

Sampling Notes

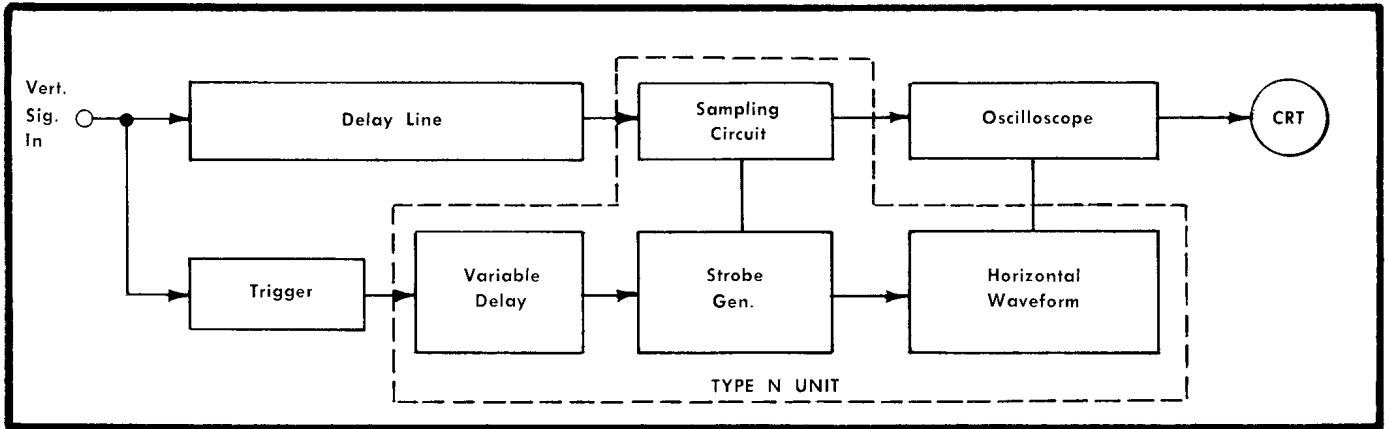


Fig. 17. Simple block diagram of Tektronix Type N Unit with external trigger system.

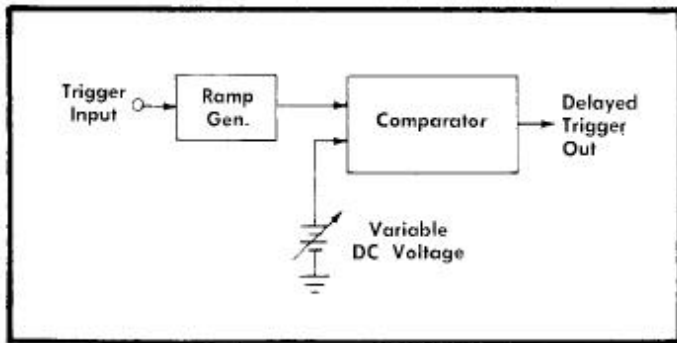


Fig. 18. Block diagram of a delayed trigger circuit.

To understand the meaning of "equivalent time", consider the following case: Recreate a repetitive pulse 12 nanoseconds wide by taking 12 samples, one sample per incoming signal. In this case, the real time between successive

samples depends on the repetition rate of the signal. However, by using 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 1 nanosecond (12 samples along the 12-nanosecond pulse). This is the **equivalent time** between samples. See Fig. 21.

To reconstruct a signal, the samples must be spaced horizontally in the proper time sequence. This is done by feeding the staircase 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, the block diagram becomes that of Fig. 22.

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 1 nanosecond.

