CHAPTER FIVE: *Use Math Tools*

In this chapter, see how

- ***To set up for math***
- ***To do multiplication***
- ***To perform an FFT***
- ***To do summed averaging***
- ***To store and recall waveforms***
- ***To obtain a waveform or memory status report***

Make Math Easy

With Waverunner math tools you can perform mathematical functions on a waveform displayed on any channel, or recalled from any of the four reference memories M1, M2, M3, or M4. To do computations in sequence, you can also set up any trace of A, B, C, or D for math.

For example: you could set up Trace A as the difference between Channels 1 and 2, Trace B as the average of A, and Trace C as the integral of B. You could then display the integral of the averaged difference between Channels 1 and 2. Any trace and function can be chained to another trace and function. For example, you could make Trace A an average of Channel 1, Trace B an FFT of A, and Trace C a zoom of B.

Waverunner math tools are available in these standard and optional packages:

STANDARD MATH *Included with all Waverunner oscilloscopes*	**Arithmetic**	Sum (add), Difference (subtract), Product (multiply), Ratio (divide)
	Averaging	Summed (linear) Average of up to 1000 sweeps
	Extrema (envelope)	
	FFT	Fast Fourier Transform to 50 000 points; Power Spectrum, Phase, Magnitude; All FFT Windows
	Functions	Identity, Negation, (Sin x)/x
	Resample (deskew)	
	Rescale	
	Enhanced Resolution (ERES)	
EXTENDED MATH AND MEASUREMENT OPTION (EMM) *All tools in Standard Math plus:*	**Functions**	Absolute Value, Derivative, Exp (base e), Exp (base 10), Integral, Log (base e), Log (base 10), Ratio, Reciprocal, Square, Square Root
	Trending	
WAVEANALYZER OPTION (WAVA) *All tools in Extended Math plus:*	**Averaging**	Summed, or linear, Average of up to one million waveforms; Continuous Average
	FFT+	Fast Fourier Transform to one million points; FFT Average; Power Averaging, Power Density, Real, Real + Imaginary
	Histograms	Histograms, Histogram Parameters

SET UP TO DO WAVEFORM MATHEMATICS

After connecting your signal to a Waverunner channel (Channel 1 in this example), do the following:

1. Press [1] to select CHANNEL 1 and display Waverunner's basic menus.
2. Press [ ] to [ZOOM]
3. Press [A] to make Trace A a zoom of Channel 1.
4. Press the button for [SETUP]
5. Press the button to select [use Math? No **Yes**] and display the SETUP OF **A** menus, shown next page.

TO SET UP FOR MATH ANOTHER WAY

First. *Press* [MATH TOOLS] *to display the ZOOM + MATH menus.*

Second. *Select* [REDEFINE A A=1] *or one of the other traces.*

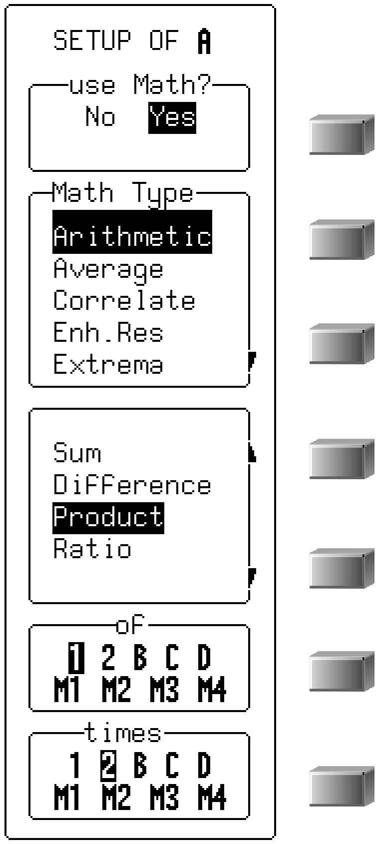
Third. *Press the button to select* [use Math? No **Yes**]

Fourth. *Follow the first three steps in the procedure above.*

NOTE: A waveform processing title for each displayed trace will be shown in its trace label. If the title is missing, the math function cannot be done and the contents of the trace will remain unchanged.

