

Dec. 9, 1969

R. J. BOUCHARD
INTENSITY CONTROL FOR VECTOR GENERATORS
HAVING UNIFORM VECTOR TRACE TIME

3,482,309

Filed April 28, 1966

2 Sheets-Sheet 1

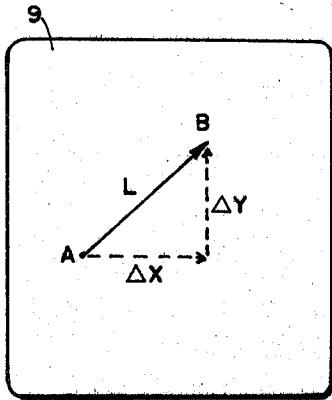


FIG. 1.

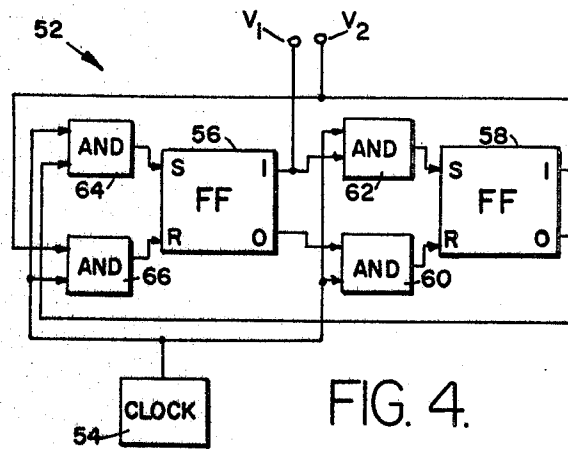


FIG. 4.

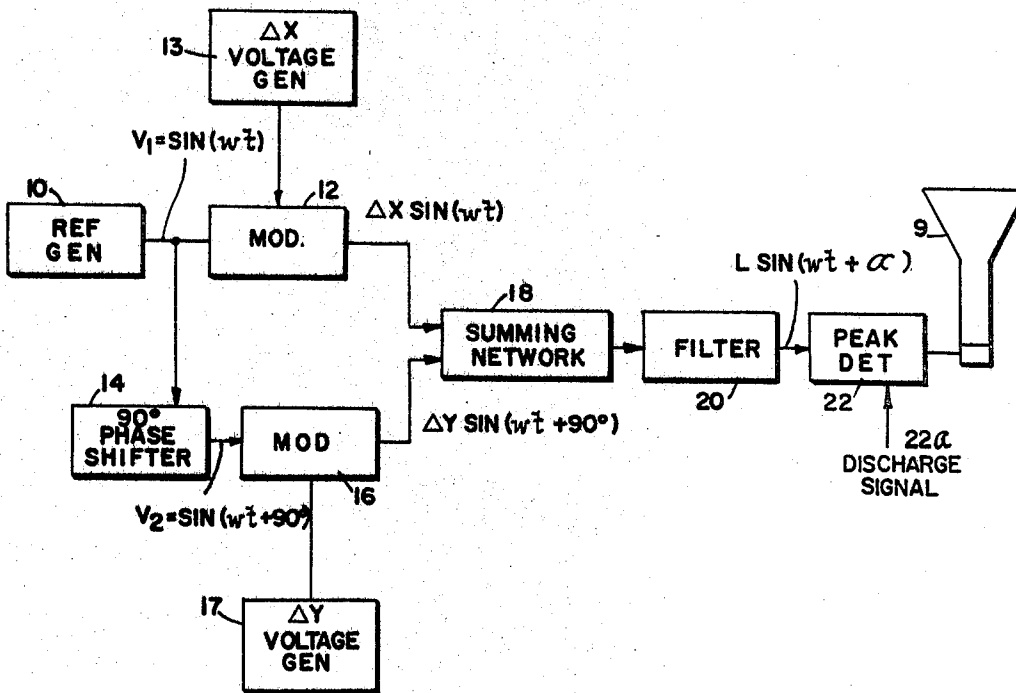


FIG. 2.