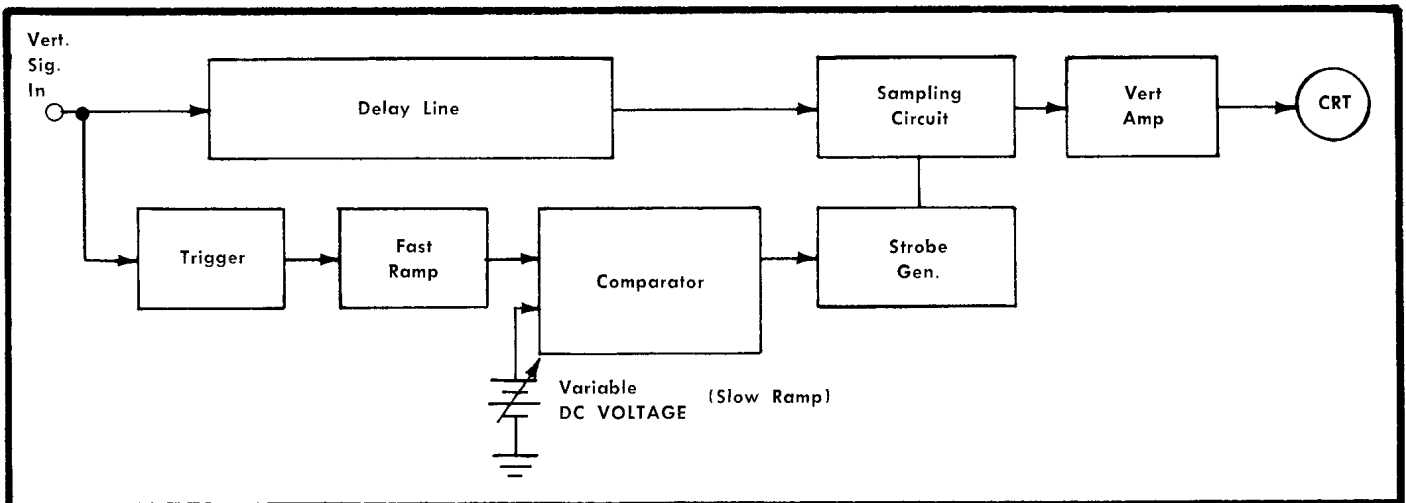


Fig. 19. Addition of a variable trigger circuit that allows triggering to progress along signal waveform.

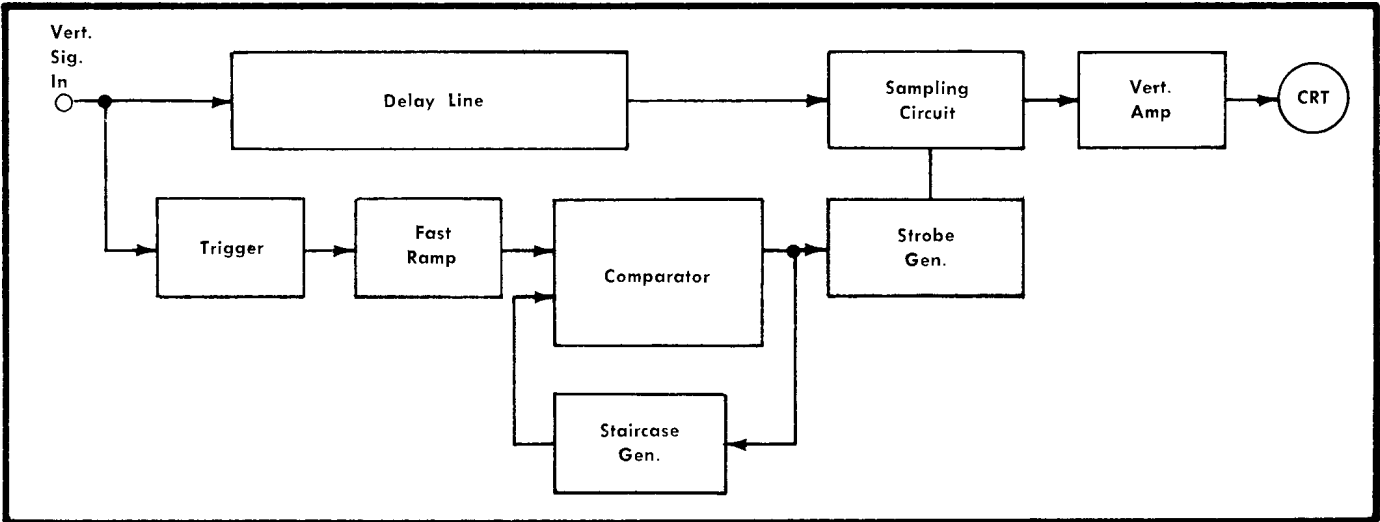


Fig. 20. An automatic variable trigger circuit.

