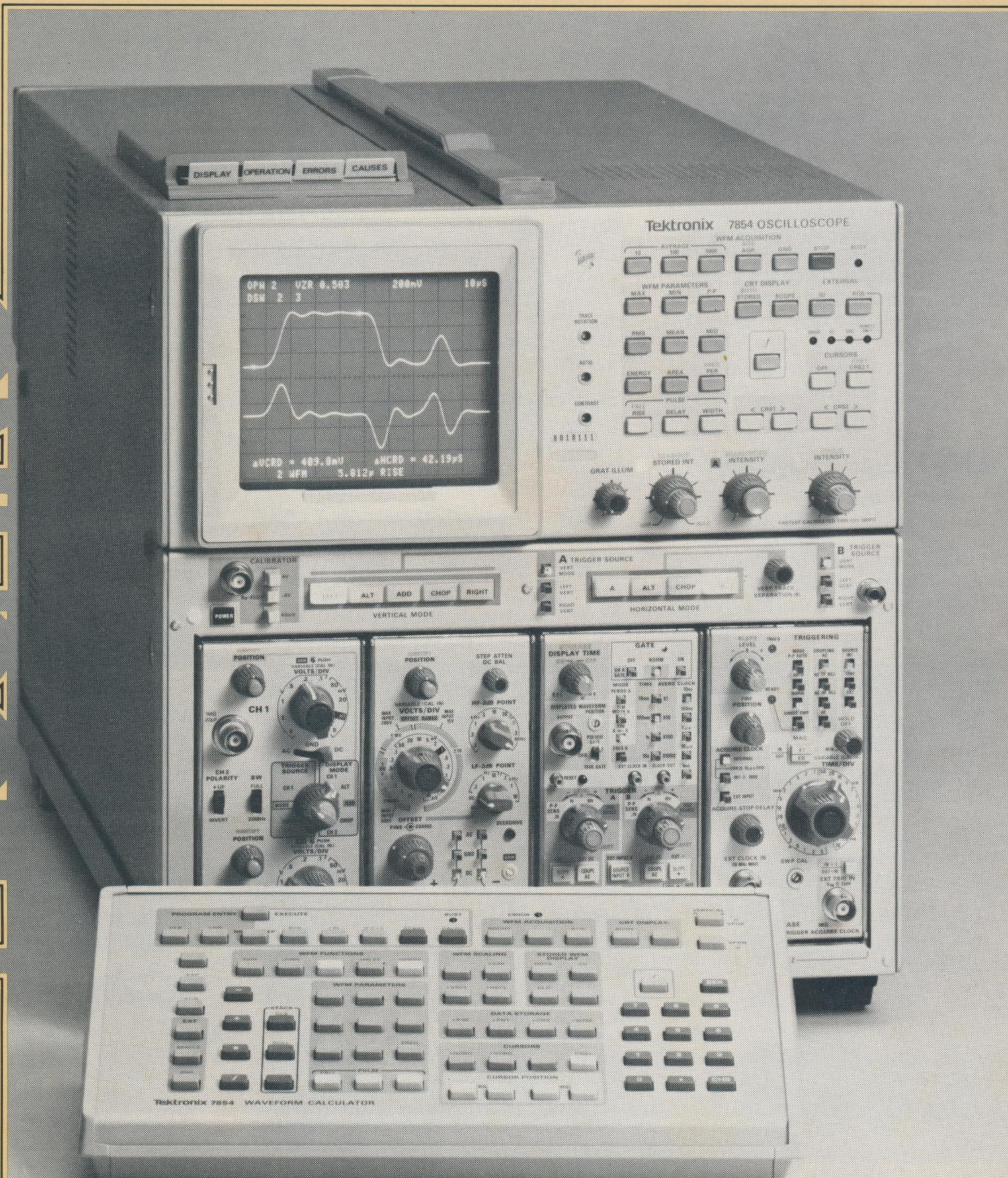
Tektronix

# Measurement Variety.
# An Engineering Challenge
# Featuring the 7854.

PLUG-INS



## 7854 Calculator Applications

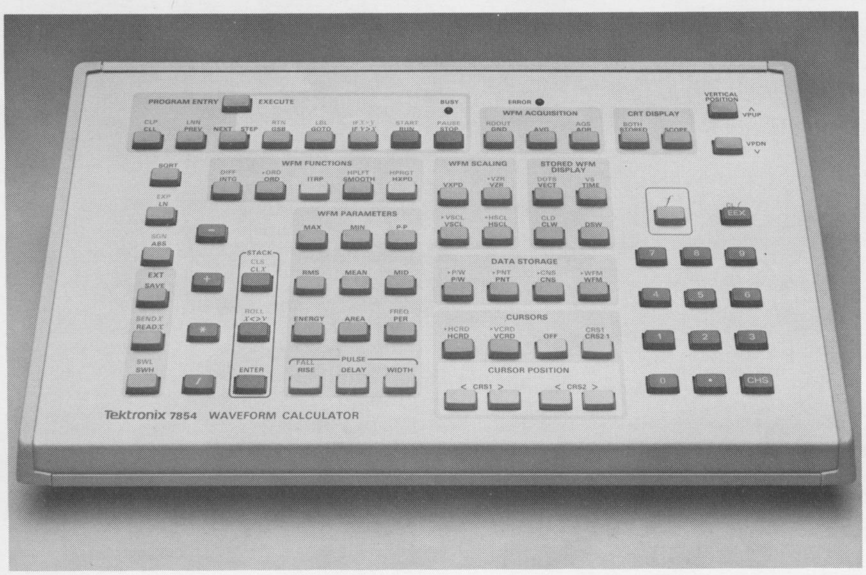
Engineers encounter a diversity of measurements which requires an instrument adaptable to the situation at hand. Timing relationships, environmental testing, power, energy, microwave VSWR, recording temperatures, and histograms of pertinent data are just a few measurements the 7854 can streamline.