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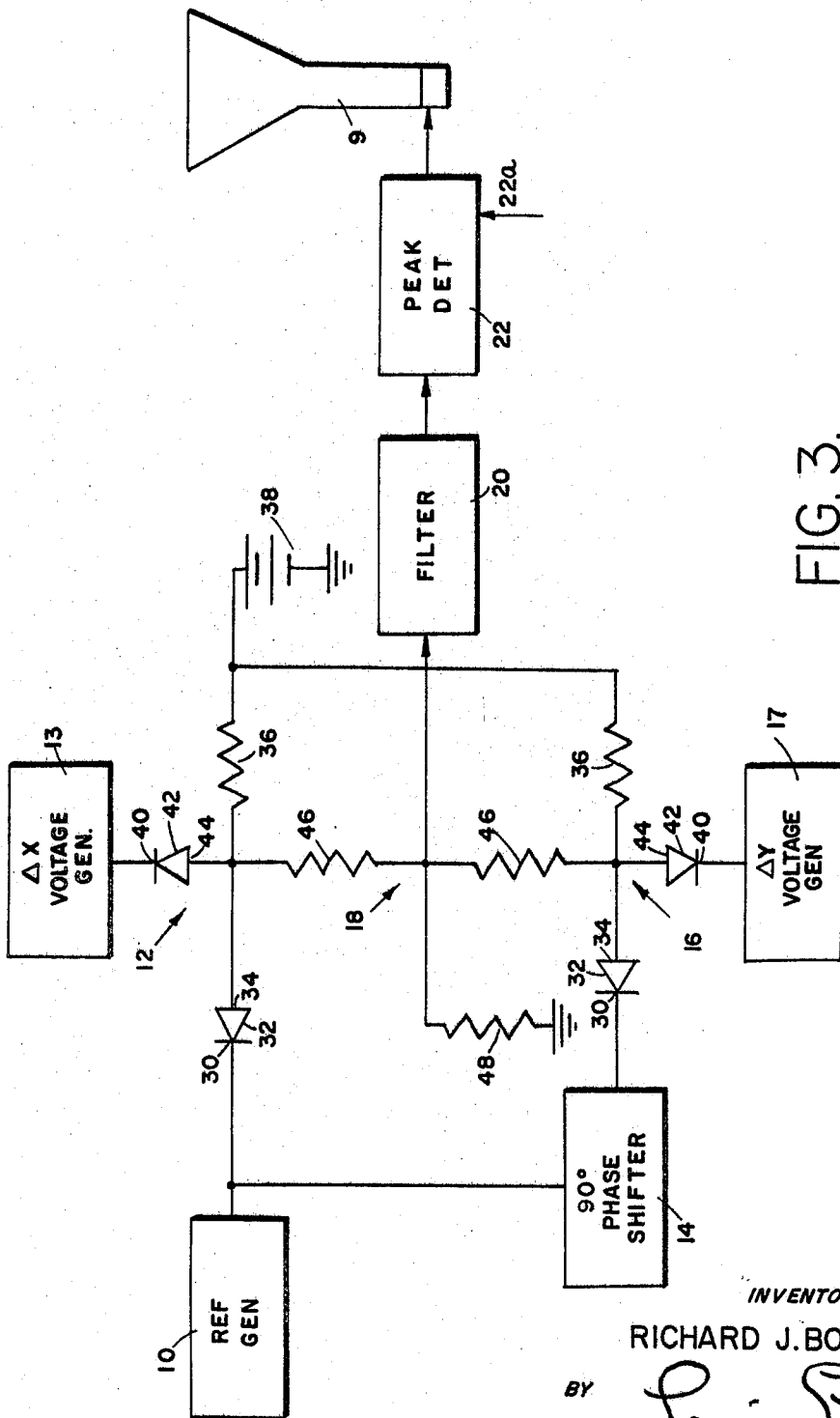


FIG. 3.

