THE LeCROY MODEL 9400

DIGITAL OSCILLOSCOPE

OPERATORS MANUAL

LeCROY

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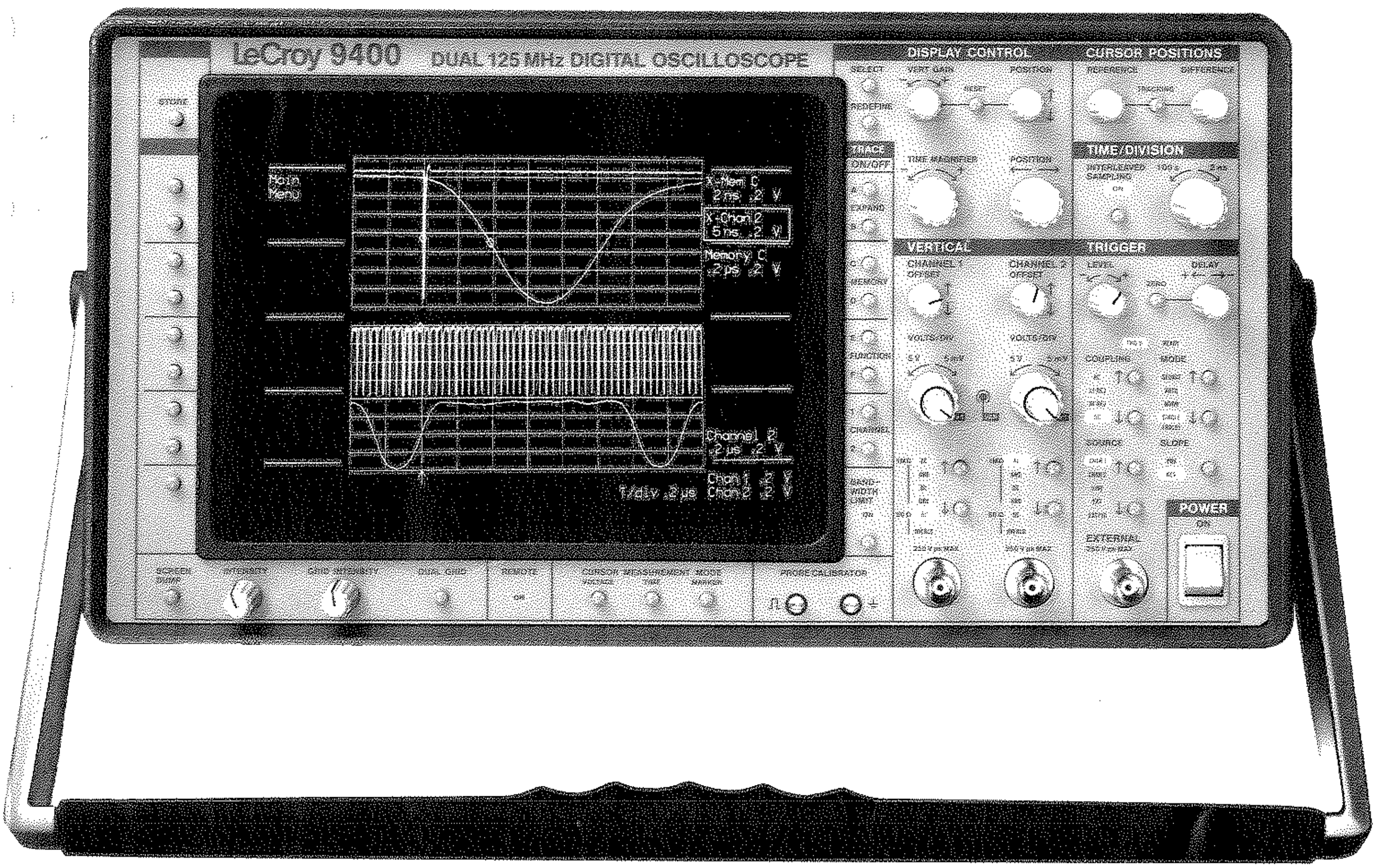
11. Fast Fourier Waveform Processing Option (WP02, V.2.05FT)

LeCroy

DUAL 125 MHz DIGITAL OSCILLOSCOPE
LeCroy 9400



DUAL 125MHz DIGITAL OSCILLOSCOPE

The LeCroy 9400 Dual Digital Oscilloscope is a powerful general purpose tool for waveform measurements. Designed to operate as easily as your familiar analog oscilloscope, the 9400 brings you a whole new range of capabilities to measure and characterize your waveforms with greater precision and confidence.

With the 9400 you gain:

HIGHER PRECISION

Two independent 125 MHz channels, each with a high performance 8-bit ADC, convert your input signals with better than 1% accuracy. Each input is sampled at a maximum rate of 5 Gigasample/sec for repetitive waveforms and 100 Megasample/sec for single events. The high sampling rate combined with extremely long 32,000 data point acquisition memories, permit time measurements with an accuracy of 0.002%. The 9400's easy to use Voltage, Time and Crosshair Cursors assist you in making precise measurements.

HIGH RESOLUTION DISPLAY

The large, high resolution display produces bright, stable, razor sharp pictures of your signal under any rate conditions. Up to 4 waveforms can be displayed simultaneously. The high resolution (1024 × 1024 pixels) display permits very accurate comparisons and waveform measurements. With "x100" time scale expansion, you zoom in on details for analysis and exact cursor placement.

SINGLE TRANSIENT RECORDING

The 9400 is an extremely powerful transient recorder with a maximum sampling rate of 100 Megasample/sec. Rare events cannot be missed. The long 32,000 data point acquisition memories, combined with the continuously adjustable trigger (from 100% pre-trigger to 10,000 × time/div post-trigger), give unparalleled flexibility. Both channels are sampled simultaneously and exact time correlation between channels is maintained.

FULL PROGRAMMABILITY

All the 9400's front panel knobs and push-buttons are fully programmable. RS232C and GPIB interfaces facilitate computer aided testing, remote-control operation and ATE applications. Up to 7 different front-panel setups can be stored and easily recalled to simplify successive test operations. A single push-button initiates a Screen Dump for accurate hard copies of the display via a wide range of digital plotters.

SIGNAL PROCESSING CAPABILITY

Elaborate signal processing can be performed on the digitally stored waveform. For specific application analysis, the captured waveform can be transfered to a computer and studied with your own software. Processed data can then be transferred back to the 9400 for reference. For front end data reduction and processing, LeCroy offers optional firmware packages including signal averaging, arithmetic array operations and Fast Fourier Transforms.

SPECIFICATIONS

VERTICAL ANALOG SECTION

Input: Two BNC connectors.

Sensitivity: 5 mV/div to 1 V/div at 50 Ohms impedance; 5 mV/div to 5 V/div at 1 Mohm impedance; continuous detents at 1-2-5.

DC Accuracy: standard < ± 2%, optional < ± 1%.

Bandwidth (–3 dB point):
50Ω: 0-125 MHz at 3 highest sensitivity ranges; 0-150 MHz typical, on other ranges
1 MΩAC: < 10 Hz-100 MHz typical
1 MΩDC: DC-100 MHz typical

Input impedance: 1 Mohm, ≈ 50 pF and 50 Ohms.

Maximum Input voltages: 250V (DC + peak AC) at 1 Mohm, 5VDC (500 mW) or ± 10V peak AC at 50 Ohms.

Offset: ± 8 divisions in 0.04-division increments.

Probe calibration squarewave: 1 KHz, remotely controllable 0-5V P-P ± 0.5%; 1V P-P ± 0.5% default.

VERTICAL DIGITAL SECTION

Analog to Digital Converters: 1 per channel, 8-bit, dual-rank flash.

Conversion rate: 100 megasamples/sec maximum, simultaneous on both channels.

Aperture uncertainty: ± 10 psecs.

Dynamic accuracy: (typical) RMS sinewave curve fit at:

Input frequency:	1 MHz	10 MHz	50 MHz
Signal-to-noise ratio:	44.0 dB	43.5 dB	42.5 dB

Acquisition memories: 32,000 8-bit words per channel (64,000 total) segmentable into 8, 15, 31, 62, 125, or 250 blocks.

Reference memories: Two 32,000 word memories store two, acquired and/or processed waveforms.

Peak detection: Permanent peak detection for events down to 0.04% of time/div setting, 10 nsec minimum.

Acquisition modes: Random Interleaved Sampling (RIS) for repetitive signals from 2 nsecs/div to 2 µsec/div; single shot for transient signals from 50 nsec/div to 200 msec/div; roll mode for slowly changing signals from 500 msec/div to 100 sec/div.

HORIZONTAL SECTION

Timebase range: 2 nsec/div to 100 sec/div,
Accuracy: better than 1 in 10^5.
Timebase Interpolator Resolution: 10 psec.

Trigger
Sources: CH 1, CH 2, LINE, EXT, EXT/10

Slope: Positive, negative, window

Coupling: AC, LF REJ, HF REJ, DC

Modes:
Sequence, stores multiple events in segmentable acquisition memories.
Auto, automatically rearms after each sweep. If no trigger occurs, one is generated at 2 Hz.
Normal, automatically rearms after each sweep. If no trigger occurs after 2 secs, display erases.
Single, (hold), single shot. Holds the display after the trigger occurs. Rearms only after "Single" button is pushed again.

RIS: accepts sufficient triggers to complete a waveform.

Roll: stops data acquisition.

Rearming: erases display after 2 seconds or at next trigger.

Pre-trigger recording: Adjustable .2% increments to 100%.

Post-trigger display: adjustable in .02 div increments up to 10,000 divisions.

External Trigger input: 1 Mohm, less than 30 pF, 250V maximum; ± 2V in EXT, ± 20V in EXT/10.

Autocalibration: performed when gain or time base parameters are changed. Provides DC accuracies of:
- Gain ± 1% full scale
- Offset ± .5% of full scale
- Time ± 20 psec RMS

Self diagnostics: checks memory and functions at power-up.

DISPLAY

CRT: 12.5 × 17.5 cm (5 × 7 inches); magnetic deflection; vector type.

Resolution: 1024 × 1024 addressable points.

Graticule: Internally generated; separate intensity control; dividable in upper and lower grid.

Screen dump: Single or multipen digital plotter controllable from front panel. Supports HP 7470, TEKTRONIX 4662, Philips PM 8151, Graphtec WX 4638/6, and compatible models.

Cursors: Two time cursors provide .2% time resolution for unexpanded trace; up to 0.002% for expanded ones. Two voltage cursors measure voltage differences to 0.2% full scale for each trace. Crosshair marker measures absolute voltage versus signal ground and time from trigger.

Menus: Waveform storage; Acquisition parameters; Memory status; Store/Recall front-panel configurations, RS232-C configuration; Plotter setup.

REMOTE CONTROL

All front-panel and internal functions are programmable, including variable gain, offset, and position controls.

GPIB PORT: (IEEE-488-1978) Configured as talker/listener for computer control and fast data transfer. 400 Kb/sec max. ASCII or binary. Rear-panel address switches.

RS232-C PORTS: One for computer or terminal control; one for plotter connection. Asynchronous up to 19,200 bauds.

WAVEFORM PROCESSING:

Provided by optional firmware package, 9400 WP01.
Arithmetic operations: addition, subtraction, multiplication, division, integration, square root, differentiation of waveform arrays.
Signal averaging: Summation and continuous averaging, selectable in steps of 1-2-5 to 1,000,000 times.
Event processing: Logs extreme max. and min. phenomena over a programmable number of sweeps. Smooths single transient signals by selecting up to 5 software filter methods.

WP02 - FFT
Digital Spectrum Analysis providing DC - 150 MHz bandwidth, 1 milli-Hz to 50 MHz resolution, record lengths up to 25000 points. Spectra formats: Real, Imaginary, Magnitude, Log-magnitude, Phase, Power, P.S.D.

GENERAL

Temperature: 5 to 40° C, rated; 0 to 50° C, operating humidity less than 80%.

Power required: 110 or 220 VAC (to specify). 48 to 65 Hz, 200 W.

Battery backup: NiCa batteries maintain stored front-panel settings for a minimum of 6 months.

Probes: Two model P9010 10X, 10 Mohm passive probes, included.
Probe power: 2 outputs; ± 15V; 5VDC on rear panel.

Enclosure: (HWD) 19.2 × 36.5 × 46.5 cm (7 1/2 × 14 3/8 × 18 3/8 inches).

Weight: 14 kg (30 lbs) net; 20 kg (44 lbs) shipping.

For over 20 years LeCroy has been supplying the scientific and industrial research communities with reliable state-of-the-art electronic instrumentation. Founded on the needs in Nuclear and High Energy Physics Research for reliable electronics to instrument experimental activities, LeCroy has been closely attuned to those specific requirements since 1964. Expertise developed over the years for these markets has yielded advanced technological capabilities in the areas of fast pulse measurement, high rate pulse counting, fast sampling transient recording, and high voltage power supplies.

Diversification has expanded LeCroy's experience to microprocessor-based data acquisition instruments, multichannel analyzers, fiberoptic systems, and digital oscilloscopes.

Thank You for your interest in our instrumentation. For more information, or to arrange a product demonstration, please contact LeCroy at any of the following locations:

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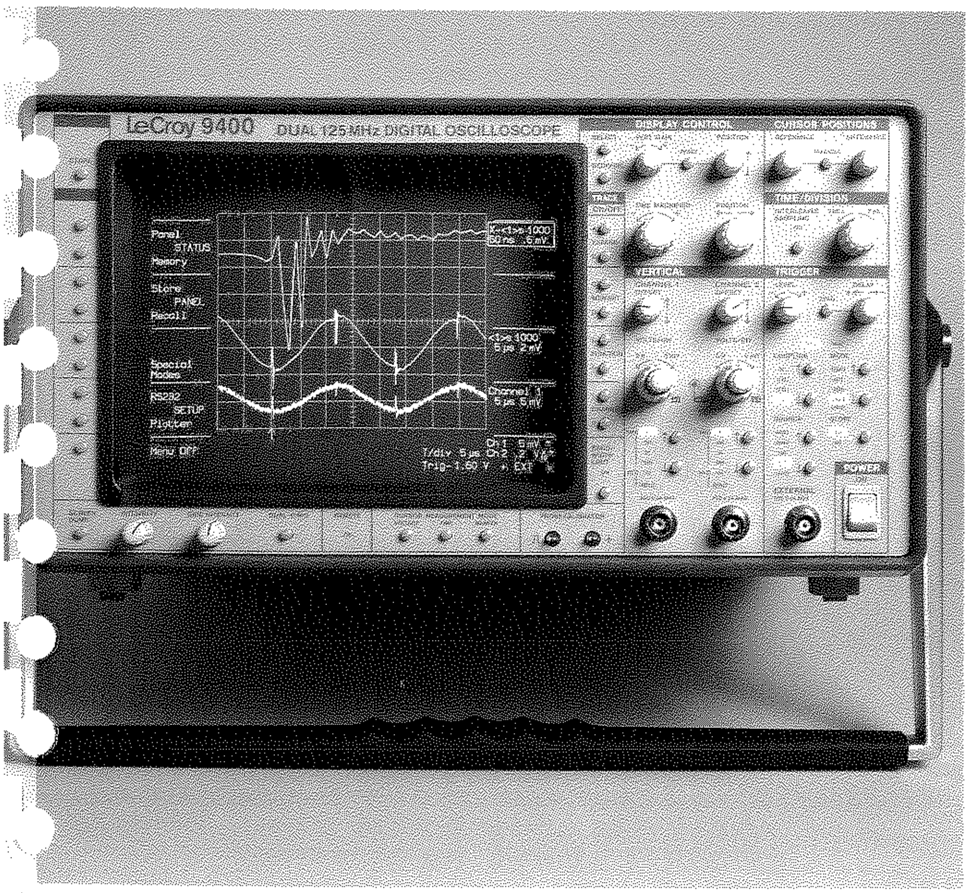
WAVEFORM PROCESSING PACKAGE
INCLUDING AVERAGING, INTEGRATION, DIFFERENTIATION

LeCroy

WP01 WAVEFORM PROCESSING FIRMWARE FOR MODEL 9400 DIGITAL OSCILLOSCOPE



Signal averaging improves dynamic range and sensitivity. Perturbation on a function generator sine wave is expanded after 1000 averages to 500 μV/div vertically (10x) and 50 ns/div horizontally (100x) showing fine details, helpful to find cause of distortion.

- **Summation and continuous averaging**
- **Arithmetic processing: addition, subtraction, multiplication, ...**
- **Mathematic processing: integration, differentiation, square root, ...**
- **Single event processing: smoothing, extreme value capturing**
- **Chaining of operations**

FOR SIGNAL CHARACTERIZATION AND ANALYSIS

The LeCroy WP01 Waveform Processing Firmware Package offers powerful routines that extend the use of the 9400 to signal characterization, mathematical analysis, and postprocessing of single events. Ordered as an option, or installed retroactively, WP01 allows for future extensions of the 9400's processing capabilities.

The 9400 Digital Oscilloscope features 125 MHz bandwith, 100 MS/s 8-bit ADCs, ± 2% DC accuracy, (optional ± 1%), 32K memory/channel, up to 192K of waveform storage memory, GPIB and RS232 interfacing, full programmability and color archiving through a wide range of digital plotters.

WAVEFORM ARITHMETICS

Addition, subtraction, multiplication, and ratio can be performed on two live waveforms from CH1 and CH2, or from stored waveforms in memories C, D and E.

Example: E = CH1 — CH2
F = CH2 * D
F = CH1 + E

Number of points processed: selectable from 50 to 32000 in 10 steps.
Multiplicative constants: selectable from 0.01 to 9.99 in steps of 0.01.
Additive constant: selectable from —9.99 divisions to 9.99 divisions in steps of .01.
Vertical expansion: 2 times maximum
Typical execution time for 1250 points: 600 ms.

WAVEFORM FUNCTIONS

Integration, differentiation, square, square root, negation (invert).

Examples: $E = \int CH1\,dt$
$F = -CH2$
$E = \frac{dD}{dt}$

Number of points processed: selectable from 50 to 32000 in 10 steps.
Multiplicative constants: selectable from 0.01 to 9.99 in steps of 0.01.
Additive constant: selectable from —9.99 divisions to 9.99 divisions in steps of .01.
Vertical expansion: 2 times maximum
Typical execution time for 1250 points: 400-1000 ms.

MEAN VALUE SMOOTHING

Number of adjacent blocks processed: 50 to 32000 in 10 steps.
The number of points per block: varies with the time base and the number of blocks selected.
Typical execution time for 1250 points: 700 ms.

N-POINT SMOOTHING

Filter coefficients with weighting factors for successive data points:
3 point - (1:2:1) 1/4
5 point - (1:4:6:4:1) 1/16
7 point - (1:6:15:20:15:6:1) 1/64
9 point - (1:8:28:56:70:56:28:8:1) 1/256

Number of points processed: 50 to 32000 in 10 steps.
Vertical expansion: 2 times maximum.
Typical execution time for 1250 points: 500 ms.

EXTREMA MODE

Logs all extreme values of a waveform over a programmable number of sweeps. Maxima and minima are displayed separately by ROOF and FLOOR traces.

Number of sweeps: selectable in 1-2-5 sequence from 1 up to 1,000,000.
Number of points processed: 50 to 32000 in 10 steps.

Glitches as short as 10 ns or 0.004% of the time setting are displayed.
Vertical expansion: 2 times
Typical execution time for 1250 points: 300 ms

CHAINING OF OPERATIONS

Two functions can be automatically chained using function E and F.

Example: E = CH1 - CH2
F = summed average of E

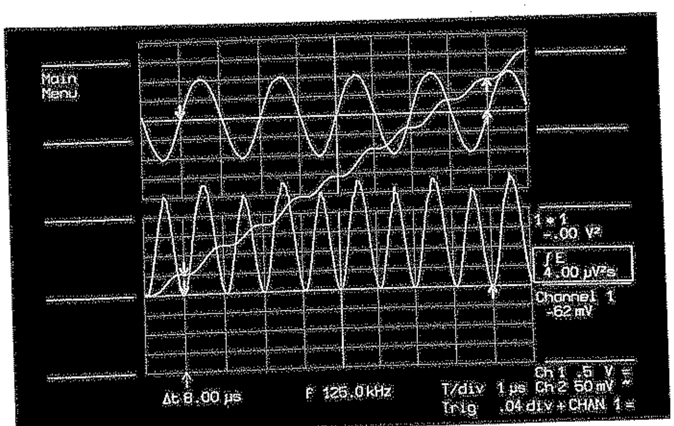
Manual chaining using memory C and D for intermediate results may continue indefinitely.

REMOTE CONTROL

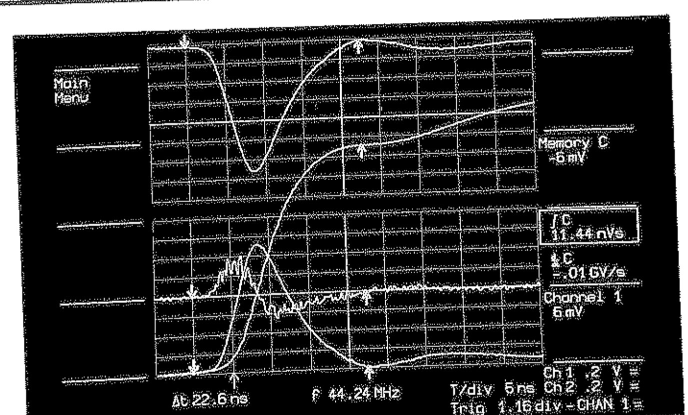
All front panel controls and Waveform Processing functions are fully programmable via the 9400 GPIB and RS232-C interfaces. Simple English-like mnemonics are used.

STORED FRONT PANELS

Up to 7 front panel setups, including WP01 menus, can be stored and recalled by the menu buttons at the left side of the 9400 screen.



*The ± 1 V amplitude sine wave in channel 1 (upper trace) is squared (function E: 1 * 1, lower trace) and then integrated (function F: ∫ E). The value of the integral between the two cursors is 4.00 µ V²s. The RMS value can be calculated with the formula RMS =* $\left(\frac{1}{\Delta t}\int V^2 dt\right)^{1/2}$*. In this case: RMS =* $\left(\frac{1}{8\,\mu s}\cdot 4\mu V^2 s\right)^{1/2} = 0.707\,V$.



Fast negative going impulse at 5 ns/div (upper trace) recorded in Random Interleaved Sampling mode is inverted and stored in memory C (lower trace). Integral and differential are shown in function E and function F. The area under the inverted curve is measured by first defining the area with the time cursors and then reading the value of ∫ C. In this case: 11.44 nVs.

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FAST FOURIER PROCESSING PACKAGE
25,000 POINT TRANSFORMS, SPECTRAL AVERAGING

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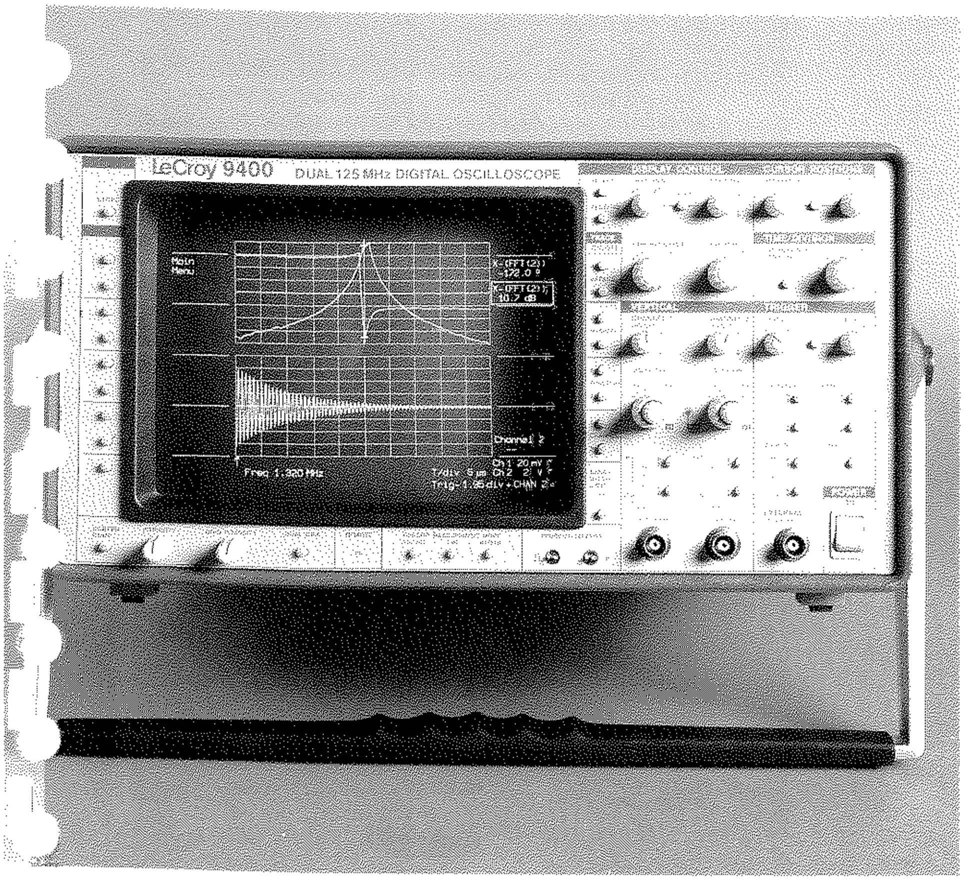
WP02 SPECTRUM ANALYSIS FIRMWARE FOR MODEL 9400 DIGITAL OSCILLOSCOPE



Logmagnitude and phase of a 50 μs damped sine wave. Primary harmonic is 1.320 MHz. Phase and amplitude are measured as function of frequency.

- **50 to 25,000 point FFTs over Two Channels Simultaneously**
- **Frequency Resolution from 1 Milli-Hz to 50 MHz**
- **Up to 5 Gs/s Sampling Rate**
- **Time and Frequency Domain Averaging**
- **Wide selection of FFT Display Formats and Window Functions**

FREQUENCY DOMAIN MEASUREMENTS AND ANALYSIS

The WP02 Spectrum Analysis Firmware Package brings powerful FFT routines to extend the capabilities of the 9400 Digital Oscilloscope into frequency domain measurement and analysis. It is available as an option, or may be retrofitted.
The LeCroy 9400 Digital Oscilloscope provides 150 MHz bandwidth (125 MHz at 5, 10, 20 mV/div), 100 Ms/s. 8-bit ADCs, ±2% DC accuracy (optional ±1%), 32K memory per channel, and up to 192K waveform storage memory. It has GPIB and RS-232C interfacing, full programmability and color archiving via a wide range of digital plotters.

FFT BRINGS STRONG SPECTRAL ANALYSIS CAPABIL
TO THE 9400

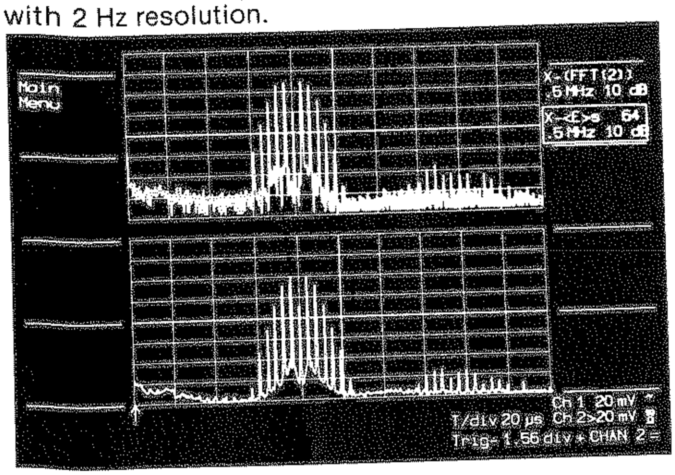
POWERFUL PERFORMANCE IN A WIDE RANGE OF APPLICATIONS

Versatility and performance of the WP02-FFT package with the 9400 make it an ideal tool for a variety of applications such as:

Electronic engineering — As a very high performance spectrum analyzer, it is extremely useful for measuring phase noise, characterizing filters, amplifier bandwidth roll-off, or harmonic distortion.

Communications — The FFT analyzer is ideal for characterizing HF links, modems and data links, cable TV, PCM, fiber optics, etc.

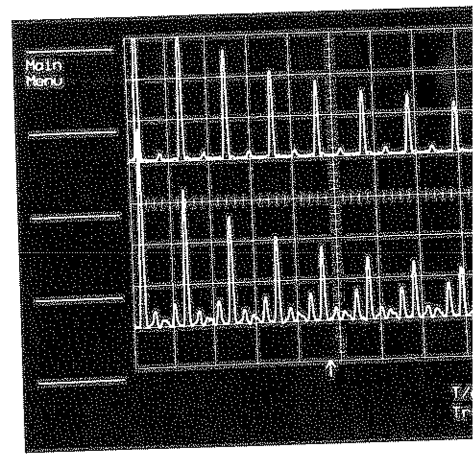
Acoustic devices — Covers the entire audio spectrum in one FFT operation from 25 KHz downwards with 2 Hz resolution.



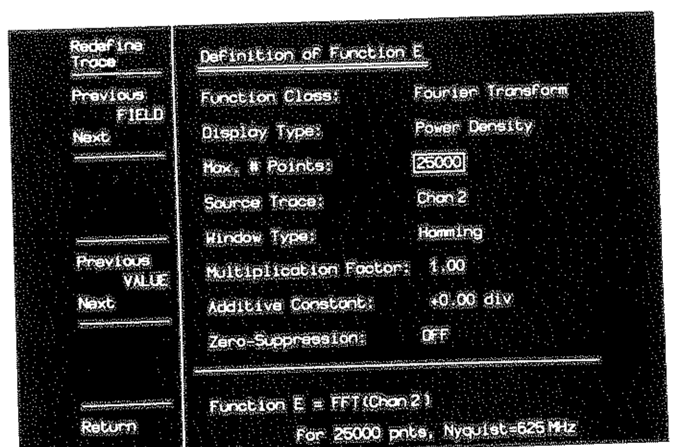
2 MHz signal is frequency modulated with 99 KHz sinewave. To improve signal to noise ratio on phase-incoherent FM signal, spectral averaging up to 64 spectra is used (bottom trace). Spectrum at righthand side is 2nd harmonic of carrier with sidebands.

Preventative maintenance systems —
tion transducer (accelerometers/veloci
displacement transducers), the 9400/V
can be used to analyze the vibration s
rotating and other machinery for timel
of wear or damage.

Non-destructive test engineering — T
width and sampling rate of the 9400,
its long memories, make it a valuable
for ultra sound non-destructive engine
testing. "Long record FFTs" provide
spectral resolution, hence improved c
tion of the material under test, and m
measuring times.



*Long records allow for higher sampling rates
110 KHz squarewave is recorded over 1250 a
sampling rates 200 and 40ns/point respectiv
short-record-transform has considerable alia
record transform (top) is aliasing-free.*



FFT menu documents all relevant parameters.

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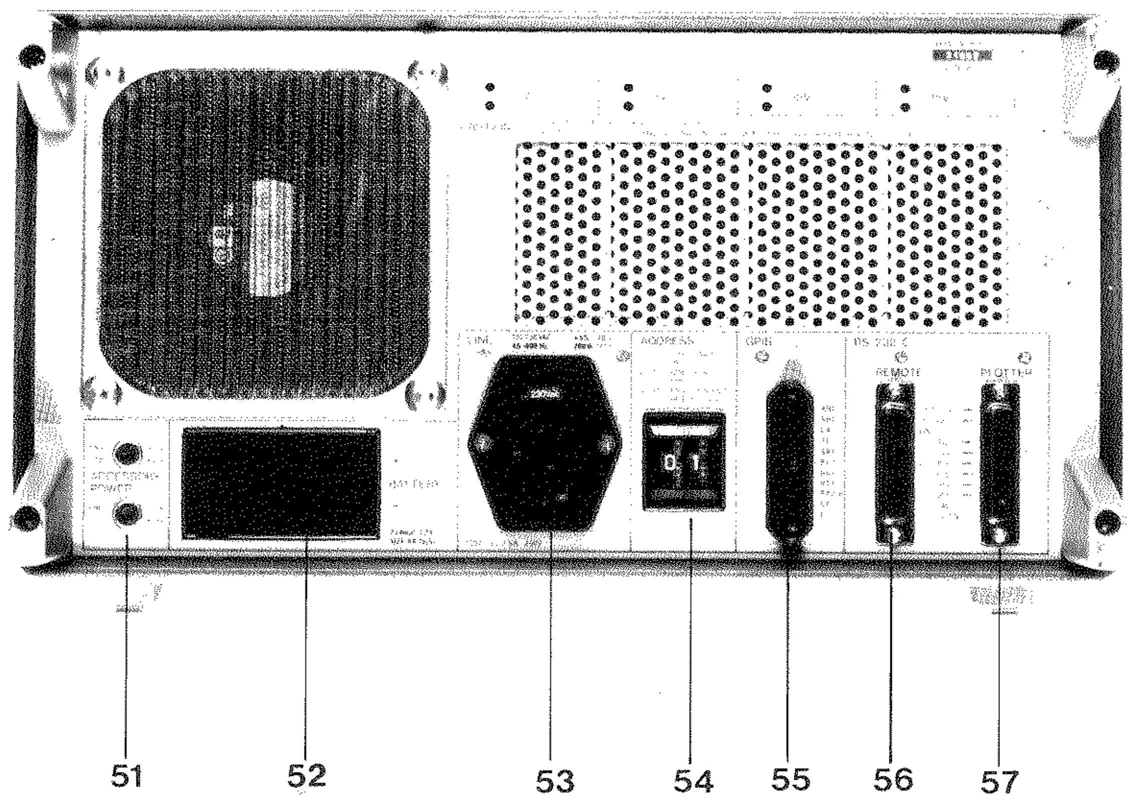


9400 REAR PANEL

Figure 1.2

SECTION 1

GENERAL INFORMATION

1.1 Warranty

LeCroy warrants its oscilloscope products to operate within specifications under normal use and services for a period of two years from the date of shipment. Spares, replacement parts and repairs are warranted for 90 days. Software is thoroughly tested and thought to be functional, but is supplied "as is" with no warranty of any kind covering detailed performance. Accessory products not manufactured by LeCroy are covered by the original equipment manufacturers warranty only.

