

[54] SCANNING DISPLAY FOR SAMPLED DATA  
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[73] Assignee: Unirad Corporation, Denver, Colo.  
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[52] U.S. Cl. .... 128/2 V; 128/2.05 Z; 340/324 AD  
[51] Int. Cl.<sup>2</sup> ..... A61B 10/00  
[58] Field of Search ..... 128/2 V, 2.05 Z;  
340/324 AD; 313/22, 30

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Attorney, Agent, or Firm—Lane, Aitken, Dunner & Ziems

[57]                      ABSTRACT

A system for displaying sampled continuous input signals on an x-y scanning CRT display with dual sampling circuitry responsive to the highest and lowest amplitude of the input signal over sampling periods corresponding to x-sweep periods of the display. The sampled peaks are compared to the x-sweep signal to generate a variable length pulse to modulate the scanning beam intensity. The length of the pulse depends on the spread between the sampled peaks. Sampled data can be displayed in this manner simultaneously with conventional ultrasonic "motion displays."

16 Claims, 10 Drawing Figures

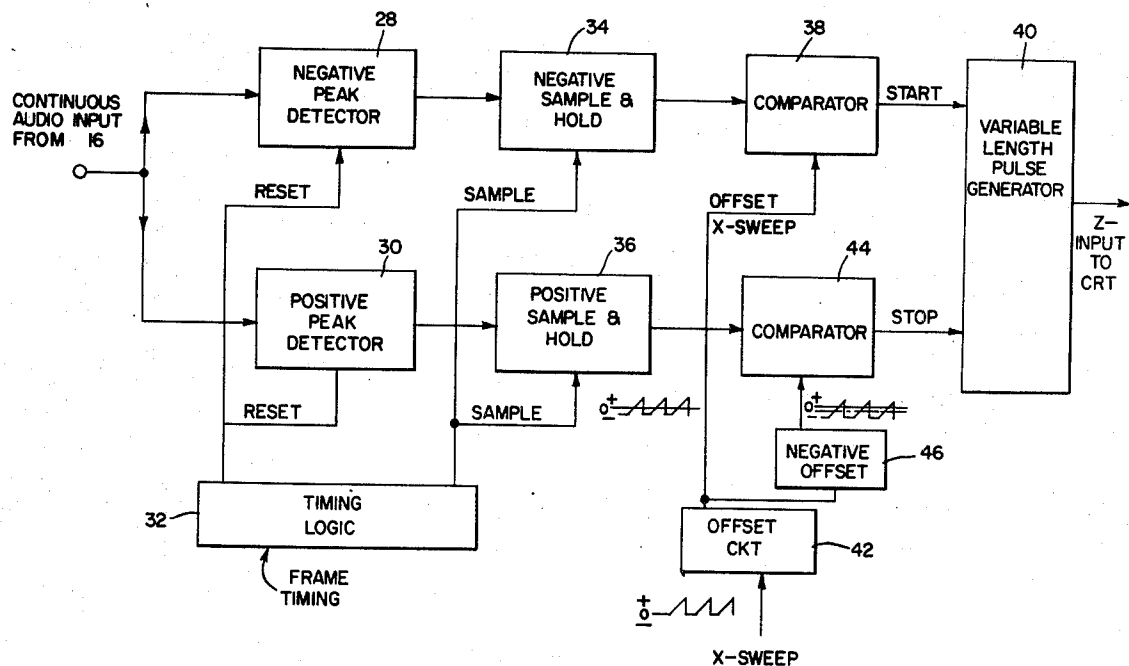


FIG. 1.  
(PRIOR ART)