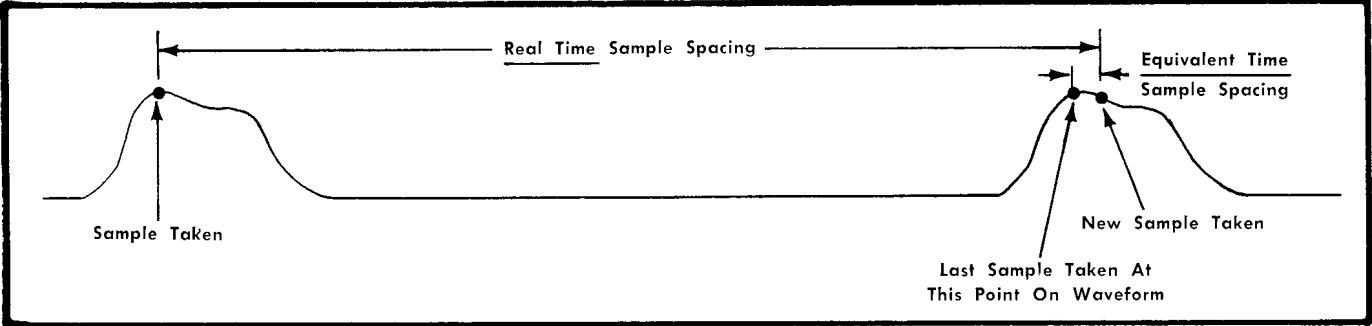


Fig. 21. Real Time and Equivalent Time relationship.

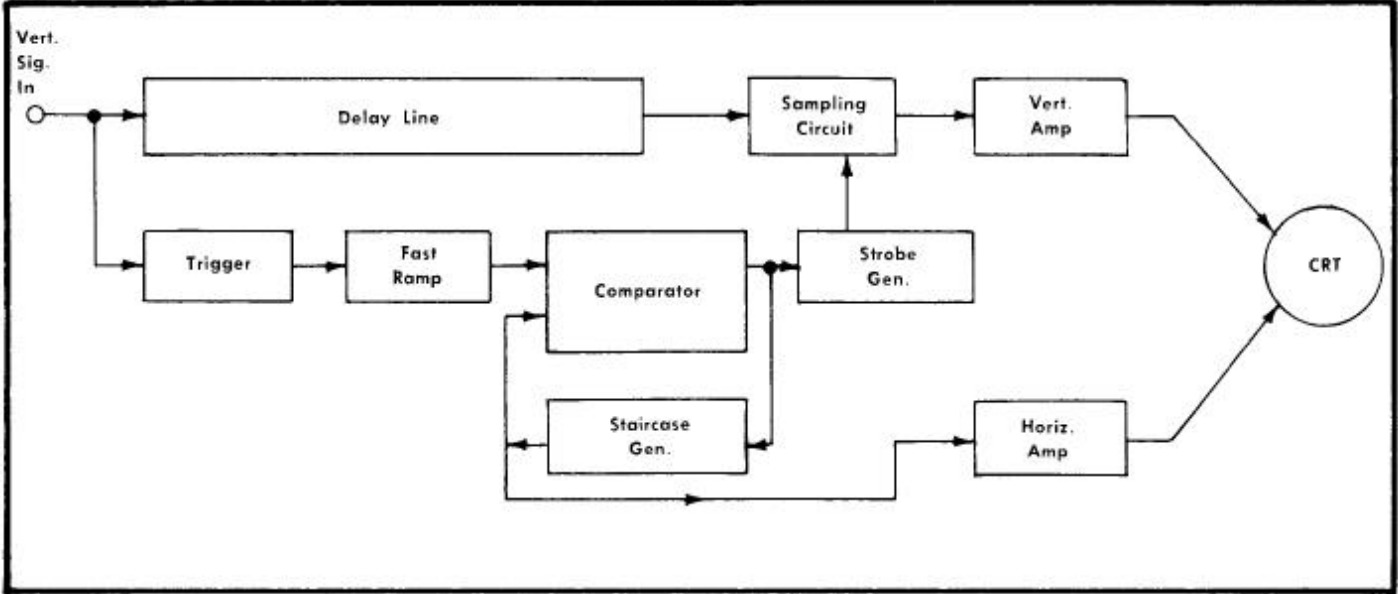


Fig. 22. Completed block diagram of the Tektronix slide-back feedback sampling systems.