In exercising this warranty, LeCroy will repair or, at its option, replace, any product returned to the Customer Service Department or an authorized service facility within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and has not been caused by misuse, neglect, accident or abnormal conditions or operations.

The purchaser is responsible for the transportation and insurance charges arising from the return of products to the servicing facility. LeCroy will return all in-warranty products with transportation prepaid.

This warranty is in lieu of all other warranties, express or implied, including but not limited to any implied warranty of merchantability, fitness, or adequacy for any particular purpose or use. LeCroy shall not be liable for any special, incidental, or consequential damages, whether in contract, or otherwise.

1.2 Assistance and Maintenance Agreements

Answers to questions concerning installation, calibration, and use of LeCroy equipment are available from the Customer Service Department, 700 South Main Street, Spring Valley, New York, 10977, U.S.A., (914)578-6059, and 101 Nant d'Avril, 1217 Meyrin, Geneva, Switzerland, (41)22/82-33-55, or your local field engineering office.

LeCroy offers a selection of customer support services.

For example, maintenance agreements provide extended warranty and allow the customer to budget maintenance costs after the initial two year warranty has expired. Other services requested by the customer such as installation, training, on-site repair, and addition of engineering improvements are made available through specific Supplemental Support Agreements.

1.3 Documentation Discrepancies

LeCroy is committed to providing state-of-the-art instrumentation and is continually refining and improving the performance of its products. While physical modifications can be implemented quite rapidly, the corrected documentation frequently requires more time to produce. Consequently, this manual may not agree in every detail with the accompanying product. There may be small discrepancies in the values of components for the purposes of pulse shape, timing, offset, etc., and, occasionally, minor logic changes. Where any such inconsistencies exist, please be assured that the unit is correct and incorporates the most up-to-date circuitry.

1.4 Service Procedure

Products requiring maintenance should be returned to the Customer Service Department or authorized service facility. If under warranty, LeCroy will repair or replace the product at no charge. The purchaser is only responsible for the transportation charges arising from return of the goods to the service facility.

For all LeCroy products in need of repair after the warranty period, the customer must provide a Purchase Order Number before any inoperative equipment can be repaired or replaced. The customer will be billed for the parts and labor for the repair as well as for shipping.

SECTION 2

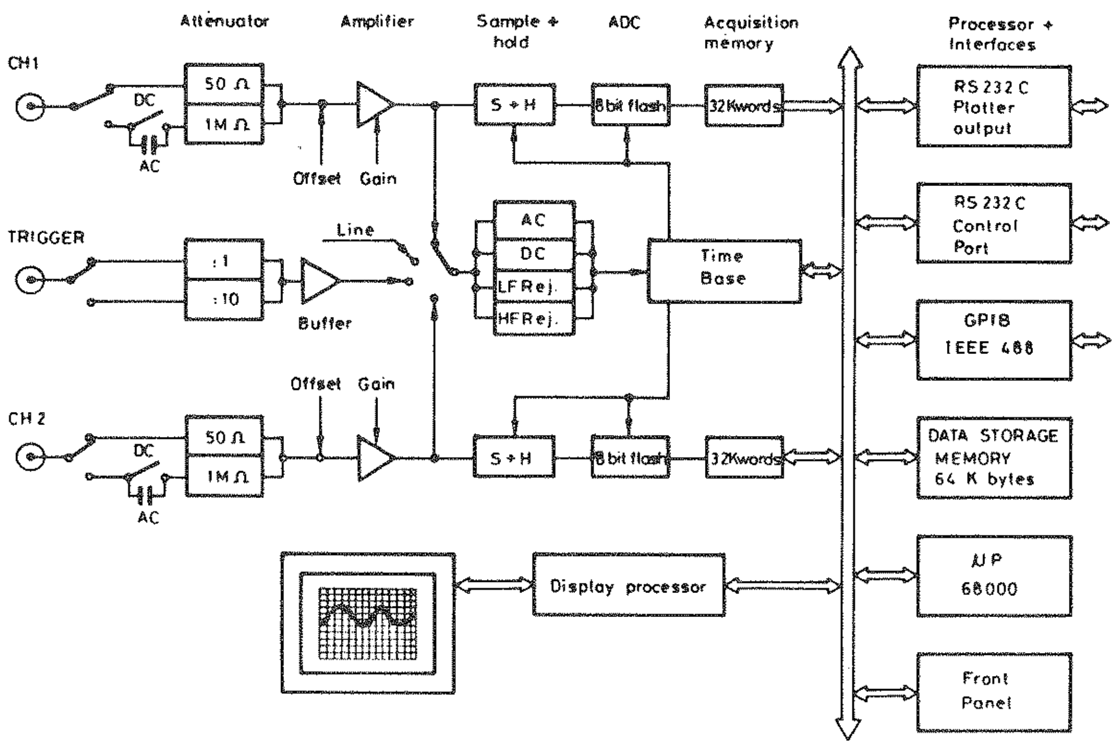
PRODUCT DESCRIPTION

2.1 Introduction

The LeCroy 9400 is a high-performance digital oscilloscope suited to research and to test and measurement applications. It is used to capture, analyze, display and archive electrical waveforms in fields such as: Electronics Engineering, Physics Research, Automated Testing and Measurement, Telecommunications, Electromagnetic Pulse and Interference Measurement, LIDAR Technology and Ultrasonics Research.

2.2 9400 Architecture

The 9400 has been built around the powerful 68000 microprocessor which is used by the unit to perform computations and control of all oscilloscope operations.



9400 BLOCK DIAGRAM

Figure 2.1

All front panel rotary knobs and pushbuttons are constantly monitored by the internal processor, and front panel set-ups are rapidly re-configured via the unit's internal 16-bit bus. Data is quickly processed according to the selected front panel set-ups, and is transferred to the acquisition memory for direct waveform display or stored in the 9400's reference memories, as desired.

The 68000 also controls GPIB (IEEE-488) operation when the oscilloscope is being interfaced with a host computer, as well as that of the unit's two RS232-C ports used to directly interface the 9400 to a digital plotter, remote terminal or other slow speed device.

2.3 ADCs and Memories

The 9400's two identical input channels equipped with a 100 megasample/second (Ms/s), 8-bit ADC and a 32 K word acquisition memory (See Figure 2.1). This dual ADC/memory architecture ensures absolute amplitude and phase correlation, maximum ADC performance for both single and dual channel acquisition modes, large record lengths and high time resolution.

The 9400's two 32 K acquisition memories simplify transient capture by providing very long waveform records that capture waveform features even when the trigger timing is uncertain. In addition, very accurate time measurement is made possible by a digitally controlled zoom providing an expansion factor of up to x 100 the time base speed.

The 9400 oscilloscope is capable of acquiring and storing repetitive signals at a Random Interleaved Sampling rate of 5 gigasamples/second (Gs/s). An exclusive high-precision time digitizing technique permits measurements of repetitive signals to a bandwidth of 125 MHz at an effective measuring interval of 200 ps.

The 9400's very low aperture uncertainty of 10 psec assures precision measurements over its entire range as indicated by the table below:

Dynamic accuracy: (typical) rms sine wave curve fit:

Input Frequency	1 MHz	10 MHz	50 MHz
Signal to Noise Ratio	41 dB	43 dB	38 dB

ADC PERFORMANCE

Table 2.1

2.4 Trigger

The 9400 digitally controlled trigger system offers facilities such as pre trigger recording, bislope and window triggering, sequence and roll modes in addition to the standard operating modes of: Auto, Normal and Single (Hold). The trigger source can be external or either of the two inputs, and the coupling selected between AC, LF REJect, HF REJect and DC.

2.5 Autocalibration

The 9400 has an automatic calibration facility that ensures overall vertical accuracies of ± 2% (optionally ± 1%) and ± 20 ps rms for the unit's crystal-controlled time base.

The time base is recalibrated each time the 9400's time base control is adjusted to a new TIME/DIV setting; vertical gain and offset calibration take place each time the front panel fixed gain control, for either CHAN 1 or CHAN 2, is adjusted to a new VOLTS/DIV setting. Calibration of both channels also takes place each time the BANDWIDTH LIMIT pushbutton is depressed.

2.6 Display

The 9400's large 12.5 cm x 17.5 cm (5 x 7 inches) screen displays analog waveforms with high precision and serves as an interactive, user-friendly interface via a set of screen-oriented pushbuttons located immediately to the left and right of the CRT.

The oscilloscope displays up to four waveforms, while simultaneously reporting the parameters controlling signal acquisition. In addition, the screen presents internal status, measurement results, as well as operational, measurement, and waveform analysis menus.

A hard copy of the 9400 screen is available via the unit's dedicated plotter port.

2.7 Manual and Programmed Control

The 9400's front panel layout and operation will be very familiar to users of analog oscilloscopes. A set of interactive software menus will assist in quickly utilizing the recording and processing capability of the 9400 to its full potential.

The 9400 has also been designed for remote control operation in automated testing and computer aided measurement applications. The entire measurement process, including dynamic modification of front panel settings and display organization, can be controlled via the rear panel RS232-C and GPIB IEEE-488 ports. The latter permit direct interfacing between the 9400 and a host computer at data transfer rates of up to 400 Kb/s.

The LeCroy 9400 is capable of storing up to seven front panel set-ups, which may be recalled either manually or by remote control, thus ensuring rapid oscilloscope front panel configuration or return to a particular set of operating conditions following unit power turn on.

SECTION 3

INSTALLATION

3.1 Safety Information

The 9400 has been designed to operate from a single-phase power source with one of the current-carrying conductors (neutral conductor) at ground (earth) potential. Operation from power sources in which both current-carrying conductors are live with respect to ground (such as phase-to-phase on a tri-phase system) is not recommended, as the 9400 is equipped with over-current protection with respect to one line conductor only.

The 9400 is provided with a three-wire electrical cord containing a three-terminal polarized plug for line voltage and safety ground connection. The plug's ground terminal is connected directly to the frame of the unit. For adequate protection against electrical hazard, this plug must be inserted into a mating outlet containing a safety ground contact.

3.2 Operating Voltage

Prior to powering up the unit, make certain that the line voltage for your area corresponds to the line voltage value appearing in the window of the selector box at the rear of the 9400.

The 9400 has been designed to operate from either a 115 V or 220 V nominal power source at 48 to 62 Hz. If the line voltage appearing in the window differs from that used in your area, refer to Section 6. - Rear Panel Controls and Connectors.

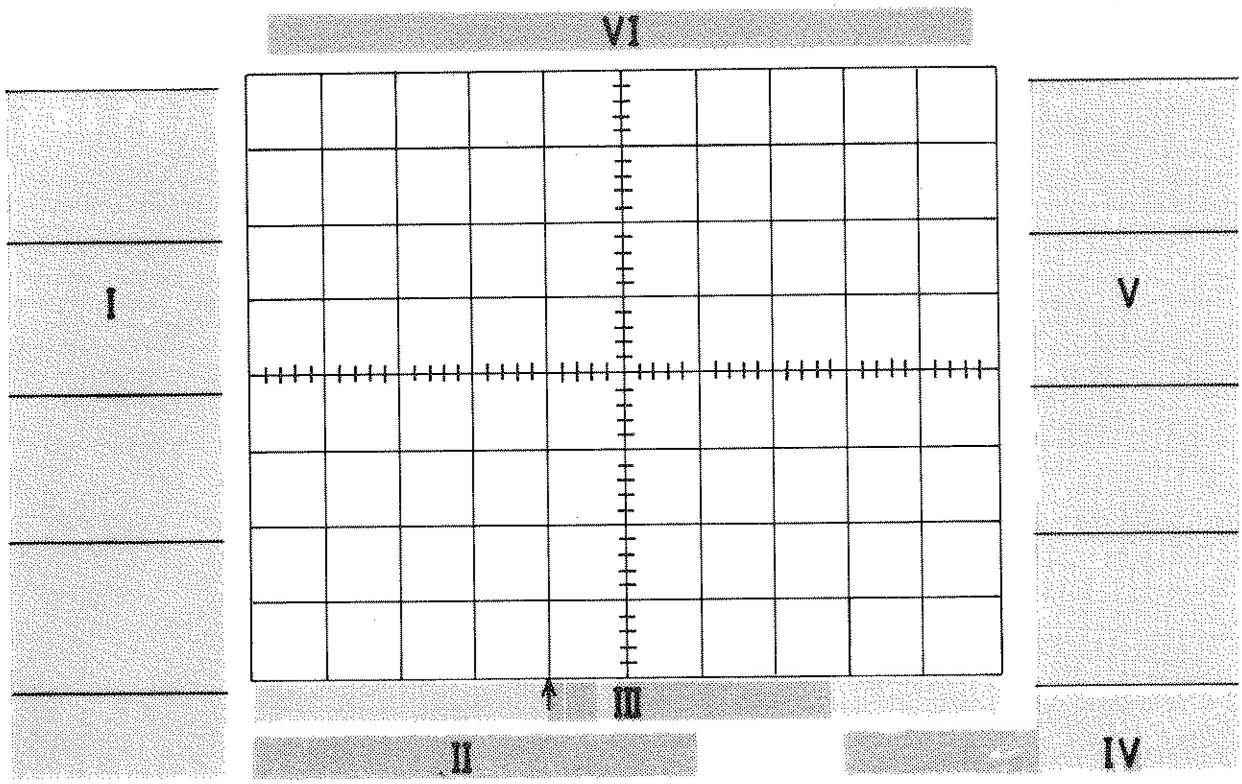
****
CAUTION
****

Although the 9400 has been designed to withstand damage if the unit should be improperly connected to a power source, the oscilloscope will fail to operate and could be damaged if plugged into 220 V when wired for 115 V. Thus, one of the first things to check for, upon delivery, is correct line voltage selection.

SECTION 4

DISPLAY LAYOUT

Besides its centrally located grid (or grids whenever the **DUAL GRID** pushbutton (14) is depressed), on which traces from the 9400's acquisition and/or reference memories are displayed, the scope's CRT is partitioned into a number of fields used to display such information as: interactive menu queries and responses, current acquisition parameters, relative and absolute time and voltage measurements, and messages used to assist the user in the proper operation of the scope.



DISPLAY LAYOUT

Figure 4.1

4.1 Menu Field (I)

This field is divided into nine sub-fields, associated with menu keys 2-10. Each field may display the name of a menu or perform an operation when the related menu key is depressed. The lowest field and related **Return** pushbutton (10) is used to restore the higher menu level.

4.2 Time and Frequency Field (II)

When the Marker cursor is activated by depressing pushbutton (18), this field displays the time difference between the Marker cross-hair and the point of triggering (common for all displayed traces).

When the Time cursors are activated, by depressing pushbutton (17), two readings are indicated. The left-hand reading indicates the time interval between the Reference and Difference arrowhead cursors, while the right-hand reading indicates the frequency corresponding to 1/(Time interval).

4.3 Trigger Delay Field (III)

This field displays either of two indications. In the pre-trigger mode, an upward-pointing arrow appears below the bottom line of the trace display grid, as shown in Figure 4.1. It is adjustable from 0 to 10 divisions, corresponding to a 0 to 100% pre-trigger setting. In the post-trigger mode, this arrow is replaced by a leftward-pointing arrow next to the post-trigger indication (in decimal fractions of a second) at the bottom of the grid. The maximum post trigger setting corresponds to 10000 screen divisions.

4.4 Abridged Front Panel Status Field (IV)

This is a short-form display of the data acquisition parameters, and is updated whenever the 9400's front panel controls are manipulated. This field indicates vertical sensitivities, input couplings, time base and trigger conditions for subsequently acquired waveforms.

See Section 5 for a detailed list of front panel parameters (including the absolute value of input offset).

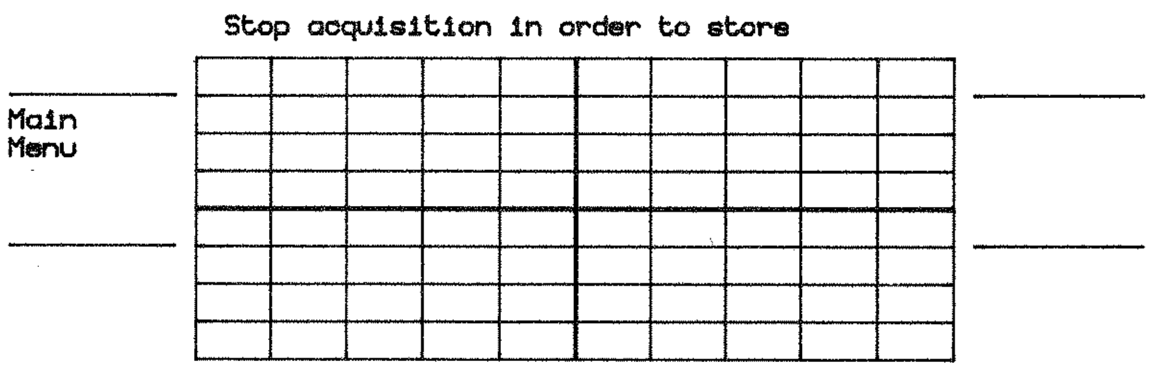
4.5 Displayed Trace Field (V)

The Displayed Trace field is associated with pushbuttons 45-50. The data displayed in this field are: the identity of the displayed trace, current time base and sensitivity settings for the acquired signal, as well as an indication of whether or not the **VAR** sensitivity vernier (28) is in the detent position. Whenever Measurement Cursors (16, 17, 18) are activated, absolute or relative waveform voltage data are displayed in this field.

A frame formed around one of the upper six signal sources in the Displayed Trace field indicates which of the traces is to be acted upon during manipulation of the various display controls ((39) through (43)).

4.6 Message Field (VI)

Messages appearing in field (VI) indicate the 9400's current acquisition status or report on improper front panel control manipulation. The following figure illustrates a typical message displayed in the Message field.



EXAMPLE of MESSAGE FIELD DISPLAY

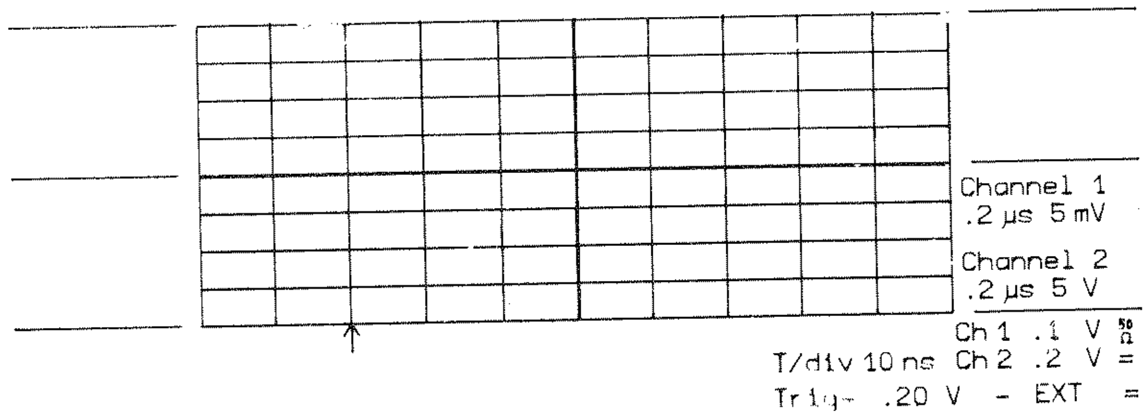
Figure 4.2

****
NOTE
****

In the following sections, Roman numerals in parentheses refer to the display field numbering scheme in Figure 4.1. Arabic numerals relate to the numbering scheme used to refer to front and rear panel controls and connectors Figures 1.1 and 1.2.

The VOLTS/DIV setting for CHAN 1 and CHAN 2 is displayed, along with signal input coupling and various other data, in the abridged Panel Status Field (IV).
Sensitivity may be modified either manually or via remote control, and is immediately updated.

Whereas acquisition control settings displayed in the abridged Panel Status Field (IV) are updated immediately upon manual or remote modifications of the VOLTS/DIV or TIME/DIV settings, the control settings in the Displayed Trace field (V), corresponding to the conditions under which the waveform was stored, are updated with every trigger.



SENSITIVITY DATA DISPLAYED in the ABRIDGED PANEL STATUS FIELD and in the DISPLAYED TRACE FIELD

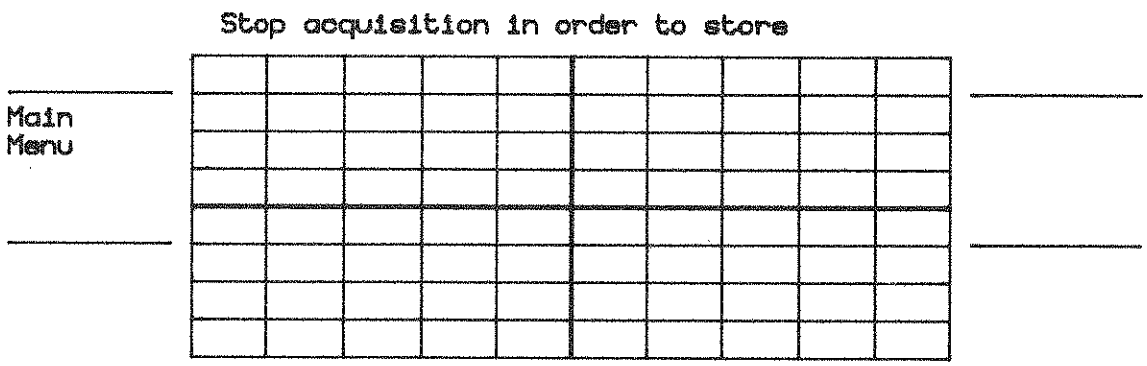
Figure 5.2

VAR (28) - Verniers provide continuously variable sensitivity within the VOLTS/DIV settings and extend the maximum vertical sensitivity factor to up to 12.5 V/div. Variable sensitivity settings are indicated by the ">" symbol in the lower portion of the abridged Front Panel status field and the calibrated value appears in the Total V/div field of the Panel Status menu (See Section 5.2.2). (Minimum sensitivity is achieved by rotating the vernier counter-clockwise.)

VERTICAL OFFSET (32) - This control vertically positions the displayed trace. The maximum offset is ± 1 grid height (± 8 divisions) from the center of the screen, and is manually adjustable (or programmable) in 0.04 division increments. A pair of upward- or downward-pointing double-shaft arrows indicates when the trace has been positioned outside of the grid.

4.6 Message Field (VI)

Messages appearing in field (VI) indicate the 9400's current acquisition status or report on improper front panel control manipulation. The following figure illustrates a typical message displayed in the Message field.



EXAMPLE of MESSAGE FIELD DISPLAY

Figure 4.2

****
NOTE
****

In the following sections, Roman numerals in parentheses refer to the display field numbering scheme in Figure 4.1. Arabic numerals relate to the numbering scheme used to refer to front and rear panel controls and connectors Figures 1.1 and 1.2.

SECTION 5

MANUAL OPERATION

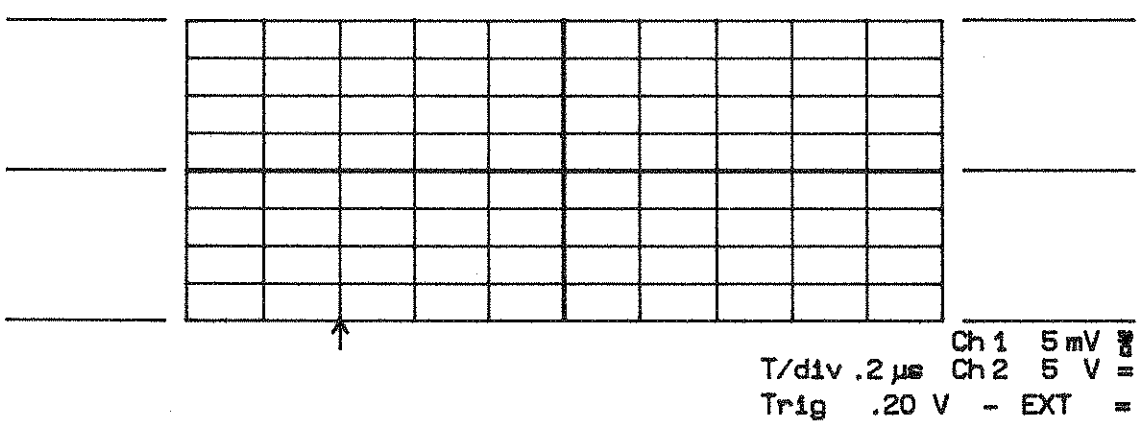
5.1 Front Panel Controls

5.1.1 Vertical

Input Connectors (21) - BNC type connectors are used for both CHAN 1 and CHAN 2 signal inputs as well as the external trigger connector. Maximum permissible input voltage is 250 V (DC + peak AC).

Signal Coupling and Input Impedance (22) - Selects the method used to couple a signal to the vertical amplifier input. In the AC positions, signals are coupled capacitively, thus blocking the input signal's DC component and limiting the lower signal frequencies to < 10Hz. In the DC position, all signal frequency components are allowed to pass through, and the input impedance is selectable between 1 MΩ and 50 Ω. The user should note that with 1MΩ input impedance the bandwidth is limited to 100 MHz. The maximum dissipation into 50 Ω is 0.5 W, and signals will automatically be disconnected whenever this occurs. A red overload LED indicates that this limit has been exceeded, and the input coupling LED (22) is simultaneously switched to GND. The overload condition is reset by removing the signal from the input and re-selecting the 50 Ω input impedance.

VOLTS/DIV (27) - Selects the vertical sensitivity factor in a 1-2-5 sequence. Sensitivity is from 5 mV to 5 V/div at 1 MΩ input impedance and 5 mV to 1V/div at 50 Ω impedance (When the **VAR** vernier (28) is in the detent position).

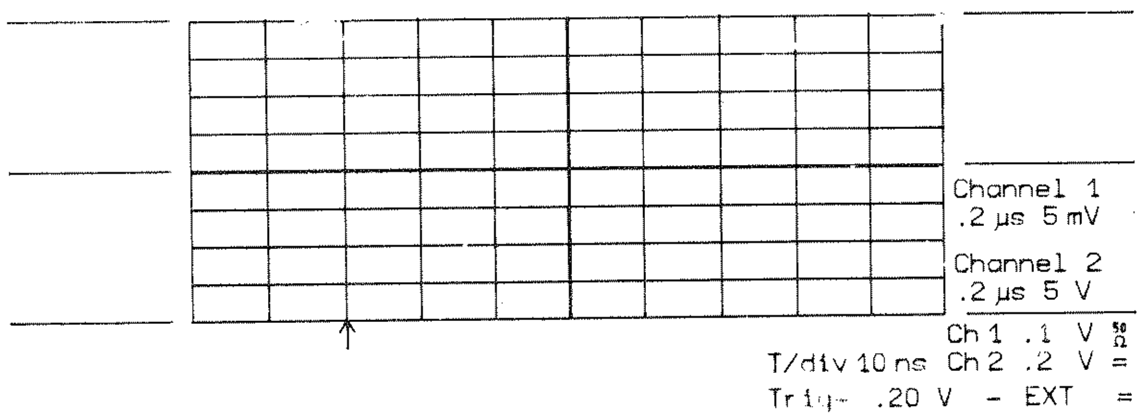


DISPLAY of VERTICAL SENSITIVITY PARAMETERS
in the ABRIDGED PANEL STATUS FIELD

Figure 5.1

The VOLTS/DIV setting for CHAN 1 and CHAN 2 is displayed, along with signal input coupling and various other data, in the abridged Panel Status Field (IV).
Sensitivity may be modified either manually or via remote control, and is immediately updated.

Whereas acquisition control settings displayed in the abridged Panel Status Field (IV) are updated immediately upon manual or remote modifications of the VOLTS/DIV or TIME/DIV settings, the control settings in the Displayed Trace field (V), corresponding to the conditions under which the waveform was stored, are updated with every trigger.

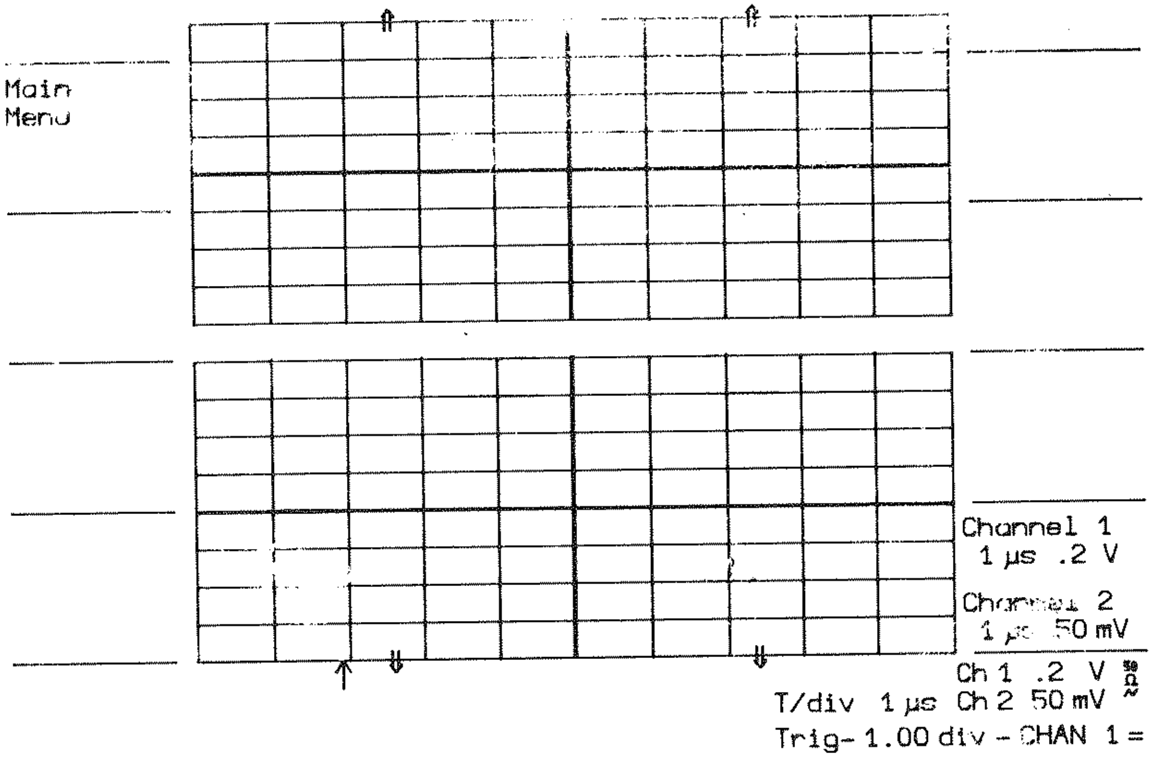


SENSITIVITY DATA DISPLAYED in the ABRIDGED PANEL
STATUS FIELD and in the DISPLAYED TRACE FIELD

Figure 5.2

VAR (28) - Verniers provide continuously variable sensitivity within the VOLTS/DIV settings and extend the maximum vertical sensitivity factor to up to 12.5 V/div. Variable sensitivity settings are indicated by the ">" symbol in the lower portion of the abridged Front Panel status field and the calibrated value appears in the Total V/div field of the Panel Status menu (See Section 5.2.2). (Minimum sensitivity is achieved by rotating the vernier counter-clockwise.)

VERTICAL OFFSET (32) - This control vertically positions the displayed trace. The maximum offset is ± 1 grid height (± 8 divisions) from the center of the screen, and is manually adjustable (or programmable) in 0.04 division increments. A pair of upward- or downward-pointing double-shaft arrows indicates when the trace has been positioned outside of the grid.



UPWARD and DOWNWARD POINTING, DOUBLE SHAFT ARROWS
INDICATING THAT CHANNEL 1 and 2 ARE OFF SCREEN

Figure 5.3

PROBES - Two Model P9010 passive probes are supplied as standard equipment with the 9400. These probes have 10 MΩ input impedance and 6pf. The system bandwidth with P9010 probes is DC to 100 MHz in 1 MΩ DC coupling and < 10 Hz to 100 MHz in AC coupling. Active FET probes (TEKTRONIX models P6201, P6202a and P6230) may be powered via rear panel probe power connectors.

PROBE CALIBRATION (19, 20) - To calibrate the P9010 Probe, connect it to the CHAN 1 or CHAN 2 BNC connector (21). Connect the probe's grounding alligator clip to the front panel ground lug (20) of the oscilloscope and the tip to lug (19).

Adjust the 9400's front panel controls as per Section 8.1. In case of over- or undershooting of the displayed signal, it is possible to adjust the P9010 Probe by inserting the small screwdriver, supplied with the probe package, into the trimmer on the probe's barrel and turning it clockwise or counter-clockwise to achieve an optimal square wave contour.

BANDWIDTH LIMIT (50) - The bandwidth can be reduced from 125 MHz to 30 MHz -3 dB. Bandwidth limiting may be useful in reducing signal and system noise or preventing high-frequency aliasing for single-shot events at time bases below 50 µsec/division.

5.1.2 Time Base

TIME/DIVISION (36) - This control selects the time per division in a 1-2-5 sequence from 2 ns to 100 s. The time base speed is displayed in the abridged Panel Status field (IV) as well as in the Displayed Trace field (V). The time base is crystal-controlled and features an overall accuracy of better than 10^{-5}.