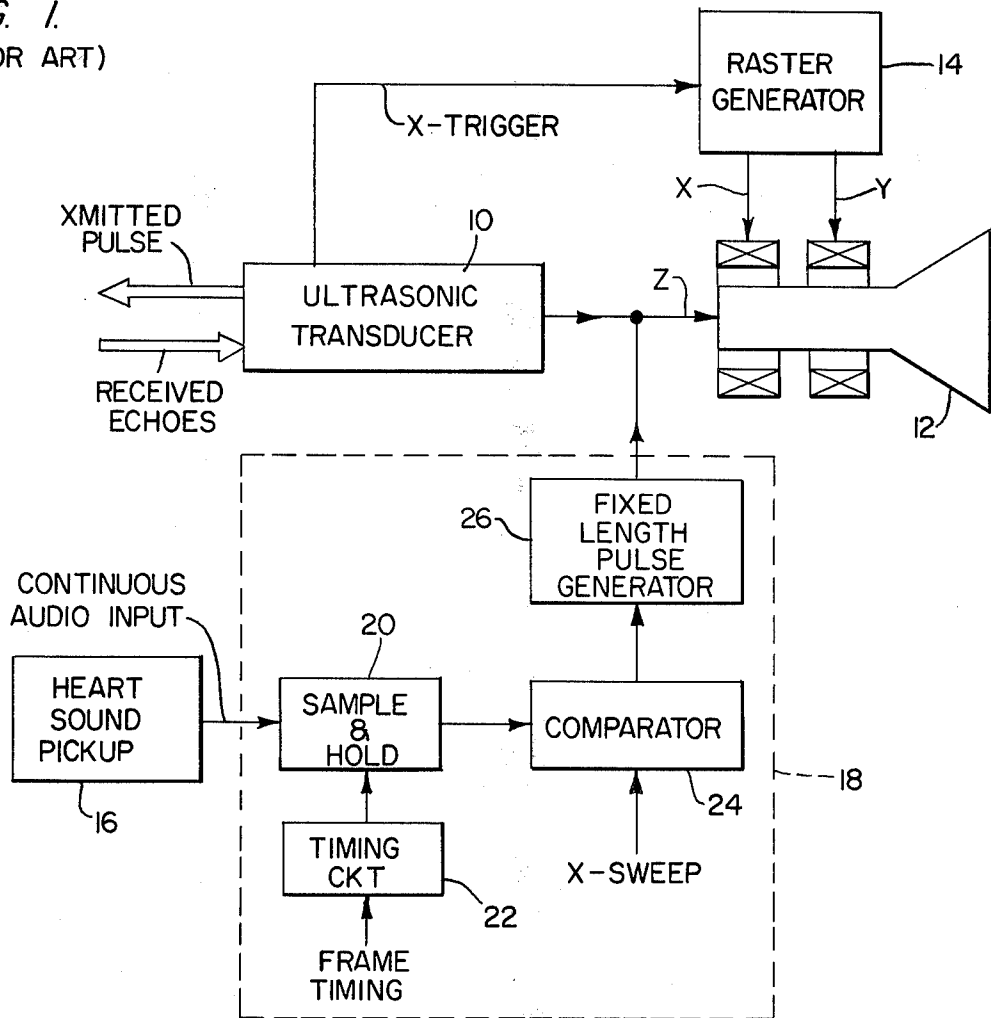


FIG. 3A.

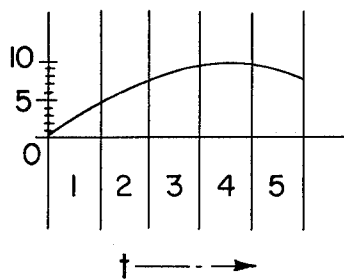


FIG. 3B.

PRIOR ART

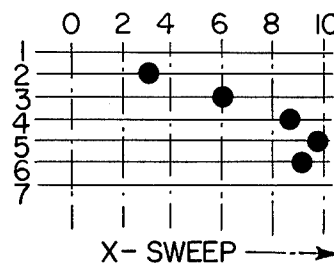


FIG. 3C.