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INTENSITY CONTROL FOR VECTOR GENERATORS HAVING UNIFORM VECTOR TRACE TIME

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Filed Apr. 28, 1966, Ser. No. 546,099

Int. Cl. H01j 29/70

U.S. Cl. 315—22

7 Claims

ABSTRACT OF THE DISCLOSURE

An electronic circuit generates an intensity control voltage proportional to the length of the vector to be traced so that all vectors in a given display frame can be traced in uniform time intervals, yet still have uniform intensity. More particularly, the basic concept makes use of the trigonometric equality

$$\Delta X \sin \theta + \Delta Y \cos \theta = \sqrt{\Delta X^2 + \Delta Y^2} \sin \left(\theta + \tan^{-1} \frac{\Delta Y}{\Delta X} \right)$$

where:

ΔX = horizontal vector

ΔY = vertical vector

θ = reference phase angle.

This invention relates to a vector intensity control system. It relates more particularly to an electronic circuit which generates an intensity control voltage proportional to the length of the vector to be traced so that all vectors in a given display frame can be traced in uniform time intervals, yet still have uniform intensity.

In a display system, when vectors are traced during a fixed period of time regardless of their lengths or reference angles, the intensity will vary from vector to vector. This is because the electron beam must move faster in tracing longer vectors than the shorter ones. Accordingly, provision is usually made for applying an intensity control or unblanking voltage to the display tube which varies depending upon the length of the vector to be traced on the tube screen.

To develop the proper control voltage, conventional intensity control systems make use of an approximation of the series expansion:

$$L = \sqrt{\Delta X^2 + \Delta Y^2} = \Delta X + \frac{1}{2} \Delta Y^2 \quad (1)$$

where ΔX and ΔY are the X and Y components of a vector of length L, and ΔX is the larger. These prior systems must first compare the X and Y components of the vector to be drawn, then find one-half the smaller vector component and finally sum the larger component and one-half the smaller component. As such, they are overly elaborate and costly.

Most importantly, however, these conventional systems generate a control voltage which merely approximates the correct one because they take into consideration only the first two terms of the aforesaid series expansion. That approximation produces an error in the intensity control voltage which may be as high as 11% as a vector is rotated through a 360° angle about a point.

Accordingly, the principal object of this invention is to provide a display system for tracing a vector whose intensity is proportional to the length of the vector being drawn.

A further object of this invention is to provide a vector display system having a fast response intensity control circuit.

A further object of this invention is to provide a display system having an intensity control circuit which requires only a relatively few circuit components.

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Another object of this invention is to provide a display system having a vector intensity control circuit which is simple to operate and to adjust.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 illustrates the screen of a display tube on which a vector is drawn;

FIG. 2 is a block diagram of a vector display system embodying the principles of this invention;

FIG. 3 is a schematic diagram showing in more detail the elements of the FIG. 2 system; and

FIG. 4 is a sample of a digital quadrature square-wave generator.

In general, my improved vector display system is an electric circuit that forms two electrical vectors at right angles corresponding to the X and Y components of the vector to be drawn and sums them to obtain the magnitude of the resultant vector, i.e. the length of the vector to be drawn.

Briefly, it generates a pair of alternating-current signals in phase quadrature and modulates each A.C. signal with a D.C. voltage proportional to the X and Y components of the vector to be drawn. This produces a pair of A.C. signals in phase quadrature whose amplitudes correspond to the lengths of the X and Y components, respectively, of that vector. These signals are then summed to produce a single A.C. signal whose amplitude is thus proportional to the length of the vector. This signal can be rectified to provide a D.C. intensity control voltage or unblanking voltage for the display tube which is essentially proportional to the length of the vector to be traced, not a rough approximation. As a general rule, only the amplitude of the resultant vector is obtained. The phase of the signal representing this vector is usually not of interest.

Since the system is completely electronic, it can operate at high frequencies giving very fast response.

Referring to FIG. 1, the vector AB, having length L is to be traced on the display tube 9. The vector AB is the resultant of an X vector component of length ΔX and a Y component of length ΔY . ΔX and ΔY represent the differences between the initial and terminal X coordinates and the initial and terminal Y coordinates, respectively, of vector AB. To provide uniform intensity regardless of the length L, an intensity control or unblanking voltage proportional to the vector length L must be generated and applied to tube 9 while the vector is being traced.