SAMPLING MODES

Three sampling modes are possible with the 9400, depending on time base setting selected by the user. They are:

* Random Interleaved Sampling (RIS)
* Single Shot (SS)
* Roll Mode

Random Interleaved Sampling (RIS)

At time base settings from 2 to 20 ns/division, the 9400 automatically uses the RIS mode for signal acquisition. Repetitive waveforms and stable trigger are required. Points are digitized every 200 ps for an equivalent sampling rate of 5 Gs/s.

Between the 50 ns and 2 µs/division range of time base settings, the user may, if desired, select the RIS acquisition mode by depressing the **INTERLEAVED SAMPLING** pushbutton (37).

Single Shot

For time base settings from 50 ns to 200 ms/division the 9400 records the waveform in a single acquisition. Sampling rates up to 100 MS/s are possible in the Single Shot mode.

Roll

From 500 ms to 100 sec/div, the 9400 samples continuously. Each point digitized updates the display, resulting in a trace moving from right to left similar to that produced by a strip-chart recorder.

TIME BASE SPEED (TIME/DIV)	SAMPLING RATE TIME/POINT RIS	SS	DISPLAYED RECORD LENGTH (Points)* RIS	SS
2.0 ns	200 ps	---	100	---
5.0 ns	200 ps	---	250	---
10.0 ns	200 ps	---	500	---
20.0 ns	200 ps	---	1000	---
50.0 ns	200 ps	10.0 ns	2500	50
0.1 µs	200 ps	10.0 ns	5000	100
0.2 µs	200 ps	10.0 ns	10000	200
0.5 µs	200 ps	10.0 ns	24000	500
1.0 µs	400 ps	10.0 ns	24800	1000
2.0 µs	800 ps	10.0 ns	25000	2000
5.0 µs	---	10.0 ns	---	5000
10.0 µs	---	10.0 ns	---	10000
20.0 µs	---	10.0 ns	---	20000
50.0 µs	---	20.0 ns	---	25000
0.1 ms	---	40.0 ns	---	25000
0.2 ms	---	80.0 ns	---	25000
0.5 ms	---	0.2 µs	---	25000
1.0 ms	---	0.4 µs	---	25000
2.0 ms	---	0.8 µs	---	25000
5.0 ms	---	2.0 µs	---	25000
10.0 ms	---	4.0 µs	---	25000
20.0 ms	---	8.0 µs	---	25000
50.0 ms	---	20.0 µs	---	25000
0.1 s	---	40.0 µs	---	25000
0.2 s	---	80.0 µs	---	25000
		ROLL MODE		
0.5 s	---	0.2 ms	---	25000
1.0 s	---	0.4 ms	---	25000
2.0 s	---	0.8 ms	---	25000
5.0 s	---	2.0 ms	---	25000
10.0 s	---	4.0 ms	---	25000
20.0 s	---	8.0 ms	---	25000
50.0 s	---	20.0 ms	---	25000
100.0s	---	40.0 ms	---	25000

* Note: When the 9400 is remotely read out, the entire memory content of 32,000 words is available at all time base speeds for single shot and roll modes. 24,000 samples are available for all RIS settings except at 1 and 2 µs/div, where 24,800 and 25,000 samples are available, respectively.

LIST of SAMPLING MODES, SAMPLING RATE, and DISPLAYED RECORD LENGTH

Table 5.1

5.1.3 Trigger

EXTERNAL Trigger Input (24) - This BNC input accepts an external trigger signal of up to 250 V (DC + peak AC). Input impedance is 1 MΩ in parallel with < 30 pF. The maximum triggering frequency is 200 MHz.

Trigger SOURCE (23) - Selects the trigger signal source as follows:

CHAN 1 - Selects Channel 1 input signal.

CHAN 2 - Selects Channel 2 input signal.

LINE - Selects the line voltage powering the oscilloscope in order to provide a stable display of signals synchronous with the power line.

EXT - With the Trigger SOURCE set to EXT, a signal applied to the BNC connector labelled EXTERNAL, can be used to trigger the scope within a range of ± 2 V.

EXT/10 - With Trigger SOURCE is set to EXT/10, a signal applied to the BNC connector labeled EXTERNAL, can be used to trigger the scope within a range of ± 20 V.

Trigger COUPLING (30) - Selects the type of signal coupling to the trigger circuit:

AC Trigger - Signals are capacitively coupled; DC levels are rejected and frequencies below 60 Hz are attenuated.

LF REJ - Signals are coupled via a capacitive high-pass filter network. DC is rejected and signal frequencies below 50 KHz are attenuated. The LF REJ trigger mode is used whenever triggering on high frequencies is desired.

HF REJ - Signals are DC-coupled to the trigger circuit and a low-pass filter network attenuates frequencies above 50 KHz. The HF REJ trigger mode is used when triggering on low frequencies is desired.

DC - All of the signal's frequency components are coupled to the trigger circuit. This coupling mode is used in the case of high frequency bursts, or where the use of AC coupling would shift the effective trigger level.

Trigger LEVEL (33) - Adjusts the level of the signal required to generate a trigger.

The trigger range is as follows:

± 5 screen divisions - with CHAN 1 or CHAN 2 as trigger source

None (zero-crossing) with LINE source

± 2 V with EXT source

± 20 V with EXT/10 source

SLOPE (25) - Selects the signal edge used to activate the trigger circuit.

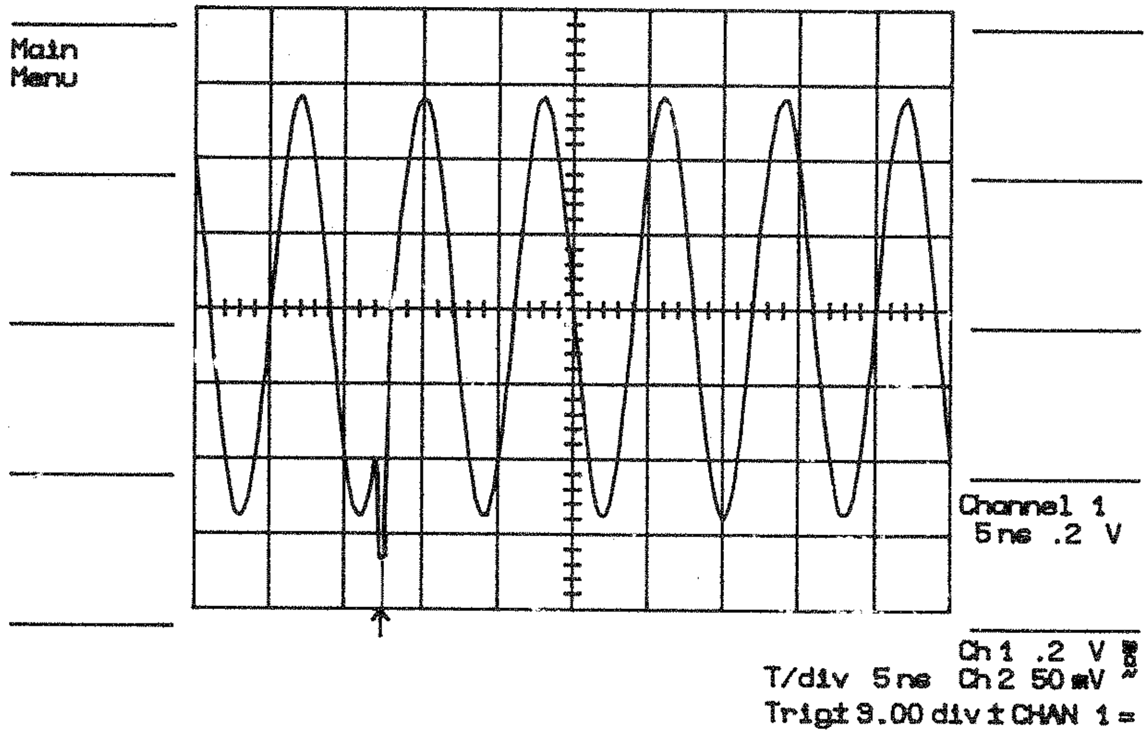
POS - Requires a positive-going edge of the trigger signal.

NEG - Requires a negative-going edge.

(POS/NEG) - Permits "window" triggering on either positive or negative-going signal edges, whichever appears first.

When the POS/NEG trigger slope is selected, the **Trigger LEVEL** control (33) is turned counter-clockwise for bislope triggering at base line level. Turning the **Trigger LEVEL** control (33) clockwise generates a variable amplitude trigger window which is symmetrical with respect to the center of the screen (internal trigger source) and to ground (external trigger source). The user may produce an asymmetrical window, when using an internal trigger source, by offsetting the base line with respect to ground via **Vertical OFFSET** control (32).

The window trigger is useful whenever triggering on normal signal conditions is to be avoided. Exceeding the pre-selected limits will generate a trigger and subsequently store the signal into memory, as shown in the following figure.



WINDOW TRIGGERING

Figure 5.4

In the above figure the trigger level is of ± 3 divisions as indicated in the abridged Panel Status field.

Trigger MODE (29) - Selects the mode of trigger operation as follows:

SINGLE (HOLD) - In this mode, the time base runs until a valid trigger is received. After the waveform has been acquired and displayed, no further signals can be acquired until the **SINGLE (HOLD)** pushbutton has once again been depressed to re-arm the trigger circuit in preparation for the next trigger signal. This type of acquisition is particularly useful for recording transient events.

When the time base is in the Random Interleaved Sampling (RIS) mode, a sufficient number of triggers are accepted to complete a waveform, after which no further samples are taken.

When the time base is in the Roll mode (≥ 500 ms/div), depressing the **SINGLE (HOLD)** pushbutton causes data acquisition to immediately halt and the display to freeze.

NORM - The time base begins to run upon selection of this mode via pushbutton (29). Whenever a valid trigger is received, the acquired waveform is displayed on the CRT, the time base re-started and the trigger circuit re-armed for the next trigger. The display of previously acquired waveforms is erased after 2 sec when no subsequent trigger is received; the absence of a valid trigger will thus result in a blank screen.

To retain the last acquired waveform indefinitely in the NORM mode, the 9400's Autostore feature is used. Autostore can be called via the Special Modes menu, described in Section 5.2.5.

When the time base is in the RIS mode, a sufficient number (typically 200) of valid triggers is required for each display of a complete waveform.

In the Roll mode ($\geq$ 500 ms/div), the 9400 samples the input signals continuously. Each point is immediately updated on the display which results in a trace moving from right to left across the CRT. In the NORM mode, triggers are ignored. The only way to halt data acquisition is to select the SINGLE (HOLD) mode.

AUTO - This mode resembles the NORM mode, except that it automatically generates an internal trigger whenever the selected trigger is not present for more than 500 ms. When the 9400 auto-triggers, the display usually moves in time as the trigger is not time-correlated with the input signal.

Auto trigger can not be used when the time base is in the RIS mode.

When the 9400 is in the Roll mode ($\geq$ 500 ms/div), it samples input signals continuously. In the AUTO mode any valid trigger will halt data acquisition once the trigger delay requirements have been satisfied.

SEQNCE - Sequence triggering enables the user to partition the 9400's acquisition memories into 8 to 250 segments. Waveform acquisition in the SEQNCE mode is particularly useful in the case of short-lived or echoed signals, such as those typically encountered in RADAR, SONAR, LIDAR, NMR.

In this mode, the time base setting determines the total duration (TIME/DIV x 10) of each segment. Changing the number of required segments does not change the time base; it only affects the number of digitized points (record length) per segment. The number of data points per division is shown in the Acquisition Parameters display, called by depressing **Panel STATUS** pushbutton(2).

The display is only updated after a sufficient number of sweeps has been acquired. If less than the required number of triggers is available the SEQNCE acquisition may be aborted by pushing the SEQNCE push button again.

The 9400 then completes the missing sweeps by auto-triggering a sufficient number of times while setting its input coupling temporarily to GND. Thus the artificially completed sweeps will appear on the display as GND lines.

Number of Segments	Points/Segment
8	2500
15	2000
31	1000
62	496
125	240
250	112

SEQUENCE TRIGGER MODE
NUMBER OF SEGMENTS VS. RECORD LENGTH

Table 5.2

When the 9400 is in the SINGLE or SEQNCE trigger mode, i.e., when no further data is being acquired, CHAN 1 or CHAN 2 display is no longer updated. Vertical positioning of the displayed trace may nevertheless be modified via the **OFFSET** control (32). The **VAR** vernier (29) also remains active. However, no other parameter modifications, such as vertical sensitivity or time changes, will act on the display of a currently acquired waveform in CHAN 1 or CHAN 2.

Of course, all parameters may be modified during this time by manipulating the appropriate front panel controls; but such modification--indicated by parameter changes in the abridged Front Panel Status field (IV)--will only be used upon acquisition of the next trace.

Whenever the 9400 is in the NORM or AUTO trigger mode, data is continuously acquired and the display updated in rapid successions. All modifications in acquisition parameters are thus followed quickly by subsequent waveform acquisition which results in their appearing to the user as changes to the CHAN 1 or CHAN 2 display.

TRIG'D and **READY LEDs** (31) - The **TRIG'D** indicator is lit whenever the time base is stopped (normally after a valid trigger). The **READY LED** indicates that the trigger circuit has been armed and the 9400 is currently digitizing input signals. Upon receiving a valid trigger signal, it will continue digitization until the trigger delay has been respected, and will then display the acquired waveform.

DELAY (34) - Adjusts the degree of pre- or post-trigger delay when recording signals in the acquisition memories. Delay operation is via a single continuously rotating knob. Turning this knob at a slow angular rate provides minute adjustment of the trigger point; turning it at a high rate results in rapid trigger point movement. The **DELAY** control makes possible pre-trigger adjustment, displayed in %, up to 100% full scale and post-trigger adjustment up to 10,000 division in .02 division increments.

The pre-trigger indicator is displayed by an upward pointing arrow on the bottom graticule line; the post-trigger indicator is displayed in decimal fractions of a second, preceded by a leftward-pointing arrow, in the left-hand corner of the Trigger Delay field (III).

ZERO (35) - Resets the trigger delay from previously set positions to the leftmost graticule line (i.e., .0% Pre-trigger position).

5.1.4 Display Control

Up to four different waveforms (out of a total of eight) may be simultaneously displayed. Whenever a trace is displayed by depressing one of the **TRACE ON/OFF** pushbuttons ((46)-(49)), the corresponding waveform will appear on the screen together with a short description in the Displayed Trace field (V). Pushbuttons (46)-(49) can be used as convenient trace identifiers, whenever several signals are being displayed simultaneously, by repeatedly depressing one of these pushbuttons and simply seeing which of the displayed traces is turned ON and OFF by this operation.

EXPAND A, B (46) - Turns the displayed expansion of a waveform ON or OFF. CHAN 1 is shown by EXPAND A and CHAN 2 is shown in EXPAND B by default. This default mode may be modified by using the **REDEFINE** pushbutton (45). The expanded portion of the waveform is displayed on the source trace by an intensified region.

MEMORY C, D (47) - Turns the display of a waveform in reference Memories C or D ON or OFF. Acquired data may be stored into these memories via the **STORE** pushbutton (1), as described in Section 5.2.1.

FUNCTION E, F (48) - If your 9400 is equipped with a waveform processing firmware option, depressing this pushbutton will turn the display of a computed waveform ON or OFF. The type of computation may be defined by depressing the **REDEFINE** pushbutton (45). See WP01 Waveform Processing Option, Section 10.

CHANNEL 1, 2 (49) - Turns the display of signals applied to either of the input connectors (21) ON or OFF. Recording of data into CHAN 1 and CHAN 2 acquisition memories always occurs simultaneously and irrespective of whether the trace display is ON or OFF.

Displayed traces may be modified within certain limits following waveform acquisition.

CHAN 1 and CHAN 2 traces are controlled by the **VERTICAL** and **Time Base** controls ((27), (28), (32) and (36), (37), respectively).

Six traces, EXPAND A, B (46), MEMORY C, D (47), and FUNCTION E, F (48) are controlled by the **Display Control** knobs and pushbuttons ((39)-(45)). Only one trace is controllable at a time. The identity of the controlled trace is indicated by a rectangular frame around the waveform descriptor in the Displayed Trace field (V).

Whenever more than one of the upper six traces is currently displayed, the frame may be moved to the next trace by depressing the **SELECT** pushbutton (44).

Horizontal POSITION (39) - Horizontally positions an expanded waveform and the intensified region along the source trace. This control is activated only after the **EXPAND A** and/or **B** pushbuttons (46) have been depressed to display the expanded trace. Normally, horizontal movement is continuous; however, if the source trace is a SEQNCE record (i.e., a number of sequentially acquired traces in partitioned memory), Horizontal POSITION will be discrete, thus allowing the selection of any single segment.

The **Horizontal POSITION** control affects only EXPAND A, B.

Vertical POSITION (40) - Vertically re-positions the trace.

RESET (41) - Serves to reset previously adjusted VERT GAIN, Vertical and/or Horizontal POSITION to the following default values:

VERT GAIN - Same as original trace

Vertical POSITION - Same as original trace

Horizontal Position - Center of original trace

In the Common Expand mode (See Section 5.2.5.2), this pushbutton is used to synchronize the two intensified regions of EXPAND A and B.

VERT GAIN (42) - Encreases or reduces the gain of displayed waveforms by a factor of up to 2.5 when turned clockwise or conter-clockwise respectively. Depressing RESET (41) returns gain control to a mid range plateau corresponding to a gain of 1. If the 9400 is equipped with WP01, VERT GAIN range is encreased from 2.5 to 10 for averages, mathematics and functions.

TIME MAGNIFIER (43) - This control horizontally expands waveforms by a factor of up to 100.

Overall timing accuracy is improved at higher magnification factors, since the expand function is controlled digitally and makes use of the scope's higher number of recorded data points. This control has no effect on MEMORY C, D or FUNCTION E, F.

SELECT (44) - Chooses one of the traces--EXPAND A through FUNCTION F--to be controlled via **Display Control** knobs and pushbuttons ((39)-(45)). The selected trace is indicated by a rectangular frame around the waveform descriptor in the Displayed Trace field (V). Depressing the **SELECT** pushbutton (44) moves the rectangle to the next displayed trace in a rolling sequence.

REDEFINE (45) - Used to redefine the identity of the selected waveform. EXPAND A, B traces may be redefined to be the expansion of CHAN 1 or CHAN 2, Memory C or D or Function E or F (for 9400's equipped with the Waveform Processing Option).

Depressing the **REDEFINE** pushbutton (45) calls a menu on the left-hand side of the screen enabling selection of the desired source redefinition. When the pushbutton corresponding to this redefinition is depressed, EXPAND A or B will be temporarily selected as the new source trace until subsequent redefinition is performed. The default signal sources are: CHAN 1 for EXPAND A and CHAN 2 for EXPAND B.

It is not possible to redefine Memories C and D; Function E and F may only be redefined if your 9400 is equipped with the Waveform Processing Option. For scopes with this option installed, see the Waveform Processing Option Section 10.

INTENSITY (12) - Adjusts the intensity of the displayed trace and all alphanumeric read-outs and messages. The **INTENSITY** control may be adjusted in either manual or programmed control mode.

GRID INTENSITY (13) - Controls grid and graticule intensity independently of displayed trace intensity.

DUAL GRID (14) - This pushbutton switches between single and dual grid patterns. The dual grid is useful when displaying multiple traces, in which case, the CHAN 1 display is permanently assigned to the upper grid and CHAN 2 to the lower grid. All other displayed traces may be re-positioned anywhere on the screen via the **Vertical POSITION** control (40).

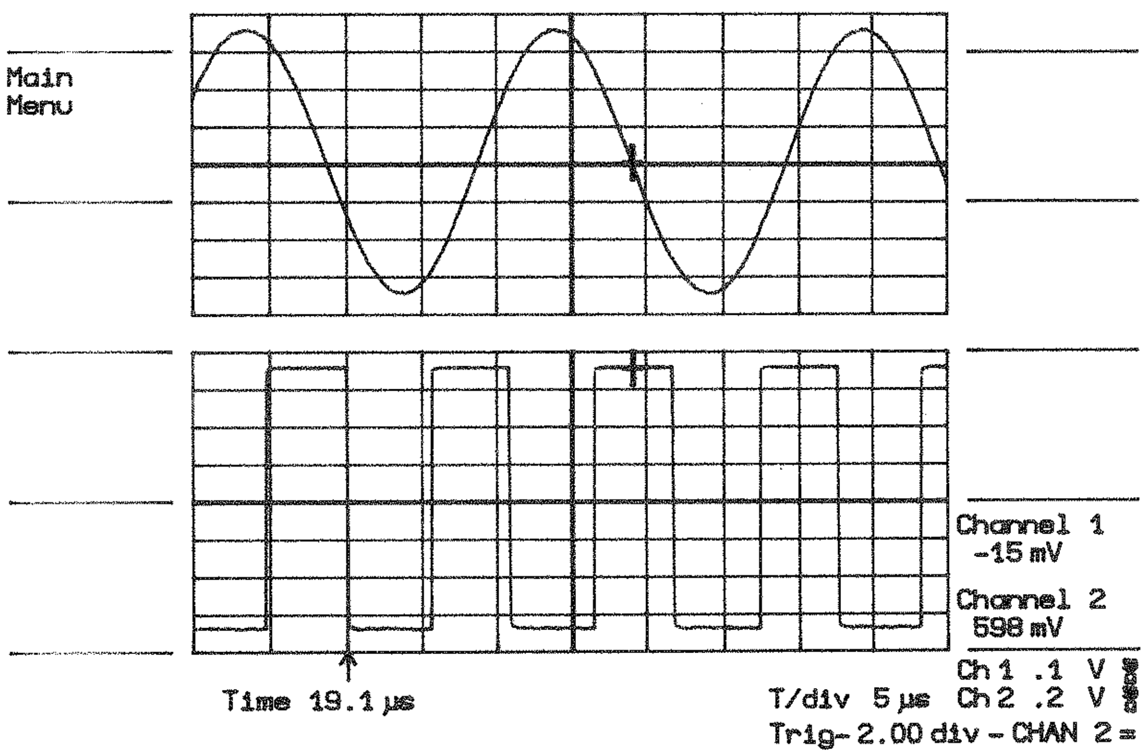
SCREEN DUMP (11) - Dumps the contents of the screen to an on-line digital plotter via the 9400's rear panel GPIB or RS232-C interface port and provides color or monochrome hard copy archiving of the display. All of the screen illustrations included throughout this manual were produced using the SCREEN DUMP function.

5.1.5 Cursors

Cursor measurements can be made with any number of displayable traces on the 9400's CRT. In the case of multiple traces cursor measurements are performed on all displayed traces simultaneously.

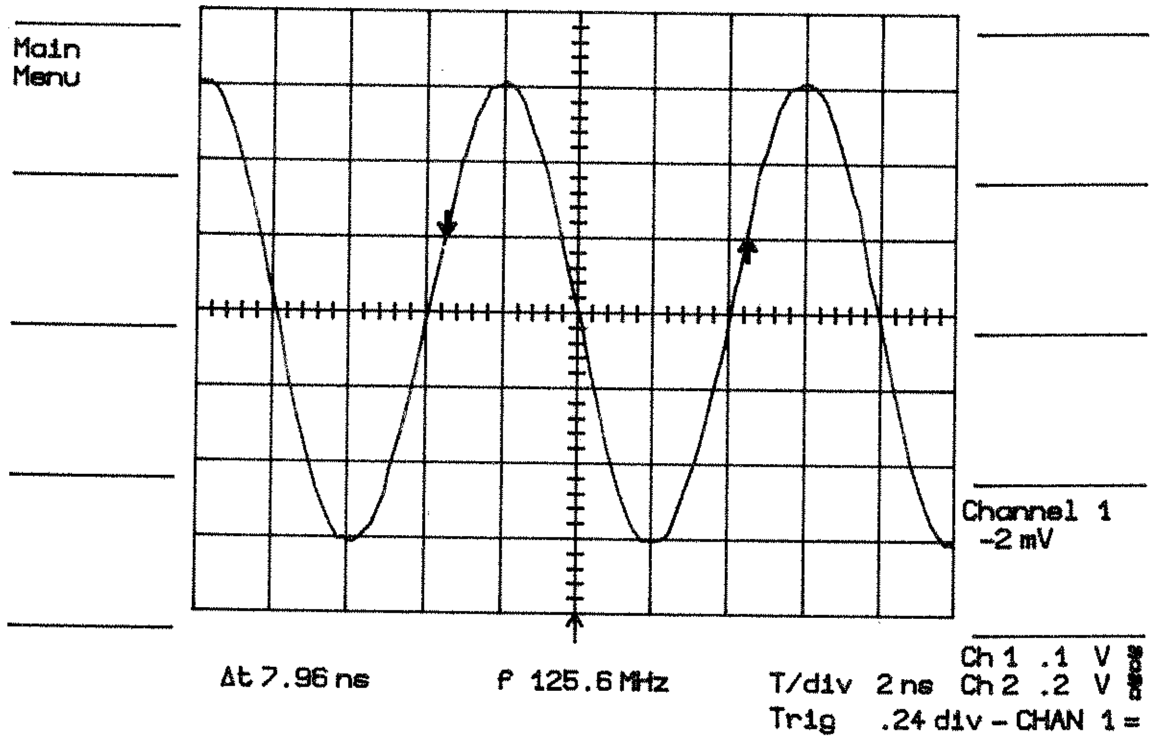
MARKER Cursor (18) - Depressing this pushbutton generates a + cross-hair marker for precise time measurements relative to the point of triggering, as well as absolute voltage measurements along the displayed waveform irrespective of the vertical offset of the trace displayed on the grid.

Note that setting the marker cursor to 0 time interval provides a visual indication of the trigger point.



DISPLAYED TRACES SHOWING MARKER CURSOR,
INTERVAL BETWEEN TRIGGER POINT and CURSOR, as
well as ALPHANUMERIC READOUT of TRACES AMPLITUDES.
Figure 5.5

TIME Cursors (17) - Generate downward-pointing and upward-pointing arrows along the currently displayed traces, permitting accurate differential time, voltage and frequency measurements. Time cursors are displayed as follows:



DISPLAYED TRACE SHOWING TIME CURSORS,
their VOLTAGE DIFFERENCE then TIME DIFFERENCES
and the CORRESPONDING FREQUENCY.

Figure 5.6

Note: Measurement resolution with Time cursors is 0.2% of full scale (10 divisions).

In the case of expanded traces, Time cursors are displayed on the trace, providing up to x100 higher resolution measurement (0.002% maximum, depending on the setting of **TIME MAGNIFIER** control(43)).

Use of the waveform expansion facility is therefore recommended to ensure the most accurate time measurements.

Memory Status

Ch 1+2 STATUS

Exp A+B

Mem C+D STATUS

Fun E+F

Return

PLOTTING

MEMORY STATUS V 2.050L

	Expand A	Expand B
Total V/div	50.0 mV	50.0 mV
Offset	152.0 mV	16.0 mV
Coupling+BW-Limit	AC 1 MΩ, OFF	DC 50 Ω, OFF
Time(Freq)/div	.2 ms	.2 ms
T(F)/pnt + Pts/div	80 ns, 2500	80 ns, 2500
Trig-Delay	10.0% Pre	10.0% Pre
Tr-Level + Slope	-- , +	-- , +
Tr-Source + Coupl	LINE , DC	LINE , DC
Memory Limits	-7000,25000	-7000,25000
Record-Type	SINGLE	SINGLE

TRACE A, B EXPAND STATUS MENU

Figure 5.13

Memory Status

Ch 1+2 STATUS

Exp A+B

Mem C+D STATUS

Fun E+F

Return

PLOTTING

MEMORY STATUS V 2.050L

	Memory C	Memory D
Total V/div	50.0 mV	50.0 mV
Offset	.0 mV	.0 mV
Coupling+BW-Limit	DC 50 Ω, OFF	DC 50 Ω, OFF
Time(Freq)/div	.5 ms	.5 ms
T(F)/pnt + Pts/div	200 ns, 2500	200 ns, 2500
Trig-Delay	.0% Pre	.0% Pre
Tr-Level + Slope	- 20.0 V , -	- 20.0 V , -
Tr-Source + Coupl	EXT/10, DC	EXT/10, DC
Memory Limits	-7000,25000	-7000,25000
Record-Type	SINGLE	SINGLE

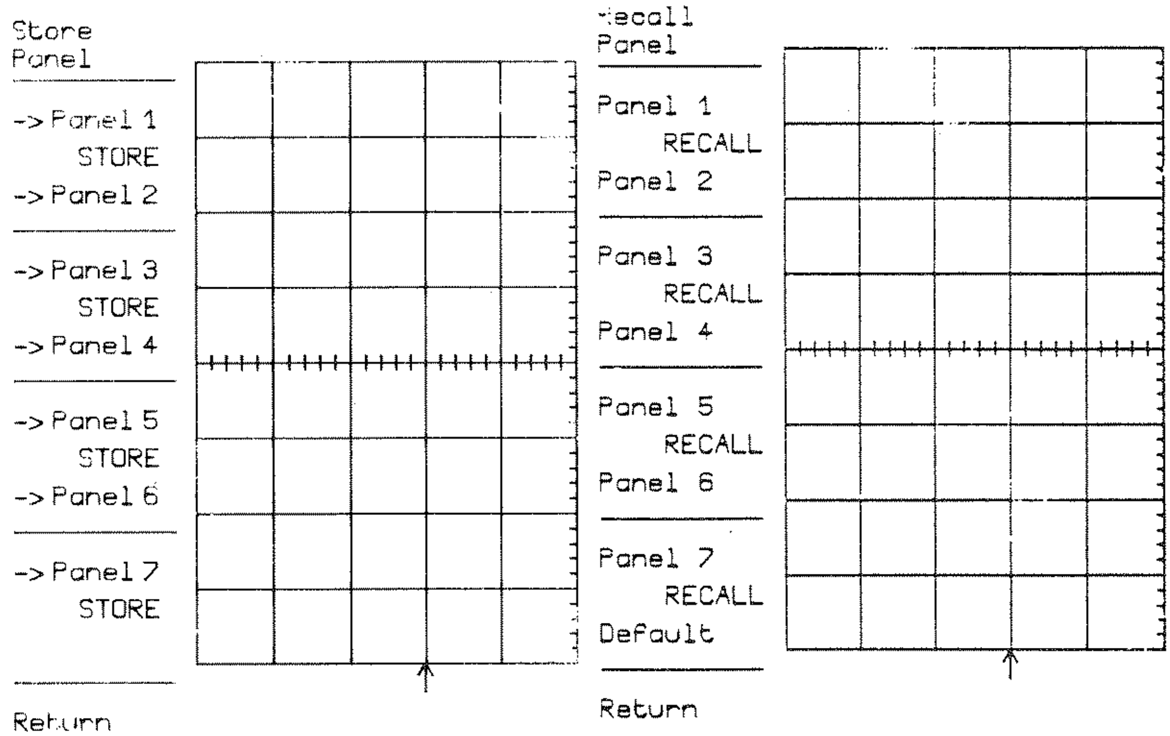
MEMORY STATUS C and D

Figure 5.14

The indication in the upper right-hand corner of Figures 5.12, 5.13, 5.14 corresponds to the software version implemented in the scope.

5.2.4 Storage and Recall of Front Panel Set-ups

Depressing **Store PANEL** or **Recall PANEL** pushbuttons ((4) and (5), respectively) enables storage or recall of up to seven different front panel acquisition parameter settings.



STORE and RECALL FRONT PANEL SET-UP MENUS

Figure 5.15

Once you have obtained a satisfactory front panel set-up, simply call the Store PANEL menu by depressing pushbutton (4); then depress keys 1 through 7 to store this front panel set-up. Depress the **Return** pushbutton (10) to go back to the Main menu and continue normal scope operation.

To recall a previously stored front panel set-up, depress the **Recall PANEL** pushbutton (5) while in the Main menu. A list of the seven stored front panel set-ups which are available will be displayed. Depress the particular pushbutton 2 to 8 which corresponds to the desired set-up, and the front panel settings will automatically be configured according to the acquisition parameters thus recalled.

5.2.5 Special Modes (7)

Softkey	Screen
	SPECIAL MODES
Modify Auto-Store	AUTO-STORE OFF
	In NORM and AUTO, the oscilloscope may be forced to automatically store one or both channels in either memory C or D after the acquisition of each wave-form. This mode slows down the display repetition rate, since a storage operation takes about 80 ms.
Mod. Common Expand	
	COMMON EXPAND OFF
	When ON, the horizontal position and time magnifier control knobs act on both expanded traces A AND B for a simultaneous horizontal scan. The vertical gain and position remain individually controlled.
Return	
PLOTTING	

SPECIAL MODES MENU

Figure 5.16

5.2.5.1 Autostore Mode

Depressing the **Special Modes** pushbutton (7) permits you to automatically store--following acquisition--CHAN 1 or CHAN 2 into the unit's two reference memories.

Depressing the **Modify Auto Store** pushbutton (2) permits the user to choose from among the following possible storage modes: CHAN 1 into Memory C or D; CHAN 2 into Memory C or D, or, alternatively, CHAN 1 into Memory C and CHAN 2 into Memory D.

This is a useful feature for very low repetition rate signals acquired in the NORMAL trigger mode. Subsequent display of the selected reference memory provides the user with a lasting waveform display which can be studied long after the originally acquired signal has been erased. In the NORMAL trigger mode CHAN 1 and CHAN 2 display is automatically erased after a two second interval in order to warn the user that a proper trigger is not available.

5.2.5.2 **Common Expand Mode**

Section 5.1.4 discusses independent expansion of single traces to display a magnified portion of the waveform from CHAN 1 and/or CHAN 2, of those stored in reference Memories C and/or D, or of function E and/or F if the 9400 is equipped with WP01 Waveform Processing firmware. In certain applications, however, it is convenient to be able to move the intensified region along two different traces simultaneously. This is the purpose of the Common Expand mode.

In this mode it is possible to either synchronize the intensified regions of the two source signals or to maintain a fixed time interval between them, in which case the intensified regions for each trace will move horizontally at a fixed interval. (See Section 8.11 for an example of intensified regions shifting on two traces expanded in the Common Expand mode).