USE A MATH TOOL

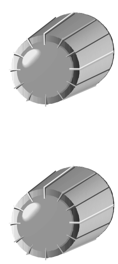
Use these menus to choose and set up any math tool. As an example, select the arithmetic tool Product to multiply Channel 1 by Channel 2.



To enable math.

6. Press to select **Arithmetic**.

7. Press to select **Product**.



8. Press to select Channel 1 as the source trace. When using Arithmetic, this sets one of the two operand sources. Using other math types, this menu may be in a different position and may set the signal offset, number of sweeps, or compensate for any DC offset in the signal.
9. Press to select the trace by which the source trace Channel 1 will be multiplied.

Now go on to set up your trace as an FFT (Fast Fourier Transform) function (next page).

PERFORM AN FFT OPERATION

Continuing from the preceding steps, set up Channel 1 for FFT. Fast Fourier Transform will convert your time domain waveform into a frequency domain spectrum similar to that of an RF spectrum analyzer display. But unlike the analyzer, which has controls for span and resolution bandwidth, with Waverunner you determine the FFT span using the scope's sampling rate (see Chapter 10, "Use Advanced Math Tools").

10. Press the button to select **FFT** from the Math Type menu.

TIP: During FFT computation, the FFT sign is shown below the grid. The computation can take a while on long time-domain records, but you can stop it at any time by pressing any front panel button.

Spectra will be shown with a linear frequency axis running from zero to the Nyquist frequency. The frequency scale factors (Hz/div) are in a 1–2–5 sequence. The processing equation is displayed at the bottom of the screen, together with the three key parameters that characterize an FFT spectrum:

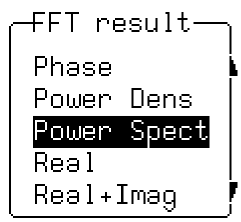
Transform size N (number of input points)

Nyquist frequency (= ½ sample rate)

Frequency increment, Δf, between two successive points of the spectrum.

These parameters are related as: Nyquist frequency = $\Delta f * N/2$, where $\Delta f = 1/T$, and T is the duration of the input waveform record (10 ∗ time/div). The number of output points is equal to N/2.

11. Press the button to select Power Spectrum from the menu



Power Spectrum is the signal power, or magnitude, represented on a logarithmic vertical scale: 0 dBm corresponds to the voltage (0.316 V peak), which is equivalent to 1 mW into 50 Ω. Power Spectrum is suitable for characterizing spectra that contain isolated peaks (dBm).

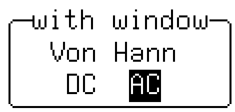
Other FFT functions available in this menu depend on the Waverunner math options installed in your scope (see page 55).

Phase is measured with respect to a cosine whose maximum occurs at the left-hand edge of the screen, at which point it has 0°. Similarly, a positive-going sine wave starting at the left-hand edge of the screen has a –90° phase. Phase is displayed in degrees.

Power Density: Signal power normalized to the bandwidth of the equivalent filter associated with the FFT calculation. Suitable for characterizing broadband noise. Power Density is displayed on a logarithmic vertical axis calibrated in dBm. It is available only with the WaveAnalyzer option for the Waverunner.

Magnitude: The peak signal amplitude is represented on a linear scale, in the same units as the input signal.

Real, Real + Imaginary, Imaginary: Complex result of the FFT processing in the same units as the input signal. These are only available with the WaveAnalyzer option.

12. Now turn the knob to select **Von Hann** 

and press the button to select **AC**.

AC forces the DC component of the input signal to zero before FFT processing, and improves the amplitude resolution. This is especially useful when your input has a large DC component.

FFT windows define the bandwidth and shape of the FFT filter. (See Chapter 10, "Use Advanced Math Tools," for the windows' filter parameters.)