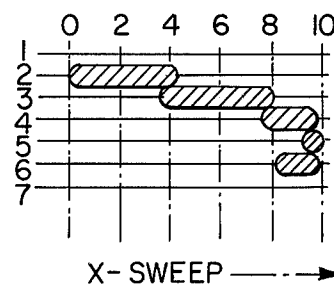
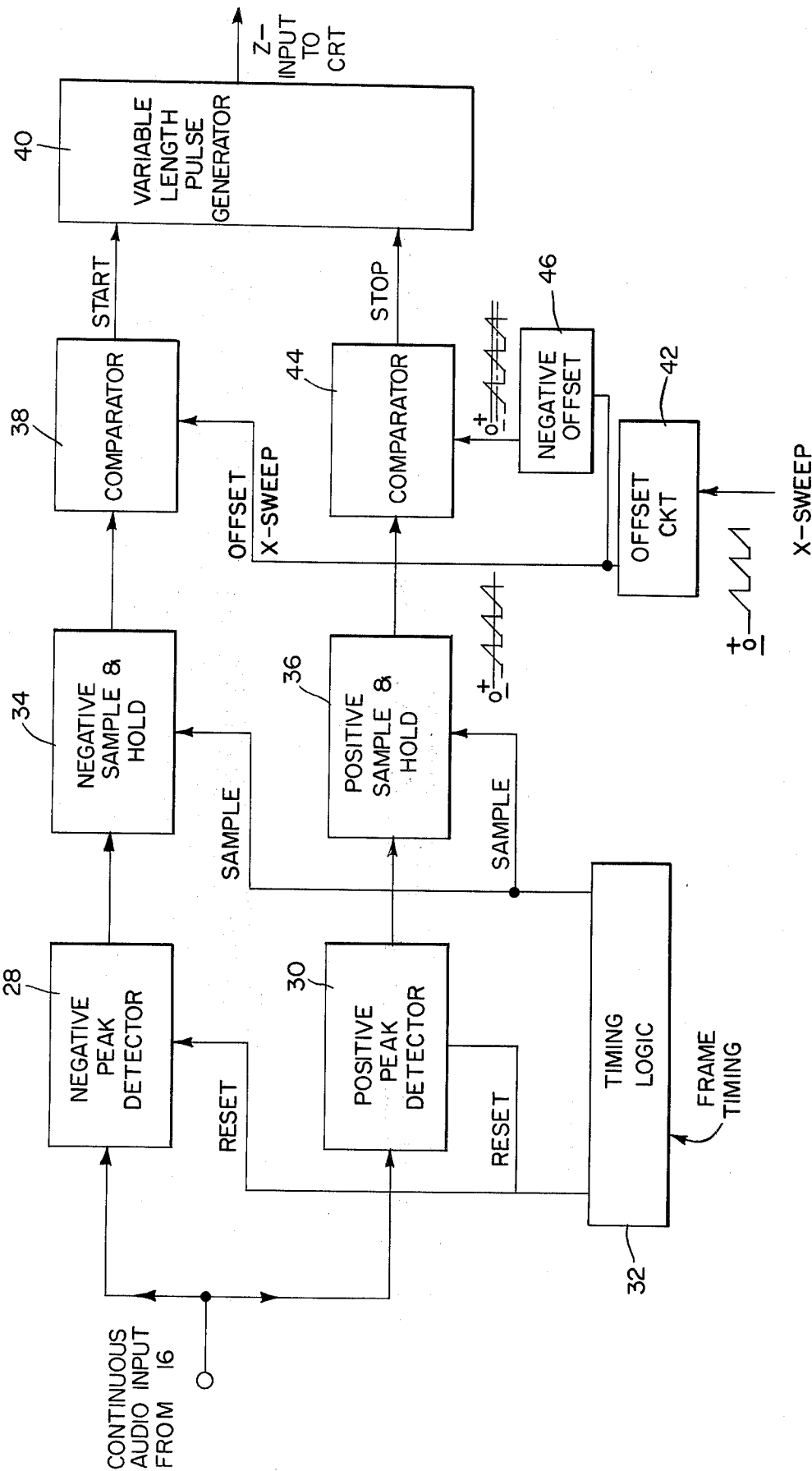


FIG. 2.