In the Common Expand mode, when the user is examining two expansions at a fixed interval (he may re-synchronize them by depressing the **RESET** pushbutton (41)) both expansions are shifted to the center of the grid. Turning the **Horizontal POSITION** control (39) until both of the intensified regions move off the screen will also re-synchronize them.

In the Common Expand mode, only the **Horizontal POSITION** control (39) and **TIME MAGNIFIER** control (43) act simultaneously on the intensified regions on both the Expand A and B signal source, while the **VERT GAIN** control (42) and **Vertical POSITION** control (40) act independently on each expanded waveform.

Note that when the Common Expand mode is called, the EXPAND A magnification factor applies to both A and B expansion.

5.2.6 **RS232-C Set-up** (8)

Two RS232-C ports are available on the rear panel of the 9400 permitting remote oscilloscope operation and data transfer, as well as convenient plotter interfacing.

When in the main menu, depressing **RS232 SETUP** pushbutton (8) calls an interactive menu enabling configuration of both of the 9400's RS232-C ports in accordance with particular application. Parameters for the plotter-dedicated RS232-C port (57) are displayed in the lower portion of the screen, while those for the remote RS232-C port (56) are presented in the upper portion of the screen.

	RS232 - Remote control port
Previous FIELD Next	Baud rate: [9600]
	Character length (bits): 8
	Parity: none
	Number of stop bits: 1
Previous VALUE Next	**RS232 - Plotter port**
	Baud rate: 9600
	Character length (bits): 8
	Parity: none
Return PLOTTING	Number of stop bits: 1

RS232-C SET-UP MENU

Figure 5.17

To modify any of the parameters displayed, first select the field to be modified. The rectangular frame around parameter values indicates the currently selected field. Depressing the **Previous FIELD** pushbutton (2) will cause the frame to move towards the top of the list, whereas depressing the **Next FIELD** pushbutton (3) will cause the frame to move downwards.

Following field selection, the current value of the field may be modified by depressing either the **Previous** or **Next VALUE** pushbutton ((6) or (7), respectively). Baud rate is selectable between 110 and 19,200 baud; character length between 6, 7, and 8; parity between none, even or odd; and the number of stop bits between 1 and 2.

5.2.7 Plotter Set-up (9)

The 9400 has been designed to permit direct interfacing of the oscilloscope with four of the most popular plotter types via the rear panel GPIB (IEEE-488) or the RS232-C dedicated plotter port.

When the 9400 is connected to a plotter via the GPIB port, with no host computer in the configuration, the oscilloscope's rear panel thumb-wheel switch must be set to the Talk Only mode (address $\geq$ 31 decimal) and the plotter to the Listen Only mode.

The method of working with the interactive plotter set-up menu is similar to that used to configure the RS232-C ports (see Section 5.2.6 above).

	PLOTTER
Previous FIELD Next	Plotter: HEWLETT PACKARD 7470A or compatible
	Plotter port: RS232
	Plot speed: NORMAL
	Number of installed pens: 2
Previous VALUE Next	PLOT SIZE
	Paper size: A4 (ISO) - US 11'/8.5' The plot area will be less than: 229 mm * 160 mm
Return PLOTTING	

PLOTTER SET-UP MENU

Figure 5.18

The various user-selectable parameters:

Plotter Type:	HP7470A (or compatible), PHILIPS PM8151 (or compatible),TEKTRONIX or GRAPHTEC FP 5301
Plotter Port:	RS232-C or GPIB (IEEE-488)
Plot Speed:	Normal or Low Speed
Number of Installed Pens:	1 to 9
Plot Size:	ISO A5 (US 8.5" x 5.5"), ISO A4 (US 11" x 8.5"), ISO A3 (US 17" x 11") or non-standard
Non-Standard:	In the case of non-standard paper sizes, the size of the grid square is selectable from 0 to 99.9 mm in .1mm steps; low left corner position from 0 to 999 mm (for both X and Y co-ordinates) in 1 mm steps.

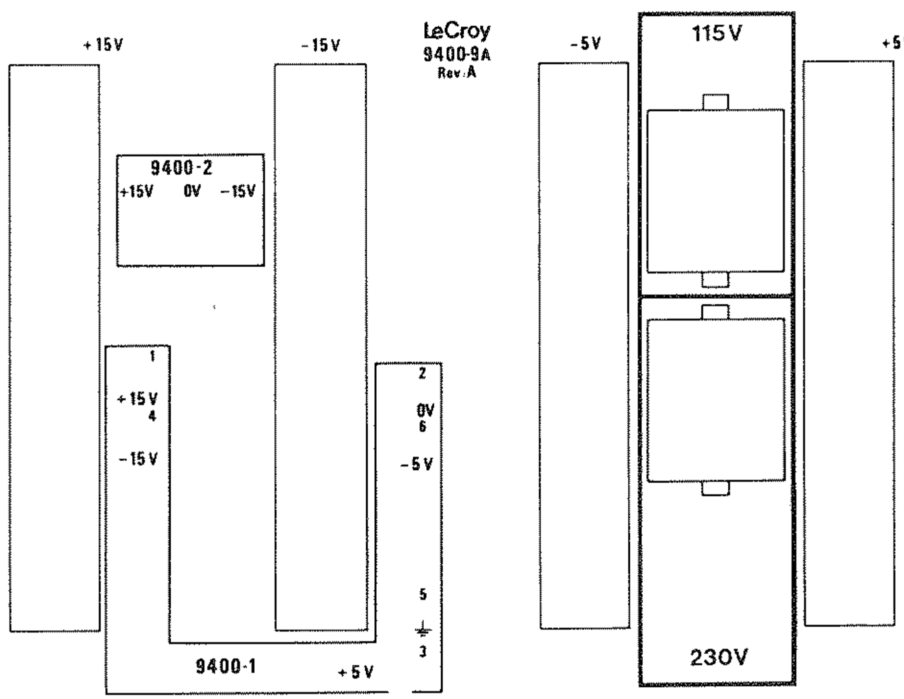
SECTION 6

REAR PANEL CONTROLS AND CONNECTORS

6.1 Line Voltage Selection (53)

In order to adapt the 9400 to local line voltages of 115 or 220 V, open the rear panel voltage selector case with a screwdriver after having first removed the unit's power cable. Next, take out, rotate, and re-insert the voltage selector drum, making certain that the proper line voltage is displayed in the window of the selection case cover when it is snapped closed.

For units with serial numbers below 86000, once the drum displays the correct line voltage, take off the upper cover of the 9400 by removing the 4 retaining screws at the sides of the cover. Next, depress the upper and lower "ears" of the power connector, located on the PC board at the end of the four 9400 power packs. (See printed board layout below). Unplug it and re-insert it into the socket corresponding to the line voltage displayed in the window of the selector case cover. In the case of units whose serial number is above 86000, the user need only adjust the rear panel drum.



LOCATION on PC BOARD of CONNECTOR for 115/220 V
LINE VOLTAGE SELECTION

Figure 6.1

6.2 Fuse Protection

The power supply of the 9400 is protected against short circuits and overload by means of a 2.5 A slow-blow fuse, located under 115 to 220 V line voltage selector drum cover. Modification is unnecessary, as the same fuse is used for both line voltages.

6.3 Accessory Power Connectors (51)

Two LEMO RA 0304 NYL connectors have been provided to permit use of FET type probes with the 9400. These connectors provide output voltages of + 5 V, ± 15 V and GND connection, suitable for most FET probes.

The maximum output current per connector must be limited to 150 mA for each of the three voltages.

6.4 Battery Pack (52)

The battery pack consists of two KR 15/51, 1.2 V rechargeable NiCd batteries, which permit retention of front panel set-ups in case of power failure or whenever the 9400 is shut off. The battery pack, with a retention capacity of 6 months, is automatically recharged during unit operation.

Battery can be accessed by depressing the plastic latch at the top of the cover and pulling downward and toward the user.

6.5 GPIB and RS232-C Port Selection (54)

The 9400's rear panel thumb-wheel switch is used to set addresses for programmed or remote oscilloscope operation. Addresses 0-30 define the 9400's address when using the GPIB (IEEE-488) port; any one of addresses 31-99 selects the RS232-C port.

GPIB and RS232-C pin assignments are clearly indicated on the rear panel next to each connector.

6.6 Plotter Connector (57)

In addition to the RS232-C port (56) used for remote 9400 operation, a second dedicated RS232-C port (57) has been incorporated to facilitate direct interfacing of the 9400 with a digital plotter. Plotters are used for hard copy archiving of displayed waveforms and other screen data. Pin assignments for the plotter connector are identical to those of the remote RS232-C port (56).

While a plotter unit connected to the 9400 RS232-C port can be computer controlled from a host computer via the GPIB, the oscilloscope's on board digital plotter drivers permit hard copy plots without the need for an external computer.

Plotter connector pin assignments:

Pin #		Description
2	T x D	Transmitted Data (from the 9400)
3	R x D	Received Data (to the 9400)
4	RTS	Request To Send (always on) (from the 9400)
5	CTS	Clear To Send (to the 9400) When TRUE, the 9400 can transmit. When FALSE, transmission stops. Used for 9400 output hardware handshake.
20	DTR	Data Terminal Ready (from the 9400) Always TRUE.
6	DSR	Data Set Ready (to the 9400)
1	GND	Protective Ground
7	SIG GND	Signal Ground

This corresponds to a DTE configuration.

SECTION 7

REMOTE OPERATIONS

7.1 Programmed Control

Most of the front panel and internal functions of the 9400 can be remotely controlled using a set of high-level, English-like commands and mnemonics. For example, a command followed by <?> tells the scope to transfer to the host computer the value of the control setting defined by the command. It is thus possible to read the complete status of the instrument by repeated queries. It is also possible to save the entire status of the instrument in binary format with a single command. The 9400's remote control facility allows complex measurement procedures and instrument set-ups, a particularly useful feature in experimental and automated testing environments.

In addition to programming the 9400 via the GPIB (IEEE-488 bus), remote control of the unit is also possible via the rear panel RS232-C port interfaced with a computer terminal or a computer. Of course, in this case data transfer rates are relatively slower.

7.2 GPIB Port (55)

The 9400's GPIB interface complies with IEEE-488 (1978) standards, and is intended to provide high-speed data transfer in either the ASCII or binary format between the 9400 and the computer to which it is interfaced. The maximum data transfer rate, depending on the controller used, may be as high as 400 Kbytes/s.

GPIB Port Selection (54)

As mentioned in Section 6.5, the 9400's rear panel thumb-wheel switch is used to set addresses for programmed or remote oscilloscope operation. Addresses 0-30 define the 9400's address when using the GPIB (IEEE-488) port; using any one of addresses 31-99 selects the RS232-C port. The thumbwheel is read at power ON only. Whenever the GPIB address is changed, the power must be turned off and on again.

GPIB functions are clearly indicated on the rear panel next to the GPIB connector.

GPIB Functions

The following is a list of the various functions provided via the 9400's rear panel GPIB connector:

AH1	Complete Acceptor Handshake
SH1	Complete Source Handshake
L4	Partial Listener Function
T5	Complete Talker Function
SR1	Complete Service Request Function
RL2	Partial Remote/Local Function
DC1	Complete Device Clear Function
DT1	Complete Device Trigger
PP1	Parallel Polling: remote configuration
C0	No Controller Functions
E2	Tri-state Drivers

7.3 RS232-C Ports (56 and 57)

The 9400 has two RS232-C ports. One is available for computer or terminal controlled oscilloscope operation, the other for plotter interfacing. The RS232-C ports provide an asynchronous data transfer rate of up to 19,200 baud.

RS232-C Pin Assignments

The remote RS232-C pin Assignments (indicated on the rear panel) are as follows:

Pin #		Description
2	T x D	Transmitted Data (from the 9400)
3	R x D	Received Data (to the 9400)
4	RTS	Request To Send (always on) (from the 9400)
5	CTS	Clear To Send (to the 9400) When TRUE, the 9400 can transmit. When FALSE, transmission stops. It is used for the 9400 output hardware handshake.
20	DTR	Data terminal ready (from9400). If the software Xon/Xoff handshake is selected: Always TRUE. Otherwise (hardware handshake): TRUE when the 9400 is able to receive characters. FALSE when the 9400 is unable to receive characters.
6	DSR	Data Set Ready (to the 9400)
1	GND	Protective Ground
7	SIG GND	Signal Ground

This corresponds to a DTE configuration.

Although descriptions vary slightly pin assignments for the dedicated plotter interface (Section 6.6) are identical to those for the remote RS232-C connector above.

7.4 GPIB and RS232-C Command Format

7.4.1 Introduction

All remote control commands apply equally to communication via the GPIB or RS232-C ports. Certain functions, however, which are part of the GPIB standard (such as Device Clear or Group Execute Trigger) must be implemented as separate commands for the RS232-C interface (see Section 7.6.10). The command syntax is compatible with IEEE Recommended Practice for Code and Format Conventions (IEEE Standard 728-1982).

In GPIB, the predefined control commands, such as Device Clear, Group Execute Trigger, Set Remote or Set Local, are part of the device driver commands. Therefore, the 9400 has no English-like commands for these functions, except for RS232. The user must consult the manual of his GPIB-interface driver in order to determine the form of these special commands.

Commands are formed of easy-to-read, unambiguous English words, with abbreviations (typically 2 to 4 characters) being used to achieve higher throughput. Short and long formats may be freely substituted for one another.

The execution of certain commands depends on whether the 9400 is in the REMOTE or LOCAL state.

When the 9400 is in LOCAL:

- All front panel controls are active.
- Reading the 9400 by remote control is possible.
- The status byte masks (see MASK command) and the communications protocol (see COMM command) may be written, status bytes may be cleared.

When the 9400 is in REMOTE:

- All front panel controls are de-activated, except the two display intensity controls.
- All remote commands are executed.
- A special command (SCREEN) de-activates the front panel display intensity controls and allows them to be set remotely.

The HEX and UNSIGNED_FIXED are fixed size formats, whereas UNSIGNED_SHORT is a variable size format. Therefore, it requires commas for the separation of the values.

Examples:

```
HEX format:      #L000A0102030405060708090A
UNSIGNED_FIXED: #L...10..1..2..3..4..5..6..7..8..9.10     . = space
UNSIGNED_SHORT: #L,10,1,2,3,4,5,6,7,8,9,10
```

Note:
The conversion type and the size must be fixed before reading AND writing data.
Data transfers via RS232 can only be made in ASCII formats.

If the Host computer allows sending or reading only small amounts of data, the transfer may be partitioned into several blocks of the selected format. The maximum length of each block is determined by the COMM_BLOCKSIZE command. The length includes all bytes or characters of the block as well as characters which may compose the <TRAILER> and <END>.

The transfer will be structured as follows:

1st Block -- <TRAILER><END> -- 2nd Block -- <TRAILER><END> -- ....
.... -- Last Block -- <TRAILER><END> -- END block -- <TRAILER><END>

Where the END block is:

#I

When reading data from the 9400, the exact form of the TRAILER is determined by the command COMM_TRAILER, and <END> is:

<END> = <CR> when using RS232 (unless modified with the command RS_CONF).

= EOI ACCOMPANYING the last character of TRAILER, when in GPIB.

If the 9400 receives another command message, terminated with <END>, while sending data, the transfer is aborted and status byte 6 (ERROR) is set to the value 1.

Data may be lost if the readout sequence is interrupted with a Serial Poll or by the untalk command.

7.6 Commands

7.6.1 Notation

In this section, the following notation is used (but must not be sent to the 9400):

```
[ to ]   denotes the range of a numerical value.

<    >   denotes the choice of parameters.
<    >
<    >

(    )   denotes the abridged format of a keyword.

  ,      denotes a separator which may be <,> or a space or <=>.
         The last two are only acceptable between the header and
         the first parameter, not between parameters.
```

* indicates commands which can be executed in REMOTE only. Queries (terminated with a <?>) are always allowed.

** indicates commands which can only be executed in REMOTE when the display intensity controls have been explicitly set to REMOTE as well.

Example:

```
TIME/DIV (TD) , < ?                  >
                < [ 2 NS to 100 S ] >          *
```

"TIME/DIV" is the long format of the command for the control of the timebase.

"TD" is the short form equivalent of "TIME/DIV". Either form may be used at all times.

The comma stands for the separator between the header and the first parameter. It may be replaced by a space or by an equal sign <=>, or by any combination of these. Note that subsequent parameters MUST be separated from each other by commas only.

The parentheses < > show that the choice of the first (and only) parameter is either <?> or a timebase value in the range of 2 ns to 100 s.

The asterisk <*> indicates that this command can only be executed when the 9400 is in the REMOTE state. The query "TIME/DIV ?", however, can always be executed.

7.6.2 Acquisition Parameter Commands

```
1) TIME/DIV (TD)     , < ?                >
                       < [ 2 NS to 100 S ] >        *
```

Other available suffixes are: US for microseconds and MS for milliseconds respectively.

Sets VALUE ADAPTED bit:
- If an out of range value is given.
- If a value outside the incremental steps of 1, 2, 5 is given.

Examples:

TD = ?	Instructs 9400 to send the current timebase value.
TD 20 US	Sets 9400 to 20 microseconds per division.
TIME/DIV 12 MS	Sets the 9400 to 10 milliseconds; since the value is modified from 12 ms to 10 ms, the VALUE ADAPTED bit in status byte 1 is set.

```
2) INTERLEAVED (IL)  , < ?          >
                       < ON         >            *
                       < OFF        >            *
```

Enables or disables Interleaved Sampling.

Sets ENVIRONMENT ERROR:
- If ON command is sent while the timebase is greater than 2 US.
- If OFF command is sent while the timebase is less than 50 NS.

```
3) TRIG_DELAY (TRD) , < ?                          >
                      < [ 0.00 % to 100.00 %      ] >   *
                      < [ -0.04 NS to -1000000 S ] >   *
```

Positive format: pre-trigger.
Negative format: post-trigger delay.

Valid delay values correspond to 0 to 10000 timebase divisions in steps of 1/50th div. If the TIME BASE is changed, the delay remains the same or may change just slightly due to rounding, provided that it does not exceed 10000 divisions.

Note:
In the case of post-trigger delay, the remote value is negative while the corresponding value displayed on the screen is positive.

Sets VALUE ADAPTED bit:
- If a positive out of range value is given.
- If a negative value corresponding to more than 10000 divisions is given.

```
4) TRIG_LEVEL (TRL) , < ?                           >

                    , < [ -5.00 DIV to 5.00 DIV ] >    *
```

When the oscilloscope is set to one of the internal trigger sources (CHANNEL_1 or CHANNEL_2).

```
                    , < [ -2.00 V to 2.00 V ]     >    *
```

When the oscilloscope is set to in the EXT trigger source.

```
                    , < [ -20.0 V to 20.0 V ]     >    *
```

When the oscilloscope is set to the EXT/10 trigger source.

When the oscilloscope is set to LINE trigger source, this command has no meaning and no error will be reported. In the case of POS_NEG triggering, only a positive value is meaningful.

Sets VALUE ADAPTED bit:
- If an out of range value is given.

Sets ENVIRONMENT ERROR:
- If the DIV suffix is sent instead of V or the V suffix is sent instead of DIV.

```
5) TRIG_COUPLING (TRC)  , < ?             >
                          < AC            >        *
                          < DC            >        *
                          < LF_REJ (LF)   >        *
                          < HF_REJ (HF)   >        *

6) TRIG_MODE (TRM)      , < ?             >
                          < SEQNCE (SE)   >        *
                          < AUTO (AU)     >        *
                          < NORM (NO)     >        *
                          < SINGLE (SI)   >        *
```

Sets ENVIRONMENT ERROR:
- If SEQNCE is sent while the 9400 is in Interleaved Sampling.

```
7) TRIG_SOURCE (TRS)    , < ?              >
                          < CHANNEL_1 (C1) >       *
                          < CHANNEL_2 (C2) >       *
                          < LINE (LI)      >       *
                          < EXT (EX)       >       *
                          < EXT/10 (E/10)  >       *
```

```
8) TRIG_SLOPE (TRP)      , < ?              >
                           < POS (PO)       >         *
                           < NEG (NE)       >         *
                           < POS_NEG (PN)   >         *

9) SEGMENTS (SEG)        , < ?              >
                           < 8              >                  *
                           < 15             >                  *
                           < 31             >                  *
                           < 62             >                  *
                           < 125            >                  *
                           < 250            >                  *
```

Indicates or selects the number of segments for waveforms acquired in SEQNCE mode.

```
10) CHANNEL_1_VOLT/DIV (C1VD)   , < ?                            >
    CHANNEL_2_VOLT/DIV (C2VD)     < [ 5.000 MV to 12.500 V ] >  *
```

Range is limited to 2.5 Volts per division in the case of 50 Ω coupling.

Note:
The value corresponds to the 9400 input gain.
It does not take probe attenuation factors into account.

Sets VALUE ADAPTED bit:
- If an out of range value is given.

Examples:

CHANNEL_2_VOLT/DIV,500 MV	Sets channel 2 to 500 mV/div
C1VD=.5	Sets channel 1 to 500 mV/div
C2VD 120 MV	Sets channel 2 to 120 mV/div by choosing 100 mV/div fixed gain and setting the variable gain to the required value.

```
11) CHANNEL_1_ATTENUATION (C1AT)   , < ?          >
    CHANNEL_2_ATTENUATION (C2AT)     < 1          >          *
                                     < 10         >          *
                                     < 100        >          *
                                     < 1000       >          *
```

Indicates or selects the attenuation factor of the probe.

```
12) CHANNEL_1_OFFSET (C1OF)   , < ?                              >
    CHANNEL_2_OFFSET (C2OF)     < [ -8.00 DIV to 8.00 DIV ] >  *
```

Sets VALUE ADAPTED bit:
- If an out of range value is given.

```
13) CHANNEL_1_COUPLING (C1CP)   , < ?                   >
    CHANNEL_2_COUPLING (C2CP)     < AC_1_MOHM (A1M)     >      *
                                  < DC_1_MOHM (D1M)     >      *
                                  < GND                 >      *
                                  < DC_50_OHM (D50)     >      *
```

```
14) BANDWIDTH (BW)    , < ?    >
                        < ON   >                               *
                        < OFF  >                               *
```

15) STOP

Stops the acquisition of a signal. This command may be used to return the 9400 from the "armed" state to the "triggered" state, when the trigger is absent. It generates records similar to those produced in the AUTO trigger mode.

It is also useful to stop a SEQNCE acquisition when the number of triggers available is insufficient to fill all sweeps. Upon receipt of the STOP command, the 9400 automatically fills the remaining sweeps with the ground line.

7.6.3 Display Commands

```
1) DUAL_GRID (DG)    , < ?    >
                       < ON   >                  *
                       < OFF  >                  *
```

Examples:

DUAL_GRID ON	Instructs the 9400 to display dual grids.
DG OFF	Instructs the 9400 to display a single grid of 8 times 10 squares.

```
2) TRACE_CHANNEL_1 (TRC1)     , < ?    >
   TRACE_CHANNEL_2 (TRC2)       < ON   >             *
   TRACE_EXPAND_A (TREA)        < OFF  >             *
   TRACE_EXPAND_B (TREB)
   TRACE_MEMORY_C (TRMC)
   TRACE_MEMORY_D (TRMD)
   TRACE_FUNCTION_E (TRFE)
   TRACE_FUNCTION_F (TRFF)
```

Sets ENVIRONMENT ERROR:
- If 4 traces are already ON, and a command is received to turn a 5th trace ON.

Examples:

TRC1 ?	Instructs the 9400 to send a message, indicating if the display of channel 1 is on or off.
TRMC = OFF	Instructs the 9400 to turn the display of memory C off.

```
3) SELECT (SEL)      , < ?              >
                       < EXPAND_A (EA)  >        *
                       < EXPAND_B (EB)  >        *
                       < MEMORY_C (MC)  >        *
                       < MEMORY_D (MD)  >        *
                       < FUNCTION_E (FE) >       *
                       < FUNCTION_F (FF) >       *
```

Selects a display trace, similar to the front panel control. Thereafter, the comands VERT_GAIN, VERT_POSITION, TIME_MAGNIFIER, HOR_POSITION and REDEFINE will be applied to the selected trace.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace is OFF.

```
4) VERT_GAIN (VG)  , < ?                  >
                     < [ 1.000 to 2.500 ] >        *
```

VERT_GAIN is applied to the SELECTed trace. This command instructs the 9400 to modify the display gain (not the acquisition gain) by a factor of up to 2.5. Note that a factor of 2.000 corresponds to a REDUCTION of the waveform image by a factor of 2, while the number of VOLTS/DIV INCREASES by a factor of 2.

Sets VALUE ADAPTED bit:
- If an out of range value is given.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace is OFF.

```
5) VERT_POSITION (VP)   , < ?                              >
                          < [ -16.00 DIV to 16.00 DIV ] >   *
```

VERT_POSITION is applied to the SELECTed trace. This command instructs the 9400 to modify the display position (not the acquisition offset) of the selected trace by up to ± 16 divisions, relative to the original position at acquisition.

Sets VALUE ADAPTED bit:
- If an out of range value is given.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace is OFF.

6) TIME_MAGNIFIER (TM) , < ? >
< [0 to 6] > *

TIME_MAGNIFIER is applied to the SELECTed trace. It may only be applied to traces EXPAND_A or EXPAND_B.
The value 0 corresponds to no expansion. Any increment of 1 corresponds to the next lower time base value (relative to the original trace). The value 6 therefore allows an expansion by a factor of 100.

Sets VALUE ADAPTED bit:
- If an out of range positive value is given. Negative values generate a semantic error.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace is OFF.
- If the SELECTed trace is neither EXPAND_A nor EXPAND_B.

7) HOR_POSITION (HP) , < ? >

, < [0.0000 DIV to 10.0000 DIV] > *

When the source trace corresponds to a single waveform (acquired in single shot or with INTERLEAVED ON).

, < [1 to max] > *

When the source trace corresponds to multiple waveforms (acquired in SEQNCE).
The parameter indicates the number of the sequence to be displayed. "max" depends on the selected number of segments (see SEGMENTS).

HOR_POSITION will be applied to the SELECTed trace. It may only be applied to traces EXPAND_A or EXPAND_B. The parameter in the range of 0 to 10 divisions corresponds to the CENTER of the intensified region on the original trace. The smallest possible step is .0004 div.

Sets VALUE ADAPTED bit:
- If an out of range value is given (Interleaved Sampling or Single Shot).
- If a positive out of range value is given (SEQNCE). Negative or zero values generate a semantic error.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace is OFF.
- If the SELECTed trace is neither EXPAND_A nor EXPAND_B.

8) REDEFINE (RDF) , < ? >
< CHANNEL_1 (C1) > *
< CHANNEL_2 (C2) > *
< MEMORY_C (MC) > *
< MEMORY_D (MD) > *

Redefines the source of the SELECTed trace to be CHANNEL_1, CHANNEL_2, MEMORY_C, or MEMORY_D. The SELECTed trace must be EXPAND_A or EXPAND_B.

Sets ENVIRONMENT ERROR:

- If the SELECTed trace is OFF.
- If the SELECTed trace is neither EXPAND_A nor EXPAND_B.

9) MESSAGE (MSG) , <String to be displayed> *

The string may be up to 43 characters in length. The message is displayed in the Message Field above the graticule (see Section 4.6).

Example:

MESSAGE "Apply probe to J11.5, then press READY"

Instructs the 9400 to display the message between the string delimiters " on the line above the graticule. The push button READY does not exist on the 9400, but any of 9 softkeys may be defined as such with the command KEY.

10) KEY , < [1 to 9] > , <String to be displayed> *

The string is displayed in the Menu Field (see Section 4.1) next to the softkey selected with the first parameter. The string may be up to 11 characters in length.

Examples:

KEY 3,!READY!

Instructs the 9400 to display the message "READY" next to the third (from the top) softkey on the left hand side of the graticule. This command is only accepted if the string delimiter has been changed from the default value <"> to <!> with the command COMM_STRDELIM=33.

KEY 1,"Restart"

Instructs the 9400 to display the message "Restart" next to the first softkey. Here, the default string delimiter is used.

```
11) SCREEN (SCR)  , < ?              >
                    < REMOTE (RM)  >                      *
                    < LOCAL (LC)   >                      *
```

or

```
SCREEN (SCR)  , < ON     >                              **
                < OFF    >                              **
```

or

```
SCREEN (SCR)  , < INTENSITY (INT)    > , [0 to 170] **
                < GRID_INTENSITY (GI)>                 **
```

"?" permits knowing the status of the screen.

"REMOTE" and "LOCAL" select the control mode of the screen. Upon entering the 9400 into the REMOTE state, the screen stays on LOCAL to still permit an operator to make display intensity adjustments. The screen must be explicitly put into the REMOTE state before the commands marked with "**" may be applied.

"ON" and "OFF" turn respectively ON and OFF the screen. When the 9400 is used as a transient recorder, i.e., without anyone looking at the display, turning off the display considerably improves the response time of the instrument since the display generation (which may take up to more than 100 msec) is suppressed.

"INTENS" and "GRID_INT" set the display intensity.

Sets VALUE ADAPTED bit:
- If a value greater than 170 is given.

7.6.4 Plotter Commands

```
1) PLOTTER (PT)  , < ?   >
```

or

```
PLOTTER (PT)  , <name> , <port> , <speed> , <pens>  *

<name>     =    < GRAPHTEC (GR)          >
                < HEWLETT_PACKARD (HP)   >
                < PHILIPS (PH)           >
                < TEKTRONIX (TEK)        >

<port>     =    < RS232 (RS) >
                < GPIB (GP)  >

<speed>    =    < NORMAL_SPEED (NS) >
                < LOW_SPEED (LS)    >
```

<pens> = [1 to 9]

Configures the 9400 for a predefined plotter.

Examples:

PLOTTER HP,RS,NS,2

Configures the 9400 for a Hewlett-Packard plotter, connected to the RS232-C plotter port, running at normal speed, with 2 pens. This is the way to configure for the HP7470 and HP7475 or compatible plotters.

PT,GR,GP,LS,4

Configures the 9400 for a Graphtec FP5301 or compatible plotter, connected through GPIB, running at low speed (for plotting on transparencies), with 4 pens.

```
2) PLOT_SIZE (PS)   , < ?   >
                      < A5  >                    *
                      < A4  >                    *
                      < A3  >                    *
```

Configures the 9400 to plot onto a predefined paper size.

A5 = 148 mm by 210 mm, compatible with U.S. 5.5" by 8.5"
A4 = 210 mm by 297 mm, compatible with U.S. 8.5" by 11"
A3 = 297 mm by 420 mm, compatible with U.S. 11" by 17"

or

PLOT_SIZE (PS) , NON_STANDARD (NSTD) , <grid> , <x> , <y> *

Configures the 9400 to plot onto a non-standard paper size.

<grid> = [00.0 MM to 99.9 MM]

<x> = [0 MM to 999 MM]

<y> = [0 MM to 999 MM]

<grid> is the size (length on a side) of the standard square within the 8 times 10 squares grid.
<x>,<y> are the positions of the lower left hand corner of the graticule with respect to the origin of the plotter.

Sets VALUE ADAPTED bit:
- If an out of range positive value is given. Negative values generate a semantic error.

3) SCREEN_DUMP (SD) *

Instructs the 9400 to dump the screen display onto the plotter.

4) TRANSMIT (TX) , <String to be transmitted to the plotter> *

Instructs the 9400 to transmit a character string to the plotter. The string may be up to 43 characters in length and may include commands such as "paper advance" or "print string". Thus the user can append additional comments to a plot, or generate multiple plots by remote control.

Sets ENVIRONMENT ERROR:
- If the 9400 is controlled through GPIB and if the plotter access port is the GPIB port.

7.6.5 Transfer Commands

1) STORE (STO) , [1 to 7] *

Instructs the 9400 to store the current front panel configuration in one of 7 non-volatile storage areas for later recall.

or

```
STORE (STO)  , < CHANNEL_1 (C1) > , < MEMORY_C (MC)  > *
               < CHANNEL_2 (C2) >   < MEMORY_D (MD)  >
```

Instructs the 9400 to store the waveform and the waveform descriptor of either Channel 1 or 2 into reference memories C or D.

Notes:
If the 9400 is acquiring data, while receiving the request to store Channel 1 or 2, the execution of the command is delayed until the trigger has arrived.

No message will be displayed on the screen when the operation is done.

2) RECALL (REC) , [1 to 8] *

Instructs the 9400 to recall one of 8 front panel configurations stored in non-volatile memory. The value "8" corresponds to a convenient default setup.

3) SETUP (SU) , ?

or

SETUP (SU) *

The first form permits reading of the complete setup in internal data representation. Transmission format depends on the selected forms by the COMM_FORMAT command. The setup data block corresponds to 257 binary bytes.

The second form permits sending setup data to the 9400 in the same form as they were read from the 9400. This command must be terminated with <END>, i.e., it must be the last of a list of commands. The data transferred to the 9400 must be contained in a separate block (see Section 7.5).

Note:
The serial port parameters are not transmitted. In particular, if the transfers are by RS232, modification of the serial port parameters by this command would bring about some strange results.

Sets VALUE ADAPTED bit:
- If a data value in the block is incorrect. DEFAULT setup will be used in this case.

Sets INVALID BLOCK ERROR:
- If the received block(s) is incorrect.

