRINT or PLOT menus, making eye comparisons very easy. Also, waveforms may be stored for direct comparisons. Eye diagrams viewed on the 54120T are repeatable by keeping the number of samples constant. In addition, the 54120T is especially tailored to making eye pattern measurements because of its fast risetime of 28 picosecond and timing accuracy of 10 picosecond. The histogram function permits the user to quantify the distortion from the eye diagram.

Example 12. 1 and 0 Measurements from the Eye Diagram

The logic 1 and 0 values can be determined using the voltage histogram. Choose a time window that contains only 1 and 0 values, avoiding the transition times as shown in FIGURE 19.
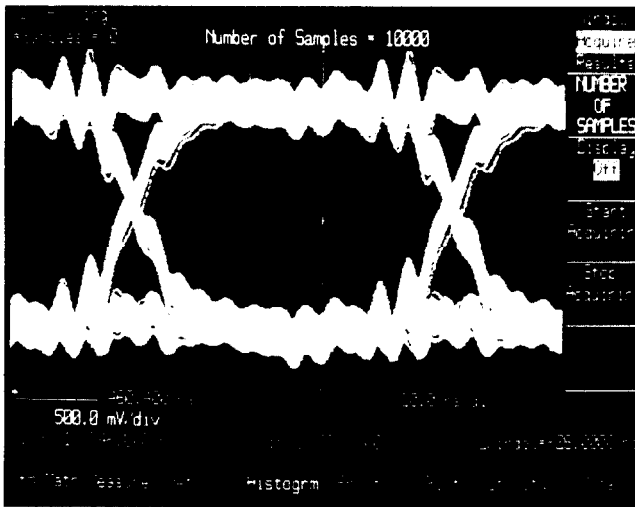

FIGURE 19. Eye Diagram and Determination of 1 and 0 Voltages

Two distributions have been found: the 1's distribution and the 0's distribution. To obtain the mean value of the 1's distribution, use the UPPER and LOWER DISTR LIMIT keys to isolate and region of interest. After setting the UPPER limit, roll the LOWER limit to the correct position and press the 0%-100% SET AT LIMITS button to enter the positions. The isolated area will be highlighted in dark blue default.

FIGURE 20. Finding the Mean One Voltage

The mean and standard deviation (sigma) of the distribution are found by pushing the respective buttons. Assuming a normal distribution, the rms noise is equal to sigma and approximately 99.74% of the data is plus or minus 3 times sigma from the mean. The same analysis can be done for the zero distribution. The eye amplitude is the voltage difference between the mean value of the 1 and 0 levels.

Example 13. Determination of Eye Opening

The eye opening is mainly a function of the voltage noise. In the absence of jitter, the optimum sampling time is where the eye is open widest. To determine the eye opening, move the Distribution Limit Markers to the points inside the distributions where there does not appear to be any data and measure DELTA V. See FIGURE 21.
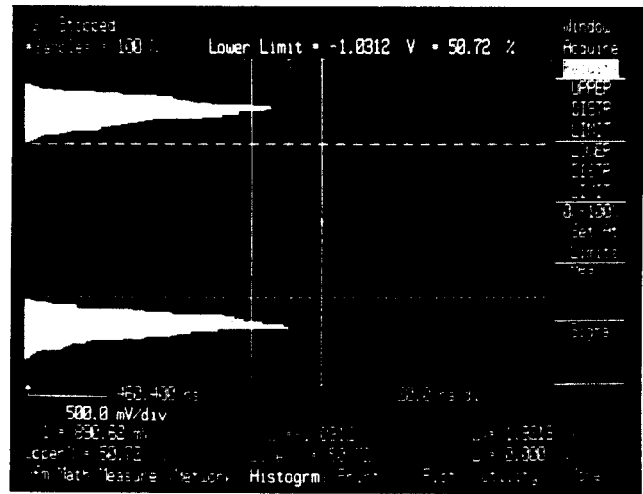

FIGURE 21. The Eye Opening

After determining the eye opening, the percent closure of the eye can be calculated using the following formula:

Equation:

$$Percent\ Closure\ =\ \frac{EYE\ OPENING}{EYE\ AMPLITUDE} \times 100\%$$

The voltage range can be determined using the Distribution Limit Markers and reading the DELTA V as before.

To determine the voltage margin for a given phase margin, place the Window Markers at the upper and lower limits of the desired phase margin. Then, proceed with the noise margin measurement in the same manner as was done in determining the eye opening.