SHEET 3 OF 3

FIG. 4A.

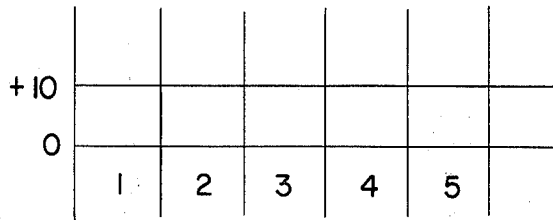


FIG. 4B.

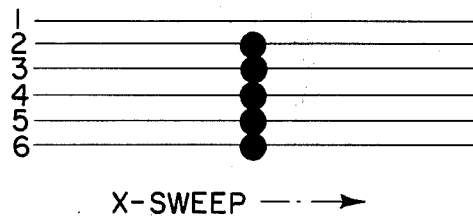


FIG. 5A.

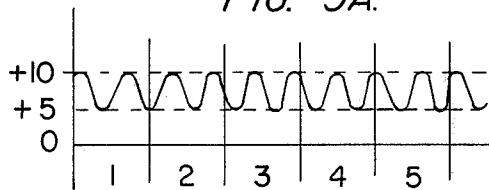


FIG. 5B. PRIOR ART

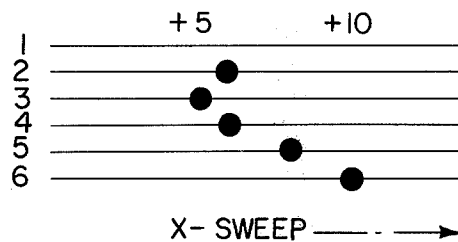
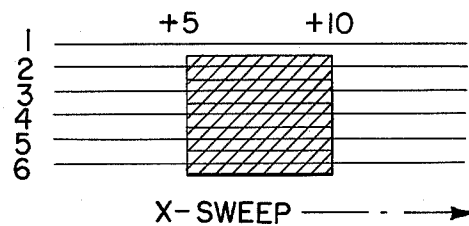


FIG. 5C.



## SCANNING DISPLAY FOR SAMPLED DATA

## BACKGROUND OF THE INVENTION

The invention relates generally to the field of scanning displays, and more particularly to scanning displays for sampled data, especially in the medical field.

Scanning type displays have been used before to display data instead of synchronized video picture signals. In the medical field, for example, diagnostic ultrasonic sonatype data can be displayed on an  $x$ - $y$  scanning display. Echoes from ultrasonic pulses passing through body tissue are converted to a display by a cathode ray tube (CRT) or oscilloscope whose  $x$ -sweep is synchronized with the repetition frequency of the transmitted ultrasonic pulses. In using the resulting display, called a motion display or M-mode display, to study heart function, it is also desirable to simultaneously record additional physiological parameters, such as the electrical activity of the heart, heart sounds, and blood pressure. However, these parameters are continuous and are therefore different in kind from the ultrasonic pulse data. The continuous signal must first be sampled, and the sample converted to appropriately timed intensity drive pulses, in order to be displayed on the scanning type display customarily used for the ultrasonic application. The basic pulse position modulation technique, used in the prior art, displays the sampled continuous input signal by means of dots generated respectively on each  $x$ -sweep in response to a fixed length intensity drive pulse. When the continuous input signal varies significantly between successive  $x$ -sweeps, the individual dots on consecutive  $x$ -sweeps separate, and the resulting display deteriorates accordingly.

## SUMMARY OF THE INVENTION

The general purpose of the invention is to improve scanning type displays of sampled data, especially to avoid displaying disconnected dots in representing a continuous input signal of varying amplitude.

Another object of the invention is to improve the appearance of scanning displays of sampled data. Still another object of the invention is to increase the apparent frequency response of a scanning type display.