4) READ (RD) , < CHANNEL_1.DESC (C1.DE) >
< CHANNEL_2.DESC (C2.DE) >
< MEMORY_C.DESC (MC.DE) >
< MEMORY_D.DESC (MD.DE) >

Transfer the descriptor of the indicated waveform from the 9400 to the host computer. See Section 7.7 for the format of this data block.

or

READ (RD) , < CHANNEL_1.DATA (C1.DA) > , <Parameter list>
< CHANNEL_2.DATA (C2.DA) >
< MEMORY_C.DATA (MC.DA) >
< MEMORY_D.DATA (MD.DA) >

```
<Parameter list> = <intval> , <# values> , <addr> , <sweep #>
```

Transfer the data values of the indicated waveform from the 9400 to the host computer. See below for explanation of the optional parameter list.

or

```
READ (RD)  , < CHANNEL_1.TIME  (C1.TI) >
             < CHANNEL_2.TIME  (C2.TI) >
             < MEMORY_C.TIME   (MC.TI) >
             < MEMORY_D.TIME   (MD.TI) >
```

Transfer the trigger time(s) of the indicated waveform from the 9400 to the host computer. See Section 7.8 for the format of this data block.

or

```
READ (RD)  , < CHANNEL_1.* (C1.*) > , <Parameter list>
             < CHANNEL_2.* (C2.*) >
             < MEMORY_C.*  (MC.*) >
             < MEMORY_D.*  (MD.*) >
```

Transfer ALL visible data of the indicated waveform from the 9400 to the host computer. Data are transferred in the order descriptor, data, time(s).

```
<Parameter list> = <intval> , <# values> , <addr> , <sweep #>

<intval>   = [ 1 to 16000 ]       Interval between data points to be
                                  read, for example:
                                   1 = read all points
                                   4 = leave out 3 of 4 data values

<# values>= [ 0 to 32000 ]         Number of data values to read

<addr>     = [ -32000 to 32000     Address of first data point
                                   relative to the left hand side of
                                   the screen

<sweep #> = [ 0 to 250 ]           Sweep number in SEQNCE waveforms,
                                   numbered from
                                   1 to max. # sweeps
                                   0 = read all sweeps
```

The parameter list is optional. Any omitted parameter is set to a default value:

```
<intval>     = 1, i.e., leave no values out
<# values>   = # values on the screen
<addr>       = address of left-most value on the screen
<sweep #>    = 0, i.e., read all sweeps
```

Thus, the omission of all parameters results in reading all data values on the screen. For a detailed explanation of the data addressing conventions, see Section 7.9.

READ DATA transfers, without specifying the number of data values, are executed over the number of data values displayed on screen + 1. I.e. if the screen shows nominally 25000 data values, 25001 values are transferred.

Data formats:

- The descriptor (.DESC), the data (.DATA) and the time(s) (.TIME) are each transmitted as a single block unless a maximum block size has been specified with the command COMM_BLOCKSIZE.

- When all data are read (.*), they are transmitted as three blocks in the order: descriptor, data, time(s).

- When all sweeps of a SEQNCE data record are read (sweep # = 0), each sweep is transmitted as a separate block.

- The parameter <# values> applies to the number of data values per sweep in the case of SEQNCE data.

Note:
In the case of reading CHANNEL_1 or CHANNEL_2, while the 9400 is acquiring data, the execution of the command will be delayed until the TRIGGER has arrived.

Sets VALUE ADAPTED bit:
- If <intval> is greater than 16000 (adapted to 16000).
- If <# values> corresponds to too large a value (adapted to the number corresponding to the last accessible value).
- If <addr> is out of range (adapted to the nearest legal address).
- If <sweep #> is higher that the selected number of sweeps (adapted to the last sweep number).

Examples:

READ,C1.DE	Instructs the 9400 to transmit the waveform descriptor of Channel1, in the format described in Section 7.7. If the 9400 is armed and waiting for a trigger, the execution is deferred until the waveform is acquired.
READ,MC.DA	Instructs the 9400 to transmit all data values of memory C which would appear on the screen, but no descriptor nor trigger time(s).

READ,MC.DA,,,-7000	Instructs the 9400 to transmit all data points of memory C, starting -7000 (invisible) points before the left hand side of the screen, up to the last value at the right hand side.
READ,C1.DA,5,100,1000	Instructs the 9400 to transmit 100 data values of Channel1, starting 1000 values to the right of the beginning of the screen. Only every 5th data value is transmitted, i.e., 4 out of 5 values are omitted.
READ,MD.DA,,,,5	Instructs the 9400 to transmit all data values of sweep #5 from the SEQNCE data record in memory D. If memory D is not a SEQNCE record, the last parameter is ignored, and the command would be interpreted as READ,MD.DA, resulting in the transmission of all (visible) data of the memory D.
READ,CHANNEL_2.*	Instructs the 9400 to transmit the waveform descriptor, data and time(s) of Channel2. This is the most complete (and safest) way to archive (the visible part of) a waveform. The host computer can restore the complete waveform in memories C or D with the command WRITE MC.*, followed by the transmission of the data records.
READ,CHANNEL_2.*,,,-32000	Instructs the 9400 to transmit the waveform descriptor, data and time(s) of Channel2, including all invisible data values on the left-hand side of the screen. The address -32000 is usually out of range, but the 9400 automatically adapts to the closest legal value. This complete data record is restored in memory C with the command WRITE MC.*,,,-32000.

```
5) WRITE (WT)   , < MEMORY_C.DESC  (MC.DE) >           *
                  < MEMORY_D.DESC  (MD.DE) >           *
```

Transfer the waveform descriptor from the host computer to the indicated waveform of the 9400. This command must be followed by the descriptor block(s). The 9400 checks the limits of each parameter transmitted. If any value is out of range, or the number of values transmitted is incorrect, the entire descriptor block is considered invalid and is discarded.

```
WRITE (WT)   , < MEMORY_C.DATA  (MC.DA) > , <Param.list> *
               < MEMORY_D.DATA  (MD.DA) >                *
```

```
<Parameter list> = <intval> , <# values> , <addr> , <sweep #>
```

Transfer data values from the host computer to the indicated waveform of the 9400. This command must be followed by the data value block(s). See READ command for an explanation of <Parameter list>.

or

```
WRITE (WT)   , < MEMORY_C.TIME  (MC.TI) >           *
               < MEMORY_D.TIME  (MD.TI) >           *
```

When transferring WRITE DATA without specifying the number of data values, the nominal number + 1 data values must be sent to the 9400 (25000 + 1 data values for example). This additional value may be needed for the generation of the last displayed point at the right hand side of the screen.

Transfer trigger time(s) from the host computer to the indicated waveform of the 9400. This command must be followed by the trigger time block. If the number of values transmitted is incorrect, the entire block is discarded.

or

```
WRITE (WT)   , < MEMORY_C.* (MC.*) > , <Parameter list>          *
               < MEMORY_D.* (MD.*) >                  *
```

```
<Parameter list> = <intval>,<# values>,<addr>,<sweep #>
```

Transfer ALL data from the host computer to the indicated waveform of the 9400. This command must be followed by the data blocks in the order descriptor, data, trigger time(s).

See READ command for an explanation of <Parameter list>.

In general, the 9400 decodes and checks the WRITE command it receives and verifies the optional parameters. If it receives a WRITE command for a complete waveform (WRITE xx.*), the parameters are only checked after the DESCRIPTOR block has been transmitted. If the <intval> parameter is not 1, intermediate points will be computed with a linear interpolation.

DESCRIPTOR values are checked for consistency after the entire block has been received. If an error is detected, the entire block is discarded and the invalid data block has no effect on the currently stored descriptor. The same is true for the time block.

The waveform DATA values, however, are directly stored into the final buffer during transmission. If an error occurs during the transfer, the data memory might be only partially filled with the new data.

Sets VALUE ADAPTED bit:
- If a numerical parameter had to be modified during checking.
- If less or more DATA values have been received than indicated by the numerical parameters (after checking) and only if the number of DATA values is not too large to overflow the MEMORY C or MEMORY D buffer.

Sets INVALID BLOCK ERROR:
- If an error in a block has been detected:
  - The preamble is incorrect (is not #A, #L or #I)
  - The preamble number (indicating how many values the block has) is greater than the number of values that are allowed (SETUP, DESCRIPTOR or TIME) or greater than the number of values remaining until the end of the sweep buffer (DATA).
  - The number of received values does not correspond to the number in the preamble.
  - In the case of ASCII blocks (#L format), there are characters which are neither digits nor separator characters (",", CR or LF).
  - In the case of ASCII blocks, a value is greater than 255 (BYTE or 8 bits transfer) or greater than 65535 (WORD or 16 bits transfer).

- Other errors:
  - Too many or too few values have been received (SETUP, DESCRIPTOR or TIME).
  - If the string beginning with a character other than "#" is received, while the 9400 expects a block.
    Such an error happens if the 9400, previously configured to work without the END block (#I), receives less data than expected, followed by a command.
  - Too many blocks have been received.

When the 9400 detects an error while receiving data blocks, the remaining values in the block, if any, as well as the following blocks are purged until the END block (#I) is received or until a command is recieved.

When a command is received instead of a block, block transfer is aborted, but the command will be decoded like any other command.

When a block is received without being preceded by the WRITE command, the block will be purged and syntax error 11 will be produced (Invalid Header).

Note: Block data must end with a legal Trailer as <CR>, <LF> or <CRLF>.

```
6) INSPECT (INS)    , < CHANNEL_1.LIMIT    (C1.LI) >
                      < CHANNEL_2.LIMIT    (C2.LI) >
                      < MEMORY_C.LIMIT     (MC.LI) >
                      < MEMORY_D.LIMIT     (MD.LI) >
```

Instructs the 9400 to return a character string, containing the lower and upper address limits of the current waveform,

or

```
INSPECT (INS)    , < CHANNEL_1.NSWEEPS  (C1.NS) >
                   < CHANNEL_2.NSWEEPS  (C2.NS) >
                   < MEMORY_C.NSWEEPS   (MC.NS) >
                   < MEMORY_D.NSWEEPS   (MD.NS) >
```

Instructs the 9400 to return a character string, containing the number of acquired (in averaging and extrema),

or

```
INSPECT (INS)    , < MEMORY_C.INTVAL    (MC.IV) >
                   < MEMORY_D.INTVAL    (MD.IV) >
```

Instructs the 9400 to return a character string, containing the interval between data points used by a waveform processing function. This value may be used as the <intval> parameter in the readout of such waveforms, if the user wishes to read only the computed data points and none of the re-interpolated points.

7.6.6 Other Remote Commands

1) CALIBRATE (CAL)

Forces the 9400 to do a calibration of both input channels at the current gain and bandwidth setting and of the time interpolator.

or

```
CALIBRATE (CAL)   , < ?   >
                    < ON  >                    *
                    < OFF >                    *
```

Permits enabling automatic calibration (ON), disabling automatic calibration (OFF) or querying the state of the automatic calibration. See Section 9.4 for the conditions under which the 9400 calibrates itself.

```
2) PROBE_CAL (PC)   , < AC >   , [ 0.000 V to 5.000 V ]   *
                      < DC >
```

This command permits generating a square signal (AC) with a period of 1.024 ms or a continuous (DC) level at the specified voltage at the probe test output.

When the 9400 returns to LOCAL, the default calibrator signal of 1 V (AC) is generated.

Sets VALUE ADAPTED bit:
- If a positive out of range value is given.

```
3) AUTO_STORE (AS)  , < ?          >
                      < [ 0 to 5 ] >           *
```

This command permits interrogating the 9400 on its AUTOSTORE state or setting the AUTOSTORE mode:

0: AUTOSTORE off
1: automatic storage of CHANNEL_1 into MEMORY_C
2: automatic storage of CHANNEL_1 into MEMORY_D
3: automatic storage of CHANNEL_2 into MEMORY_C
4: automatic storage of CHANNEL_2 into MEMORY_D
5: automatic storage of CHANNEL_1 into MEMORY_C and of CHANNEL_2 into MEMORY_D

Example:

With "COMM_FORMAT L,BYTE,UNSIGNED_SHORT,CRLF", a block will be:

```
#L
2
123
34
```

Whereas with "COMM_FORMAT L,BYTE,UNSIGNED_SHORT" it is:

```
#L,2,123,34
```

Sets ENVIRONMENT ERROR:
- If the A format is selected while the 9400 is controlled through RS232.

5) COMM_BLOCKSIZE (CBLS) , -1

The data is transmitted in one block only, and the END block (#I) is not sent nor may be received.

COMM_BLOCKSIZE (CBLS) , 0

The data is transmitted in one block only. The END block (#I) will be sent and must be received. This is the default blocksize.

COMM_BLOCKSIZE (CBLS) , [40 to 32000]

The data is transmitted in one or more blocks. The END block (#I) will be sent and must be received with the purpose of marking the end of the blocks transfer.

This command selects the maximum block size for data block transfers (READ,WRITE,SETUP). The specified block size includes all data bytes, including preamble and postamble.

Sets VALUE ADAPTED bit:
- If the numerical parameter is positive but less than 40 (it will be adapted to 40) or if it is greater than 32000 (it will be adapted to 32000).

6) COMM_STRDELIM (CSDE) , [1 to 127]

Defines the ASCII character that the 9400 recognizes as a string delimiter. Default is the character <">, whose decimal value is 35.

7) COMM_PROMPT (CPRM) , < OFF >
< prompt string >

Defines the 9400 prompt string which may be up to 10 characters long. Default is OFF. This feature simplifies interactive programming of the 9400. When set, the host computer must read the 9400 after every command, even when normally no response is expected. The 9400 responds either with the prompt string alone or with its response, followed by the prompt, indicating that it is ready for another command.

Summary of COMM default values:

COMM_HEADER	:	SHORT
COMM_TRAILER	:	CRLF
COMM_HELP	:	OFF
COMM_FORMAT	:	GPIB: A format, BYTE RS232: L format, BYTE, UFIX,COMMA
COMM_BLOCKSIZE	:	0
COMM_STRDELIM	:	" (Decimal value: 35)
COMM_PROMPT	:	OFF

7.6.8 Status Byte and Mask Register Commands

The 9400 contains a Main Status Byte (STB 1) and 5 additional status bytes, numbered from 2 to 6. Each status byte has an associated mask register, also numbered from 1 to 6. The purpose of the status bytes is to keep track of internal conditions of the 9400. The user can use 2 methods of staying informed:

- The status bytes can be read at any time, one by one or in a single block, with or without simultaneous clearing. This method ignores all mask registers. The host computer program is required to keep testing a status bit of interest, e.g., bit #0 of the OPERATION COMPLETE status byte (STB 5) after the SCREEN_DUMP command.

- The 9400 can be configured to generate an interrupt to the host computer upon the occurrence of one or several conditions. The user must demask the bit(s) of the status byte which correspond to the condition(s), by setting one's into the corresponding bit of the mask in question. In addition, the corresponding bit in the Main Status Byte (STB 1) must also be demasked in order to allow the generation of the Service Request. This method is much more time efficient, but requires a more complex setup. In addition, the host computer must be configured to handle an interrupt by the GPIB SRQ-line. See Section 7.11 for more explanations and examples.

Status bytes are cleared (except STB 4) when reading them with the command STB, but not with TSTB. They are also cleared on POWER ON and by a Device Clear command. Mask registers are cleared on POWER ON, with a Device Clear command, or by explicitly writing 0 into them.

Main Status Byte (STB 1):

DIO # (1-8)	Bit # (0-7)	Associated data byte	Significance (to generate an SRQ)
DIO-1	0	none	VALUE ADAPTED
DIO-2	1	STB 2	unspecified
DIO-3	2	STB 3	SOFTKEY PRESSED or CALL TO HOST
DIO-4	3	STB 4	INTERNAL STATE has CHANGED
DIO-5	4	STB 5	OPERATION COMPLETE
DIO-6	5	STB 6	ERROR detected
DIO-7	6	none	RQS (request for service)
DIO-8	7	none	MESSAGE READY

If one of the bits DIO-1 to DIO-6 or DIO-8 becomes 1 and the corresponding bit is set in the Main Mask register (MASK 1), the RQS bit is set to 1, and a service request (SRQ) is generated if it is not already pending. The bits associated with the lower status bytes (STB 2 to 6) are only set inside STB1, if their masks allow the propagation of the bits to STB1 (see description of the individual status bytes below).

VALUE ADAPTED: set if a value associated with a remote control command is out of range, and adapted to the closest legal value.

Bit 1 (DIO-2): unused, reserved for future extensions.

SOFTKEY PRESSED: set if one of the 9 softkeys (in REMOTE) or if the key CALL TO HOST (in LOCAL) has been pressed. The last key is only active after setup by the command CALL_HOST. The identity of the softkey is coded in the SOFTKEY PRESSED status byte (STB3).

INTERNAL STATE CHANGE: set if an internal state within the 9400 has changed. The identity of the internal state is recorded in the INTERNAL STATE status byte (STB 4).

OPERATION COMPLETE: set if an operation in the 9400 has been completed. The associated OPERATION COMPLETE status byte (STB5) contains the information about which operation has been completed.

ERROR: set if an error condition has been detected.
The error is coded in the associated ERROR status byte (STB 6).

RQS: GPIB RQS bit, indicating if a service request is pending.

MESSAGE READY: set to indicate that a message is ready for transmission to the remote controller.

STB 2:

This status byte is unused and has no meaning. However, it exists and has an associated mask. The commands STB, MASK and TSTB act on all 6 status bytes or masks, including STB 2.

SOFTKEY PRESSED Status Byte (STB 3):

This status byte contains the coded value of the most recently pressed softkey. Whenever the MASK 3 is non-zero, and the code in STB 3 is set to a non-zero value, the SOFTKEY PRESSED bit (DIO-3) in STB 1 is set.

Codes:

- 0 : No softkey pressed.
- 1 - 9 : One of softkeys 1 - 9 pressed (in REMOTE)
- 10 : CALL TO HOST softkey pressed (in LOCAL)

INTERNAL STATE Status Byte (STB 4):

This status byte contains status bits, reflecting the internal state of the 9400. Since the internal states cannot be directly controlled, reading this byte does NOT reset it. Whenever a bit of this status byte gets set, and the corresponding bit in MASK 4 is also set, the INTERNAL STATE bit (DIO-4) in STB 1 is set.

Bits:

- 0 : TRIGGERED: cleared when the 9400 is armed, i.e. acquiring data, set when the 9400 is triggered, i.e. not acquiring data.
- 1 : OVERLOAD1: set when channel 1 is in overload, reset otherwise.
- 2 : OVERLOAD2: set when channel 2 is in overload, reset otherwise.
- 3 : FIRST SEQNCE sweep triggered

Note:
Overload are cleared by removing the overloading signal from the input and by returning the input coupling to 50 Ohms. Overloads never occur in 1 MOhm coupling.

OPERATION COMPLETE Status Byte (STB 5):

This status byte contains status bits, reflecting the identity of the operation which has been completed.
Whenever a bit of this status byte gets set, and the corresponding bit in MASK5 is also set, the OPERATION COMPLETE bit (DIO-5) in STB1 is set.

Bits:

- 0 : Set when a screen dump (in REMOTE only) is finished
- 1 : Set when an internal computation is done (Waveform Processing Options only)
- 2 : Set when calibration is done (in REMOTE only)
- 3 : Average END

ERROR Status Byte (STB 6):

This status byte contains the coded value of the most recently detected error. The individual bits have no well defined meaning. Whenever MASK 6 is non-zero, and the code in STB 6 is set to a non-zero value, the ERROR bit (DIO-6) in STB1 is set.

Code:

0	:	No error
1	:	Not all 9400 responses have been read upon receipt of a new command string, terminated with <END>. Output buffer has been flushed.

Syntax errors:

10	:	Invalid separator or too many parameters
11	:	Invalid header
12	:	Invalid number format
13	:	Invalid keyword
14	:	Invalid block
15	:	2 or more strings in the same command
20	:	Command permission error: REMOTE only command has been received while the 9400 is in LOCAL or SCREEN control command has been received while SCREEN control is LOCAL
30	:	The 9400 has received a command for an option that is not installed
40	:	Semantic error: false number of parameters or false parameter in a command
50	:	Environment error: the 9400 is not set to the proper status to accept the received command (trace OFF, false format...)
60	:	Descriptor error: an inconsistency has been detected in the data received with a WRITE descriptor command
100	:	Command not yet implemented

1) STB , [1 to 6] , ?

Reads the contents of one of the 6 status bytes and clears it. STB1 is the Main Status Byte. STB 4 is not cleared.

or

STB , ?

Reads all 6 status bytes in the order 1 to 6 and clears them (except STB 4).

2) MASK , [1 to 6] , ?

Reads the contents of one of the 6 mask registers. Mask register 1 is the mask register corresponding to the Main Status Byte.

or

MASK , ?

Reads the contents of the 6 mask registers in the order 1 to 6.

or

MASK , [1 to 6] , [0 to 255]

Sets the contents of one of the 6 mask registers to a decimal value between 0 to 255.

3) TSTB , [1 to 6] , ?

Reads the contents of one of the 6 status bytes but does not clear it. Status Byte 1 is the Main Status Byte.

or

TSTB , ?

Reads the contents of all status bytes in the order 1 to 6, but does not clear them.

7.6.9 GPIB Interface Message Interpretation

1) Device clear: DCL (GPIB hexa code: 14) or SDC (GPIB hexa code: 4)

Clears the input and output buffers, terminates plotting and data transmission. All the status bytes, except STB 4, and all the corresponding masks as well as the SRQ line are reset.

THIS COMMMAND IS IMMEDIATELY EXECUTED.

2) Trig: GET (GPIB hexa code: 8)

Rearms the oscilloscope. Valid only in SINGLE or SEQNCE mode and only when the 9400 is in REMOTE.

3) REMOTE/LOCAL commands:

If the 9400 receives a command to go into REMOTE or go back to LOCAL while it is acquiring a signal, the front panel REMOTE Led doesn't change, although the internal state as well as the display will change.

7.6.10 RS232-Only Commands

The following commands are only valid when the 9400 is controlled via the RS232 ports. <ESC> stands for the ASCII ESCAPE character.

1) RS_CONF , <duplex> , <end1> , <end2> , <echo> , <delay>

Configures the RS232 remote control protocol.

<duplex>	=	[0 to 127]	If 0: Selects full duplex mode, otherwise selects half duplex mode. The number represents the decimal ASCII value of the trigger (or talk) character.
<end1>	=	[0 to 127]	
<end2>	=	[0 to 127]	Selects <END> message string of 1 or 2 characters in length, as it will be used in commands sent to the 9400. In transfers from the 9400 to the host computer, messages or data blocks are terminated with <TRAILER> (as defined with the command COMM_TRAILER), followed by <END>. Default: <CR>.
<echo>	=	[0 to 127]	Selects the echo character (in half duplex only). If zero, no echo mode is selected. Default: no echo character.
<delay>	=	[0 to 127]	Selects the delay before talk in msec (half duplex only). Default: 0 msec.

Sets VALUE ADAPTED bit:
- If an out of range positive value is given for the 5th parameter.

The 9400 may be configured to work either in full duplex mode or in half duplex mode. Full duplex mode may be selected if the host computer does not echo the characters it receives from the 9400 and if it is able to store the received characters in a buffer. In half duplex mode, the host computer tells the 9400 to talk by sending a trigger character to the 9400.

In full duplex mode, the 9400 sends its message(s) immediately.

In half duplex mode, the 9400 sends its message (until <END> Message) one at a time after it has received the trigger character and after the selected delay has elapsed. It needs a trigger for each message. If the host echoes received characters, echo mode must be selected. In that case, the 9400 discards any received characters (except those of Device Clear Command) until it receives the <echo> character.

The 9400 may be configured for Half Duplex mode in two situations:

1) If the computer which controls the 9400 through the RS232 Remote port, does not support full duplex communication and cannot support data flow between the 9400 and itself in both directions simultaneously (e.g. if the port on the computer may be open in only one direction at the same time).

2) If the computer which controls the 9400 echoes characters it receives from the 9400 (the port acting as a terminal port).

In the first case, the 9400 can be configured with the following sequence of commands:

<ESC>	disables echoing of characters received by the 9400.
COMM_TRAILER OFF	disables trailer.
RS_CONF 9,13,10,0,0	selects half duplex mode with <TAB> (decimal9) as trigger (or talk) character, <CR> <LF> (decimal 13 and 10) as <END> message string, no echo character and no turnaround delay.

Whenever the computer interrogates the 9400 to get one or several responses or to get one more blocks of data, it sends the command followed by <CR> (optional) and <LF> and then by <TAB>. This last character instructs the 9400 to send one response or one block of data. To get more information or more blocks, <TAB> must be resent whenever it is necessary.

Example:

The computer wants to know time base and bandwidth limit settings.

Computer sends:	TIME/DIV ?; BANDWIDTH ?<CR><LF><TAB>
9400 answers:	TIME/DIV 2.00E-03<CR><LF>
Computer sends:	<TAB>
9400 answers:	BANDWIDTH ON<CR><LF>

It is important that the trigger character and the characters of the <END> message string are not the same. Otherwise the second ouput will be flushed because <END> does so.

If turnaround delay is necessary, i.e. if a certain amount of time is necessary between the time the 9400 receives the trigger character and the time it sends the first character, the last parameter of the RS_CONF must be non-zero.

Example: RS_CONF 9,13,10,0,1000 with a turnaround delay of 1second.

Notice that during this delay, the 9400 may appear as dead!

In the second case, i.e. when the controller echoes characters, the 9400 can be configured with the following sequence of commands:

<ESC>	disables echoing of characters received by the 9400.
COMM_TRAILER OFF	disables trailer.
RS_CONF 9,13,10,10,0	selects half duplex mode with <TAB> (decimal9) as trigger (or talk) character, <CR> <LF> (decimal 13 and 10) as <END> message string, <LF> as echo character and no turnaround delay.

Whenever the controller interrogates the 9400 to get one or several responses or to get one or more blocks of data, it sends the command followed by <CR> (optional) and <LF> and then by <TAB>. This last character instructs the 9400 to send one response or one block of data. To get more information or more blocks <TAB> must be resent whenever it is necessary.

Example:

The computer wants to get the setup configuration. If the 9400 has been configured to sends blocks of data in hex format in blocks of 300 characters, the computer will receive 3 blocks.

Computer sends: SU ?<CR><LF><TAB>
9400 answers: #L.......<CR><LF>
Each character including <LF> will be echoed by the computer.
Computer sends: <TAB>
9400 answers: #L.......<CR><LF>
Each character including <LF> will be echoed by the computer.
Computer sends: <TAB>
9400 answers: #I<CR><LF>
#I<CR><LF> will be echoed by the computer.

Notice that <LF> is used both as the last character of <END> message string and as the <ECHO> character. Character strings (except <ESC> C string for DEVICE CLEAR and <ESC>, <ESC>, <ESC>, <ESC>) will be lost if sent between <TAB> and <LF>.

In both cases, if service request has been activated, the string will be sent only when the trigger character is received.

In both cases, DEVICE CLEAR (<ESC>C) resets the RS232 Remote port to DEFAULT setting. i.e.:

- ECHO ON
- full duplex mode with <CR> as <END> message string.
- Overwrite mode if the output buffer becomes full.

2) RS_SRQ , [0 to 127] , [0 to 127] , [0 to 127]

Defines a 3-character service request (SRQ) string that is sent by the 9400 each time the RQS bit (bit 6) of the Main Status Byte (STB 1) is set to 1. A null character (value 0) terminates the string, i.e., a string of 1 or 2 characters may be defined by setting the rest of the characters to 0. If the first character is set to null (value0), the default string is selected. Default is the bell (value 7). If half duplex mode is selected, the transmission of this string may be delayed until the trigger character has been received. The 9400 appends <END> to the SRQ-string, but not the <TRAILER>.

3) <ESC> (

Selects DTR / CTS hardwire handshake protocol.

THIS COMMMAND IS IMMEDIATELY EXECUTED.

4) <ESC>)

Selects Xon (ASCII DC1 character) / XOFF (ASCII DC3 character) handshake protocol. (DEFAULT)

THIS COMMAND IS IMMEDIATELY EXECUTED.

5) <ESC>[

The 9400 does not echo characters received.

THIS COMMMAND IS IMMEDIATELY EXECUTED.

6) <ESC>]

The DSO echoes characters received. (DEFAULT).

THIS COMMMAND IS IMMEDIATELY EXECUTED.

7) <ESC> <

When its output buffer is full, the 9400 stops until more space is created in the output buffer (i.e. until the host computer has read some characters).

THIS COMMMAND IS IMMEDIATELY EXECUTED.

8) <ESC> >

If the output buffer becomes full, the 9400 overwrites last character. (DEFAULT).

THIS COMMMAND IS IMMEDIATELY EXECUTED.

9) <ESC> R

Sets the 9400 to REMOTE.

10) <ESC> L

Sets the 9400 to LOCAL.

11) <ESC> C

The 9400 executes a DEVICE CLEAR command, clears the input and output buffers, all the status bytes, except STB 4, and all the corresponding masks and terminates plotting and data transmission. Resets the RS232-C REMOTE port to DEFAULT setting.

THIS COMMMAND IS IMMEDIATELY EXECUTED.

12) <ESC> T

The 9400 executes a TRIGGER command (see Section 7.6.9).

7.7 Binary Format of Waveform Descriptors

The waveform descriptor contains all information needed to correctly interpret the waveform data. In addition, there are some values that apply only to some records, in particular to waveforms that are the result of data processing.
The descriptor contains 8-bit values, 16-bit values and 32-bit integer values. There are no floating point values. Multi-byte values are always transferred with the most significant byte first. In the following list, each parameter is identified by its (decimal) address relative to the beginning of the descriptor, and by the number of bits. Data values shown are always in decimal.

Pos	Size	Meaning
0	8-bit	Fixed vertical gain, coded as an integer. 22 = 5 mV/div 23 = 10 mV/div 24 = 20 mV/div 25 = 50 mV/div .... 31 = 5 V/div Values below 22 may occur on processed data records. See Section 7.10 for the explicit use of this variable in the conversion of the data values to volts.
1	8-bit	Variable vertical gain, in units of .005 of unity. 0 = gain of .4 120 = gain of 1.000 See Section 7.10 for the explicit use of this variable in the conversion of the data values to volts.
2	16-bit	Unused
4	16-bit	Vertical offset in units of .04 of the vertical deflection factor, i.e. .04V/div. 0 = - 8 div 25 = - 7 div 50 = - 6 div ..... 200 = 0 div 225 = 1 div 250 = 2 div ..... 400 = 8 div See Section 7.10 for the explicit use of this parameter in the conversion of the data values to volts.
6	8-bit	Input channel coupling at acquisition. 0 = DC, 50 Ohms 1 = Ground 2 = DC, 1 MOhm 3 = Ground 4 = AC, 1 MOhm
7	8-bit	Attenuation of external probe (must have been set up manually or by remote control) 0 = *1 1 = *10 2 = *100 3 = *1000 This value is already absorbed into the fixed vertical gain (position0), it serves only as a reminder here.
8	8-bit	Bandwidth limit at acquisition. 0 = off 1 = on
9	8-bit	Timebase at acquisition, coded as an integer. 4 = 2 ns/div 5 = 5 ns/div 6 = 10 ns/div 7 = 20 ns/div ..... 34 = 20 s/div 35 = 50 s/div 36 = 100 s/div

10		8-bit Sampling interval at acquisition, coded as an integer. In interleaved sampling, 11 = .2 ns 12 = .4 ns 13 = .8 ns In non-interleaved sampling, 16 = 10 ns 17 = 20 ns 18 = 40 ns 19 = 80 ns 20 = 200 ns 21 = 400 ns .... 34 = 8 ms 35 = 20 ms 36 = 40 ms SEQNCE mode uses, in addition to the intervals of the non-interleaved sampling, also 40 = 100 ns 41 = 1 us 42 = 10 us 43 = 100 us 44 = 1 ms 45 = 10 ms
11	8-bit	Record type 0 = non-interleaved 3 = interleaved with 25 sweeps at .8ns interval 4 = interleaved with 50 sweeps at .4ns interval 5 = interleaved with 100 sweeps at .2ns interval -3 = SEQNCE with 8 segments -4 = SEQNCE with 15 segments -5 = SEQNCE with 31 segments -6 = SEQNCE with 62 segments -7 = SEQNCE with 125 segments -8 = SEQNCE with 250 segments
12	8-bit	Trigger coupling at acquisition 0 = DC 1 = HF REJ 2 = LF REJ 3 = AC
13	8-bit	Trigger mode at acquisition 0 = SINGLE 1 = NORM 2 = AUTO 3 = SEQNCE
14	8-bit	Trigger source at acquisition 0 = EXT/10 1 = EXT 2 = LINE 3 = CHAN 2 4 = CHAN 1
15	8-bit	Trigger slope at acquisition 0 = negative 1 = positive 2 = window
16	16-bit	Trigger level at acquisition The coding depends on the trigger slope and on the trigger source.

Positive or negative trigger slope

Parameter	CHAN 1,2	EXT
0	- 5.00 div	- 2.00 V
25	- 4.00 div	- 1.60 V
50	- 3.00 div	- 1.20 V
100	- 1.00 div	- .40 V
125	0 div	0 V
150	+ 1.00 div	+ .40 V
200	+ 3.00 div	+ 1.20 V
250	+ 5.00 div	+ 2.00 V

In EXT/10, the trigger voltages are multiplied by 10.

Window trigger

Parameter	CHAN 1,2	EXT
<25	± .50 div	± .20 V
25	± .50 div	± .20 V
50	± 1.00 div	± .40 V
100	± 2.00 div	± .80 V
125	± 2.50 div	± 1.00 V
150	± 3.00 div	± 1.20 V
200	± 4.00 div	± 1.60 V
250	± 5.00 div	± 2.00 V

In EXT/10, the trigger voltages are multiplied by 10. Note that the window size is limited to ±.5 div (or ± .20 V), due to the nature of the trigger hardware.

18 32-bit Trigger delay at acquisition, in units of .02 of TIME/DIV, relative to the left hand side of the screen.

500 =	+ 10 div,	i.e. 100 % pretrigger
0 =	0 div,	i.e. 0 % pretrigger
-50 =	- 1 div,	i.e. posttrigger of 1 TIME/DIV
-500000 =	-10000 div,	i.e. maximum posttrigger of 10000 divisions

22 16-bit Number of measured data points per division, at the time of acquisition. This number is independent of whether the user reads all or a fraction of the data values, by specifying <intval> larger than 1 (See READ command).