Referring now to FIG. 2, my improved circuit for controlling vector intensity comprises a reference generator 10 which delivers an A.C. signal (V_1) directly to a modulator 12. This signal may be expressed mathematically as

$$V_1 = \sin(\omega t) \quad (2)$$

A direct voltage proportional to the length ΔX of the X component of vector AB is also applied by a voltage generator 13 to modulator 12. The output of the modulator is an alternating voltage whose amplitude is proportional to ΔX and whose phase angle is zero degrees (assuming the phase of the generator 10 as a phase

reference). This signal thus represents the X component of vector AB, that is,

$$\bar{X} = \Delta X \sin(\omega t) \quad (3)$$

The output (V_1) of generator 10 is also fed via a fixed 90° phase shifter 14 to a similar modulator 16. The voltage (V_2) applied to the modulator 16 is thus given by

$$V_2 = \sin(\omega t + 90^\circ) \quad (4)$$

A second direct voltage proportional to the length ΔY of the Y component of vector AB is also coupled from a voltage generator 17 to modulator 16. The output of modulator 16, is therefore, an alternating voltage representative of the Y component of the vector AB, that is,

$$\bar{Y} = \Delta Y \cos(\omega t) \quad (5)$$

Electrical signals corresponding to the X and Y components are conventionally developed in display systems to provide the corresponding X and Y deflection fields required to trace out the vector AB. The generators 13 and 17 represent those portions of the system that develop these signals.

The outputs of both modulators 12 and 16 are fed to a summing network 18 which sums the two signals and, in accordance with well-known principles, produces a single A.C. voltage representative of the resultant voltage V_3 . V_3 , which is the analog of the vector AB, is related to V_1 and V_2 by

$$V_3 = \sqrt{\Delta X^2 + \Delta Y^2} \sin(\omega t + \alpha) \quad (6)$$

where

$$\alpha = \tan^{-1} \frac{\Delta Y}{\Delta X}$$

The quantity $\sqrt{\Delta X^2 + \Delta Y^2}$ which is the amplitude of V_3 is also the analog of L, the length of the vector AB. Specifically, L is related to ΔX and ΔY by the same expression.

The output of the summing network 18 is coupled to a filter 20 which filters out unwanted harmonics and then to a peak detector 22. The output of the peak detector is thus a direct voltage which is proportional to the length L of vector AB. The voltage is then applied as an intensity control voltage to cathode ray tube 9. Thus, the system displays vectors with electron beam intensities proportional to the vector lengths. Since all vectors are displayed in equal time intervals, they therefore have equal optical intensities on the screen of the tube 9.

Refer now to FIG. 3 which illustrates in greater detail the elements of my system. The reference generator 10 should be crystal-controlled for accuracy. Also, desirably it generates signals having a square wave form so that the circuit may employ the simple diode modulators 12 and 16 to be described presently.

The signal from generator 10 is coupled to the cathode 30 of a diode 32 in modulator 12. Anode 34 of diode 32 is connected via biasing resistor 36 to a positive voltage source illustrated by the battery 38.

A direct voltage proportional to the length ΔX of the X vector component (FIG. 1) is developed by voltage generator 13 and applied to the cathode 40 of a diode 42. The anode 44 of diode 42 is connected to anode 34 and to ground by ways of summing resistors 46 and 48.

Assume that the voltage of battery 38 is greater than the voltage applied to the cathode 40 of diode 42 and that the latter voltage is positive. Also assume that the square-wave signal from generator 10 varies between ground and a positive voltage greater than the voltage applied to cathode 40. With the arrival of the square-wave signal from generator 10, the potential at the junction of anode 44 and resistor 46 varies between ground and the voltage, representing length ΔX , applied to the cathode 40. The diode 32 is identical to diode 42 so as to compensate for the voltage drop across diode 42.

