Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

NUMBER 14 PRINTED IN U.S.A JUNE 1962

HORIZONTAL SAMPLING THEORY

By Hal Hardenbergh; until recently, assigned to our West Los Angeles Field Office.

To recreate a waveform using sampling techniques, samples must be taken over the entire waveform. Taking a sample of the leading edge of the waveform is easy; a trigger circuit is used to trip a strobe pulse generator directly. A block diagram of this system would take this form:

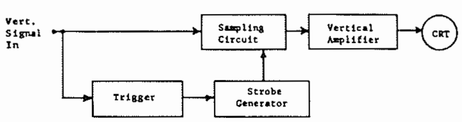


Figure 1

In practice, the system represented by the block diagram above wouldn't be able to sample on the very front of the waveform, because of the finite time delay in the trigger and strobe generator circuits. Therefore, a time delay must be introduced between the trigger input and the sampling circuit. If the vertical signal input is 50 Ω, a 50-Ω coax cable may be used to obtain the necessary delay. A delay of approximately 50 nanosec, representing about 33 feet of 50-Ω coax, is generally used.

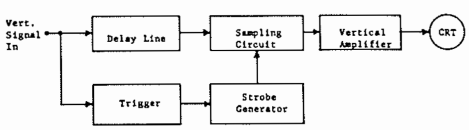


Figure 2

Although the system represented by Fig. 2 would be able to sample an incoming waveform on its leading edge, it probably wouldn't be able to sample in the middle of the waveform, or at the trailing edge. Practical trigger circuits can generally "recognize" only the leading edge (or transition) of a waveform. In order to sample in the middle of the waveform, a time delay must be inserted between the trigger circuit and the strobe generator.

Since long time delays may be necessary (up to a millisecond) and since the delay should be continuously variable, an electronic delay is used. The strobe generator is now tripped by the delayed trigger output of the variable delay circuit. If a sufficient range of delay is available, samples may now be taken over the entire waveform. Our block diagram now takes this form:

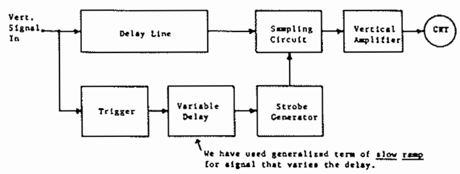


Figure 3

Functionally, this variable delay circuit is identical to the delayed trigger pick-off in the Tektronix Type 535/535A Oscilloscopes. The trigger circuit recognizes the incoming waveform and initiates a voltage ramp or sweep. The voltage ramp is fed into a comparison circuit, or comparator, along with a DC voltage. When the ramp reaches the level of the DC voltage, the comparator puts out a trigger pulse called the delayed trigger. The time delay between the trigger input and the delayed trigger output may be changed by varying either the DC voltage or the slope of the ramp. Usually the DC voltage is changed (by the DELAY TIME helipot on the Type 535 or Type 535A) to obtain a vernier delay, and the slope of the ramp is changed to change the range of the vernier. A block diagram of the delayed trigger circuits in the Type 535 or Type 535A would take this form:

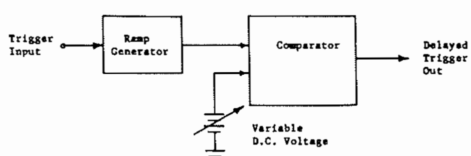


Figure 4

The delays needed in sampling systems are generally much shorter than those available from the delayed trigger of a Type 535 or Type 535A; therefore, the circuitry is different. However, a voltage ramp, now called the "fast ramp," is still compared to a variable DC voltage to obtain the variable time delay needed to sample along the full length of our waveform. Our sampling system block diagram now takes the following form:

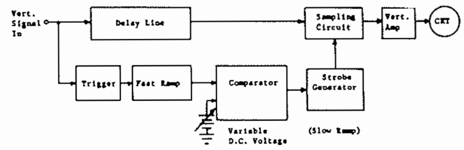


Figure 5

If the DC voltage in the above block diagram is increased each time a sample is taken, comparison will take place progressively further along the fast ramp. Thus, there is a progressive increase in the time delay between recognition and sampling. This causes each sample to be taken on a different part of the incoming signal.