The 7854 oscilloscope has a calculator keyboard designed to accommodate a wide variety of measurements. The purpose of this Application Note is to acquaint you with the 7854's potential to simplify many of your measurement procedures.

The application possibilities for the 7854 depend on (1) Your imagination and ingenuity, and (2) the flexibility of the 7854, including a wide choice of plug-ins, a variety of waveform functions, and keystroke programming. Data storage, custom waveform functions and keystroke examples are covered.

### Waveform Calculator Keyboard

The 7854 has a waveform calculator keyboard which is the heart of the command system. The keyboard is divided into different sections depending upon its function. The different sections include:




#### Numeric entry, stack control, and basic four functions

This section contains the number keys 0-9, decimal point, change sign and enter exponent. Multiply, divide, add, and subtract are the basic four operators. Normal stack control keys are also present; clear stack, clear X, roll, X<>Y, and enter.

#### Cursors

This section controls the display of the cursors and their positioning. The vertical and horizontal coordinates of the cursors may also be recalled and set with this group of keys.

#### Wfm Acquisition

This group of keys controls the acquisition system whether it be for repetitive waveforms, single-shot waveforms, ground or readout. Averaging of the signal is also provided to reduce random noise on the input signal.

#### Crt Display

These command keys control what is displayed on the crt, whether it be normal scope display or the stored digital display or both. Vertical positioning of the operational waveform is also provided.

#### Stored Waveform Display

This group of keys controls the stored digital display, which waveforms are to be displayed and what the mode of the digital display is – time, X-Y, dots, or vectors.

#### Waveform Scaling

These buttons recall and set the vertical and horizontal scale factors as well as the reference level of the operational waveform. Vertical expansion of the operational waveform is also available.

#### Waveform Parameters

With this set of keys measurements may be made on the operational waveform. Basic common measurements include maximum, minimum, peak-to-peak, rms, mean, mid, energy, area, frequency, period, rise, fall, delay, and width.

#### Waveform Functions

These keys perform operations on the operational waveform. Functions such as differentiation, integration, linear interpolation, smoothing, and horizontal positioning and expansion are available.

#### Special Functions

These keys perform special functions on either waveforms or numbers. Included functions are square root, natural logarithm, exponentiation, signum, and absolute value.

#### External

These keys control action which is external to the 7854, such as GPIB and the TTL output on the rear panel.

#### Programming

These keys provide programming capability for the 7854. Except for editing commands, all of the key commands are programmable. Programming functions include labeling, subroutine handling, and decision making. Program editing and positioning keys are also available. Program execution keys are also available.

## I. STORING AND DISPLAYING WAVEFORMS

The 7854's calculator controls the storage and display of data, waveforms, and programs. In cases where the timing relationships of several waveforms are needed or where signal comparisons under various conditions are required, the 7854 provides the solutions. Up to nine waveforms can be displayed at one time. They may be chosen from up to 40 waveforms held in storage (with the optional memory).

The first step in storing multiple waveforms is to decide on the number of points per waveform (P/W) required. Fig. 1 shows the tradeoff between P/W and the number of waveforms possible with each memory option.

| | Number of Waveforms | | | Horizontal |
|---|---|---|---|---|
| P/W | Standard | Option 0D | Option 2D | Nominal Resolution |
| 128 | 16 | N.A. | 40 | 0.0784 Div. |
| 256 | 8 | N.A. | 20 | 0.0392 Div. |
| 512 | 4 | 1 | 10 | 0.0196 Div. |
| 1024 | 2 | N.A. | 5 | 0.0098 Div. |

Fig. 1

Selecting 128 points per waveform adds a horizontal measurement uncertainty of ±0.039 divisions:
10 divisions/128 point X (±0.5).

At 1024 P/W, the uncertainty equals ±0.0049 divisions.

Pressing the P/W key displays the points per waveform in the X register. Pressing 1, 2, 8, >P/W keys changes the points per waveform to 128.

### The Stored Crt Display

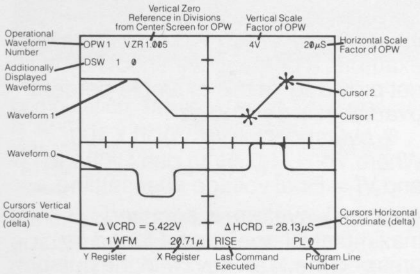



Fig. 2.

### Operational Waveform Number (OPW)

The Operational Waveform (OPW) is the waveform which is currently being manipulated or operated upon.

### Vertical Zero (VZR)

The Vertical Zero indicates the reference level of the Operational Waveform. Measured from center screen in divisions.

### Vertical Scale Factor

Vertical Scale Factor of the Operational Waveform.

### Horizontal Scale Factor

Horizontal Scale Factor of the Operational Waveform.

### Displayed Waveforms (DSW)

The waveform numbers of the stored waveforms displayed. The numbers as shown in left to right sequence are the same as the top to bottom sequence of the corresponding first point (left edge of crt) vertical display position.

### X-Y Display (VS)

Waveform number that is used as the horizontal axis. Used only in X-Y Display mode.

### Cursor 1

Position of cursor 1 on the OPW.

### Cursor 2

Position of cursor 2 on the OPW.

### Cursor Vertical Coordinate (VCRD or Δ VCRD)

If one cursor is displayed, the vertical coordinate of cursor 1. If two cursors are displayed, the change in vertical coordinates from cursor 2 to cursor 1.

### Cursor Horizontal Coordinate

If one cursor is displayed, the horizontal coordinate of the cursor. If two cursors are displayed, the change in horizontal coordinates from cursor 2 to cursor 1.