These and other objects of the invention are accomplished, generally speaking, by incorporating positive and negative peak detecting circuitry into the sampling circuit and displaying a line which connects the positive and negative peak points. For continuous input signal data, lines on adjacent  $x$ -sweeps are either overlapping or contiguous end-to-end.

The display system includes negative and positive peak detectors which charge to the most negative and positive relative values of the input signal during a sampling period. At the end of the sampling period the peak values retained by the detector are transferred to respective sample and hold circuits. When the  $x$ -sweep voltage for the CRT-type display reaches the corresponding negative sample and hold level, a comparator causes an intensity drive pulse to be initiated by a variable length pulse generator. The  $x$ -sweep voltage continues to ramp upward until it reaches the corresponding positive sample and hold value at which time another comparator causes the variable length pulse generator to terminate the intensity drive pulse. The  $x$ -sweep signal applied to the positive comparator is offset slightly to provide a delay in the termination of the variable length pulse so that if the input signal remains

at a constant level, dots of fixed length will be generated on each  $x$ -sweep. For input signals which vary at a rate below the sampling rate the resulting display will be a continuous line actually composed of connected line segments approximating the actual waveform. For very slowly varying input signals and DC signals, the new system will produce a continuous line of fixed width similar to those produced by the prior art pulse position modulation method. For extremely rapidly varying signals, at rates in excess of the sampling period, the display produces a solid continuous line in the  $y$ -direction whose width in the  $x$ -direction is proportional to the peak amplitude of the high frequency input signal.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a prior art system for displaying heart sounds on a scanning type system normally used for ultrasonic motion display.

FIG. 2 is a block diagram of the display system according to the invention.

FIG. 3A is a graph illustrating a continuous input signal below the sampling rate.

FIGS. 3B and 3C are pictorial representations of the corresponding old display and the new display, respectively.

FIG. 4A is a graph illustrating a constant level input signal.

FIG. 4B is a pictorial representation of the corresponding display by either the old or new technique.

FIG. 5A is a graph illustrating a high frequency input signal above the sampling rate.

FIGS. 5B and 5C are pictorial representations of the corresponding old display and the new display, respectively.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

In order to gain a better understanding of the subject matter of the invention in relation to other systems, FIG. 1 illustrates a prior art arrangement pertinent to the invention. A transducer 10 generates an ultrasonic pulse which propagates into the patient's body. A fraction of the pulse is reflected from internal body organs, and these echoes are picked up by the transducer 10, amplified and converted to a display by means of a standard CRT 12 whose intensity input ( $z$ ) is supplied by the output of the transducer 10. The horizontal and vertical deflection coils of the CRT 12 are driven by  $x$  and  $y$ -sweep signals from a raster generator 14 of conventional design, including the necessary timing circuitry. The  $x$ -sweep is triggered by the generation of the ultrasonic pulse from the transducer 10. Thus the  $x$ -sweep of the CRT 12 is synchronized with the transmitted pulses. The  $y$ -sweep is driven in the conventional manner by a relatively slow sweep signal which causes each succeeding horizontal  $x$ -sweep to be offset on the display by about one line-width. The resulting display provides a representation of the motion of the reflecting organ in the direction of the transmitted pulse.

The same type of scanning display can be utilized to represent continuous input signals as well as discrete echoes. Thus in FIG. 1 a heart sound pick-up provides a phonocardiographic continuous audio input (pick-up 16) to a display converter system 18 whose task is to sample and convert the continuous input signals into

appropriately timed intensity drive pulses (z-input) for the CRT 12. Conventionally, the display system 18 employs a sample and hold circuit 20 which samples the audio input once during each sampling period according to a timing circuit 22 operated by the same frame timing circuitry as that in the raster generator 14. The output of the sample and hold circuit 20 is applied to a comparator 24 which produces an output when the x-sweep signal from the raster generator 14 reaches a level which corresponds to the sample and hold output. The output of the comparator 24 activates the fixed length pulse generator 26 which causes a dot to be generated at a corresponding position along one horizontal line of the x-y display on the CRT 12.