A complete sampling system, therefore, includes an incremental voltage-advancing circuit or "staircase generator." The staircase generator is made to advance one increment immediately after each sample is taken, by feeding the delayed trigger output of the comparator into the staircase generator. By advancing the staircase immediately after a sample is taken, the staircase generator is given the maximum time to reach its new DC level before the next ramp arrives. We now substitute a staircase generator for the variable DC voltage in our block diagram:

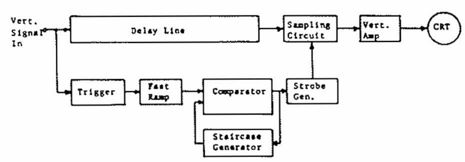


Figure 6

The *real time* spacing is determined only by the repetition rate of the waveform (up to the maximum sampling rate of the oscilloscope). The *equivalent time* spacing is determined only by the fast ramp slope and the amplitude of each stairstep. Therefore, the *equivalent time* of a sampling display is independent of the *real time* of the display and vice-versa.

When we reconstruct the shape of a waveform on the CRT of a sampling oscilloscope, we in effect pretend that all of the samples contained in one sweep were taken on one waveform. Therefore, the time/div calibration of a sampling scope is in *equivalent time*.

If the fast ramp is a linear voltage/time ramp and if the stairstep is advanced in uniform increments, the spacing of the samples along the incoming waveform will be uniform in *equivalent time.*

To understand the meaning of "equivalent time," consider the following case: If we reconstruct a repetitive pulse 12 nanoseconds wide by taking 12 samples, one *real time* between successive samples depends on the repetition rate of the waveform. However, by using our 12 samples to reconstruct a picture of the waveform, we are in effect pretending that all of the samples were taken on one pulse. If this were true, the time between samples would be only one nanosecond (12 samples along our 12 nsec pulse). This is the *equivalent time* between samples.

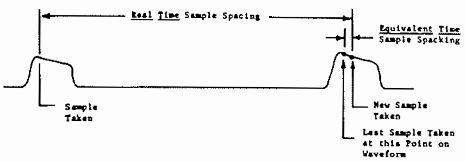


Figure 7

To reconstruct a waveform, the samples must be spaced horizontally in the proper time sequence. This is done by feeding the stairstep into the horizontal amplifier so that the trace moves one increment horizontally as each sample is taken. The relationship between the increment of horizontal distance per sample and the equivalent time per sample will determine the (equivalent) sweep time/div. Adding this function to our block diagram, we now have:

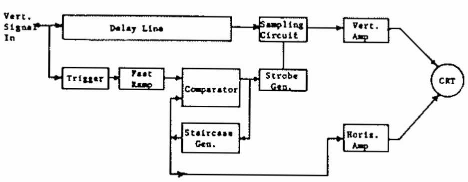


Figure 8

To take a specific example, suppose that the amplitude of staircase going into the comparator is 50 mv/step, where one step equals one sample. If the fast ramp rises 50 mv/nsec, the equivalent time per sample will be one nsec.

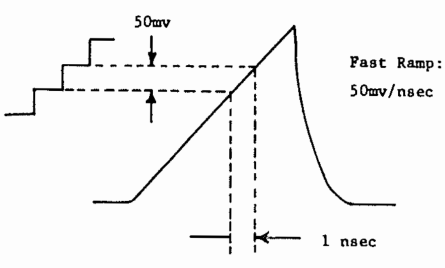


Figure 9

If we adjust the gain of the horizontal amplifier so that each step advances the trace horizontally 1 millimeter, 10 samples (at an equivalent time per sample of 1 nsec) will be required per cm; the sweep time/cm, therefore, will be 10 nsec.

In other words, the (equivalent) time per sample, times the number of samples per division, equals the (equivalent) time per division:

(Time/sample) (samples/div) = Time/div

Returning to our specific example, let's see what happens if we leave the fast ramp and the horizontal gain unchanged, but change the amplitude of each stairstep from 50 mv to 100 mv. This will result in a horizontal step of *two* mm/sample or 5 samples/cm. The equivalent time/sample will increase from 1 nsec to 2 nsec. The resulting time/cm may now be calculated:

(2 nsec/sample) (5 samples/cm) = 10 nsec/cm

Changing only the amplitude of each step within the staircase generator does not affect the time/cm calibration of the crt display—only the equivalent time between samples. However, attenuating the overall amplitude of a given staircase to the comparator will decrease the time/cm by an amount equal to the attenuation.