24 16-bit Address of first measured data point, relative to the left-hand edge of the screen.

26 16-bit Address of last measured data point, relative to the left-hand edge of the screen.

28 16-bit Internal use.

30 16-bit Internal use.

32 16-bit Internal use.

34 8-bit Data processing of this record
99 = no processing, raw data
0 = averaging 1 = extrema
2 = arithmetics 3 = functions
4 = smoothing

35 8-bit Unused

36 - 149 Additional parameters, reserved for the description of the waveform processing (if any).

7.8 Format of Trigger Time(s)

The trigger time is the time difference from the occurrence of the trigger to the measurement of the next data sample. This time is always expressed in units of 2**(-14) of the nominal sampling interval, and spans integer values from 0 to 2**(14)-1 = 16383. The transmission format is as a 16-bit integer, with the most significant byte sent before the least significant byte.

In single-shot acquisition (INTERLEAVED OFF), there is a single time value.

In SEQNCE acquisition, there are as many times as there are sweeps. The times are transmitted in the order 1 to N, where N is the number of sweeps.

In INTERLEAVED acquisition, there are as many times as there are interleaved sweeps making up the acquired trace:

- At 2 us/div, there are 25 sweeps at a nominal interval of 800psec.
- At 1 us/div, there are 50 sweeps at a nominal interval of 400psec.
- At 500 ns/div and below, there are 100 sweeps at a nominal interval of 200psec.

The times are transmitted in the order 0 to N-1, where N is the number of sweeps. Note that time i (0 <= i < N) corresponds to the data points at address i, N + i, 2N + i, 3N + i, etc., i.e. to all data points of a single sweep.

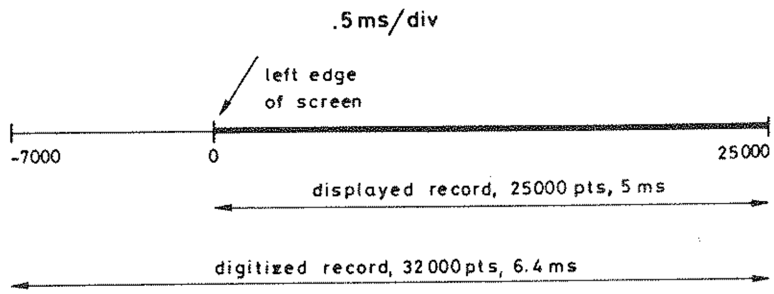
In many data analyses, the trigger times may be ignored, especially if relative time measurements are made. In INTERLEAVED acquisition, however, ignoring the trigger times results in putting the interleaved sweeps on an equidistant timing grid, although they are not necessarily equidistant at acquisition. This is equivalent to introducing an acquisition jitter of up to .5 nominal sampling interval, degrading the (apparent) dynamic behaviour of the ADC.

7.9 Data Addressing Conventions

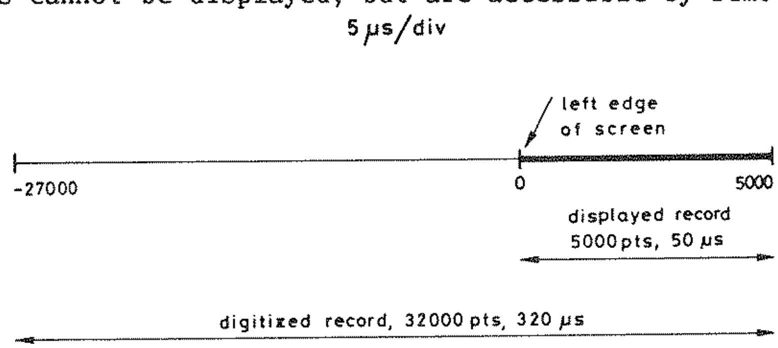
Data values are always addressed in a screen-oriented manner. Address 0 always corresponds to the data value at the left hand edge of the display screen. Although the 9400 always digitizes 32000 points (except in interleaved sampling or in SEQNCE mode), it is not possible to display all of them on the screen, because of the ratio TIME/DIV to sampling interval. Points which are inaccessible to the screen, always are positioned to the LEFT of the display screen, and can be read by remote control (using negative address values).

Examples:

At .5 ms/div, a sampling interval of 200 ns is used, covering a total time of 32000 * 200 ns = 6.4 msec. However, only 10 * .5 ms = 5 ms can be shown on the screen. Thus, only 25000 out of 32000 acquired points are shown. The other 7000 points cannot be displayed on the screen, but are accessible by remote control with the READ command (using negative addresses).



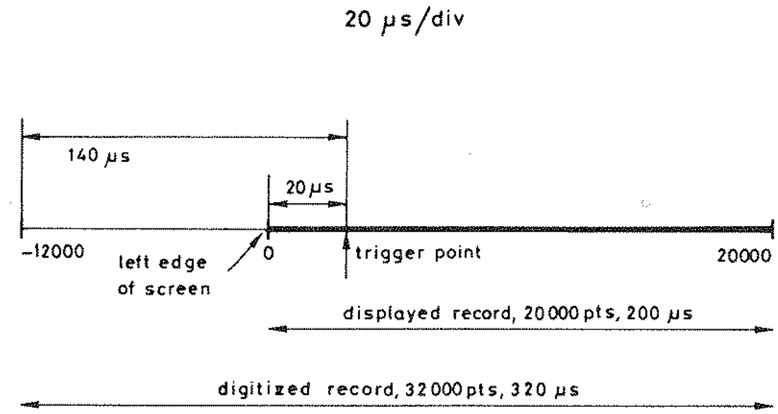
At 5 us/div, a sampling interval of 10 ns is used, covering a total time of 32000 * 10 ns = 320 us. However, only 10 * 5 us = 50 us can be shown on the screen at this timebase setting. Thus, only 5000 out of 32000 acquired points are shown. The other 27000 values cannot be displayed, but are accessible by remote control.

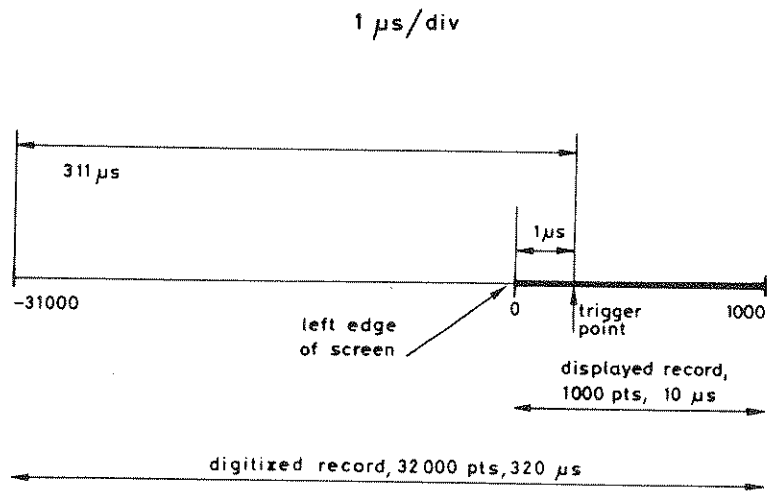


It is important to realize that at the fastest sampling rate of 10 ns per point, a record always covers a time interval of 320 us, regardless of the timebase (which can range from 50 ns/div to 20 us/div). However, the trigger point is always interpreted relative to the left hand edge of the screen, i.e. relative to the address point 0 of the record.

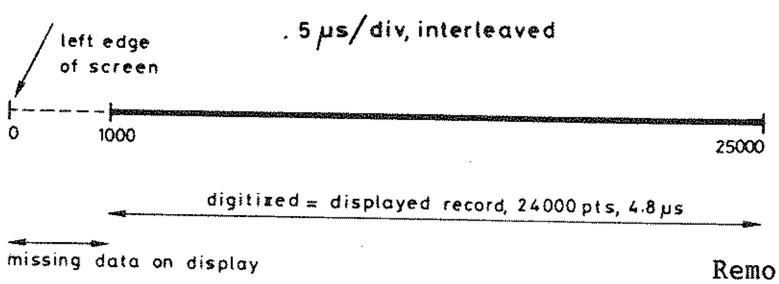
Example:

Compare a timebase of 20 us/div to a timebase of 1 us/div, both with a pretrigger of 10 percent, i.e. 1 division to the right of the left edge of the screen.





In interleaved sampling, the 9400 digitizes 24000 data points (except: 24800 at 1 us/div, and 25000 at 2 us/div; see also Section 5.1.2). In this mode, and in SEQNCE mode, it may happen that the memory is slightly too small to cover the entire screen. In this case, the waveform does not extend all the way to the left hand side of the display screen, and the address of the first valid data point of the record is a positive number. The principle is still maintained, that address 0 corresponds to the data point at the left edge of The screen, even if it refers to a virtual data point. This case occurs in interleaved sampling at .5 us/div:



Since the data record limits depend on the timebase and on the acquisition mode, the 9400 provides the user with the possibility of reading these address limits with the command "INSPECT xx.LIMIT". The response is a data block of 2 16-bit words, corresponding to the lowest and the highest address of the data record in question. If the user specifies larger limits than valid, the 9400 automatically replaces them with the legal ones (and sets the VALUE ADAPTED bit in the Main Status Byte STB 1).

7.10 Interpretation of Waveform Data Values

The conversion of the integer waveform data into volts requires the use of 3 scale and offset parameters found in the descriptor (see Section 7.7):

- Fixed gain, transmitted as an 8-bit BYTE at address 0 relative to the beginning of the descriptor. This coded value can be transformed into a number of VOLTS/DIV with a user-defined table. This transformed value is called 'gain' in the following formula.
- Variable gain, transmitted as an 8-bit BYTE at address 1 relative to the beginning of the descriptor. This value is called 'vgain' in the following formula.
- Offset, transmitted as a 16-bit (signed) WORD at address 4 relative to the beginning of the descriptor. This value is called 'offset' in the following formula.

7.10.1 Waveform Data in 8-bit Format

This is the default format of all data records (if a Waveform Processing Option is installed, it is possible to modify it to 16-bits with the command COMM_FORMAT). The unsigned 8-bit "data" values in the numerical range 0....255 are transformed to volts as follows:

V = gain * ((data - 128)/32 - (offset - 200)/25) * 200/(vgain + 80)

- The first expression "(data - 128)/32" transforms the unsigned data value to a signed value, in units of vertical divisions.
- The second expression "(offset - 200)/25" translates the internal coding of the offset into a signed offset in units of vertical divisions.
- The third expression "200/(vgain + 80)" takes into account the variable gain. It reduces, of course, to the value 1 when "vgain" assumes the "calibrated" value of 120.

Since transfers over RS232 can only be in ASCII, the bell character is rather easily recognized as a special message. Also, the user may redefine the SRQ characters to some other sequence with the command "RS_SRQ". The Serial Poll does not exist either on a RS232 connection. The only way to get more information about the status of the 9400, or the reasons for an "interrupt", is to explicitly read the value of STB 1 or the other status bytes.

Of course, the user has always the choice of working without any Service Requests at all by explicitly "polling" the Main Status Byte (STB 1) with the command "STB 1,?" (See Section 7.6.8).

Example:

MASK 1,40	Sets the mask of the Main Status Byte (STB 1) to the binary value 00101000, allowing the ERROR bit or the INTERNAL STATE CHANGE to generate an RQS bit, i.e., to generate a service request.
MASK 4,6	Sets the mask of the INTERNAL STATE byte (STB 4) to the binary value 00000110, i.e., it demasks the 2 overload bits. If an overload occurs, the mask now allows the propagation of the bit to the INTERNAL STATE CHANGE bit of STB 1.
MASK 6,1	Sets of the ERROR byte (STB 6) to a non-zero value, allowing the propagation of errors to the ERROR bit of STB 1.
TIME/DIV ?	This legal command generates a response message which should be read by the host computer. In addition, the MESSAGE READY bit is set in STB 1. Because this bit is not demasked, it does not generate a Service Request. However, if STB 1 were now read with "STB 1,?", the binary value 10000000 (=80 in hexadecimal or = 128 in decimal) would be read, and this bit would be cleared.
Overload 1	This event, internal to the 9400 (but due to too large a signal at the input 1, at 50 ohm coupling), sets the OVERLOAD1 bit of STB 4. Since this bit is demasked, the INTERNAL STATE CHANGE bit of STB 1 is also set. And because this bit is also demasked, the RQS bit is set and the Service Request is generated. If set to the default string, it consists of sending 1 bell character (decimal 7), followed by the carriage return character (default value of <END>), via RS232 to the host computer.
AAA ?	This illegal command generates a syntax error, and sets the ERROR byte (STB 6) to the value 11. Since this byte is demasked, the ERROR bit in STB 1 is also set. And because this bit is also demasked, it should also set the RQS bit and generate a Service Request. However, it cannot since it is already pending.

If the host computer reads the Main Status byte with the command "STB 1,?" at this moment, it will read the binary value 11110000, coded as the decimal value 240 = 128+64+32+16. The Main Status Byte (STB 1) acts as an accumulator of all condition bits. Thus several bits are set. After reading STB 1, all bits will be cleared and no more Service Requests are generated until some new event occurs.

SECTION 8

BASIC 9400 WAVEFORM MEASUREMENTS AND OPERATING PROCEDURES

The purpose of this section is to provide the user with a concise overview of the wide range of measurement capabilities offered by the LeCroy 9400. While you may already be familiar with traditional oscilloscope operation, this brief outline will help to acquaint you with the many powerful features of the 9400.

****
NOTE
****

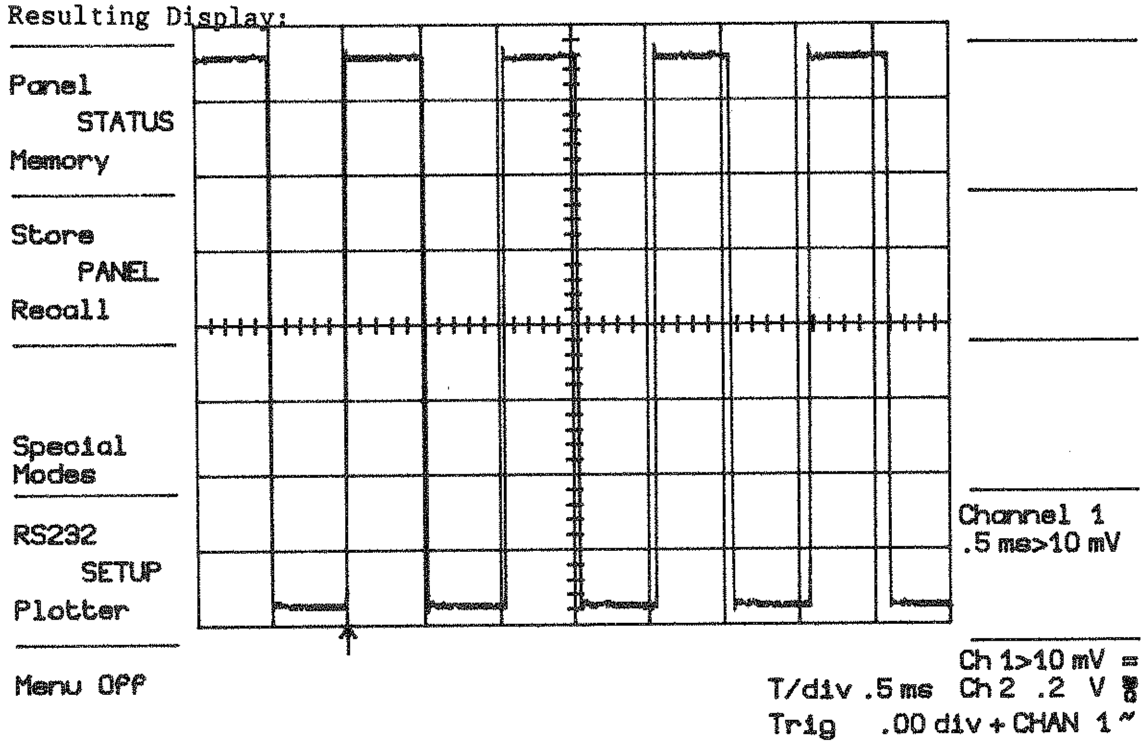
In the following section we have chosen to set all acquisition parameters from **THE PANEL STATUS MENU**; however, it is not necessary to be in this menu to make front panel setting changes. In the majority of cases, viewing the **ABRIDGED PANEL STATUS FIELD (IV)** will provide all necessary indications.

8.1 Repetitive Signal Acquisition

I. Applying Probe Calibration Signal

1) Connect the P9010 probe connector to CHAN 1 input (21).
2) Connect the probe's grounding clip to lug (20) and touch the tip to lug (19).
3) If you are in the Main Menu, call the Panel Status menu (2).
4) Set CHAN 1 Fixed VOLTS/DIV to 10 mV (28).
5) Adjust CHAN 1 **VAR** vernier (29) for a Total V/div of 13.0 mV.
6) Set CHAN 1 OFFSET to -50 mV.
7) Set CHAN 1 COUPLING to DC 1MΩ
8) Adjust **TRIGGER DELAY** control (34) to 20.0% Pre.
9) Adjust **TRIGGER LEVEL** control (33) to .00 division.
10) Set TRIGGER COUPLING to AC (30).
11) Set TRIGGER SOURCE to CHAN 1 (23).
12) Set TRIGGER SLOPE to POS (25).
13) Set TRIGGER MODE to AUTO (29).
14) Set **TIME/DIV** control (36) to .5 ms.
15) Set INTERLEAVED SAMPLING (RIS) to OFF (30).
16) Set BW-Limit to OFF (50).
17) Return to the Main Menu by depressing the **Return** pushbutton (10).
18) Set CHAN 1 to ON and CHAN 2 OFF (49).
19) Set DUAL GRID mode to OFF (14).

Resulting Display:

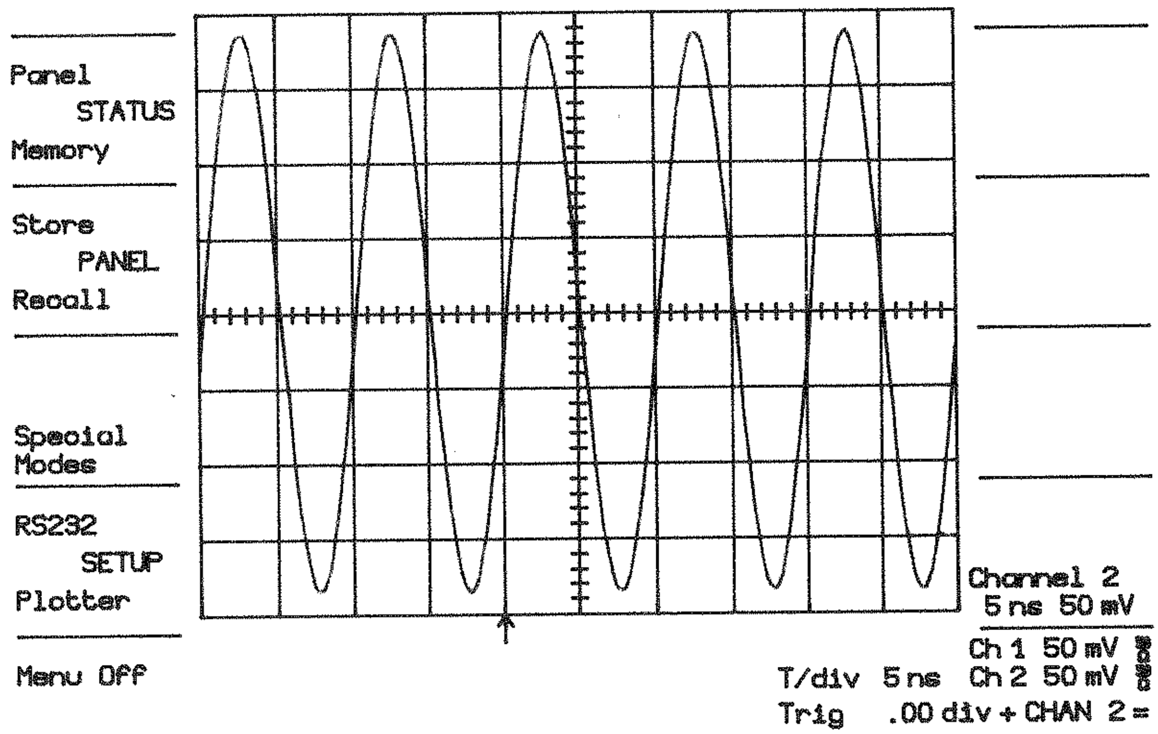


The P9010 probe has a x10 attenuation factor. Thus, the 1V, 976Hz output calibration signal is displayed with a total amplitude of approximately 7.7 divisions at a Total V/div setting of 130 mV. In case of over- or under-shoot, adjust the probe compensation trimmer, located on the barrel of the P9010 for a clean square wave contour.

II. Acquisition of a 10-20 ns Repetitive Signal

1) Connect a fast pulse generator providing an output signal having a 10 to 20 ns period to CHAN 2 input (21).
2) If you are in the Main Menu, call the Panel Status menu(2).
3) Set CHAN 2 Fixed VOLTS/DIV as appropriate (28).
4) Set CHAN 2 OFFSET to ZERO.
5) Set CHAN 2 COUPLING to DC 50Ω
6) Adjust CHAN 2 **VAR** vernier (29) as appropriate.
7) Adjust **TRIGGER DELAY** control (34) to 40.0% Pre.
8) Adjust **TRIGGER LEVEL** control (33) to .00 division.
9) Set TRIGGER COUPLING to AC (30).
10) Set TRIGGER SOURCE to CHAN 2 (23).
11) Set TRIGGER SLOPE to POS (25).
12) Set TRIGGER MODE to NORMAL (29).
13) Set **TIME/DIV** control (36) to 5 ns/div (36).
14) At this point INTERLEAVED SAMPLING (RIS) is ON.
15) Set BW-Limit to OFF (50).
16) Return to the Main Menu by depressing the **Return** pushbutton (10).
17) Set CHAN 2 to ON and CHAN 1 to OFF (49).
18) Set DUAL GRID mode to OFF (14).

Resulting Display:



A waveform is displayed in the center of your screen.
Signal acquisition is performed in the Random Interleaved Sampling mode.

8.2 Single Shot Acquisition

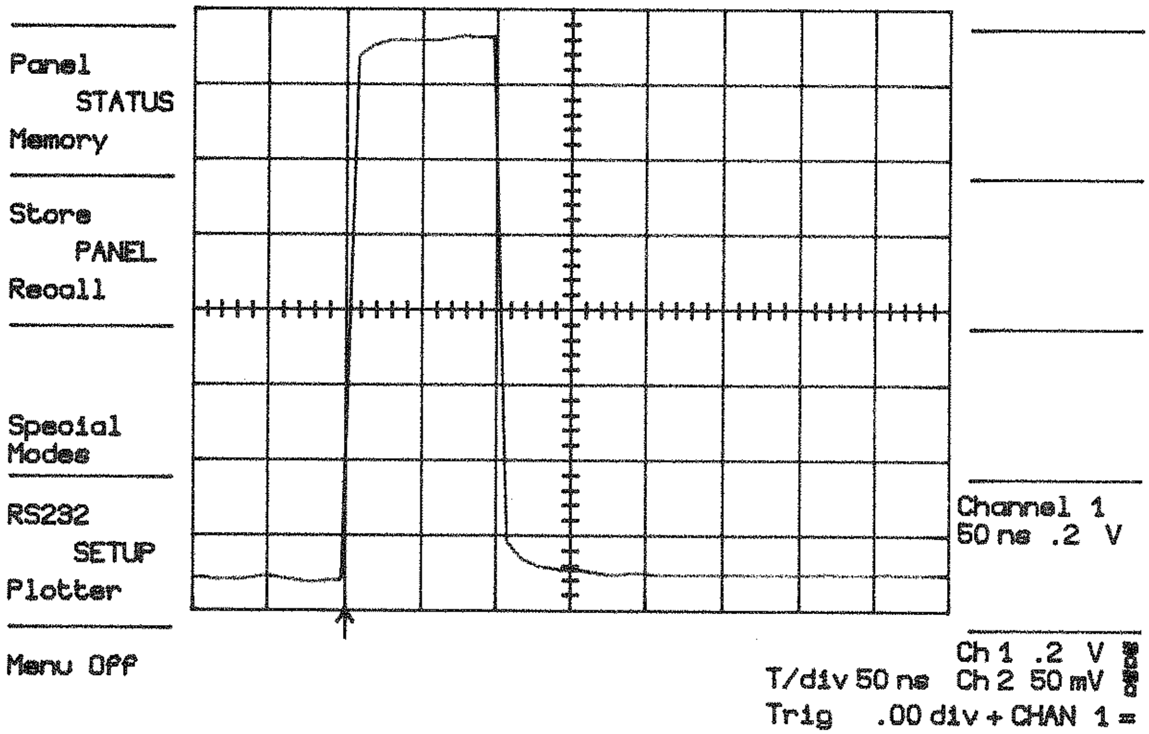
Acquisition of a single 100ns wide pulse.

In this case the pulse generator is not free-running. It must be in external or manual trigger, and set to provide a 100ns wide pulse with an amplitude of your choice.

1) Connect signal source to CHAN 1 input (21).
2) If you are in the Main Menu, call the Panel Status menu (2).
3) Set CHAN 1 Fixed VOLTS/DIV as appropriate (28) to match the generator.
4) Adjust CHAN 1 **VAR** vernier (29) as appropriate to match the generator.
5) Set CHAN 1 OFFSET as appropriate.
6) Set CHAN 1 COUPLING to DC 50Ω
7) Adjust **TRIGGER DELAY** control (34) to 20.0% Pre.
8) Adjust **TRIGGER LEVEL** control (33) to .00 division.
9) Set TRIGGER COUPLING to AC (30).
10) Set TRIGGER SOURCE to CHAN 1 (23).
11) Set TRIGGER SLOPE to POS (25).
12) Arm the trigger by setting the TRIGGER MODE (29) to single.

13) Set **TIME/DIV** control (36) to 50 ns/div (36).
14) Set INTERLEAVED SAMPLING to OFF (37).
15) Set BW-Limit to OFF (50).
16) Return to the Main Menu by depressing the **Return** pushbutton (10).
17) Set CHAN 1 to ON and CHAN 2 to OFF (49).
18) Set DUAL GRID mode to OFF (14).
19) Now trigger the signal source.

Resulting Display:



8.3 Trace Expansion - Expand A/B

Using the same 100ns signal and front panel settings described in Section 8.2, but with your pulse generator free-running this time, perform the following procedure:

1) Set pushbutton (14) to DUAL GRID mode.
2) Depress EXPAND A (46) in order to expand CHAN 1 trace.

As the likelihood that source for signal expansion shown in the Displayed Trace field (V) is not **X-Chan 1**, you must perform the following procedure to redefine the expansion signal source to CHAN 1.

a) Depress **REDEFINE** pushbutton (47) to display the Redefine Source menu in the Menu Field (I).
b) Depress pushbutton (1) in order to redefine CHAN 1 as the new source for the expanded (X-Chan 1) display.

At this point the new source for the expanded (X-Chan 1) line in the Displayed Trace Field (V) is updated to **X-Chan 1** and all or a portion of CHAN 1 trace is intensified.

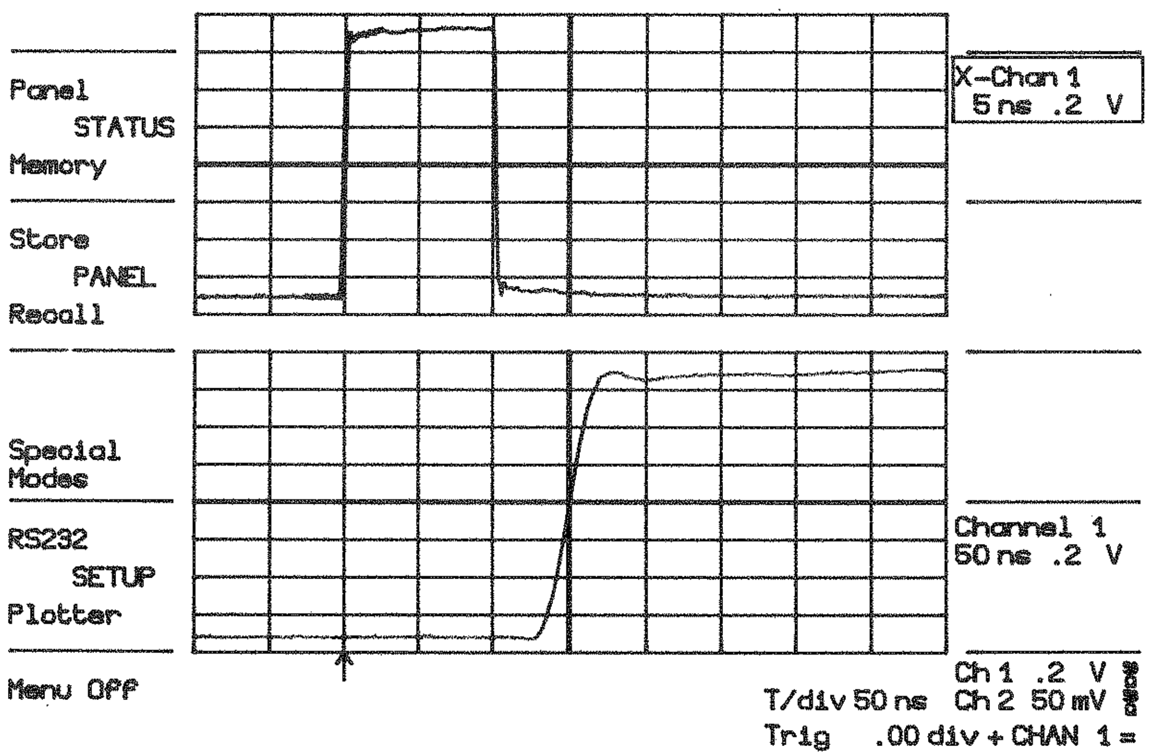
3) Turn **TIME MAGNIFIER** control (43) to adjust magnification factor (length of the intensified section) as desired (i.e. 5 ns).
4) Displace the intensified section by adjusting **Horizontal POSITION** control (39) and position it on the risetime of your pulse.
5) Position expanded trace in lower grid by adjusting the **Vertical POSITION** control (40).
6) Adjust **VERT GAIN** control (42) if required.

At this point the digitized points are clearly seen every 10ns.

7) Set INTERLEAVED SAMPLING to ON.

The equivalent sampling frequency is now 5 Gs/s and the risetime of the pulse is very clearly defined.

Note: The procedure to follow for Expand B is identical to the above, except that in Step 2 the **EXPAND B** pushbutton (46) is depressed rather than the **EXPAND A** pushbutton.



8.4 Sequential Recording of Single Events in Segmented Memory

I. 31 Segment Memory Partitioning

Using the same 100ns signal and front panel settings described in Section 8.2., your pulse generator in external or manual trigger, perform the following procedure:

1) Call the Panel Status menu by depressing pushbutton (2).
2) Depress **Modify # Segments** pushbutton (4) as often as necessary in order to display the value 31 in the **# Segments for SEQNCE** line.
3) RANDOM INTERLEAVED SAMPLING to OFF.
4) Set Time Base to .1µs/division.
5) Select SEQNCE trigger mode (29).
6) Set DUAL GRID mode (14) to ON.
7) Depress **Return** pushbutton (10) to return to the main menu.
8) Actuate your generator external trigger a total of 31 times in order to generate 31 signals to be recorded.

At this point a compacted trace of 31 segments is displayed in the upper grid. Trace expansions EXPAND A and EXPAND B must be used to display details of one or two selected segments.

9) Depress EXPANDA (46) in order to expand CHAN 1.

As the likelihood that the source for signal expansion shown in the Displayed Trace field (V) is not X-Chan1, you must redefine the expansion signal source to CHAN 1 (see Section 8.3).

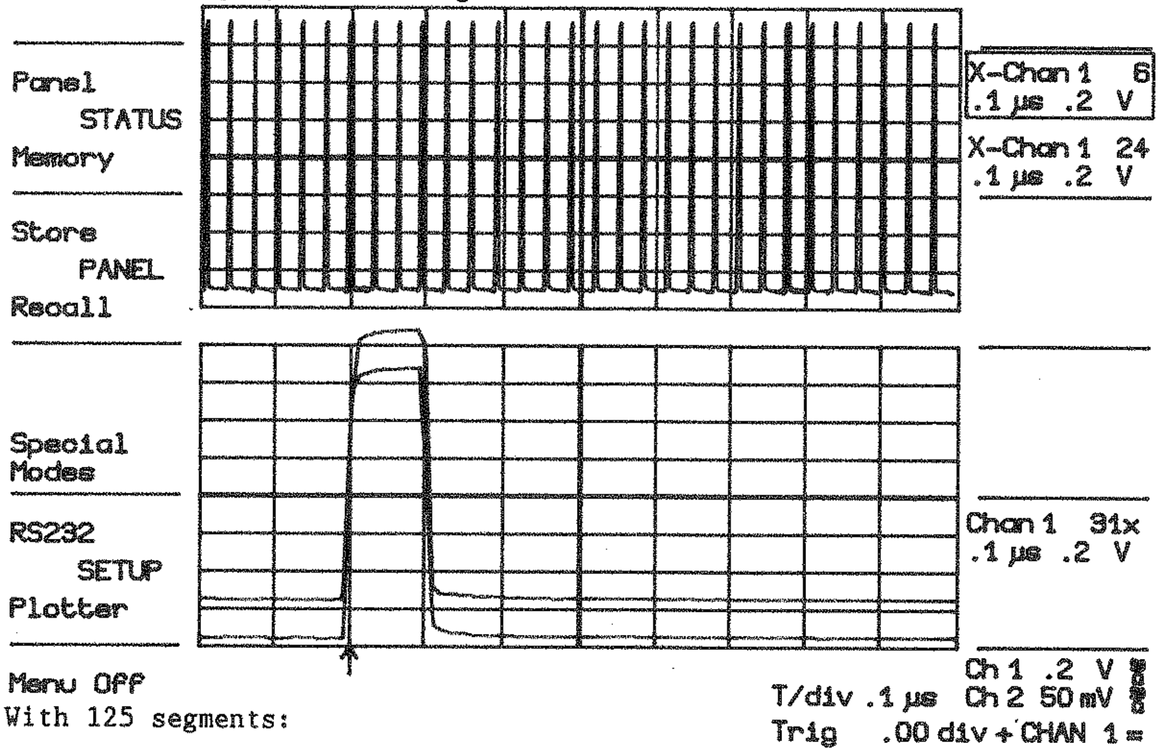
10) Depress EXPAND B (47) in order to expand a second portion (segment) of CHAN 1.
11) Select EXPAND B for display control by depressing the SELECT pushbutton (). Redefine EXPAND B to be an expansion of channel 1 if necessary.
12) Choose the segment of interest by adjusting Horizontal POSITION control (39). The number of the selected segment is displayed in the upper right corner of the Displayed Trace field.
13) Position expanded trace in lower grid by adjusting the vertical POSITION control (40).
14) Select EXPAND A for display control (?).
15) Choose second segment of interest (39).