Von Hann (Hanning) windows reduce leakage and improve amplitude accuracy. But they also reduce frequency resolution.

Rectangular windows should be used when the signal is transient (completely contained in the time-domain window) or you know it to have a fundamental frequency component that is an integer multiple of the fundamental frequency of the window. Other signal types will show varying amounts of spectral leakage and scallop loss when you use a Rectangular window. To correct this, use another window type.

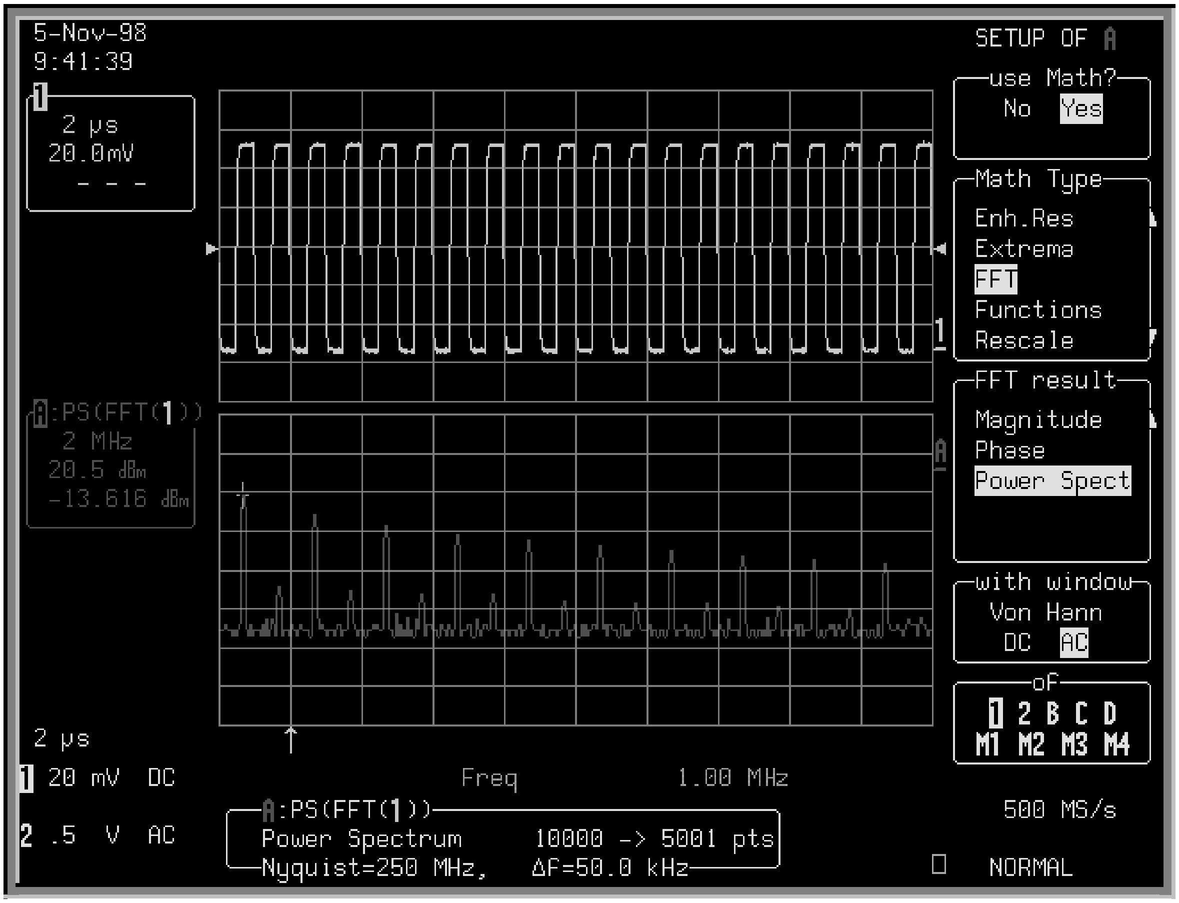
Hamming reduces leakage and improves amplitude accuracy, but also reduces frequency resolution.