We've been using a staircase to sample at various points along a waveform (common practice is to say that the strobe pulse "slews" along the waveform). Under certain conditions the stairstep waveform won't resemble its namesake very closely. Actually, the staircase advances one step per sample, so that if we plot the voltage versus the number of samples taken, the graph looks like this:

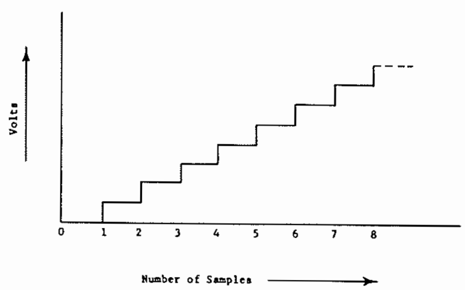


Figure 10

If the incoming waveform repeats at regular intervals, the spacing of the steps on the staircase will be uniform in real time; the waveform observed on a conventional scope will look like this:

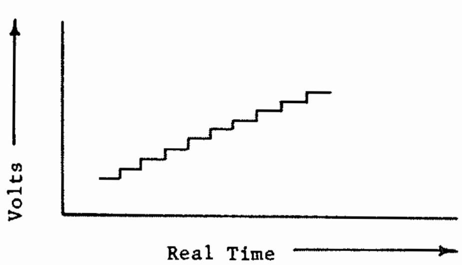


Figure 11

However, if the incoming waveform recurs at an irregular rate, the spacing of the samples (and steps) will be non-uniform in real time:

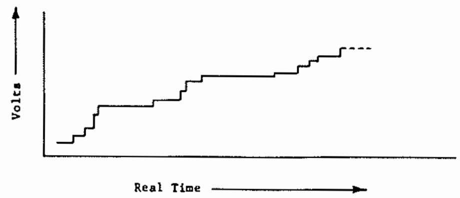


Figure 12

Therefore, do not expect the stairstep *always* to look like a uniform stairstep when observed in *real time.* Note that irregular spacing of samples in *real time* will not cause irregular spacing in *equivalent time,* since the equivalent time calibration is independent of the repetition rate of the incoming waveform. Problems will arise, however, when equivalent time phenomena are viewed on a real time (conventional) oscilloscope.

MEASURING N-PORT PARAMETERS OF NETWORKS

Research engineers at Page Communications Engineers, Inc., Washington, D. C., a subsidiary of Northrup Corporation, have developed techniques for measuring n-port parameters of networks with the aid of the Tektronix P6016 Current Probe and Type 131 Amplifier. Used together with a conventional voltage probe and either a dual-beam or electronically switched dual-channel oscilloscope, with the time base synchronized to the voltage-input channel, the current-probe channel provides both magnitude and phase measurements. With known terminations, such as open circuit and short circuit, a complete set of complex n-port parameters for the component z, y, and h matrixes can easily be determined.

Since the Tektronix Current Probe inserts very little reactance in the lead under test, short-circuit current measurements are feasible. Similarly, driving current and load current can usually be determined directly with little extraneous effort. In general, since the current probe disturbs the measurement less than the shunt capacitance of the voltage probe, the current probe should usually be clipped to a lead directly into the network, while the voltage probe should be on the generator side, not the network side of the current probe.

For passive systems, a check on the measured values is the fact that $z_{ij} = z_{ji}$ and $Y_{ij} = Y_{ji}$. Nonlinearities are made evident by distortion of the sine-wave signal. In the past, distorted current waveforms were difficult to detect, but this technique clearly displays any such effects.

SLAVING TYPE 560-SERIES SCOPES

In response to customer interest, Russ Fillinger, Project Engineer with the Medical-Instrument Development Group has come up with a method of slaving one Type 560-Series scope to another. Cost is low and minor modifications are required on the instruments.

The Master scope must furnish four signals to the Slave scope:

1. Vertical signal (single, dual, or four trace)
2. Sweep sawtooth
3. Deflection blanking (for sweep retrace)
4. Transient-spike blanking to CRT cathode (for dual-and four-trace applications)

Modifications required on the Master scope—refer to accompanying diagram:

1. *Vertical System*
   - A. Plug-in
     - (a) Improve transient response of internal trigger C.F.) For Type 72 remove C487 and replace with 1.5 to 7 pf variable.)
   - B. Indicator
     - (a) Bring out vertical signal from pin 11 of the indicator left-side Amphenol connector (or pin 12 of the right-side Amphenol connector) to the vertical input connector of the Slave.
     - (b) Bring out chopped transient blanking signal from pin 24 of the indicator left-side Amphenol connector to pin 24 of the left-side Amphenol connector of the Slave indicator. (For convenience, the first notch on the ceramic strip under the HV supply may be used instead.)
2. *Horizontal System*
   - A. Plug-In
     - (a) Patch sweep signal to pin 24 of right-side Amphenol connector (in Type 67 install a lead from the cathode of V333A to pin 24 of the Amphenol plug).
     - (b) For fast sweeps in Type 67, it may be necessary to decrease R138 to compensate for additional capacitive loading.
   - B. Indicator
     - (a) Bring out sweep signal from pin 24 of the right-side Amphenol connector in the indicator to the horizontal input connector of the Slave.
     - (b) Bring out sweep blanking signal from pin 13 of the right-side Amphenol connector of the indicator to pin 13 on the left-side Amphenol connector of the Slave indicator.