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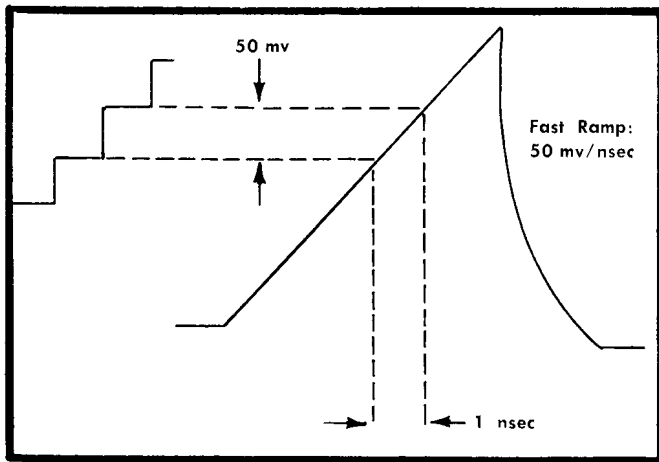


Fig. 23. Fast ramp waveform that will produce an equivalent time per sample of 1 nanosecond.

See Fig. 23. To 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 nanosecond) will be required per cm; the sweep time/cm, therefore, will be 10 nanoseconds. In other words, the (equivalent) time per sample, times the number of samples per division, equals the (equivalent) time per division:

$$(\text{Time/sample}) (\text{Samples/div}) = \text{Time/div.}$$

Returning to the specific example, 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 2 mm/sample or 5 sample/cm. The equivalent time/sample will increase from 1 nanosecond to 2 nanoseconds. The resulting time/cm may now be calculated:

$$(2 \text{ nsec/sample}) (5 \text{ samples/cm}) = 10 \text{ nsec/cm.}$$

Changing the amplitude of the stairstep thus does not affect the time/cm calibration of the display, provided the horizontal gain and the fast ramp slope remain unchanged. The SAMPLES/DIV. control on sampling oscilloscopes merely changes the amplitude of each step in the staircase.

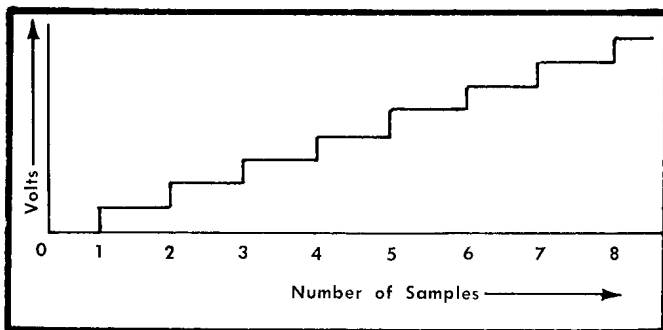


Fig. 24. Staircase voltage changes with synchronously repetitive signal sampling.

The previous discussion referred to a staircase to sample at various points along a signal (common practice is to say that the strobe pulse "slews" along the signal). Under certain conditions the stairstep waveform will not resemble its namesake very closely. Actually, the staircase advances one step per sample, so that the voltage versus the number of samples taken looks like Fig. 24. If the incoming signal repeats at regular intervals, the spacing of the steps on the staircase will be uniform in real time, as shown in Fig. 24.

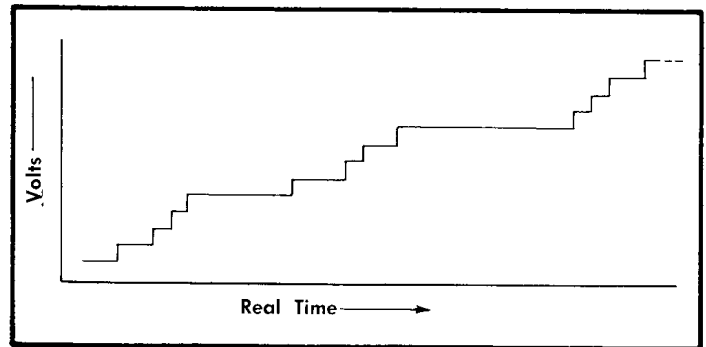


Fig. 25. Staircase voltage changes with irregular repetitive signal sampling.

However, if the incoming signal recurs at an irregular rate, the spacing of the samples (and steps) will be nonlinear in real time as shown in Fig. 25.

Therefore, do not expect the stairstep to always look like a uniform stairstep when observed in real time. Note that irregular spacing of the 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 signal. Problems will arise, however, when equivalent time phenomena are viewed on a real time (conventional) oscilloscope.

References

1. Transient Analysis Of Coaxial Cables, Considering Skin Effect, Wiginton and Nahman, Proc. IRE, Vol. [4?] pp 166-174. February 1957.
2. Sampled-Data Control Systems, Ragazzini and Franklin McGraw-Hill Book Co. 1958.
3. In And Out Of Circuits With Probes, Winningstad, Tektronix Publication 061-996, N.E.C. Paper. 1963