### X, Y Registers

X and Y registers of the user stack (X, Y, Z, T, and W registers comprise the stack). All data enters the stack via the X register.

### Last Command Executed

Displays the last command executed and any warning or error if one has occurred.

### Program Line Number (PL)

If a program exists, displays the line number of the program pointer.

## Acquiring a Waveform

Acquiring a waveform with the 7854 is quite simple. Just set up a triggered real time waveform display. Then ground the input signal and push the GND button on the 7854 keyboard. This operation acquires the ground reference for the signal about to be acquired, and stores its constant ground value in memory. It also displays the value in the X register. All subsequent acquisitions will use this ground reference until another ground reference is acquired. Next, unground the input signal and push the STORED button.

Now, push the AQR button and watch the waveform being acquired. Notice that the vertical zero reference level has been changed to the ground reference that was just acquired. The acquisition may be performed from any of the three display modes; SCOPE, STORED, OR BOTH. If there is noise on the input signal then signal averaging may be used to reduce the effect of the noise on the resulting waveform. To use averaging, just key in the number of averages desired (up to 1023) and then press the AVG key. The 7854 will then start to average the input signal the desired number of times before stopping. An alternate way of averaging is to press the 10, 100, or 1000 AVG key on the measurement keyboard (the keyboard on the front panel of the scope). After the desired waveform has been acquired into memory, the measurement procedure may now begin.

Note on the Acquisition System: Equivalent-time random sampling is used to construct the waveform into memory from as many repetitions of the real-time waveform as required. This command may be used at all sweep speeds.

The digitizer simultaneously samples and quantizes the repetitive real-time waveform. This sampling is asynchronous with respect to the sweep. Only the samples acquired within the horizontal limits of the graticule while the waveform is visible are considered valid. When digitizing, most of the waveform points will have been sampled more than once, while some may not have been filled at all. The most recent data is retained in memory.

Waveform acquisition is terminated when at least 99% of all valid points have been sampled and stored into memory and at least one complete sweep has occurred, or when a STOP command is received.

### Acquisition Of Several Waveforms

For discussion purposes, assume that each circuit node of interest has been labeled from 1 to N-1, where N is the number of waveform storage locations. Place your probe on the ground reference node and press GND to acquire the reference value for the circuit. Next place your probe on any circuit node, and press the AQR key. Then press the number of the node you have just acquired, followed by >WFM key. For example, at node 5 press: AQR, 5, >WFM.

This stores the newly acquired waveform and labels it as waveform number 5 (i.e., 5 WFM). After waveforms from all the nodes have been acquired, any one of them may be displayed by keying in the node number and then pressing the WFM key. Note: if timing relationships from one waveform to another waveform are to be made, the signals should have a common trigger signal.

### Displaying Several Waveforms

To display several waveforms for timing relationships or other comparisons, recall each waveform, adjust its vertical display size and position the waveform to the desired position on the crt. The vertical expand key (VXPD, see note below) should be used to change the waveform's size on screen; i.e., 0.5 VXPD. The vertical position control commands (VPUP    or VPDN    ) position the waveform to the desired location on the crt. The final step is to display the waveform with the DSW key. Key the waveform number and press DSW. The DSW command displays the designated waveform when it is not the OPW. Fig. 3-9 illustrate the process.