The square-wave signal from reference generator 10 is also applied to the fixed 90° phase shifter 14. Phase shifter 14 is conveniently a conventional delay element. For example, it may take the form of a delay line or a pair of cascaded one-shot multivibrators. The modulator 16 is identical to modulator 12 and functions in the same way, except that it modulates its input according to the voltage, proportional to the length ΔY (FIG. 1), developed by voltage generator 17.

The summing network 18, comprising resistors 46 and 48, sums the two out-of-phase modulator outputs, weighting them equally and producing a single square-wave output voltage including both a fundamental frequency and higher harmonics. The magnitude of this signal is proportional to the length L of vector AB as given by Equation 6.

This signal is coupled to a conventional band pass or low pass filter 20. Filter 20 should eliminate all but the fundamental component of the modulated square-wave, since the phase shift imparted by the phase shifter 14 is referenced to the fundamental. Alternatively, the phase shift may be accomplished in terms of another component, with the filter 20 passing that component. However, the fundamental frequency will usually be chosen because it is the strongest signal component. In any event, the band pass of filter 20 should be as wide as possible, while still rejecting unwanted components, so as to minimize the filter time constant and thereby give the system a fast response at the chosen operating frequency.

The output of filter 20 is a sinusoidal signal whose amplitude is the analog of the length L of the vector AB (FIG. 1). The output of peak detector 22 is thus a direct voltage proportional to length L. This voltage is then applied as an unblanking voltage to display tube 9. It is, however, equally useful as an intensity control voltage for other types of display elements, such as an X-Y recorder, for example. Also, of course, a conventional voltage amplifier and a suitable offset circuit may, if needed, be included between detector 22 and tube 9.

The speed of my control system depends upon the frequency of the reference generator 10 and the time constants of the filter 20 and peak detector 22.

Since there is a finite response time for my intensity control system, the voltage proportional to the vector lengths ΔX and ΔY should be present before the vector AB is traced on the tube 9. In the case of a display system employing the square-wave carrier signal described above, the system preferably synchronizes the drawing of vector AB with the signal from generator 10 so that detector 22 develops an intensity control voltage as soon as the vector starts to be drawn. However, before the control voltage can be developed, the ΔX and ΔY modulated voltages must both be present. Therefore, if for example, the vector start is synchronous with the start of the positive going portion of the generator 10 signal, the maximum delay time before a sample is taken is 1/4 cycle (i.e. the time until the positive going portion of the signal is applied to modulator 16).

If, on the other hand, the vector start is synchronous with the end of the negative going portion of the generator 10 signal, the maximum sampling delay is 1/2 cycle (i.e. the time until the next positive going portion of the generator 10 signal). The desirability of prompt development of the control voltage is also the principal reason for employing peak detector 22. The peak detector by the nature of the function it performs inherently has a fast rise but slowly decay time. If a string of vectors is to be drawn, the new decay time is not desirable. To overcome this situation, a discharge signal 22a is applied to the peak detector at the end of the vector draw time. Other components for developing the control voltage, such as an averaging circuit, for example, may require several cycles of the generator 10 signal to develop the proper control voltage. This would unduly limit the response time of the system.

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As noted above, the voltage generators 13 and 17 are meant to include any element capable of producing voltages proportional to the vector component lengths ΔX and ΔY . In a typical display system, for example, ΔX and ΔY may be stored in digital form in a suitable memory and then converted to analog form (i.e. voltages) and applied to modulators 12 and 16 as described above.

Also, the quadrature square-waves applied to the modulators 12 and 16 may be generated digitally. FIG. 4 illustrates such a digital quadrature square-wave generator indicated generally at 52. It comprises a conventional clock 54 and a pair of flip-flops 56 and 58. The ZERO and ONE output terminals of flip-flop 56 are connected via AND gates 60 and 62 to the RESET and SET input terminals respectively of flip-flop 58. Conversely, the ZERO and ONE output terminals of flip-flop 58 are connected via AND gates 64 and 66 to the SET and RESET input terminals respectively of flip-flop 56. The signal from clock 54 constitutes the other input for each of the AND gates 60-66. Successive pulses from clock 54 step the flip-flop so that square-wave voltage V_1 and V_2 in phase quadrature appear at the ONE output terminals of the flip-flop 56 and 58 respectively. If the intensity control system employing generator 52 is to have a one megacycle carrier signal, then the clock 54 should operate at a four megacycle rate.