Modifications required on the Slave plug-ins are:

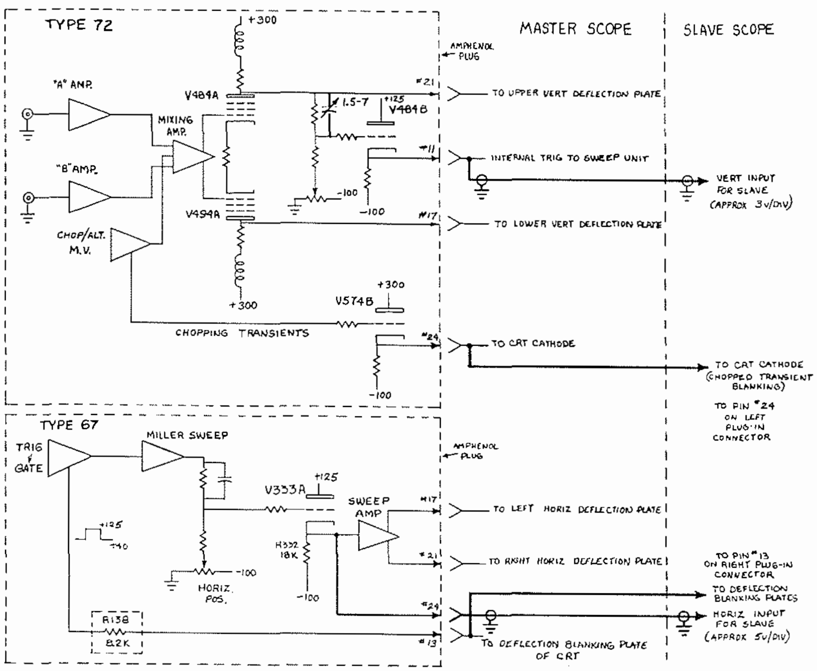
1. Cut tie strap between pins 13 and 14.
2. Remove ground strap from pin 24 (may not be present in early units)

By doing Steps 1 and 2 on both Slave plug-ins, you make them interchangeable from side to side in the Slave indicator.

Russ used a 561/72/67 for the Master and a 561/60/60 for a Slave. The Master had a frequency response of approximately 650 kc; the Slave 390 kc. You may wish to use a 561/59/59 combination for economy.

Linearity of signal will be approximately ±6% in 8 cm because we are using a single-ended sample of the vertical signal from the Master. Linearity is dependent on the output stage of the Master plug-in.

You may wish to install connectors on the back panel of the indicators. If so, you're cautioned that in this case we limited our coax length to four feet.



USED INSTRUMENTS WANTED

1 Type 121 Preamplifier	Harry W. Hammond 1095 Arlington Ave. Teaneck, New Jersey
1 Type 310, 316, 317 or 321 Oscilloscope	Phil Boehme U.S. Navy Electronics Laboratory Code 2623 San Diego 52, California
1 Type 531 or Type 535 with a Plug-In Preamplifier	Alex Levin Bureau of Ships Code 679C3F Washington 25, D. C.
1 Tektronix 5" crt oscilloscope. DC to 10 MC.	G. Servos 686 Fairview Avenue Elmhurst, Illinois
1 Type 502	S. Winston 104 MS U.C. Medical Center San Francisco, California
1 Type 310 or Type 321	James F. Bockelman Aircraft Space Electronics Apalachicola, Florida
1 Tektronix General Purpose Oscilloscope (10-15 mc.	Robert E. Jones 2406 Eastern Avenue Wesleyville, Pa. Phone: TW 9-3456

USED INSTRUMENTS FOR SALE

1 Type 575 Transistor Characteristic Curve Tracer, s/n 3565	Ortho Industries, Inc. 7-11 Paterson Street Paterson, New Jersey

Owner says this instrument was used only briefly to evaluate 24 transistors.
Price $800.00

1 Type 127 Power Supply 1 Type E Plug-In Unit	Frank G. Carpenter Assoc. Professor of Physiology Dartmouth Medical School Hanover, New Hampshire
1 Type 541A, s/n 21509, with a Type L Plug-In Unit, s/n 11618	Sprague Engineering Co. 18435 Susana Road Compton, California
1 Type 517, s/n 625. Will sell or trade for either a Type 545A or Type 585 and cash	Ian Isdale 825 Tall Timber Road Orange, Connecticut