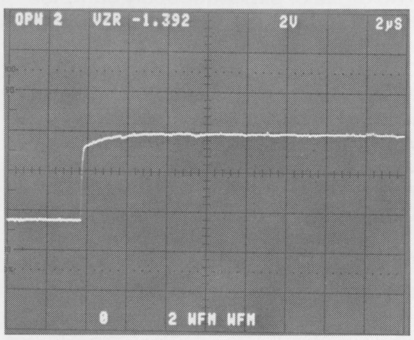



**Fig. 3.** Display of stored waveform number two (2 WFM). Press 2, WFM.

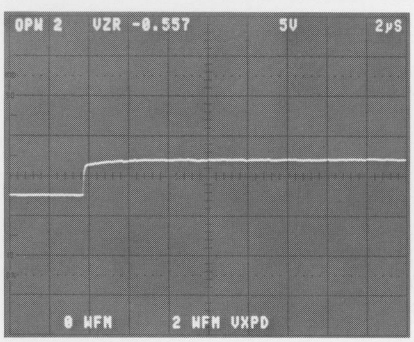



**Fig. 4.** 2 WFM being vertically expanded by a factor of 0.5. Press • , 5 , VXPD.

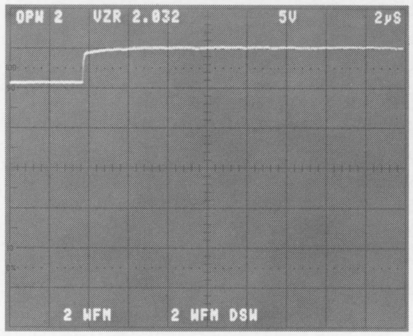



**Fig. 5.** 2 WFM vertically positioned using VPUPΛ and displayed with the DSW (display waveform) command. Press 2, DSW.

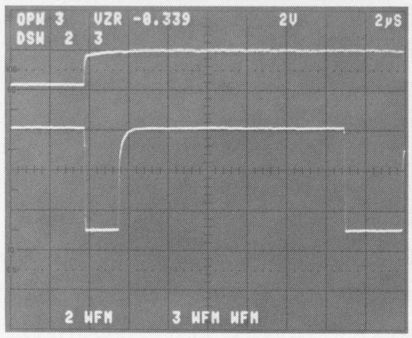



**Fig. 6.** Recall waveform number three (3 WFM). Press 3, WFM.

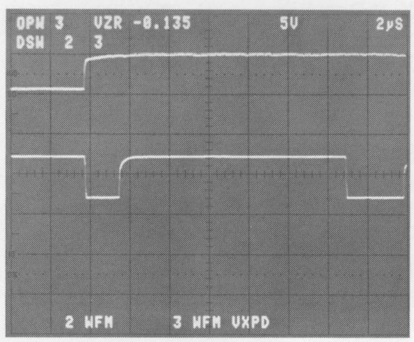



**Fig. 7.** 3 WFM vertically expanded by a factor of 0.5.

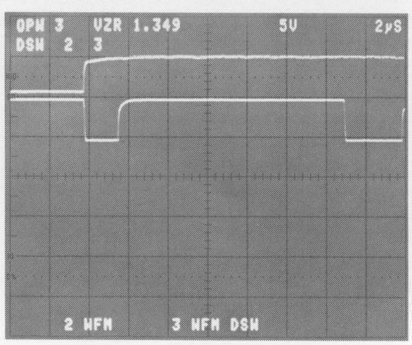



**Fig. 8.** 3 WFM positioned and displayed with the DSW command.

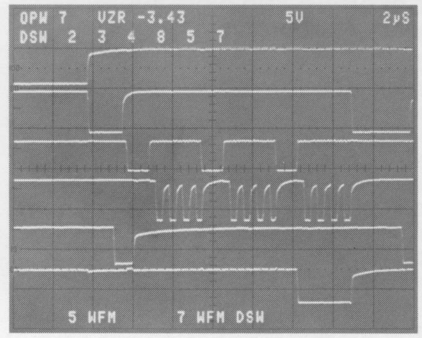



**Fig. 9.** Waveforms 2, 3, 4, 5, 6, and 8 are displayed.

The calculator keyboard can organize and simplify the storage and display of multiple waveforms. To simultaneously hold probes, adjust scope controls, and note measurements in your head can be quite complex and cumbersome. With the 7854, you can concentrate on acquiring the waveforms then recall and analyze them with your hands and mind free to concentrate on the task at hand.

Note on VXPD:

Care should be taken when using the VXPD key. VXPD expands about center screen. In order to prevent the waveform from being expanded off screen (for expansion >1), the waveform should first be positioned to approximately center screen. Refer to 7854 manual for other restrictions on VXPD.

## II. WAVEFORM FUNCTIONS

### A. Custom Waveform Functions

Sometimes it is necessary to create your own waveform function "key." For example, a percent overshoot key is not provided. In this example percent overshoot is defined as:

% overshoot = (Vp-Vf)/Vf X 100

Where Vp = Maximum peak voltage and Vf = Final voltage after settling.

After the waveform is acquired maximum voltage can be found by pressing the MAX key (with the cursors turned off). Then by turning on cursor one (CRS1) and moving the cursor (with CRS1> or CRS1<) to the voltage after settling and pressing VCRD, Vf is entered into the X register. After a few calculations, the 7854 can provide the % overshoot.

However, the program in Fig. 10 provides the % overshoot with one button. Press PROGRAM ENTRY/EXECUTE key, enter the program, press PROGRAM ENTRY/EXECUTE once again, and set up your analog input waveform. Press START to initialize execution of the program. The program will acquire the waveform and make the % overshoot calculation. The program assumes a single rising edge with the final voltage, Vf, occurring at the right edge of the crt. The resulting answer is shown in the X register. See Fig. 11.

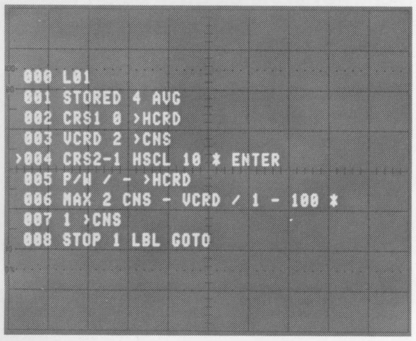



Fig. 10.

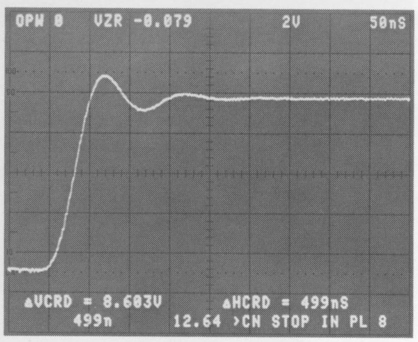



**Fig. 11.** Results of Percent Overshoot computation. The value in the X-register is 12.64%. The three characters ">CN" was the last executed command and the "STOP" is the processor status.

If the resulting answer is unsatisfactory, adjustments to the circuit under test may be made and the % overshoot measurement may be made again by just pressing the RUN key. The program will again acquire the new waveform and calculate the new % overshoot. Now the RUN button has become the % OVERSHOOT command. Perhaps you would like to make circuit adjustments while the program is running. Just replace line 008 with 008 PAUSE 1 LBL GOTO

The program now stops for about one second (PAUSE) to display the % overshoot in the X register before resuming execution. Using this method, you only have to start your program once, and circuit adjustment may proceed interactively with the program.

Going one step further, the % overshoot calculated may be compared to acceptable limits with the command IFY>X. The tolerance limits may be stored in constants and recalled for the comparisons (>CNS and CNS keys respectively). In this way the program can continue to make the % overshoot until the circuit is adjusted to within acceptable tolerance levels.

By constructing a program, you can eliminate many repetitive keystrokes that require extra time and mental effort. You work out the routine once, enter the commands into a program, and then press START or RUN each time you want the answer.

### B. Multiple Functions or Test

Often you will have a series of tests that are used repeatedly. The 7854 can retain them all in memory, allowing you to select each test individually. Here is an example of multiple test programming:

Suppose you have an enable pulse which initiates a ramp from $-V_1$ to $+V_2$ volts. The parameters of the waveforms you wish to measure are these: See Fig. 12.