The system according to the invention, as shown in FIG. 2, replaces the display converter system 18 of FIG. 1 with a system requiring the sampling of two different values during the same sampling period and the application of a variable length pulse to the z-input of the CRT. Accordingly, the system of the invention provides a negative peak detector 28 and a positive peak detector 30 respectively receiving the continuous audio input, for example, from the heart sound pick-up 16. At the start of each sampling period, T, the timing logic 32 resets the peak detectors 28 and 30 to the level of the input signal at that time so that the negative and positive peaks will be sampled in relation to the signal level at the start of the sampling period. After being reset, the peak detectors will each charge to the highest positive and negative excursions respectively which occur in the input signal during the timing period T. At the end of the timing period, the peak values are transferred from the respective peak detectors to corresponding sample and hold circuits 34 and 36. The timing logic 32 applies sample control inputs or "gate" signals to the circuits 34 and 36 immediately at the end of a sampling period T. The sample and hold circuits 34 and 36 both hold the peak values for the duration of the next sampling period. When the offset x-sweep voltage in the next period reaches the output level of the negative sample and hold circuit 34, a comparator 38 causes a z-drive pulse to be initiated by a variable length pulse generator 40. The sweep input to the comparator 38 is offset by means of offset circuit 42 such that the x-sweep begins at a "negative" level below that of the most negative signal to be displayed and ends at a "positive" level above the most positive signal to be displayed. The x-sweep will continue to ramp upward and the electron beam on the CRT will continue to traverse the corresponding horizontal line on the screen, until the x-sweep voltage corresponds to or matches the output of the positive sample and hold circuit 36. The other comparator 44 senses the coincidence of the negative offset x-sweep and the positive sample and hold voltage and causes the pulse generator 40 to terminate the pulse which has continued to be generated up until this time.

The sweep input to the comparator 44 is via the standard offset circuit 42 followed by a special negative offset 46 which slightly lowers the level of the ramp waveform applied to one input of the comparator 44 relative to the sweep input to the comparator 38. This relationship can be seen in the aligned waveform in FIG. 2. The effect is to delay the termination point of the variable length pulse produced by the generator 40 so that even if the input signal is a constant level or DC signal and the sample and hold circuit outputs are the same there

will be a pulse of fixed, minimum length applied to the z-input of the CRT.

FIG. 3 illustrates a graph of the input signal with a frequency below the sampling rate of the system of FIG. 2 according to the invention. The horizontal axis in FIG. 3A is divided into five consecutive sampling periods numbered accordingly. A continuous sinusoidal input waveform is shown, with less than one-half cycle being represented. If the conventional system shown in FIG. 1 were used and sampling signal applied to the sample and hold circuit 20 occurred arbitrarily, for example, at the midpoint of each sampling period, the sampled voltage level of the input signal in FIG. 3A during the first sampling period would be about 3.0 volts. Thus in FIG. 3B the conventional display would illuminate a dot at the corresponding horizontal line (x-sweep) at a point in the horizontal or x-direction corresponding to 3.0 volts. Because the sampling period occurred during the first x-sweep, the corresponding dot will be displayed during the second x-sweep. In the second sampling period the input waveform increases from 4.0 volts to about 8.0 volts and thus the sampled midpoint would be about 6.0 volts and a dot would be illuminated at the corresponding position along the second line of the conventional display in FIG. 3B. Similarly, dots corresponding to the sampled midpoint of the waveform in the succeeding sampling periods would be applied consecutively in the conventional manner. The result would be a disjoint array of dots as shown in FIG. 3B.