Service Scope

USEFUL INFORMATION FOR USERS OF TEKTRONIX INSTRUMENTS

Tektronix, Inc.
P. O. Box 500
Beaverton, Oregon

1 Type 316, s/n 187 1 Type 181, s/n 259	Dale Brocker 3008 Lakeshore Avenue Apartment 6 Oakland, California
1 Type 517, s/n 1680	John Ivimey Room 2001 1428 South Penn Square Philadelphia 2, Penn. Phone: LO 3-6531
1 Type 512 with flat faced crt. Price $275. F.O.B San Francisco	S. Winston 104 MS U.C. Medical Center San Francisco, California

MISSING INSTRUMENTS

The University of Alabama reports a Tektronix Type 503 Oscilloscope, serial number 759, as missing from their Electrical Engineering Department. They presume it to be stolen. Information concerning this instrument should be sent to: Willard F. Gray, Department of Electrical Engineering, University of Alabama, University, Alabama.

A Tektronix C12 Camera, serial number 008-980, belonging to the Columbia University in New York City disappeared from the University and is presumed to be stolen. Information concerning the whereabouts of this camera should be sent to: Tektronix, Inc., 840 Willis Avenue, Albertson, Long Island, New York.

Our Chicago Office notifies us that a Tektronix Type 310A Oscilloscope is missing from the General Electric X-Ray Division in Chicago. This instrument is also believed to be stolen. If you have any information pertinent to this instrument, please notify: Tektronix, Inc., 400 Higgins Road, Park Ridge, Illinois.

QUESTIONS FROM THE FIELD

Q. When using my Type 543 at the fastest sweep speeds, the trace intensity is not uniform because of a 5-volt dip in the unblanking waveform. This intensity nonlinearity sometimes makes it difficult to take satisfactory photographs of the crt display. What will cure this?

A. Types 533 and 543 after serial numbers 3000 were modified to overcome this problem. You can make the modification to the sweep-gating multivibrator in the time-base-generator circuit of your instrument. Simply replace L 133 with a strap. Connect an 8 pf, 500 v, ceramic (Tektronix No. 281-503) between pin 8 of V135 and the junction of R133 and R134.

Q. The multivibrator in my 53/54C and CA Plug-In Units will not self-start when the units are warming up in the CHOPPED mode. How can I correct this problem?

A. This problem was solved by a modification installed in CA units with serial numbers above 34790. You can correct the condition in CA units below this number and in 53/54C units, all serial numbers, by adding R3383, a 330 k, ¼ w, 10%, comp. resistor (Tektronix No. 316-334) between the cathode of V3382* (6AL5, pin 5) and +225 v.

The 6AL5 caused the problem. Its cathodes were returned to —150 v through a 1.8 megohm resistor located in the oscilloscope (via pin 16 of the interconnecting plug). This resistor provided a current source for the 6AL5 that tended to balance the multi (V3375, 12AT7) plates; both halves saturated and prevented multi action. The 330 k resistor forms a divider that biases off the diodes.

*V3803 in Type 53/54C Units.

Q. What can I do to correct intensity modulation (noticeable at some sweep speeds when using low intensity) on my Type 321 Oscilloscope?

A. Change C852, an 0.01 μf, 1000 v, Hicap capacitor to an 0.02 μf, 1400 v, DC, Type U capacitor (Tektronix No. 283-022). Type 321's after s/n 1389 have this modification.

PINPOINTING INFORMATION ON POLAROID PRINTS

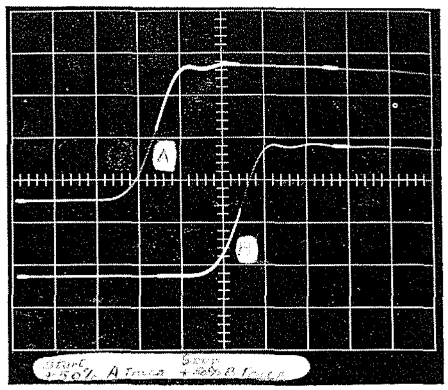


Figure 1

Use a draftsman's thin metal erasing shield and an eraser (an electric eraser is ideal if you're lucky enough to have one handy) to label or pinpoint information on Polaroid* Land prints. The shield and eraser will enable you to erase through the print to the underlying white paper. You can erase away a portion of the print to form an arrow or a space to write in a number or a brief description. See Figure 1.

* Polaroid is a registered trademark of the Polaroid Corporation.

Tektronix Instrument-Repair Facilities: There is a fully-equipped and properly-staffed Tektronix Instrument Repair Station near you. Ask your Field Engineer about Tektronix Instrument-Repair facilities.