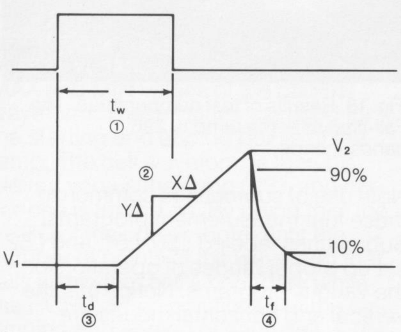



Fig. 12.

1) The width of the enable pulse.
2) The slope of the ramp.
3) The delay from the rising edge of the enable pulse to the start of the ramp.
4) The fall time of the ramp.

See Fig. 13 for the instrument set-up.

INSTRUMENT SET-UP

**7854 Settings**

Display Mode . . . . . . . . . . . . . . . SCOPE
*Vert Mode . . . . . . . . . . . . . . . . . . . N.A.
*Horiz Mode . . . . . . . . . . . . . . . . . . N.A.
B Trigger Source . . . . . . . . . . . . . . LEFT

**7B80 Setting**

Trigger
Slope . . . . . . . . . . . . . . . . . . . . . . . . +
Source . . . . . . . . . . . . . . . . . . . . . INT
Coupling . . . . . . . . . . . . . . . . . . . . AC
Mode . . . . . . . . . . . . . . . . . . . . NORM
Tim/Div . . . . . . . . . . . . . . . . . As required

Fig. 13.

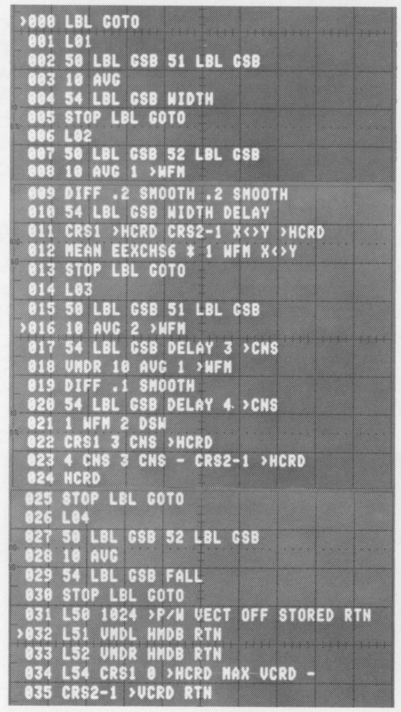



**Fig. 14.** Program Listing for Multiple Functions and Tests.

Test 1 (starting at L01; see Fig. 14) measures the width of the enable pulse by determining the time between the 50% levels in the rising and falling edges of the pulse. To make this measurement, the cursors must be positioned in appropriate positions. The subroutine starting at L54 properly positions the cursors for this measurement. Notice that the measurement is displayed in the X register with WID displayed to remind the user of the measurement made. See Fig. 15.

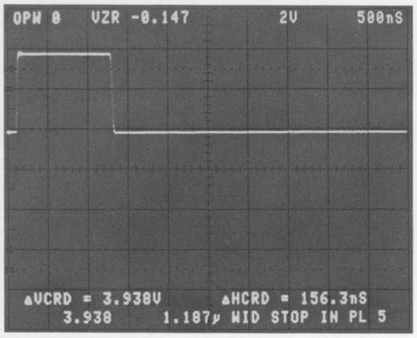



**Fig. 15.** Results of test number one. The width is 1.187 micro seconds.

Test 2 (starting at L02; see Fig. 14) determines the average slope of the ramp. Once again, to make this measurement the cursors must be positioned appropriately on the differentiated waveform of the ramp. The differential (DIFF) of the ramp will provide the slope information after being smoothed. The accuracy of the measurement is dependent upon the amount of smoothing performed on the differential of the ramp. The error here is less than 3%. Again, the slope is displayed in the X register, expressed in V/μs with the cursors positioned at beginning and end of the ramp. See Fig. 16.

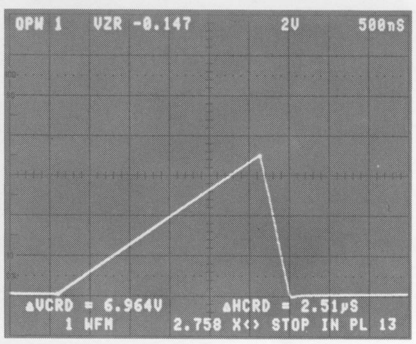



**Fig. 16.** Results of test number two. The slope of the ramp is 2.758 V/μs.

Test 3 (starting at L03; see Fig. 14) measures the delay from the rising edge of the enable pulse to the beginning of the ramp. The first operation is to find the time of the rising edge of the enable pulse and then find the time of the beginning of the ramp (via DIFF again) and subtract the two times to find the delay. The answer is displayed in the X register along with HCR to remind the user that the last command executed was that of the horizontal coordinate of the cursors. See Fig. 17.

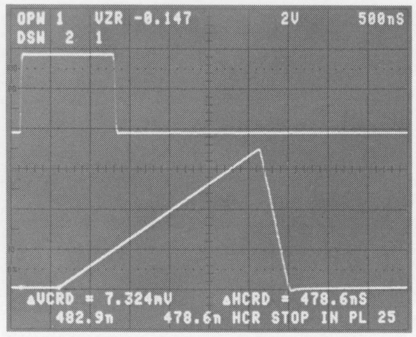



**Fig. 17.** Results of test number three. The Delay-time from the rising edge of the pulse to the start of the ramp is 478.6 nanoseconds.

Test 4 (starting at L04; see Fig. 14) measures the fall time of the ramp. Again, the cursors are positioned appropriately by the subroutine for this measurement. The answer is displayed in the X register along with FAL to remind the user of the measurement just performed. See Fig. 18.