Using the system according to the invention, however, the peak detectors 28 and 30 (FIG. 2) would store the negative and positive peak values of 0.0 and 4.0 volts, respectively, for the first sampling period. While these values are held, the corresponding x-sweep would occur; and during that period, a pulse of corresponding length, shown in the second line of the display in FIG. 3C, would be displayed between the corresponding points along the line. In the second sampling period the peak detectors 28 and 30 would store the values 4.0 and 8.0 respectively, and the pulse generator 40 would cause a line to be drawn on the third x-sweep in FIG. 3C between the positions corresponding to these values. Note that the second line segment begins where the first line segment on the preceding sweep leaves off. The display system operates in a similar manner in the other sampling periods. However, in sampling period No. 4 the level of the input waveform begins at 9.5 increases to 10.0 volts and ends at about 9.8 volts. In the fifth sampling period the waveform begins at 9.8 volts. The corresponding fifth and sixth lines of the display in FIG. 3 have overlapping line segments accordingly. Because of the close spacing of adjacent lines in the display the series of line segments appear to blend together forming a continuous line which reproduces the input waveform.

FIG. 4A illustrates a constant level input signal with a value of 10.0 volts over five consecutive sampling periods. The conventional system of FIG. 1, would cause dots to be applied at the same point on each consecutive line of the display by virtue of the identical samples taken in each sampling period. The same effect occurs with the system according to the invention because the negative and positive peaks within each sampling period are identical. As a result, the outputs of the sample and hold circuits 34 and 36 (FIG. 2) are the same and the entire length of the pulse generated by

the generator 40 is attributed to the special negative offset 46 applied to the positive comparator 44. Accordingly, the same pulse or dot will be represented at the same point on each line of the display. Thus the appearance of the conventional display and of the display according to the invention will be substantially identical as illustrated in FIG. 4B.

FIG. 5A is a graph in an input waveform with a high frequency in excess of the sampling rate. The conventional display system of FIG. 1 would cause a succession of spaced pulses to appear on consecutive lines of the display as shown in FIG. 5B. If the waveform were an integral multiple of the sampling rate, the conventional system of FIG. 1 would mistake it for a DC signal because the input signal would be at precisely the same level each time a sample was taken. On the other hand, the display system according to the invention produces contiguous lines. The "width" of the composite line display in the horizontal direction provides a measurement of the peak amplitude of the input signal. Because the input signal has at least one cycle per sampling period, if the amplitude of the input signal remains the same over a number of sampling periods, the same negative and positive peaks will be detected in each sampling consecutive sampling period. Thus the same length pulse will be generated at the same time during each x-sweep. Consequently the display, as shown in FIG. 5C, will appear as a stack of parallel equal-length lines. Because of the width of each line in the y-direction, the lines overlap and appear to be a single line in the y-direction having a width equal to the difference between the negative and positive peaks, i.e., the signal amplitude. It should be particularly noted that a nonsampled display would also appear to be a solid wide line at the same y-sweep rate due to the lines from successive cycles merging. Thus, the apparent frequency response of the display system according to the invention exceeds its sampling rate.

While the invention has particular value in the field of medical diagnostic equipment, especially ultrasonic equipment used in conjunction with continuous monitors, for example, phonocardiograms, a number of other uses of the display system are possible, and the general principles by which the display system operates are equally applicable to other situations in an analogous manner. Therefore, the description of the present embodiment is intended to be taken as illustrative of the principles of the invention and not as restrictive of the scope of the invention, which is indicated by the appended claims and is intended to embrace systems using equivalent elements.

I claim:

1. A system for generating a scanning display of sampled data, comprising means for repetitively generating an x-sweep signal having a ramp-like waveform indicative of progressive displacement in one direction in said display, means for detecting the highest and lowest relative levels of an input signal in each of consecutive sampling periods corresponding respectively to repetitions of said x-sweep signal, means for initiating a variable length control pulse when the x-sweep attains a level corresponding to the lowest level detected in said input signal in a corresponding sampling period, means for terminating said control pulse when said x-sweep signal attains the level of the highest level of the input signal detected in said corresponding sampling period, and means responsive to said control pulse for generat-

ing a line of variable length in said one direction corresponding to said control pulse.