Example 14. Jitter Measurements from the Eye Diagram

In the absence of ISI, jitter can be easily determined with a time histogram. From the eye diagram, specify a thin slice of voltage in the center of the eye. Remember to expand up the region of interest as large as possible using the SEC/DIV and VOLTS/DIV. Now, pick a sample number and obtain a time histogram.
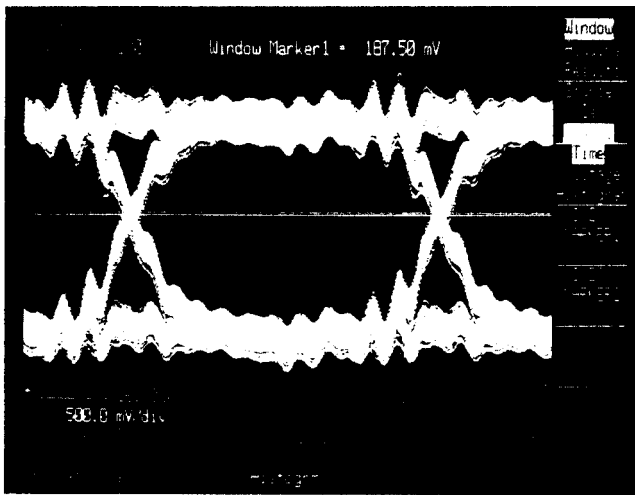

FIGURE 22. Jitter Measurement from the Eye

The distribution on the right will be examined. Assuming a normal distribution, the rms jitter is one sigma. The peak-to-peak jitter could be defined as plus or minus 3 sigma of the mean, the jitter is 6 times the standard deviation, which contains 99.74% of the jitter distribution.
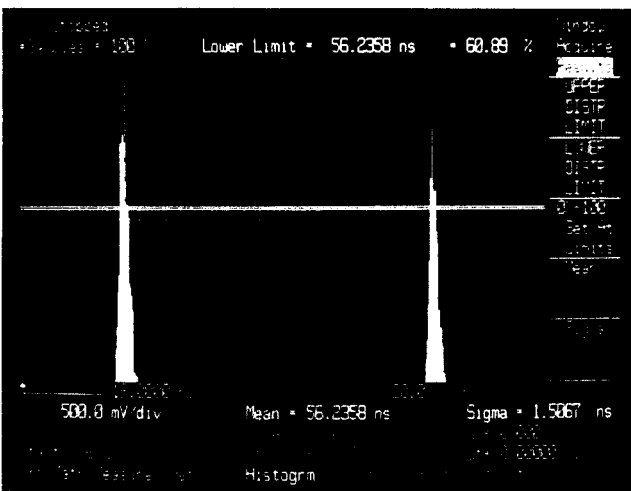

FIGURE 23. Histogram of Jitter from the Eye

EXAMPLE 15. THE EYE WIDTH

To determine the eye width, set the voltage markers at the threshold 1 and 0 voltages plus some predetermined noise margin. Again, obtain a time histogram. Going to the RESULTS menu and positioning the UPPER and LOWER DISTR MARKERS to the inside extremes of the histograms where there is no data, the eye width may be measured.
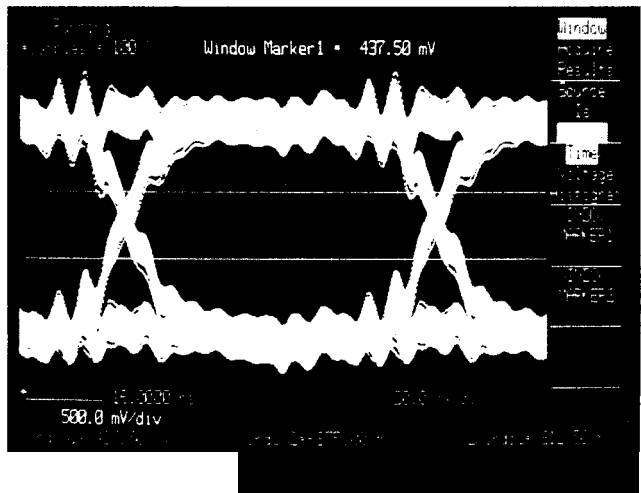

FIGURE 24. The Eye Width and Window Size

FIGURE 25. The Eye Width and Time Histogram

In this application the type of distribution is not of concern. Only the inside points of the distributions is needed to be known.

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Analog Oscilloscope Eye Diagrams

The analog scope gives the user a subjective idea of the excursion about the mean, but it gives no quantitative information. This data is subject to operator interpretation, as well as the settings of the instruments intensity and focus settings. How does one eye compare to another? Repeatability is a major drawback of analog scopes.

Analog storage oscilloscopes have been used to view worst-case jitter and noise, but these scopes have many operating disadvantages. The viewing time is limited after the signal is captured. The display tends to "bloom" or fade positive and the trace tends to "fatten" as the display builds up. This increases the apparent distortion, showing an incorrect display.

However, analog oscilloscopes do have the ability to show qualitative statistical information in the form of gray shades. Occasionally it is possible to locate the "centroid" of the signal by looking for the brightest region on the analog scope.

VII. Summary

The HP 54120T digitizing oscilloscope offers a new technique in signal analysis, the Histogram function. It allows the user to make quantitative measurements that were previously impossible. Jitter and noise may be measured by their rms value or their peak-to-peak value. With the 54120T the mean and the standard deviation are given with the push of a button. Therefore, distortion is automatically quantified because the rms value is equal to one sigma, assuming a normal distribution. Also, eye diagrams may be viewed and quantified accurately via time and voltage histograms. The histogram has in a small amount of time become a valuable and indispensable tool in signal analysis, making it a permanent fixture in the oscilloscope marketplace.

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