II. 125 Segment Memory Partitioning

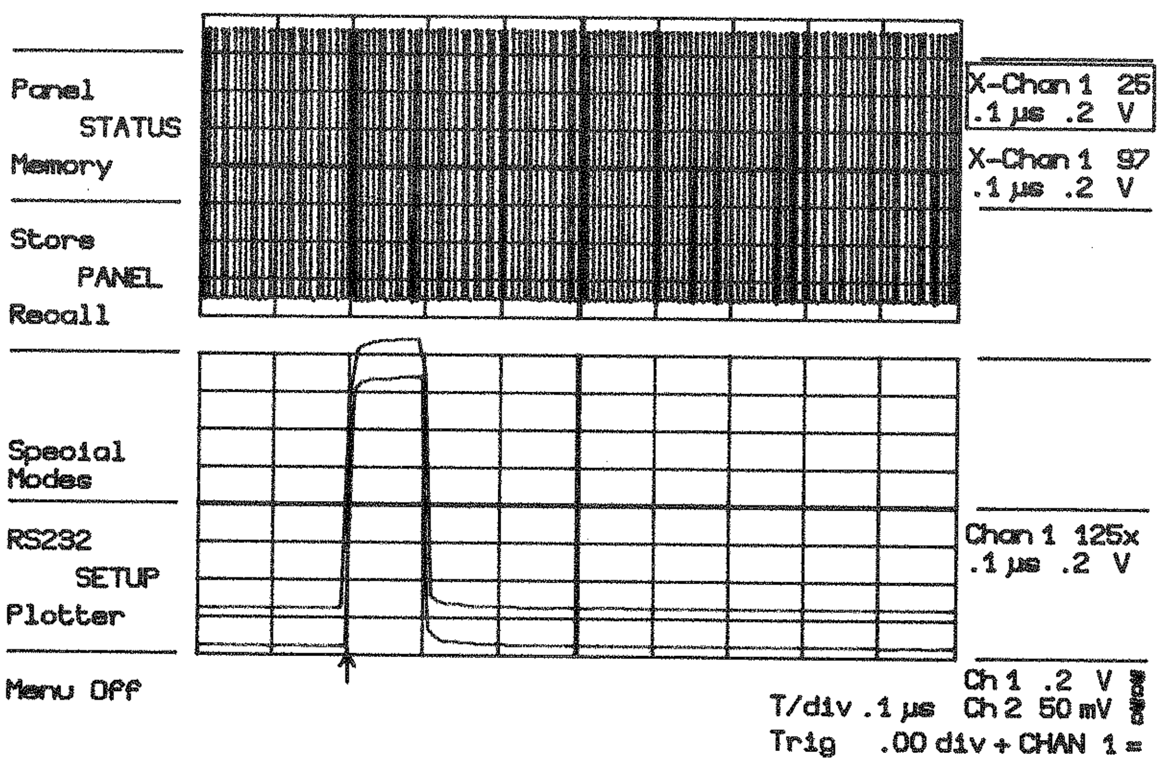
In the case of sequential recording of 125 single event, you need only modify the value displayed in the **# Segments for SEQNCE** line of the Panel Status menu by depressing **Modify # Segments** pushbutton (4) until the value 125 appears in the **# Segments for SEQNCE** line.

Keeping all other settings as above, generate 125 triggers. The resulting display shows the same waveform; the number of digitized points per segment only has changed from 1024 to 256.

Resulting display with 31 segments:



With 125 segments:



8.5 Slow Signal Recording

Acquisition of a 1Hz sine wave signal.

1) Connect a 1 Hz, signal source to CHAN 2 input connector (21).
2) Call the Panel Status menu by depressing pushbutton (2).
3) Set CHAN 2 sensitivity to 1 V/div (27).
4) Adjust CHAN 2 OFFSET to .00 V (32).
5) Set CHAN 2 COUPLING (22) to DC-1 MΩ
6) Set Time Base to 1sec/div (36).
7) Set TRIGGER LEVEL to 1.00 div (33).
8) Set TRIGGER DELAY to 50% Pre (34).
9) Set TRIGGER MODE to NORM (29).
10) Set TRIGGER SLOPE to POS (25).
11) Set TRIGGER SOURCE to CHAN 2 (23).
12) Depress **Return** pushbutton (10) to return to the main menu.
13) Set CHAN 1 to OFF and CHAN 2 to ON by depressing pushbutton (49).
14) Set DUAL GRID mode to OFF (14).

Resulting Display:

A sine wave signal will be displayed, rolling from right to left across the screen. Halting the display can be done by pressing the SINGLE pushbutton (29) when in NORMAL trigger mode. When in AUTO trigger mode, the display is halted upon receipt of an external trigger signal.

8.6 Window Triggering

Window triggering permits capturing signals exceeding the positive or negative limits set around the base line (in internal trigger) or ground (in external trigger) with the **TRIGGER LEVEL** control (33).

Using the same basic acquisition parameters and signal used in Section 8.5, it is possible to halt the rolling signal by increasing its amplitude until it crosses the positive or negative "window", which pre-defines the conditions under which triggering is desired.

Procedure:

1) Set the **TRIGGER SLOPE** pushbutton (25) to POS/NEG. (Both the **POS** and **NEG** LEDs will light when pushbutton (25) has been depressed the correct number of times).
2) Set **COUPLING MODE** pushbutton (30) to the AUTO Trigger Mode.
3) Adjust CHAN 2 **OFFSET** control (32) in order to center the sine wave display at mid-screen.
4) Select a trigger "window" just beyond the positive or negative half cycle of the currently displayed sine wave by adjusting **TRIGGER LEVEL** control (33) to approximately ± 3.0 division.

Note that when Window Triggering has been selected via pushbutton (25), a corresponding message is displayed below the bottom graticule line on the right-hand portion of the screen in the abridged Panel Status field. This field enables you to adjust the positive/negative trigger window desired without having to call the Panel Status menu.

5) Gradually increase the amplitude of the output signal from your signal generator until the positive and negative half-cycle of the displayed sine wave exceeds 3.0 divisions with reference to the zero base line.

Resulting Display:

Rolling will cease when the rolling waveform reaches ± 3 divisions in amplitude.

8.7 Storing and Recalling Front Panel Set-up

Storing repetitive signal.

1) Follow the same procedure as in Section 8.1 applying the probe calibrator signal.

2) Depress STORE PANEL (4) pushbutton.

   At this point the listing of 7 possible front panel set storage locations appears in the MENU FIELD.

3) Depress the pushbutton adjacent to the storage location you have selected (i.e., 2).

All front panel settings are now stored.

4) Set CHAN 1 Fixed VOLTS/DIV to 20 mV (28) and TIME/DIV (36) to .2 ms.

Your display is now half the amplitude and the sweep speed 2.5 times faster.

5) Depress STORE PANEL (4) pushbutton.
6) Depress pushbutton to store new second panel settings (3).
7) Depress RECALL PANEL (5) pushbutton.
8) Depress corresponding pushbutton (2).

At this point the first setting stored is called back with corresponding display.

Recalling second set up is performed in the same way by pressing the corresponding pushbutton (3).

8.8 Signal Storage in Memories C, D

I. Storage of CHAN 1 Waveform into Memory C

Apply the same signal as per Section 8.1 - I and recall front panel set-up by depressing pushbuttons (5) and (2) in that order.

Procedure:

1) Stop acquisition by setting the TRIGGER MODE (29) to single.
2) Depress STORE pushbutton (1) to call Store Trace menu.
3) Store CHAN 1 into Memory C (2).
4) Set CHAN 1 to OFF by depressing pushbutton (49).
5) Set MEMORY C to ON by depressing pushbutton (47).

II. Storage of CHAN 2 Waveform into Memory D

Apply a second signal, as per Section 8.3, from your pulse generator to CHAN 2 BNC connector (21).

Procedure:

1) Depress **STORE** pushbutton (1) to call Store Trace menu.
2) Store CHAN 2 into Memory D (5).
3) Set CHAN 2 to OFF (49).
4) Set MEMORY D to ON (47).
5) Set DUAL GRID to ON by depressing pushbutton (14).
6) Select Memory D by depressing **SELECT** pushbutton (44).
7) Adjust **VERT GAIN** control (42) and **Vertical POSITION** control (40) to center trace.

The above procedure permits simultaneous storing and displaying of two independent waveforms. Calling the Memory Status menu (3) enables the user to review all acquisition parameters.

Note that instead of storing the currently acquired CHAN 1 waveform into Memory C and CHAN 2 waveform into Memory D, the Store Trace menu also allows the user to inverse this configuration, and to store the CHAN 1 waveform into Memory D and the CHAN 2 waveform into Memory C.

8.9 Redefinition Function - Expand Memories C, D

As mentioned in Section (5.2.4), the default signal sources for Expand A and B are CHAN 1 and 2, respectively. It is possible, however, to expand a waveform stored in reference Memories C and/or D by redefining these memories as the new signal expansion source.

I. Expansion of MEMORY C with EXPAND A

Procedure:

1) Store signal into Memory C as per Section 8.8.
2) Depress **EXPAND A** pushbutton (46).
3) Depress **SELECT** pushbutton (44) to frame the X-Chan 1 message.
4) Depress **REDEFINE** pushbutton (45).
5) Depress pushbutton (4) to define Memory C as the new signal source for Expand A.

From this step on, the procedure to follow is identical to that described in Section 8.3 for CHAN 1, 2 Expansion.

II. Expansion of Memory D with Expand B

The procedure used here is identical to that detailed above, except that Expand B is substituted for Expand A in Step 1, and Memory D is redefined as the new source for expansion (Step 4).

Just as Expand A and B enabled the user in Section 8.3 to expand the signals contained in the CHAN 1 and 2 acquisition memories, here can be expanded, for detailed observation, signals contained in reference Memories C and/or D.

It is possible, while studying these reference waveforms, to simultaneously acquire signals via the CHAN 1 and CHAN 2 acquisition memories in real time. Note that you can not display more than 4traces on the 9400's screen at any one time.

8.10 Autostore in Memory C, D

As mentioned in Section 5.5, depressing the **Special Modes** pushbutton (7) permits one to automatically store the current CHAN 1 and/or CHAN 2 display into the unit's two 32 K reference memories following acquisition of each waveform.

The Autostore mode is particularly useful whenever the user wishes to acquire single events in the Normal trigger mode appearing at intervals > 2 (As explained in Section 5.2.5, in the Normal trigger mode the trigger circuit automatically re-arms after 2 sec, causing the currently stored waveform to be erased from memory).

8.12 Remote Control Via RS232-C Port

The 9400 has been designed to permit control of all of the scopes's functions by means of a remotely located computer or terminal. For a complete listing of the various commands used to program the 9400 see Section 7.6.

The following examples are given to present the 9400's remote control from a terminal. If one wants to use a computer, send

<ESC> [

to the 9400 to disable echoing character from the scope.

Preliminary Hardware Set-up:

1) Before connecting the host computer, be sure to power up the 9400.
2) Connect a terminal through RS232 cable to Remote Port connector (56) on the rear panel of the 9400, paying close attention to proper pin matching between the connectors of the terminal and oscilloscope.
3) Call the RS232-C menu by depressing pushbutton (8) to match the data transfer speed and character formats of the terminal and oscilloscope (See Section 7.12).

I. Remote Operation in the Interrogation Mode

Programming Example: Terminal Display of Current Time Base Setting.

Programming Procedure:

1) Using any combination of upper or lower case characters, enter the letters TD on your keyboard, followed by a space, comma or by the equal sign, followed by a question mark, followed by <CR> as follows:

TD ?

Resulting Display:

Immediately upon execution of the above sequence you will see the 9400's current time base setting displayed on your terminal, e.g.:

TIME/DIV 100. S

II. Remote Operation in the Control Mode

In order for the user to modify currently selected oscilloscope parameters, he must first set the 9400 to Remote use, which is performed by entering <ESC>R (i.e. the character <ESC> followed by <R> upper case).

Programming Example: Set the Time Base to 2 ms.

Programming Procedure:

1) Enter TD 2MS <CR> (upper or lower case characters). Other possible character formats are:

TIME/DIV 2 MS <CR>	(upper or lower case characters)
TD 2E-3 <CR>	(upper or lower case characters)
TD .002 <CR>	(upper or lower case characters)

Resulting Display:

Observe the abridged Panel Status field in the lower right-hand portion of the screen while the above character sequence is entered via the terminal keyboard. When (<CR> is depressed, you will see the currently displayed time base setting change to 2 ms.

In order to return the 9400 to Local use, type <ESC>L (i.e. the character <ESC> followed by <L> upper case), at which point you will be returned to the 9400's initial menu (i.e., the menu appearing at unit power up).

8.13 Remote Control Via GPIB

It is not only possible to control the various functions of the 9400 via the RS232-C port, but also to do so via the General Purpose Interface Bus (GPIB).

I. First example: Set the Time Base to 1ms.

This example is given to present the different steps necessary to use a GPIB bus. Note that most languages offer high-level routines that make these steps automatically.

In this example an IBM PC or compatible computer equipped with a National Instruments GPIB-PC2 or PC2A GPIB adapter and National Instrum ents IBIC* program (default settings are selected) is used.

Preliminary Hardware Set-up:

1) Before powering up the 9400, select GPIB operation by setting the 9400's rear panel thumb-wheel address switch (54) to 4.

2) Connect a GPIB cable to the 9400's rear panel GPIB connector (55) and to the GPIB connector of the PC.

Note that upon system initialization, the PC must be at address 0.

3) In the Handler default configuration and with the prompt A> displayed on your PC's CRT, enter:

IBIC <CR> (upper or lower case letters)

The following message will be displayed on your CRT:

```
National Instruments
Interface Bus Interactive Control Program (IBIC Rev C.0)
Copyright (C) 1984 National Instruments, Inc.
All rights reserved
```

In the following lines, commands which must be sent are in upper case. Answers or comments are in lower case. Each command must be followed by <CR>.

4) Enter IBFIND GPIBØ (in upper or lower case), at which point the following program will execute:

	Meaning:
IBSIC Status Message Returned	PC acts as controller
IBTMO 12 Status Message Returned	3 sec time-out
IBEOT 1 Status Message Returned	PC automatically enables <EOI> line on final character of message
IBSRE 1 Status Message Returned	Enable Remote 9400 operation
IBCMD "?_@$" Status Message Returned	PC Talker; 9400 Listener 9400 enters REMOTE
IBWRT "TD 1MS;TD?" Status Message Returned	TIME/DIV set to 1 ms; read current value
IBCMD "?_D" Status Message Returned	PC Listener; 9400 Talker
IBRD 120 Status Message Returned	PC to read $\leq$ 120 characters and stop when it encounters <EOI>

****

At this point the following message will be displayed (with corresponding Hexadecimal ASCII codes to the left):

```
54 44 20 31 2E 30 30 45     T D  1 . 0 0 E
2D 30 33 20 53 0D 0A        - 0 3  S
```

****

IBONL Status Message Returned	Disconnect PC from GPIB; set 9400 to Local operation
E	Exit IBIC program

II. Second example: Read 10 values from Channel 1.

The controller is an HP 9836 running BASIC 2.1.
The 9400's rear panel thumb-wheel address must be set to4.

```
CLEAR 704                          (sends Device Clear)
REMOTE 704                         (sets 9400 in Remote)
ENABLE INTR 7;2
ASSIGN A TO 704
DIM A$[100 ]
DIM F$[20  ] BUFFER
ASSIGN @F TO BUFFER F$
OUTPUT @A;"BS ?" END               (reads the Status Bytes)
ENTER @A;A$
PRINT A$
        OUTPUT @A: "MASK 1,8; MASK 4,1"; END
        ON INTR 7 GOTO Bep              (wait for "Trigger")
        TRIGGER 704
     Bc:   GOTO Bc
     Bep:  !
           OUTPUT @A;"STB?" END
           ENTER @A:A$
           PRINT @A$
           CLEAR 704
           OUTPUT @A;"READ,C1,DA,,10" END  (reads   10   values   from
                                            Channel 1)
        ENTER @A USING "#,2A";B$
        ENTER @A USING "#,W":S
        PRINT "B$=";B$
        PRINT "NUMBER OF RECEIVED BYTES=";S
        TRANSFER @A TO F;WAIT
        PAUSE
        FOR I=1 TO 10
        PRINT NUM(F$[I,I])
        NEXT I
     END
```

8.14 Making a Plot when the Computer, the 9400, and the Plotter are all Connected Together on a GPIB Bus

In this configuration, the computer controls the GPIB bus and the devices that are on the bus, such as the 9400 and the plotter. The 9400 cannot directly send plot data to the plotter even when it is in LOCAL. It is the task of the computer to organize the data transfer. The following sequence may do the job.

1) The computer sets the 9400 into REMOTE.

2) The computer sets itself to Talker and the 9400 to Listener and sends the command:

   "SCREEN_DUMP"

3) The computer organizes the transfer between the 9400 and the plotter, in one of the ways described below. The choice depends on the computer GPIB software.

   The controller tells the 9400 to talk and the plotter to listen. It puts itself in Standby Mode waiting for EOI that will be set by the 9400 when the plot is finished.

   or

   The controller tells the 9400 to talk and the plotter to listen. It puts itself in Listener mode reading but NOT storing the plot data.

   or

   The controller tells the 9400 to talk and sets itself to Listener. It reads AND stores the plot data. Afterwards it sets itself to Talker and tells the plotter to Listen and sends the stored data to the plotter.
   Notice that a larger amount of data has to be stored: up to 50 Kbytes if all the traces are on.

4) The controller terminates the transfer by sending UNT (UNTalk) and UNL (UNListen) and setting the 9400 into LOCAL for example.

8.15 Configuring the Parallel Polling

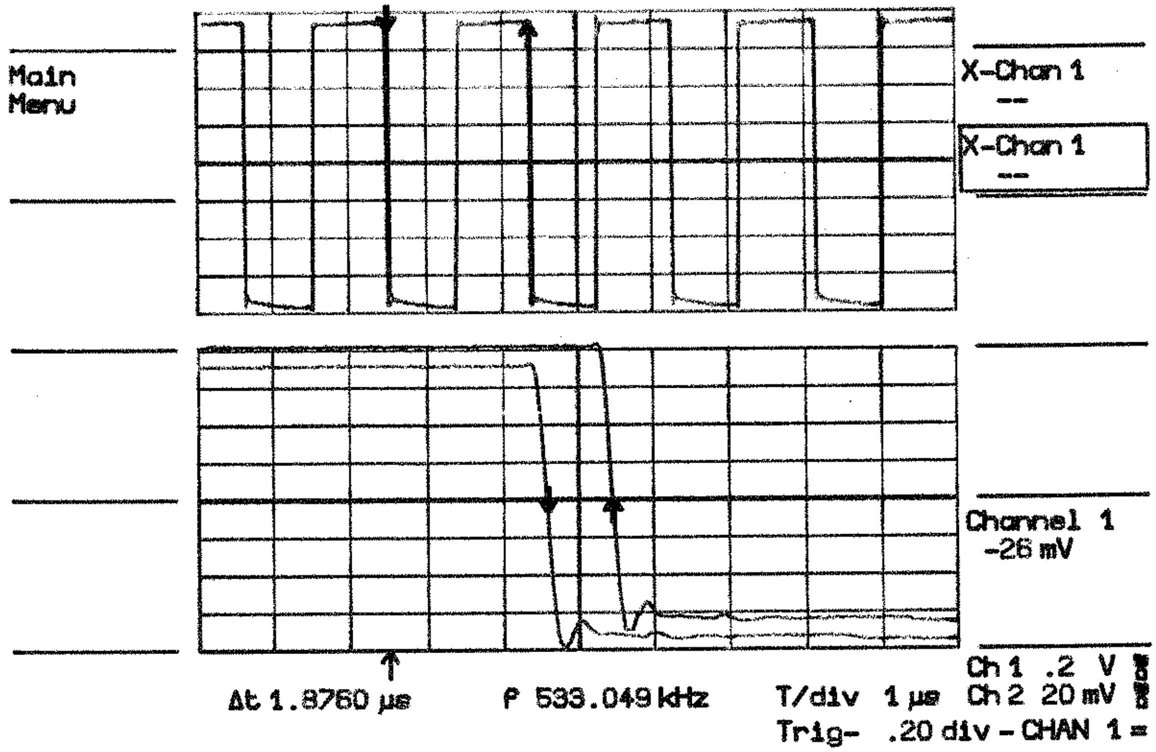
Send the following sequence of GPIB commands to the 9400:

- listen address of the 9400.
- PPC (Parallel Poll Configure).
- PPE (Parallel Poll Enable).
  in binary : 0 1 1 0 S P3 P2 P1
  Where P3 to P1 represents DIO line number - 1
  S = 1 if 1 must be sent while Service Request is active.
  = 0 otherwise.
- UNT (UNTalk) and UNL (UNLlisten) non obligatory.

To "unconfigure" the parallel polling, send the following sequence of GPIB commands to the 9400:

- Listen address of the 9400.
- PPD (Parallel Poll Disable).
  in binary : 0 1 1 1 S P3 P2 P1
  as mentioned above.
- PPU (Parallel Poll Unconfigure).
- UNT or UNL non obligatory.

Other sequences of commands are also possible.



9.4 Auto-Calibration

The 9400 recalibrates its time interpolator relative to the internal 100 MHz crystal-controlled clock generator every time the timebase is modified, by front panel operation or by remote control.

The vertical gain and offset of an input channel are calibrated by means of an internal 12-bit very stable digital-to-analog converter every time the fixed gain control of this channel is modified. Calibration of both channels also takes place whenever the bandwidth limit is changed.

Recalibrations are mostly necessary because of drifts due to temperature changes. Since the 9400 might be left in the same state for a very long time, no calibration might be done for a long time. To avoid measurement errors due to potential drifts, an internal timer of the 9400 forces a complete auto-calibration every minute during the first 10 minutes after powe-up and every 20 minutes thereafter. this operation is transparent to the user, but is audible due to relay switching.

In remote control, all auto-calibration can be turned off, and it may be executed whenever requested (see CALIBRATE command in Section 7.6.6).

SECTION 10

WP01 WAVEFORM PROCESSING OPTION

10.1 Processing Capabilities

The WP01 Waveform Processing Option includes an additional .5 Mb random access memory for accumulation, computation and waveform buffers. This makes it possible to accumulate averaged waveforms up to over 32000 data points in 32-bit form.

All waveform processing occurs through the waveforms E and F which may be displayed on the screen by depressing the corresponding FUNCTION E, F (48) pushbutton. Whenever the FUNCTION E or F trace or its expansion (in EXPAND A or B) is turned ON, the corresponding waveform processing is executed. Whenever the trace (and its expansion) is turned OFF, the processing is suspended. This is true even for remote control. The display may be turned off by remote control in order to gain speed (command SCREEN OFF, Section 7.6.3); however, even in this case the corresponding function trace must be turned ON although it will not be displayed.

FUNCTIONS E and F are waveforms that exist independently (i.e. in addition to) of the acquisition memories of CHANNELS 1 and 2 and of the reference memories C and D. At display, they are treated similarly as memories C and D, i.e. the vertical display gain and the vertical position can be modified, but not the horizontal position and the time magnifier. Of course, they can be expanded by redefining the source waveform of the traces EXPAND A or B.

Two different processing functions can be executed simultaneously. They may be read by remote control just as the other traces, with the additional option of reading 16-bit data values. They may be stored in reference memories C or D, just like the CHANNELS 1 or 2, by depressing the STORE pushbutton (1). Waveform processing functions operate on one or two source waveforms which may be CHANNEL 1 or 2, Memory C or D. FUNCTION F may also operate on FUNCTION E. Since the results of the processing functions can be stored in the reference memories, and since FUNCTIONS E and F may operate on these reference memories (and F may operate on E), chaining of operations is possible.

Waveform processing can take an appreciable execution time when operating on many data points. The user has the option of reducing the execution time by limiting the number of data points which are used in the computation.

The 9400 executes the waveform processing function on the entire waveform (as displayed on the screen) by taking every N'th point, N depending on the timebase. The first point of such a reduced record is always the data value at address 0 (i.e. the point on the left hand edge of the screen). For readout and display, the data record is re-expanded to the original number of data points by linear interpolation. The user can read by remote control either the entire expanded record or the reduced record. In the second case, the user must know the "skip factor", i.e. the value of <intval> in the READ command (see Section 7.6.5). This factor can be inspected on the Memory STATUS display screen, or by the INSPECT command.

10.2 Manual Setup of a Waveform Processing Function

It is generally a good practice to stop data acquisition while preparing new conditions for the waveform processing (by setting the trigger mode to SINGLE) because the response time might otherwise be slow, depending on the current function setup. In order to prepare the FUNCTION E or F for new conditions or to inspect the current setup, the trace FUNCTION E or F (48) must be turned ON. Select this trace for display control with the SELECT (44) pushbutton and depress REDEFINE (45). A full page setup menu for this function appears on the screen. Return to the normal waveform display by either depressing the "Return" softkey (10) or the REDEFINE (45) pushbutton.

The currently selected processing function and its parameters may be modified with the softkeys. First select the field to be modified. The rectangular frame around parameter values indicates the currently selected field. Depressing the Previous FIELD pushbutton (2) will cause the frame to move towards the top of the list, whereas depressing the Next FIELD pushbutton (3) will cause the frame to move downwards.

Following field selection, the current value of the field may be modified by depressing either the Previous or Next VALUE pushbutton (6 or 7). Since the identity of the lower fields may depend on the function chosen, modify the parameters from top to bottom.

The following function classes are available:

- Average, including summed and continuous averaging
- Extrema, i.e. "Roof" for maxima, "Floor" for minima
- Arithmetic, for Sum, Difference, Product and Ratio
- Functions, for Negation, Integral, Differentiation and Square Root
- Smoothing, for 3-, 5-, 7-, 9-point filters

10.2.1 Summed Average

Summed averaging consists of the repeated addition, with equal weight, of recurrences of the source waveform. Whenever the maximum number of waveforms is reached, the averaging process stops. The averaging process may be interrupted by switching the trigger mode from NORM to SINGLE (29) or by turning the function trace OFF (48). Averaging will continue when this action is reversed.

The currently accumulated average may be reset by either changing an acquisition parameter, such as input gain, offset or coupling, trigger condition or the timebase, or by depressing the RESET pushbutton (41) twice in quick succession (Remember that the FUNCTION E or F must be selected). The number of currently averaged waveforms is displayed in the Displayed Trace Field (V in Figure 4.1) of the corresponding function, or of its expansion.

Whenever the maximum number of sweeps is reached, a larger number of sweeps may be accumulated by simply changing the maximum number of sweeps in the setup menu. In this case, care must be taken to leave the other parameters unchanged, otherwise the average is reset.

Summed averaging may be performed over CHANNEL 1 or 2. The FUNCTION F may also average over FUNCTION E, therefore allowing averaging over functions.

Whenever a waveform containing overflow or underflow values must be added to an average, unknown values must be added. The user may choose the action to be taken:

- If "Artifact Rejection" is OFF, overflows are set to the maximum possible value (of the ADC) and underflows to the minimum. The waveform is then added to the average. Of course, the average will be incorrect at the overflow positions.

- If "Artifact Rejection" is ON, waveforms containing at least one overflow or underflow are rejected from the average, i.e. not added at all. If waveforms consistently contain overflows or underflows, averaging cannot proceed, the number of accumulated sweeps may stay zero indefinitely.

In order to improve the signal to noise ratio even further, the 9400 offers the possibility of performing "offset dithering". When turned on (i.e. when set to > 0 least significant bits of the ADC), the 9400 adds a small "hardware" offset to each acquired waveform. This offset is different for different waveforms, and the values are chosen such that their average is negligibly small. The function setup menu allows a choice of the maximum excursion of this offset.

When set to the largest possible value of 6 LSB, the waveforms are offset by up to ± .2 vertical divisions (remember that a vertical division corresponds to 32 least significant bits of the ADC). In this case, care must be taken that the waveform to be averaged is contained within 1/5 of a vertical division from the top and the bottom of the display grid; otherwise overflows or underflows might occur. Whenever dithering is ON, the displays of CHANNELS 1 or 2 vary vertically with the dithering offset. Their waveform descriptors take the additional offset into account so that waveforms, as read out by remote control, and cursor measurements are always correct.

Offset dithering is interesting when the waveform to be averaged is already relatively "clean", i.e. contains noise variations of the order of 1/5 of a division or less. In this case, dithering makes the sequentially acquired waveforms use slightly different portions of the ADC. Thus the differential non-linearities (that any flash ADC has) are averaged out. It can be expected that the differential non-linearities are reduced by up to a factor of 4, when using 6 LSB dithering. Waveforms which have high levels of noise (>1/5 of a vertical division) do their own "dithering", making artificial offset variations unnecessary.

10.2.2 Continuous Average

Continuous averaging (sometimes called exponential averaging) consists of the repeated addition, with UNEQUAL weight, of recurrences of the source waveform. Each newly acquired waveform is added to the accumulated average according to the formula:

$$S(i,new) = (N-1)/N * S(i,old) + 1/N * W(i)$$

Where

i	Index over all data points of the waveforms
W(i)	Newly acquired waveform
S(i,old)	"old" accumulated average
S(i,new)	"new" accumulated average
N	May be 2, 4, 8, 16, 32, 64 or 128

The coefficients (N-1)/N and 1/N are the weighting factors which determine the speed at which the continuous average follows any modification of the source waveform. Note that they add up to the value of 1 so that the continuous average of noisy, but otherwise unmodified waveforms resembles the summed average of such waveforms.

However, the statistical significance of a continuous average is less good, since the last acquired waveform has more weight than all previously acquired ones. Thus the continuous average is dominated by the statistical fluctuations of the most recently acquired waveforms.

The continuous average never stops at a maximum number of sweeps. The weight of "old" waveforms gradually tends to zero, but they are theoretically never completely forgotten. The averaging process may be interrupted by switching the trigger mode from NORM to SINGLE (29) or by turning the function trace OFF (48). Averaging will continue when this action is reversed. The currently accumulated average may be reset by either changing an acquisition parameter, such as input gain, offset or coupling, trigger condition or the timebase, or by depressing the RESET pushbutton (41) twice in quick succession (remember that the FUNCTION E or F must be selected).

Continuous averaging may be performed over CHANNEL 1 or 2. The FUNCTION F may also average over FUNCTION E, therefore allowing averaging over functions.

10.2.3 Extrema

The computation of extrema consists of a repeated comparison of recurrences of the source waveform with the already accumulated extrema waveform. Whenever a given data point of the new waveform exceeds (either positively or negatively) the corresponding data point of the accumulated extrema waveform, it replaces the former value in the extrema waveform. Thus a maximum (called "roof") or a minimum (called "floor") envelope of all waveforms is accumulated.

Whenever the maximum number of waveforms is reached, the accumulation process stops. The accumulation process may be interrupted by switching the trigger mode from NORM to SINGLE (29) or by turning the function trace OFF (48). Accumulation will continue when this action is reversed. The currently accumulated extrema waveform may be reset by either changing an acquisition parameter, such as input gain, offset or coupling, trigger condition or the timebase, or by depressing the RESET pushbutton (41) twice in quick succession (remember that the FUNCTION E or F must be selected). The number of currently accumulated waveforms is displayed in the Displayed Trace Field (V in figure 4.1) of the corresponding function, or of its expansion.

Whenever the maximum number of sweeps is reached, a larger number of sweeps may be accumulated by simply changing the maximum number of sweeps in the setup menu. In this case, care must be taken to leave the other parameters unchanged, otherwise the extrema waveform is reset.

Extrema may be performed over CHANNEL 1 or 2. The FUNCTION F may also generate extrema over FUNCTION E, therefore allowing extrema over functions.

10.2.4 Arithmetic

Arithmetic waveform processing options consist of the basic arithmetic functions performed on two source waveforms on a data point per data point basis. Different vertical gains and offsets of the two sources are automatically taken into account. However, both source waveforms must have the same timebase, and must have either both INTERLEAVED OFF or both INTERLEAVED ON. The trigger point may be different in the two source waveforms, although such a case usually would give results that are difficult to interpret.

The first source waveform may be multiplied by a constant factor in the range .01 to 9.99 and be offset by an additional constant in the range of ± 9.99 times the volts/division setting (of the first source waveform).

10.2.5 Functions

This option includes mathematical functions on single waveform sources: negation, square root, integral and differentiation. The first source waveform may be multiplied by a constant factor in the range .01 to 9.99 and be offset by an additional constant in the range of ± 9.99 times the volts/division setting (of the first source waveform).