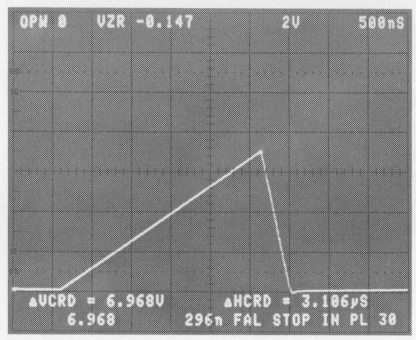



**Fig. 18.** Results of test number three. The Fall-time after the ramp is 296 nanoseconds.

Note use of subroutines common to these four measurement programs. Subroutines labeled L50, L51, and L52 set up proper modes of operation for the various programs. Notice that the vertical and horizontal modes are programmable.

Notice that each test ends with the statement,

STOP LBL GOTO.

After each test the program will STOP. Then the user enters the number of the test he wishes to execute next; i.e., '1' for Test 1, '2' for Test 2, etc., and then pushes the RUN key to resume execution of the selected Test. The first time the program is executed, the sequence should be '1,' '2,' '3,' or '4' and then press START key. Any one of the tests may be performed independently as many times as needed.

## III. RECORDING DATA

### A. Monitoring Temperature

This example shows how the 7854 can save time in monitoring temperature and in summarizing the data. In addition, it shows how the 7000 digital plug-ins (DVM's, counter/timers and delay units) gain extra power in the 7854.

The 7D13 plug-in is used in the temperature mode and the 7854 records the highest, lowest, and average temperature values until stopped. Place the 7D13 in the right vertical compartment, key in the program below (see Fig. 19) and press START. Each time you wish to add new temperature information to the data, just press RUN. The program acquires the new temperature and performs the proper comparisons and calculations with the previous data.

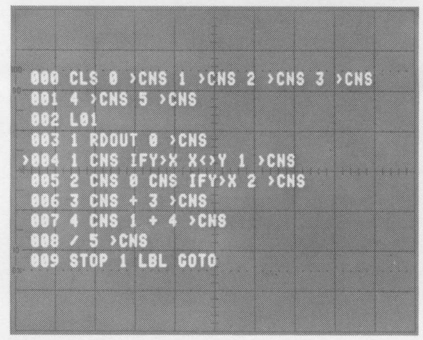



**Fig. 19.**

CNS stands for constant registers. The temperatures are stored in these registers.

Pressing:

0 CNS recalls the latest temperature measurement
1 CNS recalls the highest temperature
2 CNS recalls the lowest temperature
3 CNS recalls the sum of the temperatures
4 CNS recalls the number of measurements
5 CNS recalls the average temperature

In this example, temperature was used. However, we could just as easily have recorded volts, OHMS, RMS, risetime or energy the same way.

In addition, the same type of program could be used with the 7D15 universal counter/timer, monitoring a flip-flop's set up time.

### B. Storing And Displaying Data

The 7854 has 100 constant registers (with 2D option) to store calculations or measurements. However, what if you are evaluating a new design and need to plot 200 or more measurements? In the 7854 you can build a waveform point by point with data. Your storage of data points is limited by the maximum memory of 5120 waveform points plus 100 constant registers.