Flat Top provides excellent amplitude accuracy with moderate leakage reduction, but also reduces frequency resolution.

Blackman–Harris windows reduce leakage to a minimum, but reduce frequency resolution.

13. In the final FFT step, press the button to select the source trace.

The "before" and "after" of your FFT computation is shown on the next page.

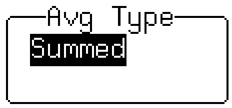


FFT Power Spectrum: The top grid shows the waveform in the time domain, while the bottom one shows it in the frequency domain, after FFT Power Spectrum has been applied. With the cursor measure tool (positioned here on the left-most peak of the FFT trace) you can read either the time or frequency of your waveform. Trace A's label indicates 2 MHz per division in the frequency domain. The memory status field beneath the grids gives other FFT information.

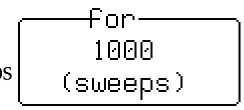
DO SUMMED AVERAGING

Now make a Summed Average of your waveform — again, going on from the previous steps. Averaging is normally used to eliminate noise.

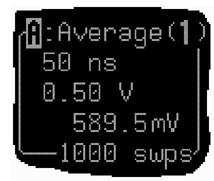
14. Press the button to select **Average** from the Math Type menu.

15. Press the button to select 

Waverunner starts the calculation immediately.

16. Turn the upper knob to set the number of sweeps 

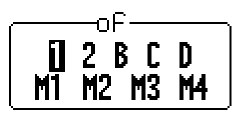
(up to 4000)



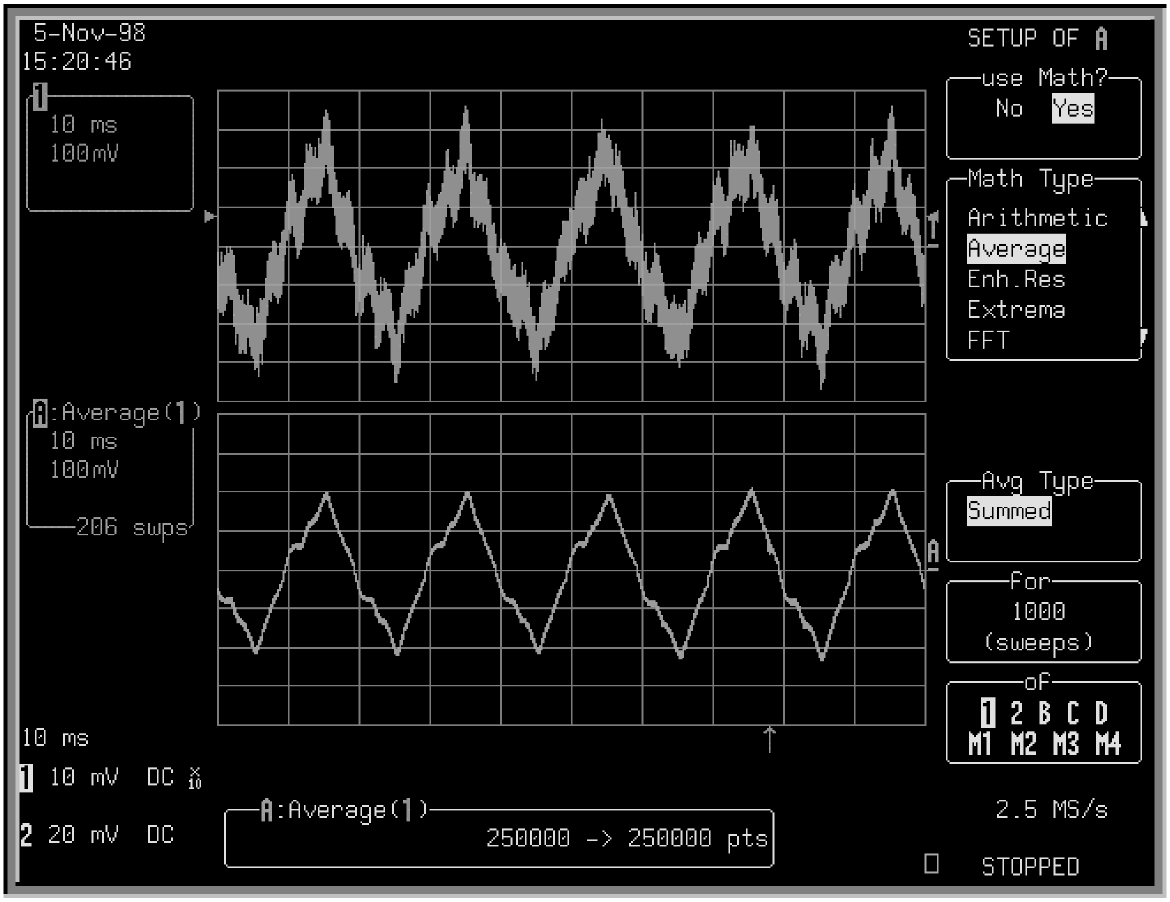
This is counted in the trace label, as shown here, at right:

If the optional Continuous Average is selected, the "for" menu becomes "with…weighting". Use it to define the weight.

(See Chapter 10, "Use Advanced Math Tools," for the difference between summed and continuous averaging.)

17. Finally, press the button to select the source trace: 

The type of result you can expect is illustrated on the next page.



Summed Average: Noise evident in the signal shown in the top trace has been eliminated from the averaged waveform on the lower grid. The calculation was stopped after 206 sweeps. The number of points used in the calculation is shown in the information field at the bottom of the screen. The same number of points means that all points were used in the calculation.

Save and Recall Waveforms

Save your waveforms to internal reference memory — M1, M2, M3 or M4 — or to floppy disk or the optional PC Card slot (Memory card or HDD). Recall them later for further analysis. You could zoom them or perform more math.

NOTE: For each unit of record length per channel, or per zoom and math trace, a point can be stored in the waveform reference memories M1, M2, M3, or M4.

1. Press WAVE STORAGE and then the button for

2. Use these menus to store your displayed waveform.

To store the waveform, which you first select from the menu below, to the memory or floppy disk (also selected below).

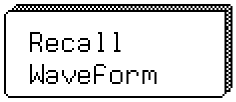
To select the channel or trace whose waveform you wish to store.

To select the internal reference memory, floppy, or optional storage device the waveform is to be saved to.

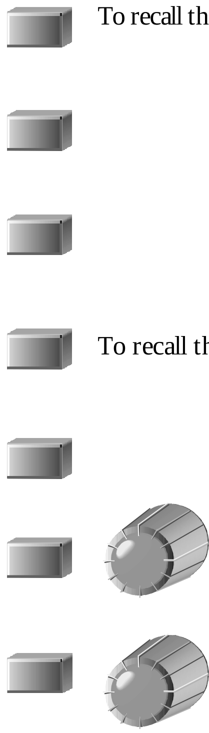
See Chapter 12, "Use Waverunner with PC," for how to save waveforms in ASCII format.

RETURN

3. Press to go back to the "W'FORM" menus in order to recall the waveform you have stored.

4. Press the button for 

5. These menus will be displayed. Use them to recall your waveform.



To recall the waveform from memory or portable storage device.

To recall the selected waveform to the selected trace (see menus below).