2. The system of claim 1, wherein, said means for initiating said variable length pulse includes a first sample and hold circuit means for sampling at the end of said sampling period the output of said detecting means representing the lowest level attained by said input signal during said sampling period, first comparator means operatively comparing said x-sweep signal to the output of said first sample and hold circuit, and a variable length pulse generator means responsive to the output of said first comparator means indicating coincidence of said x-sweep and first sample and hold circuit means output levels for initiating a pulse.

3. The system of claim 2 wherein said means for terminating said pulse includes a second sample and hold circuit means for sampling at the end of a sampling period the output of said detecting means representing the highest level attained by said input signal during said sampling period, and second comparator means operatively receiving the x-sweep signal indicating coincidence thereof with the output of said second sample and hold circuit means, said pulse generator means being responsive to the output of said second comparator means for terminating said pulse when the levels of said x-sweep signal and said second sample and hold circuit means output correspond.

4. The system of claim 3, wherein said means for terminating said pulse includes means for slightly offsetting said x-sweep input to said second comparator means relative to the input of said first comparator means such that constant level input signals will result in a control pulse of fixed length.

5. A scanning display for sampled data, comprising a CRT unit including means for generating an electron beam of modulated intensity in accordance with a z-input and means for deflecting said beam in the orthogonal x and the y directions in accordance with x-sweep and y-sweep signals, means for generating said x-sweep signal in the form of a repetitive ramp-like waveform, each repetition of said x-sweep signal defining a sampling period, a pair of peak detector means for registering respectively the highest and lowest relative levels of an input signal during a given sampling period, first gate means for generating a start signal when said x-sweep signal attains a level which corresponds to the output of one of the peak detectors, second gate means for generating a stop signal when said x-sweep signal attains a level which corresponds to the output of said other peak detector, and variable length pulse generator means responsive to said start and stop signals respectively for initiating and terminating a control pulse output to said z-input.

6. The display of claim 5, further comprising transducer means for transmitting a pulse signal synchronized with said x-sweep signal and for producing an output to said z-input indicative of received reflected portions of said transmitted pulse signal.

7. The display of claim 6, further comprising analog pick-up means for furnishing a continuous electrical signal representative of a physiological parameter as said input signal to said peak detector means.

8. The display of claim 6, wherein said transducer is an ultrasonic transducer.

9. The display of claim 8, further comprising a heart sound pick-up means furnishing said input signal.

10. A system for displaying a continuously varying waveform, comprising sampling means for dividing said waveform into sampling periods and detecting the maximum and minimum of said waveform during each of said sampling periods, and graphical display means responsive to the peaks and amplitudes detected by said sampling means for generating a visual indication for each sampling period having a length corresponding to the difference between the maximum and the minimum detected by said sampling means for such sampling period and having a position corresponding to the values of such maximum and minimum.

11. A method of displaying diagnostic data, comprising the steps of detecting and transducing a continuous time-varying parameter to provide an electrical signal representing the value of said parameter, detecting the maximum and minimum value of said electrical signal during each one of consecutive sampling periods, and generating a visual indication for each sampling period having a length corresponding to the difference between the maximum and the minimum detected for a corresponding sampling period and having a position

corresponding to the values of said maximum and minimum.

12. The method of claim 11, wherein said parameter is a physiological parameter.

13. The method of claim 11, wherein said parameter is heart sound.

14. The method of claim 11, further comprising the steps of transmitting a pulse at the start of each sampling period, subsequently receiving within each corresponding sampling period a reflected portion of said transmitted pulse, and generating another visual indication for each sampling period having a position corresponding to the elapsed time from the start of each sampling period to receipt of said reflected portion of said pulse.

15. The method of claim 14, wherein said pulse is an ultrasonic pulse and said parameter is a physiological parameter.

16. The method of claim 15, wherein said parameter is heart sound.

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