The program in Fig. 20 builds a waveform point by point placing risetime measurements in each waveform point (512 measurements if P/W = 512). Each time the RUN key is pressed a new waveform is acquired and the risetime measured. These risetime measurements are then stored in another waveform sequentially from point number 0 to P/W-1. Fig. 21 shows 512 risetime measurements.

```
 000 STORED TIME OFF
 001 CLS WFM * 2 >WFM P/W 0 >CNS
 002 3 RDOUT >VSCL P/W 10 / >HSCL
 003 L00
 004 4 AVG RISE 2 WFM X<>Y P/W 0 CNS
 005 - >PNT 0 CNS 1
 006 IFY>X - 0 >CNS STOP 0 LBL GOTO
>007 2 WFM 0 >WFM STOP
 008 25
 009 ENTER ENTER 11 + 0 >CNS CLX
 010 L01
 011 0 ENTER 0 CNS >CNS CLX 0 CNS 1
 012 IFY>X - 0 >CNS CLX 1 LBL GOTO
 013 CLX CLX 0 >CNS
 014 L02
 015 STORED TIME OFF CLD
 016 0 WFM 2 >WFM MIN -
 017 P-P 0 CNS / 2 >CNS
 018 HSCL 10 * P/W 5 >CNS / 4 >CNS
 019 L03
 020 5 CNS 1 - PNT 2 CNS / 10.5 + ENTER
 021 CNS 1 + X<>Y >CNS
 022 5 CNS 1 IFY>X - 5 >CNS 3 LBL GOTO
>023 0 CNS 10 + ENTER ENTER
 024 1 + CNS X<>Y CNS + X<>Y >CNS
 025 0 CNS 10 + 5 >CNS 4 >CNS
 026 L04
 027 5 CNS CNS 4 CNS CNS
 028 IFY>X 5 CNS 4 >CNS
 029 5 CNS 11 IFX=Y 5 LBL GOTO
 030 5 CNS 1 - 5 >CNS 4 LBL GOTO
 031 L05
 032 CLS WFM *
 033 P/W 10 / >HSCL 4 CNS CNS 6 / >VSCL
 034 3CHS >VZR
 035 11 ENTER 4 >CNS
 036 1 ENTER 5 >CNS
 037 HSCL 10 * 0 CNS / 1 >CNS
 038 4 CNS CNS 0 >PNT 0
>039 L06
 040 1 CNS 5 CNS * 1 -
 041 ENTER 4 CNS CNS X<>Y >PNT CLX ITRP
 042 4 CNS 1 + 4 >CNS
 043 1 CNS 5 CNS * ENTER 4 CNS CNS X<>Y
 044 >PNT CLX
 045 5 CNS 1 + 5 >CNS
 046 0 CNS IFX=Y 7 LBL GOTO
 047 CLX CLX 6 LBL GOTO
 048 L07
 049 CLX CLX 4 CNS CNS P/W 1 - >PNT
 050 CLX P/W 1 - ITRP 0 WFM 3 >WFM
 051 CLS WFM * CLX
 052 >PNT 1 ENTER 1 >PNT
 053 HSCL 10 * P/W / 2 * 2 >CNS
 054 P/W LN 2 LN / 1 - 1 >CNS
>055 L08
 056 0 WFM 1 >WFM
 057 1 CNS 0 IFX=Y 9 LBL GOTO
 058 1 WFM 2 CNS HPRGT 0 WFM +
 059 1 CNS 1 - 1 >CNS
 060 2 CNS 2 * 2 >CNS
 061 0 LBL GOTO
 062 L09
 063 0 WFM P-P /
 064 3 WFM * MID VSCL CNS / >VZR
 065 6 MAX VSCL / / VXPD 3CHS >VZR
 066 0 WFM 1 >WFM
 067 2 WFM 1 * MIN 0 >PNT
 068 MAX P/W 1 - >PNT
 069 0 HSCL 10 * ENTER P/W / -
 070 ITRP MID VSCL / CHS >VZR
>071 9.9955
 072 P-P VSCL / / ENTER ENTER
 073 MAX VSCL / * ABS 20 X<>Y
 074 IFY>X CLX CLX VXPD 11 LBL GOTO
 075 19.995 VSCL * MAX / VXPD
 076 L11
 077 1 WFM 0 VS CRS1 CRS1>
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Fig. 20.

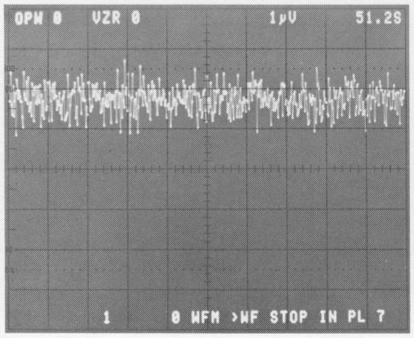


Fig. 21.

With the data now acquired and stored in one waveform, you can find the MAX, MIN, or MEAN values by just pressing the respective key. Assuming the sampling is random in nature, then the standard deviation is calculated as thus – 1 WFM, MEAN, –(minus), RMS.

Finally, by pressing RUN a histogram of the data is displayed (see Fig. 22). The histogram is derived by means of the data in the created risetime measurement waveform. The values in the risetime waveform are divided into N divisions (number of cells as entered in line 008, 25 in this case). Each point of the waveform is examined and its corresponding cell is incremented. Once all the points have been examined, a cell outline waveform is created (3 WFM). Then the cell outline waveform is multiplied by a waveform that alternates between 0 and 1 to create a closed cell pattern when the waveform is displayed in Vector (VECT) mode. Finally a ramp is created from finding the MAX and MIN values of the original waveform. These values are used for the starting and ending points of the ramp. The cell waveform is then displayed versus the ramp (VS), and cursor one is turned on. By doing this, the VCRD of the cursor represents the number of points of the waveform that falls within that cell's boundary while the HCRD, when positioned at the beginning and ending of each cell, represents the values of the cell boundaries.

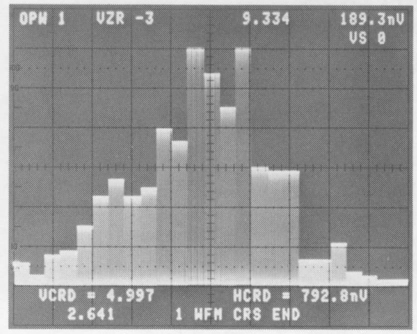


Fig. 22.

The histogram provides a good means of reducing data from the originally acquired risetimes to a useful display which is more easily interpreted. The 7854 makes this and other types of data reduction possible and saves your time so you can spend it solving tough problems.

## IV. SUMMARY

Whether you use a 7A22 differential amplifier, time domain reflectomiter (TDR), spectrum analyzer, 7A19 vertical, or DVM plug-in, the 7854 with its calculator keyboard can aid in waveform analysis, monitoring and collecting data, and organizing the display of data. Custom functions can be quickly programmed using the 7854's keystroke programming, which is similar to that of hand held programmable calculators. Complex measurements are more repeatable and there is less chance for error.

Can the 7854 streamline some of your measurements? That is left to your imagination and ingenuity. By the way, if you come up with an application you would like to share, send it to Tektronix Lab Scopes Marketing, P.O. Box 500, Beaverton, OR 97077, or telephone (503) 644-0161 Ext. 7489.

## APPENDIX

### Programming Hints:

1. To enter a program, press the PROGRAM ENTRY/EXECUTE key. Then enter the steps desired, ending each line with the NEXT key. After the program is entered, press PROGRAM ENTRY/EXECUTE again. Finally press START to begin execution of the program at line 000.
2. The 7854 provides a way to label program lines. Press LNN and the line label numbers. Example:
   LNN, 2, 2 = L22