10.2.6 Smoothing

Five options are available: 1-,3-,5-,7-, and 9- point smoothing.

1-point smoothing consists of adding adjacent data points to each other with equal weight. The data points of the source waveform are considered as members of adjacent bins, each containing N1/N2 data points. N1 is the number of data points in the source waveform, whereas N2 is the number of data points specified by the third line of the setup menu. The data points within each bin are averaged, resulting in a waveform consisting of N2 data points. This reduced record is then re-expanded for readout and display to the original number of data points by linear expansion.

3-point smoothing consists of recomputing each data point of the source waveform according to the formula:

$$Y(i) = W(i-1)/4 + W(i)/2 + W(i+1)/4$$

Where W(i) is the i'th point of the source waveform and Y(i) is the i'th point of the computed waveform. If the maximum number of data points, specified in the third line of the setup menu, is smaller than the original number of points, the smoothing is applied to the reduced data record.

5-point smoothing consists of the application of 3-point smoothing, twice in sequence. Similarly, 7-point and 9-point smoothing are computed by applying 3-point smoothing 3 and 4 times.

The resulting averaging formula for 5-point smoothing is:

$$Y(i) = W(i-2)/16 + W(i-1)/4 + W(i)*6/16 + W(i+1)/4 + W(i+2)/16$$

Whereas, for 7-point smoothing, it is:

$$Y(i) = W(i-3)/64 + W(i-2)*6/64 + W(i-1)*15/64 + W(i)*20/64$$

$$+ W(i+1)*15/64 + W(i+2)*6/64 + W(i+3)/64$$

And for 9-point smoothing:

$$Y(i) = W(i-4)/256 + W(i-3)*8/256 + W(i-2)*28/256 + W(i-1)*56/256$$

$$+ W(i)*70/256 + W(i+1)*56/256 + W(i+2)*28/256 + W(i+3)*8/256 + W(i+4)/256$$

10.3 Remote Control of Waveform Processing Functions

The remote control of the waveform processing is essentially achieved with extensions of existing commands. No processing occurs if the corresponding TRACE_FUNCTION_E (TRFE) or TRACE_FUNCTION_F (TRFF) is OFF (see Section 7.6.3). This is true even if the SCREEN has been turned OFF. Averaging can be stopped and continued by switching from TRIG_MODE NORM to TRIG_MODE SINGLE and vice versa. Of course, it can also be stopped by turning its corresponding trace OFF. An average or an accumulation of extrema can be reset by a new command, AVERAGE_RESET. A new function or new processing parameters are defined with extensions to the command REDEFINE. In addition, the command INSPECT allows knowing some characteristics of the waveform before reading it out.

1) AVERAGE_RESET (ARST) *

The accumulated average or extrema of the SELECTed trace is reset. This command can only be applied to FUNCTION_E or to FUNCTION_F.

Sets ENVIRONMENT ERROR:
- If the SELECTed trace if OFF.
- If the SELECTed trace is neither FUNCTION_E nor FUNCTION_F.

The INSPECT commands of Section 7.6.5 are augmented by the memories for the inspection of FUNCTIONS E and F.

2) INSPECT (INS) , < FUNCTION_E.LIMIT (FE.LI) >
< FUNCTION_F.LIMIT (FF.LI) >

instructs the 9400 to return a character string, containing the lower and upper address limits of the current waveform,

or

INSPECT (INS) , < FUNCTION_E.NSWEEPS (FE.NS) >
< FUNCTION_F.NSWEEPS (FF.NS) >

instructs the 9400 to return a character string, containing the number of acquired sweeps (in averaging and extrema),

or

INSPECT (INS) , < FUNCTION_E.INTVAL (FE.IV) >
< FUNCTION_F.INTVAL (FF.IV) >

instructs the 9400 to return a character string, containing the interval between data points used by a waveform processing function. This value may be used as the <intval> parameter in the readout of such waveforms, if the user wishes to read only the computed data points and none of the re-interpolated points,

3) REDEFINE (RDF) , ?

Instructs the 9400 to report the current configuration of the SELECTed trace,

or

REDEFINE (RDF) , AVERAGE (AVG) , SUMMED , <maxpts> , *
<source> , <maxswps> , <reject> , <dither>

configures the SELECTed trace for a summed average,

or

REDEFINE (RDF) , AVERAGE(AVG) , CONTINUOUS(CONT) , <maxpts> , *
<source> , <weight>

configures the SELECTed trace for a continuous average,

or

REDEFINE (RDF) , EXTREMA (EXTR) , <e-type> , <maxpts> , *
<source> , <maxswps>

configures the SELECTed trace for an extrema accumulation,

or

REDEFINE (RDF) , ARITHMETICS (ARI) , <a-type> , <maxpts> , *
<source1> , <source2> , <m-fact> , <a-const>

configures the SELECTed trace for waveform arithmetics on two sources,

or

REDEFINE (RDF) , FUNCTIONS (FNC) , <f-type> , <maxpts> , *
<source1> , <m-fact> , <a-const>

configures the SELECTed trace for a mathematical waveform function on a single source,

or

REDEFINE (RDF) , SMOOTHING (SMO) , <s-type> , <maxpts> , *
<source1>

configures the SELECTed trace for a smoothing operation.

The parameters have the following options:

, <maxpts>	=	<50 >	Maximum number of data Points to be used in the Computation
		< 125 >	
		< 250 >	
		< 625 >	
		< 1250 >	Default: 1250
		< 2500 >	
		< 6250 >	
		< 12500>	
		< 25000>	
		< 32000>	

Any other number generates a semantic error.

<source>	=	< CHANNEL_1	(C1) >	Source waveform
		< CHANNEL_2	(C2) >	
		< FUNCTION_E	(FE) >	Default: CHANNEL_1

<source1>	=	< CHANNEL_1	(C1) >	Source waveform(s)
<source2>		< CHANNEL_2	(C2) >	
		< MEMORY_C	(MC) >	Default: CHANNEL_1
		< MEMORY_D	(MD) >	
		< FUNCTION_E	(FE) >	

NOTE: a distinction is made between <source> and <source1>, to indicate the fact that averaging and extrema cannot be executed on MEMORY_C or MEMORY_D, whereas all the other functions can. FUNCTION_E can only be a source for waveform FUNCTION_F.

<maxswps>	=	< 10 >	Maximum number of sweeps
		< 20 >	
		< 50 >	Default: 1000
		< 100 >	
		.	
		.	
		< 500000 >	
		< 1000000 >	

Any number outside the 1-2-5 progression generates a semantic error.

<reject>	=	< ON >	Overflow rejection
		< OFF >	Default: OFF

<dither> = [0 to 6] — Dithering range; 0 = no dithering
Default: 0

Any other number generates a semantic error.

<weight> = < 1 > — Continuous averaging weight
< 3 >
< 7 > — Default: 7
< 15 >
< 31 >
< 63 >
< 127 >

Any other number generates a semantic error.

<e-type> = < ROOF > — Extrema type
< FLOOR > — Default: ROOF

<a-type> = < SUM > — Arithmetics type
< DIFFERENCE (DIF) >
< PRODUCT (PRD) > — Default: SUM
< RATION (RIO) >

<f-type> = < DIFFERENTIATE (DIFF) > — Function type
< INTEGRAL (INTEG) >
< NEGATION (NEGAT) > — Default: NEGATION
< SQUAREROOT (SQRT) >
< SQUARE (SQR) >

<s-type> = < 1 > — Smoothing type
< 3 >
< 5 > — Default: 3-pt smoothing
< 7 >
< 9 >

Any other number generates a semantic error.

<m-fact> = [0.01 to 9.99] — Multiplication factor
Default: 1.00

Any value smaller than 0.01 or greater than 9.99 is adapted to the nearest legal value.

<a-const> = [-9.99 to 9.99]   Additive constant
Default: 0.00

Any value smaller than 0.01 or greater than 9.99 is adapted to the nearest legal value.

NOTE: <a-const> is interpreted as the number of vertical divisions of <source1>

Whenever a parameter is not specified, the default value is substituted.

Examples:

RDF,AVG,SUMMED,,C2

Configures the SELECTed trace (which must be FUNCTION_E or FUNCTION_F) for the summed averaging of CHANNEL_2 with a maximum of 1250 data points over 1000 sweeps. By default, overflow rejection and dithering are off.

RDF,ARI,PRD,2500,C1,MD,2.00,1.00

Configures the SELECTed trace to compute the waveform 2.00*(CHANNEL_1 + 1 div)*Memory_D. A maximum of 2500 of data points (equidistantly distributed over the screen) are to be used.

REDEFINE,FNC,INTEG,25000,FE

Configures the SELECTed trace (which must be FUNCTION_F, since FUNCTION_E is specified as source waveform) to compute the integral over the waveform in FUNCTION_E, using a maximum of 25000 data points. Note that the use of 25000 data points implies that all data points on the screen are to be used, independently of the timebase setting.

4) The READ commands of Section 7.6.5 are augmented by the mnemonics for the readout of FUNCTIONS E and F:

```
READ (RD) , < FUNCTION_E.DESC (FE.DE) >
            < FUNCTION_F.DESC (FF.DE) >

READ (RD) , < FUNCTION_E.DATA (FE.DA) > , <Parameter list>
            < FUNCTION_F.DATA (FF.DA) >

READ (RD) , < FUNCTION_E.TIME (FE.TI) >
            < FUNCTION_F.TIME (FF.TI) >

READ (RD) , < FUNCTION_E.*    (FE.*)  > , <Parameter list>
            < FUNCTION_F.*    (FF.*)  >

<Parameter list> = <intval> , <# values> , <addr> , <sweep #>
```

See Section 7.6.5 for more detailed explanations.

10.4 Additional Values in the Descriptors of Processed Waveforms

The waveform descriptor contains all information needed to correctly interpret the waveform data. The parameters which describe the raw data records are explained in Section 7.7; they are still valid for processed waveforms. However, some additional parameters describe the processing which was applied to obtain the current waveform.

IMPORTANT: The parameters in the following list have NO meaning if the "Data Processing" byte (number 34 of the descriptor record) is set to 99 (raw data).

In the following list, each parameter is identified by its (decimal) address relative to the beginning of the descriptor, and by the number of bits. Data values shown are always in decimal.

Pos.	Size	Meaning
36	16-bit	256*Power of volts (see explanation in Section 10.5).
38	16-bit	256*Power of seconds (see explanation in Section 10.5).
40 - 63		Reserved
64	8-bit	Identity of function waveform; 4 = E, 5 = F.

65	8-bit	Function type. 0 = Average 1 = Extrema 2 = Arithmetics 3 = Functions 4 = Smoothing
66	8-bit	Subfunction type, depending on function type. Takes on values between 0 and (n-1), where n is the number of subfunctions possible. The order is the same as in the subfunction lists of Section 10.3.
67	8-bit	Primary source of this waveform. 0 = CHANNEL 1 1 = CHANNEL 2 2 = Memory C 3 = Memory D 4 = FUNCTION E
68	8-bit	Secondary source of this waveform (arithmetics only), with the same interpretation as the previous byte (67).
69	8-bit	Continuous averaging weight. 0 = 1 : 1 1 = 1 : 3 2 = 1 : 7 3 = 1 : 15 4 = 1 : 31 5 = 1 : 63 6 = 1 : 127
70	32-bit	Maximum number of sweeps (summed averaging and extrema).
74	16-bit	Multiplication factor * 100
76	16-bit	Additive constant * 100
78	16-bit	Maximum number of data points = <maxpts> in the REDEFINE command.
80	8-bit	Reject (summed averaging only). 0 = Reject off 1 = Reject on
81	8-bit	Dithering (summed averaging only). 0 = No dithering Otherwise = approximate number of ADC least significant bits, corresponding to the maximum dithering excursion.
82 - 97		Reserved
98	32-bit	Actually acquired number of sweeps (summed averaging and extrema).
102	32-bit	Number of acquired waveforms with overflows (summed averaging).

106 32-bit	Number of acquired waveforms with underflows (summed averaging).
110 32-bit	Number of rejected waveforms (summed averaging with Reject ON).
114 16-bit	Number (+ 1) of data points used in the computation of this data record (may be less than <maxpts>).
116 16-bit	Ratio of the number of data points in the source waveform over the number of data points used.
118 - 149	Reserved

10.5 Vertical Scaling Units

With the introduction of waveform processing functions, such as multiplication, division, square-root, integration and differentiation, which alter the vertical scaling units, a more general system for the vertical scales must be introduced. Three variables are now involved:

"fgain" (byte 0) = "fixed vertical gain" is now interpreted slightly differently, by dropping the notion of volts (Compare with Section 7.7).

22	= 5 mU/div	23	= 10 mU/div
24	= 20 mU/div	25	= 50 mU/div
.....		31	= 5 U/div

Where U now stands for a general unit, which may be a product of a power of volts and of a power of seconds.

"P_V" (bytes 118 + 119) = 256*power of volts
"P_s" (bytes 120 + 121) = 256*power of seconds

Thus, U = Volts**(P_V/256) * Seconds**(P_s/256).

NOTE: Whenever the WP01 waveform processing option is installed, "P_V" and "P_s" are always valid, even in raw data records (see following example). However, in software versions without waveform processing, they cannot be relied upon. (Of course, in these cases the vertical scales are always in volts).

Examples:

"fgain" =	22	corresponding to 5 mU/div
"P_V" =	256	corresponding to power of 1
"P_s" =	0	corresponding to power of 0

The resulting vertical scale is thus 5mV/div. Such a scale might occur in raw data records, in averaging, extrema or sums of raw data records.

"fgain" =	17	corresponding to 100 micro-U/div
"P_V" =	512	corresponding to power of 2
"P_s" =	0	corresponding to power of 0

The resulting vertical scale is thus 100micro-Volts-squared/div. Such a scale would result from the multiplication of two raw data records.

"fgain" =	26	corresponding to 100 mU/div
"P_V" =	64	corresponding to power of 1/4
"P_s" =	0	corresponding to power of 0

The resulting vertical scale is thus 100 mV**(1/4)/div (i.e. one-tenth of the fourth root of volts per division). Such a scale might result from the double application of the square-root operation on a raw data record.

"fgain" =	-2	corresponding to 50 pU/div
"P_V" =	256	corresponding to power of 1
"P_s" =	256	corresponding to power of 1

The resulting vertical scale is thus 50pVs/div. This scale might result from an integration over a raw data record.

The following cases can also occur:

- Both powers may be zero, corresponding to a dimensionless record, e.g. resulting from a division of raw data records.

- Powers may be negative, e.g. due to a division of raw data records, followed by another division. Differentiation also gives negative powers of the time unit.

10.6 Index of Topics

SECTION 11

FAST FOURIER WAVEFORM PROCESSING OPTION (WP02, V 2.05FT)

11.1 Processing Capabilities

The FFT option (WP02) adds the spectrum analysis capability to the 9400 DSO, in addition to the waveform processing functions already available under the WP01 option.

The DSO functions E and F can be defined as the fast Fourier transform of one of the source waveforms - Channel 1, Channel 2, Memory C, Memory D, and function E (for Function F only).

Values of the following FFT processing parameters can be selected in the FFT redefine menu or with remote control commands:

==

Function Type	:	Fourier Transform
Display Type	:	Power Spectrum (dBm) Power Density (dBm) Magnitude Phase Real Part Imaginary Part
Transform size	:	50 to 25000
Source Trace	:	Channel 1 Channel 2 Memory C Memory D Function E (for Function F only)
Window Type	:	Rectangular von Hann (Hanning) Hamming Flat Top Blackman-Harris
Multiplication Factor	:	0.01 to 9.99
Additive Constant	:	-9.99 to +9.99
Zero Suppression	:	OFF or ON.

==

The frequency resolution is now increased (the harmonic peaks are further apart), but the frequency range is reduced.

You can use the Marker to check the Nyquist frequency of 25.0 kHz at the right hand end of the spectrum trace, in agreement with the value displayed in the FFT menu.

11) Increase further the time record duration by switching to 10 ms/div, push Single Trigger button

The Nyquist frequency is now only 6.25 kHz, so that only the harmonics 1, 3 and 5, at approximately 1, 3 and 5 kHz fit into the frequency range. The 7th harmonic, at about 7 kHz, has been aliased (folded back) into the peak visible at 2 * 6.25 - 7 = 5.5 khz. Further aliased harmonics, of decreasing amplitude, are also visible between the original peaks.

12) Redefine the Display Type to Power Spectrum, and the Window Type back to Rectangular.

You now see the harmonics on the logarithmic scale, at 10 dB/div.

Look at the broad skirts exhibited by the peaks: this is the leakage of the signal energy of each peak into the neighbouring frequency bins.

13) Redefine the Window Type to von Hann (also called Hanning)

The skirts are reduced considerably: the leakage is diminished.

14) Redefine the Transform size to 2500

You will obtain N = 2500 and the Nyquist frequency of 125 KHz, while the interval between the points (bins) will remain unchanged at 1 / 0.01 sec = 100 Hz.

15) Define Function F as the FFT Power Average of Function E

Using the Normal or Auto trigger mode, you can average up to 200 spectra and see the intermediate or final average on linear scale (Magnitude) or dBm scale (Power Spectrum or Power Density).

16) Experiment

Try other time base settings, display modes, numbers of points, window types and signals, to become familiarised with the system. Try combinations of FFT and the WP01 processing functions.

You can define both functions E and F as FFT of the same source waveform, but with different parameters, and compare the resulting traces.

11.4 Remote Control of FFT Processing

Please consult the Sections 7 and 10.3-10.4 for the general information on the Remote Control, either using the GPIB or the RS232 interface. This Section describes only additional forms of commands, specific to the FFT option, and the related fields of the Waveform Descriptor.

11.4.1 Remote Commands

The 'redefine' command has been extended to accept the parameters related to the FFT:

```
REDEFINE    (RDF),    FFT,    <disp_type>,    <maxpts>,    <source>,
                  <window>, <m_fact>, <a_const>, <z_suppr>
```

The parameters have the following options:

```
<disp_type> = < POWER_SPECTRUM  (PWS)    > (default)
              < POWER_DENSITY   (PWD)    >
              < MAGNITUDE       (MAG)    >
              < PHASE           (PHASE)  >
              < REAL_PART       (REAL)   >
              < IMAGINARY_PART  (IMAG)   >

<maxpts> = <    50     >
           <   125     >
           <   250     >
           <   625     >
           <  1250     >      (default)
           <  2500     >
           <  6250     >
           < 12500     >
           < 25000     >
```

Any other number generates a semantic error.

```
<source> =  < CHANNEL_1   (C1)    >            (default)
            < CHANNEL_2   (C2)    >
            < MEMORY_C    (MC)    >
            < MEMORY_D    (MD)    >
            < FUNCTION_E  (FE)    >
```

NOTE: FUNCTION_E can be a source only for FUNCTION_F.

```
<window> =  < RECTANGULAR        (RECT)    > (default)
            < VON_HANN           (HANN)    >
            < HAMMING            (HAMM)    >
            < FLAT_TOP           (FLT)     >
            < BLACKMAN_HARRIS    (BH)      >
```

<m_fact> = 0.01 to 9.99 (default = 1.0)

Multiplication factor applied to the source waveform, before FFT computation.

<a_const> = -9.99 to 9.99 (default = 0.0)

Additive constant (divisions), applied to the source waveform, before multiplication.

```
<z_suppr> = <OFF>
            <ON>          (default)
```

If ON, the DC component of the source waveform is forced to 0.

The 'redefine' command has also been extended to accept the parameters related to the FFT Power Average:

REDEFINE (RDF), FFT_AVG, <disp_type>, <nsweeps>

The parameters have the following options:

```
<disp_type> = < POWER_SPECTRUM   (PWS)     > (default)
              < POWER_DENSITY    (PWD)     >
              < MAGNITUDE        (MAG)     >

<nsweeps> = <     10      >
            <     20      >
            <     50      >
            <    100      >
            <    200      >       (default)
```

Any other number generates a semantic error.

NOTE: This definition can be applied only to the Function F.

It will be executed only if the function E is defined as FFT (any display mode).

The number of points will be that of the output of the FFT (i.e. N / 2).

Examples:

RDF,FFT,MAG,1250,C1

Redefine the SELECTed trace (E or F) for the FFT of Channel 1 with maximum 1250 points, displaying the Magnitude on a linear scale.

Default settings are applied to the remaining parameters (Rectangular window, m_fact = 1.0, a_const = 0.0, zero suppression is ON).

RDF,FFT,PWS,625,C2,BH,2.0,,OFF

Redefine the SELECTED trace (E or F) for the FF FFT of Channel 2 with maximum 625 points, displaying the Power Spectrum on a logarithmic (dBm) scale. Window Type is Blackman-Harris, m_fact = 2.0, a_const = 0.0, zero suppression is OFF.

RDF,FFTA,PWD,20

Redefine the SELECTED trace (must be F) for the FFT Power Average of FFT computed simultaneously by the function E. Number of sweeps is 20.

11.4.2 Additionnal Values in the Descriptors of FFT Processd Waveform

You can read the DSO waveform and descriptors into a host computer (see Section 7.6.5).

With the WP02 option, the Waveform Descriptor length is unchanged (150 bytes). However, in addition to the Descriptor field values defined in Section 7.7 and 10.4, the following

With transient signals use the Rectangular window. You should adjust the time base and the triggering conditions so that the transient is completely contained in the time domain window (i.e. on the screen).

For best amplitude accuracy of isolated spectrum peaks, use the Flat Top window.

For best reduction of leakage and good detection of small peaks several bins apart from a large peak, use the Blackman-Harris window.

For moderate improvement of amplitude accuracy and of leakage rejection, use von Hann or Hamming window.

If your time domain signal is repetitive but noisy, preventing you from having a stable trigger, you can define the Function E as the FFT of the signal channel and the Function F as the FFT Power Average of the Function E, to obtain a stable spectrum of the input signal.

You can display the FFT Power Average either on a linear scale (Magnitude) or on a dBm scale (Power Spectrum or Power Density).

11.5.2 Relations of 9400 DSO FFT output waveforms to the FFT computation steps

If you wish to compare the 9400 DSO FFT results with those obtained with other FFT systems, you may find the following information useful:

In the 9400 FFT computation, the first step is the subsampling of the source waveform. Data points for the input to FFT are taken from the record displayed on the screen, at regular intervals, covering the full length of the record.

You can select, in the FFT menu or via Remote Control link, the maximum Transform Size. The actual transform size, N, is selected to be equal to or smaller than the Displayed Record Length (see Table 5.1). Exception : you may get 125 point transform when you have specified 50 points.

The subsampling interval and the actual transform size selected provide the frequency scale factor in the 1-2-5 sequence.

The second step is the addition of the selected constant to the subsampled source waveform, followed by the multiplication by the selected factor.

The third step is the multiplication of the source waveform by the selected window function.

The fourth step is the computation of FFT, using a fast implementation of the DFT (Discrete Fourier transform)

$$X_n = \frac{1}{N} \sum_{k=0}^{k=N-1} x_k * W^{(n * k)}$$

where x_k is a complex array whose real part is the modified source time domain waveform, and whose imaginary part is 0,

X_n is the resulting complex frequency domain waveform,

$W = e^{(-j * 2 * \pi / N)}$

N is the number of points in x_k and X_n

The generalised FFT algorithm, implemented in 9400 DSO, works on N which need not be a power of 2.

The fifth step is the division of the resulting complex vector X_n by the coherent gain of the window function, to compensate for the loss of the signal energy due to the windowing. This compensation provides accurate amplitude values for isolated spectrum peaks.

The real part of X_n is symmetric about the Nyquist frequency, that is

$R_n = R_{N-n}$,

while the imaginary part is antisymmetric, that is

$$I_n = - I_{N-n}.$$

Thus it can be considered that the energy of the signal at some frequency n is distributed 50/50 between the first half and the second half of the spectrum; the energy at 0 frequency is completely contained in the 0 term.

The sixth step is the elimination of the redundancy in the results, keeping only the first half of the spectrum (Re, Im), 0 to the Nyquist frequency:

$$R'_n = 2 * R_n, \qquad 0 <= n < N/2$$
$$I'_n = 2 * I_n, \qquad 0 <= n < N/2$$

The seventh and last step is the computation of the output display waveform.

If you select Real Part or Imaginary Part Display Type, no further computation is done: the displayed waveform is R' or I' as defined above.

If you select Magnitude mode, the magnitude is computed as

$$M_n = \sqrt{(R'^2_n + I'^2_n)}$$

In practice, above described steps lead to the following result:

> A sine wave with peak value of 1.0 volt, with integral number of periods in the time window, transformed with the rectangular window results in 1.0 volt magnitude point.
>
> However, a dc component of 1.0 volt, transformed with the rectangular window, results in 2.0 volts magnitude point.

The displayed waveforms for the other available modes are computed as follows:

Phase: $\text{angle} = \arctan (I_n/R_n), \qquad M_n > M_{min}$
$\text{angle} = 0, \qquad M_n <= M_{min}$

where M_{min} is the minimal magnitude, fixed at about 10^{-3} of the full scale (i.e. 64 units on the scale of 65536, 16 bits), at any gain setting.

dBm Power Spectrum:

$$\log PS_n = 10 * \log10(M_n^2 / M_{ref}^2)$$

where M_{ref} = 0.316 V (that is, 0 dBm is defined as the sine wave of 0.316 V peak or 0.224 V rms, giving 1.0 mW into 50 Ω.

dBm Power Density:

$$\log PD_n = \log PS_n - 10 * \log10(ENBW * \Delta f)$$

where ENBW is the equivalent noise bandwidth of the filter corresponding to the selected window
Δf is the current frequency resolution (bin width).

The FFT Power Average (function F only) takes the complex frequency domain data R'_n, I'_n, generated by the function E in the step 6 above and computes the square of magnitude

$$M_n^2 = R'_n{}^2 + I'_n{}^2$$

and cumulates the result in a buffer.

The last step in the FFT Power Average is similar to the step seven above, and computes the selected Display Type format (Magnitude, Power Spectrum, Power Density).

11.5.3 Speed of computation of FFT

In the 9400 DSO the Fourier transform computation takes about 1.7 sec for a 1250 point FFT and just under one minute for a 25000 point FFT. These times depend somewhat on the Window Type and the Display Type selected.

You can speed up the computation by selecting Transform Size smaller than 25000. The DSO will select for you the effective Transform Size, N, equal or smaller than your selected value, depending on the actual number of points in the time domain record.

11.6 FFT / 9400 Glossary

Aliasing

If the input signal to a sampling acquisition system contains components whose frequency is greater than the Nyquist frequency (half the sampling frequency, resulting in less than two samples per signal period), such components will be aliased. That is, their contribution to the sampled waveform will be indistinguishable from that of the components below the Nyquist frequency.

In 9400 DSO, the FFT definition menu displays the effective Nyquist frequency. You should select the time base and Transform Size resulting in a Nyquist frequency higher than the highest significant component in your time domain record.

Coherent Gain

Coherent gain of a filter corresponding to each window function is 1.0 (0 dB) for the Rectangular window and lesser for other windows. It defines the loss of signal energy due to the multiplication by the window function. In the 9400 DSO this loss is compensated. Table 11.3 lists the values for the windows implemented.

ENBW (Equivalent Noise Bandwidth)

For a filter associated with each frequency bin, ENBW is the bandwidth of an equivalent rectangular filter (having the same gain at the center frequency) which would collect the same power from a white noise signal as the filter considered. In Table 11.3, ENBW is listed for the window functions implemented, in bins (i.e. relative to the Rectangular window).

Filters

Computing an N point FFT is equivalent to passing the time domain input signal through N / 2 filters and plotting the outputs of filters along the frequency axis. The spacing of filters is $\Delta f = 1 / T$ and the bandwidth depends on the window function used (see Frequency bins).

Frequency bins

The FFT algorithm takes a discrete source waveform, defined over N points, and computes N complex Fourier coefficients, which are interpreted as harmonic components of the input signal.

For a real source waveform (imaginary part equals to 0), there are only N / 2 independent harmonic components.

The FFT corresponds to analyzing the input signal with a bank of N / 2 filters, all having the same shape and width, and centered at N / 2 discrete frequencies. Each filter collects the signal energy falling into the immediate neighbourhood of its center frequency, and thus it can be said that there are N / 2 'frequency bins'.

The distance, in Hz, between the center frequencies of the bins, is always

$$\Delta f = 1 / T$$

where T is the duration of the time domain record, in seconds.

The width of a bin is equal to Δf.

The width of the main lobe of the filter centered at each bin depends on the window function used. With the Rectangular window, the width at -3.92 dB is 1.0 bins. Other windows have wider main lobes (consult Table 11.3).

Frequency Range

The range of frequencies computed and displayed in the 9400 DSO is from 0 Hz at the left hand edge of the screen to the Nyquist frequency, at 5 or 6.25 divisions.

Frequency Resolution

In a narrow sense, the frequency resolution is equal to the bin width, Δf. That is, if the input signal changes its frequency by Δf, the corresponding spectrum peak will be displaced by Δf. For smaller changes of frequency, only the shape of the peak will change.

However, the effective frequency resolution (i.e. the ability to actually resolve two signals having close frequencies) is further limited by the use of window functions. All windows other than the rectangular have the width (ENBW) greater than 1 Δf (bin width). Table 11.3 lists the ENBW for the windows implemented.

Leakage

Observe the Power Spectrum of a sinusoidal waveform having an integral number of periods in the time window (i.e. the source frequency equals one of the bin frequencies), using the Rectangular window. The spectrum is is a sharp peak whose value reflects accurately the source waveform's amplitude. For other input frequencies the spectrum peak is lower and broader.

The broadening of the base of the peak, stretching out into many neighbouring bins is termed the Leakage. It is due to the relatively high sidelobes of the filter associated with each frequency bin.

The filter sidelobes, and the resulting leakage, are reduced when one of the available window functions are applied. The best reduction is provided by the Blackman-Harris and the Flat Top windows. However, this reduction is paid for by a broadening of the main lobe of the filter.

Numbers of Points

In the 9400 DSO, FFT is computed over a number of points (Transform Size) which you can select in the Redefine Menu. The effective number of points, N, is displayed at the bottom of the FFT Redefine Menu screen. It is always a submultiple of the number of points actually displayed in the time domain.

FFT generates N / 2 output spectrum points. These points are expanded by linear interpolation to 12500 points (10000 points in the case of 10 MHz / div).

Nyquist Frequency

Equal to one half of the total sampling frequency.

Also, $f_{Nyquist} = \Delta f * N / 2$.

In the 9400 DSO, the value of Nyquist frequency is displayed at the bottom of the FFT Redefine Menu screen.

Picket Fence Effect

Observe again the Power Spectrum of a sinusoidal waveform having an integral number of periods in the time window (i.e. the source frequency equals one of the bin frequencies), using the Rectangular window. The spectrum is is a sharp peak whose value reflects accurately the source waveform's amplitude. For other input frequencies the spectrum peak is lower and broader.

Its highest point can be lower by 3.92 dB (1.57 times), when the source frequency is at mid value between two bin frequencies. This variation of the spectrum magnitude is called the Picket Fence Effect (the loss is called the Scallop Loss).

All window functions compensate to some extent this loss; the Flat Top window provides the best correction (see Table 11.3).

11.7 Errors and Warnings

Certain combinations of source waveform properties and processing functions may result in an Error or raise a Warning. The appropriate message is displayed at the top of the DSO screen.

On Error, processing is abandoned.

On Warning, processing is performed, but the results are corrupted.

ERROR: FFT src wfm is in sequence mode.

FFT of sequence mode waveform has not been implemented.
Processing abandoned.

ERROR: FFT src wfm is in frequency domain.

FFT of a frequency domain waveform has not been implemented. Processing abandoned.

ERROR: FFT AVG src wfm not in freq domain.

FFT Power Average mode (function F only) is active only if the function E is defined as FFT. Processing abandoned.

You should define function E as FFT.

WARNING: FFT src wfm (ils mode) extended.

In the Interleaved Sampling Mode, there are two time base settings (1 µs/div and 0.5 µs/div), in which the record of 25000 points shown on the screen is incomplete (0.08 and 0.4 div, respectively, starting at the left hand edge of the screen, are blanked). Before computing FFT, the leftmost valid point of such records is copied leftwards, through to the left edge of the screen. This will generate harmonic components not present in the original record.

If possible, you should use the Single Shot mode before FFT at these time base settings.

WARNING: FFT src wfm (roll mode) incomplete.

In the Roll Mode (time / div <= 0.5 s), the you can stop the acquisition of a trace before it fills the full screen width. The remaining portion of the record is blanked for the display, but the memory contents remain undefined. FFT is computed on this partially undefined record.

You should avoid stopping the acquisition in this manner if you wish to obtain meaningful FFT results.

WARNING: FFT src wfm over/underflow.

The source waveform has been clipped in amplitude, either in the acquisition (you have used too high gain or inappropriate offset) or in the previous processing. The resulting FFT contains harmonic components which were not present in the unclipped waveform.

You should repeat the acquisition or previous processing of the source waveform, with changed settings.

11.8 References

Bergland, G. D., "A guided tour of the fast Fourier transform", IEEE Spectrum, July 1969, pp. 41 - 52.

A general introduction to the FFT theory and applications.

Harris, F. J., On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform", Proceedings of the IEEE, vol 66, No 1, January 1978, pp. 51 - 83.

Classical paper on window functions and their figures of merit, with many examples of windows.

Brigham, E. O., "The Fast Fourier Transform", Prentice Hall, Inc., Englewood Cliffs, N. J., 1974.

Theory, applications and implementation of FFT. Includes discussion of FFT algorithms for N not a power of 2.

Ramirez, R, W., "The FFT Fundamentals and Concepts", Prentice Hall, Inc., Englewood Cliffs, N. J., 1985.

Practice oriented, many examples of applications.

11.9 INDEX OF TOPICS

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Additional RS232 only remote commands

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