Referring again to FIG. 3, I have shown a vector display system having an intensity control circuit employing a reference or carrier signal having a square waveform because this permits use of simple diode modulators in the circuit. Thus, the circuit generally must include a filter 20 to eliminate unwanted harmonics from the output of the summing network 18. Such filtering is not necessary if generator 10 generates a sinusoidal signal. But in that event, conventional modulators must be used which are more complex than the modulators shown here.

Thus, it will be apparent from the foregoing that my simple, all-electronic vector display system offers a vastly improved technique for controlling the intensity of vectors traced in uniform time intervals. It quickly develops a voltage which is exactly proportional to the length of the vector to be traced and applies it as a control to the display element while the vector is being formed. As a result, the system maintains extremely accurate intensity control over all vectors in a display whatever their lengths or reference angles.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A vector display system comprising,
 - (A) means for displaying said vector,
 - (B) means for producing a first alternating-current signal whose amplitude is proportional to the length of a first component of said vector,
 - (C) means for producing a second alternating-current signal,
 - (1) in phase quadrature with said first signal, and
 - (2) whose amplitude is proportional to the length of a second component of said vector,
 - (D) means for summing said signals, thereby producing a third alternating-current signal whose amplitude is proportional to the length of said vector, and
 - (E) means for applying said third signal as an intensity control to said display means.
2. A vector display system as defined in claim 1, wherein

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- (A) said first signal is one component of a plurality of components of a first carrier signal,
 - (B) said second signal is the corresponding component of a plurality of components of a second carrier signal, and further including
 - (C) means for removing said plurality of components except said one component and said corresponding component of said carrier signals from said third signal.
3. A vector display system comprising,
 - (A) means for displaying a vector,
 - (B) means for producing a pair of alternating-current signals in phase quadrature,
 - (C) means for modulating one of said signals with a voltage proportional to the length of a first component of said vector,
 - (D) means for modulating the other of said signals with a voltage proportional to the length of a second component of said vector, said second vector component being orthogonal to said first vector component,
 - (E) means for summing said modulated signals, thereby obtaining a third alternating-current signal whose amplitude is proportional to the length of said vector, and
 - (F) means for applying a voltage proportional to the amplitude of said third signal to said display means as an intensity control therefor.
 4. A vector display system for displaying vectors traced in uniform time intervals comprising
 - (A) a vector display means,
 - (B) an oscillator,
 - (C) processing means connected to receive the output from said oscillator, said processing means including,
 - (1) a first modulator,
 - (2) means for applying a first voltage proportional to the length of a first component of one of said vectors to said first modulator thereby producing an output which includes a first alternating-current component whose amplitude is proportional to said length of said first vector component,
 - (3) a second modulator,
 - (4) means for applying a second voltage proportional to the length of a second component of said one of said vectors to said second modulator, said second vector component being orthogonal to said first vector component, thereby producing an output which includes a second alternating-current component whose amplitude is proportional to said length of said second vector component, and
 - (5) means for producing a 90° phase difference between said alternating-current components,
 - (D) means for summing said alternating-current components so as to produce a single alternating-current signal whose amplitude is proportional to the length of said one of said vectors, and
 - (E) means coupled between said summing means and said display means for detecting said single signal and applying the voltage out of said detecting means to said display means as an intensity control therefor.
 5. A vector display system as defined in claim 4 including filter means for eliminating all but said single signal from the input to said detecting means.
 6. A vector display system as defined in claim 4 wherein said detecting means comprises a peak detector.
 7. A vector display system as defined in claim 4 and further including
 - (A) means for generating said first voltage,
 - (B) means for generating said second voltage and wherein
 - (1) said oscillator generates a signal having a square waveform, and
 - (2) said processing means comprises

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- (a) means for clamping the amplitude of said square-wave signal to said first voltage, and
 (b) means for clamping the amplitude of said square-wave signal to said second voltage.

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