   for the line labeled 22. It is wise to use the label at the beginning of each program and in each section you plan to enter by program control. Besides clarity, this simplifies program development since you don't have to change branching instructions as you delete or add program lines.
3. STOP LBL GOTO. This statement is a useful human interface. After executing a section of a program and coming to this statement, the program will STOP. Now upon resumption of the execution of the program, a branch to the line label entered in the X register will be executed. Pressing 1, 7, RUN would send the program to the line labeled 17 (L17) to resume execution.
4. IFY>X 22 LBL GOTO. This statement sends the program to the line labeled 22 (L22), providing the Y register is greater than the X register. Otherwise it proceeds to the next line. If the statement is true — Y>X — then the remainder of the line is executed, e.g., 22 LBL GOTO.

### Description of Keys

**ACQUISITION**

| | |
|---|---|
| AQR | Acquire repetitive signals |
| AQS | Acquire single shot signals |
| AVG | Signal average |
| GND | Acquire ground reference |
| RDOUT | Acquire plug-ins readout |

**WAVEFORM PARAMETERS**

| | |
|---|---|
| DELAY | Delay time |
| WIDTH | Pulse width |
| RISE | Rise time |
| FALL | Fall time |
| PER | Period |
| FREQ | Frequency |
| MAX | Maximum |
| MIN | Minimum |
| P-P | Peak-to-Peak |
| MID | Vertical mid-point |
| RMS | Root mean square |
| MEAN | Average value |
| AREA | Area under curve |
| ENERGY | Energy |

**CURSOR**

| | |
|---|---|
| CRS1 | One cursor |
| CRS2-1 | Delta cursors |
| OFF | Cursor(s) off |
| VCRD | Recall vertical coordinate |
| >VCRD | Move to vertical coordinate |
| HCRD | Recall horizontal coordinate |
| >HCRD | Move to horizontal coordinate |

**WAVEFORM FUNCTIONS**

| | |
|---|---|
| SMOOTH | Smooth |
| INTG | Integrate |
| DIFF | Differentiate |
| ITRP | Interpolate |
| ORD | Recall Ordinate |
| >ORD | Change Ordinate |

***ARITHMETIC FUNCTIONS**

| | |
|---|---|
| SQRT | Square Root |
| LN | Natural log |
| EXP | Exponential |
| ABS | Absolute value |
| SGN | Signum either +1, 0, or −1 |

**STACK CONTROL**

| | |
|---|---|
| ENTER | Pushes stack |
| ROLL | Circulates stack |
| X< >Y | Interchange X and Y |
| CLS | Clears all stack registers |
| CLX | Pops stack |

***ARITHMETIC OPERATORS**

| | |
|---|---|
| − | Subtract X from Y |
| + | Add X to Y |
| * | Multiply X by Y |
| / | Divide Y by X |

**PROGRAM ENTRY**

| | |
|---|---|
| PROG | Switch to program entry mode |
| CLL | Delete program line |
| CLP | Deletes all program lines |
| NEXT | Advance to next line |
| PREV | Back up to previous line |
| EXEC | Return to execute mode |

**EXECUTE CONTROL**

| | |
|---|---|
| STEP | Executes a single line |
| *IFY>X | Test if Y is greater than X |
| *IFX=Y | Test if X is equal to Y |
| LBL | Line label |
| GOTO | Unconditional jump |
| START | Begins execution at line ØØØ |
| RUN | Begins execution at next command |
| GSB | Go to subroutine |
| RTN | Return from subroutine |

**CRT DISPLAY**

| | |
|---|---|
| SCOPE | Conventional scope display |
| STORED | Stored data display |
| BOTH | Stored data plus real time waveforms |

**WAVEFORM DISPLAY**

| | |
|---|---|
| DOT | Discrete dot display |
| VECT | Continuous vectored display |
| DSW | Display waveform |
| VS | Waveform versus waveform display |
| TIME | Waveform versus time display |
| CLW | Clears one waveform from display |
| CLD | Clears all waveforms from display |

**DATA STORAGE**

| | |
|---|---|
| WFM | Recall waveform |
| >WFM | Store waveform |
| PNT | Recall waveform point |
| >PNT | Store waveform point |
| CNS | Recall constant |
| >CNS | Store constant |

**EXPANSION**

| | |
|---|---|
| VXPD | Vertical expand |
| HXPD | Horizontal expand |

**SCALE FACTORS**

| | |
|---|---|
| VSCL | Recall vertical scale |
| >VSCL | Change vertical scale |
| HSCL | Recall horizontal scale |
| >HSCL | Change horizontal scale |

**WAVEFORM POSITIONING**

| | |
|---|---|
| VZR | Recall vertical zero |
| >VZR | Change vertical zero |
| VPUP | Vertical position up |
| VPDN | Vertical position down |
| HPRGT | Horizontal position right |
| HPLFT | Horizontal position left |

**GPIB INTERFACE I/O**

| | |
|---|---|
| SAVE | Transmit user program |
| SENDX | Transmit waveform or constants |
| READX | Receive waveforms, and constants |
| TEXT | Transmit all alphanumerics as displayed in SCOPE, STORED, or BOTH |
| >TEXT | Receive text |

**TTL OUTPUT**

| | |
|---|---|
| SWL | Set level to TTL low |
| SWH | Set level to TTL high |

**NUMBER ENTRY**

| | |
|---|---|
| . | Decimal point |
| 0-9 | Digit keys |
| EEX | Enter exponent |

**SIGN CHS**

| | |
|---|---|
| CHS | Change Sign |

*Note: Operate on waveforms as well as on constants.

**For additional literature, or the address and phone number of the Tektronix Sales Office nearest you, contact:**


**U.S.A., Asia, Australia, Central & South America, Japan**
Tektronix, Inc.
P.O. Box 4828
Portland, OR 97208
Phone: 800/547-1512
Oregon only: 800/644-9051
Telex: 910-467-8708
Cable: TEKTRONIX

**Europe, Africa, Middle East**
Tektronix Europe B.V.
Postbox 827
1180 AV Amstelveen
The Netherlands
Telex: 18312

**Canada**
Tektronix Canada, Inc.
P.O. Box 6500
Barrie, Ontario L4M4V3
Phone: 705/737-2700




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