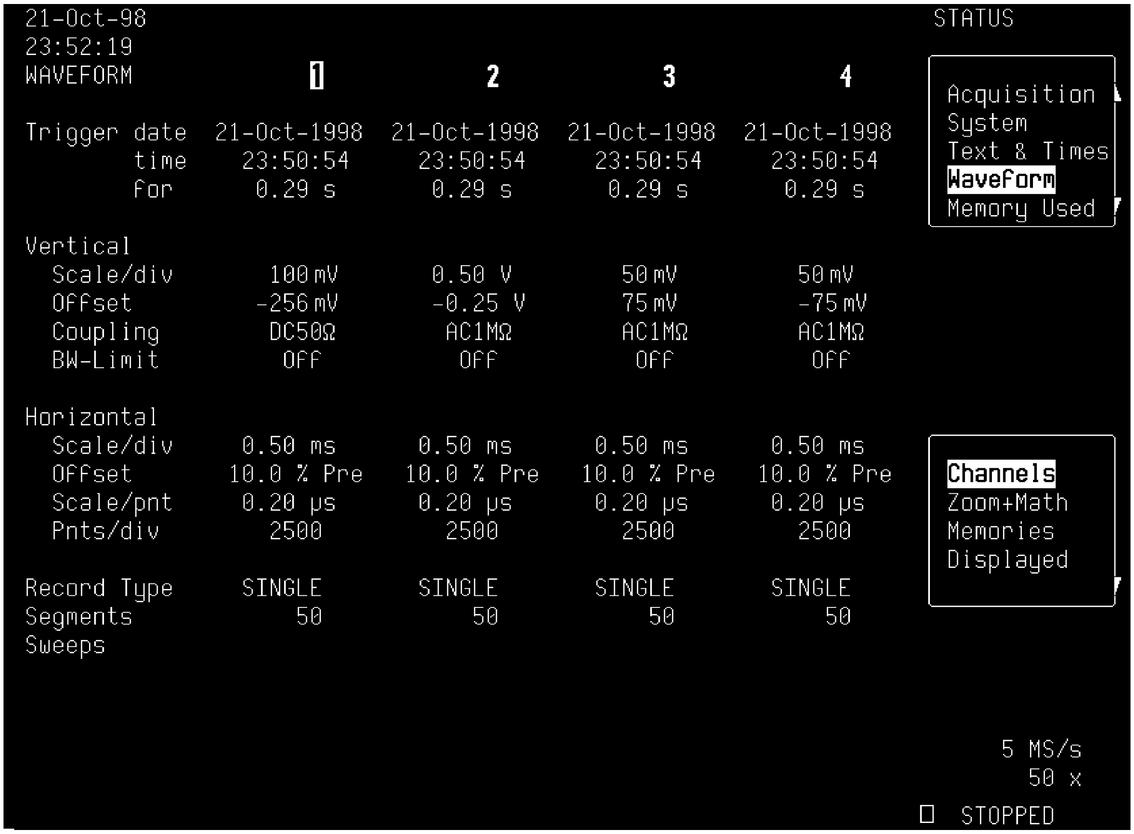
To select the memory in which the waveform you wish to display is stored.

To select the trace on which the recalled waveform is to be displayed.

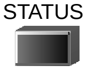
TIP: Transfer waveform data to PC and use the data for calculations with spreadsheet or math software. To do this, save your waveforms to floppy or an optional storage device in the ASCII format. Waverunner can save to floppy in ASCII traces of up to 50 000 points. You should remember that waveforms stored in ASCII cannot be called back into the oscilloscope. See Chapter 12, "Use Waverunner with PC."

OBTAIN A WAVEFORM OR MEMORY STATUS REPORT

Display a summary of the status of your channels, zoom and math functions, waveform memories, and displayed traces. View the settings on your vertical and horizontal controls. Check on how much memory your Waverunner scope is using for storage of records. Clear and free up memory.



SCOPE STATUS

1. Press  to show the STATUS menus.

2. Press the button to select **Waveform** and the button for the waveform status summary of choice.

3. Press the button to select **Memory Used** to obtain a similar report on what you have stored and how much memory is available. Memories occupied by waveforms will be boxed, and empty ones indicated as such. You can also clear occupied memories by pressing the corresponding menu buttons.