NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

MAY 1 1974

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	: 3,803,445
Government or Corporate Employee	: U.S. Government
Supplementary Corporate Source (if applicable)	: —
NASA Patent Case No.	: ARC-10,071-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES [ ] NO [X]

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Bonnie L. Woerner

Bonnie L. Woerner
Enclosure

United States Patent [19]

Wagner

[11] **3,803,445**

[45] **Apr. 9, 1974**

[54] **ROTATING RASTER GENERATOR**

[75] Inventor: **Charles A. Wagner,** Edwards, Calif.

[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration,** Washington, D.C.

[22] Filed: **Nov. 17, 1972**

[21] Appl. No.: **307,727**

[52] **U.S. Cl.** **315/18,** 315/22, 178/7.7

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search** .... 315/18, 22, 23, 24; 178/7.7, DIG. 35

[56] **References Cited**

UNITED STATES PATENTS

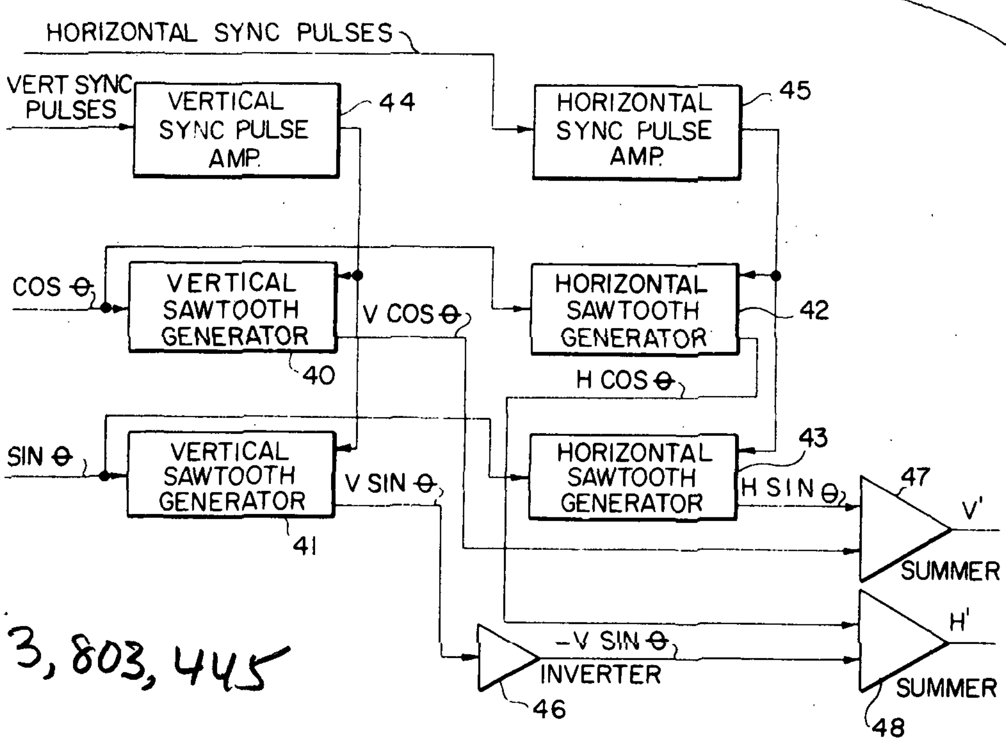
3,459,991	8/1969	Harrison	315/18
3,471,742	10/1969	Kendall et al.	315/18
3,590,309	6/1971	Berg	315/18
3,641,260	2/1972	Herndon	315/24 X
3,700,792	8/1972	Harrison et al.	315/18 X
3,720,860	3/1973	Wadlow	315/24 X

Primary Examiner—Carl D. Quarforth
Assistant Examiner—P. A. Nelson
Attorney, Agent, or Firm—Darrell G. Brekke; Armand G. Morin, Sr.; John R. Manning

[57] **ABSTRACT**

A rotating raster generator is provided which enables display of a television raster at any arbitrary roll angle. The generator includes four integrator circuits each of which receives a first voltage input corresponding to the sine or cosine of the desired roll angle and a second input comprising conventional horizontal or vertical sync pulses. The integrator circuits form the product of the sine or cosine inputs thereto with the conventional deflection control voltages (describing a normal non-rolled raster), using integration techniques, to generate four zero-centered sawtooth outputs which when summed algebraically in pairs produce horizontal and vertical deflection control voltages corresponding to desired roll angle. The integrator circuits each comprise an operational amplifier and a capacitor connected thereacross for producing a ramp output having a rate of change proportional to the roll angle input (sinθ or cos θ) thereto, an electronic switch responsive to the sync input (horizontal or vertical) for resetting the integrator, and a summer that adds the ramp output of the integrator to the roll angle input so as to provide a zero-centered deflection control voltage.

2 Claims, 8 Drawing Figures



BLOCK DIAGRAM OF ROTATING RASTER GENERATOR

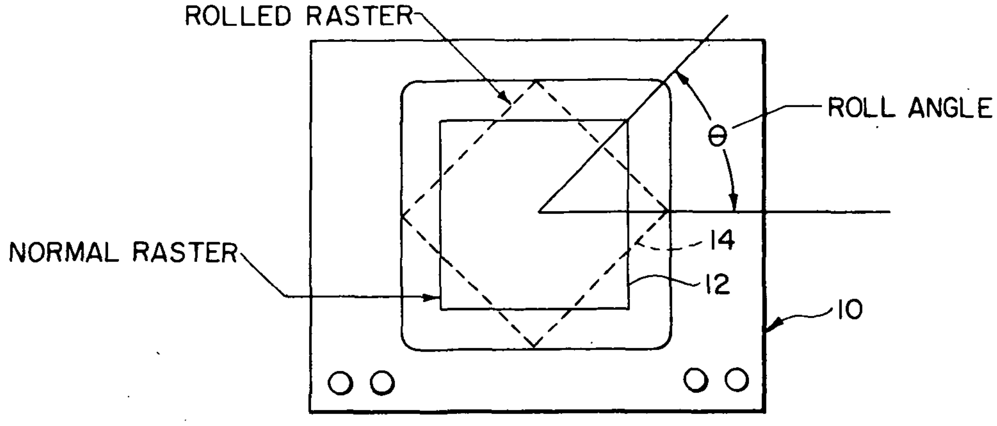

ROLLED RASTER
ROLL ANGLE
θ
NORMAL RASTER
14
12
10

FIG. 1

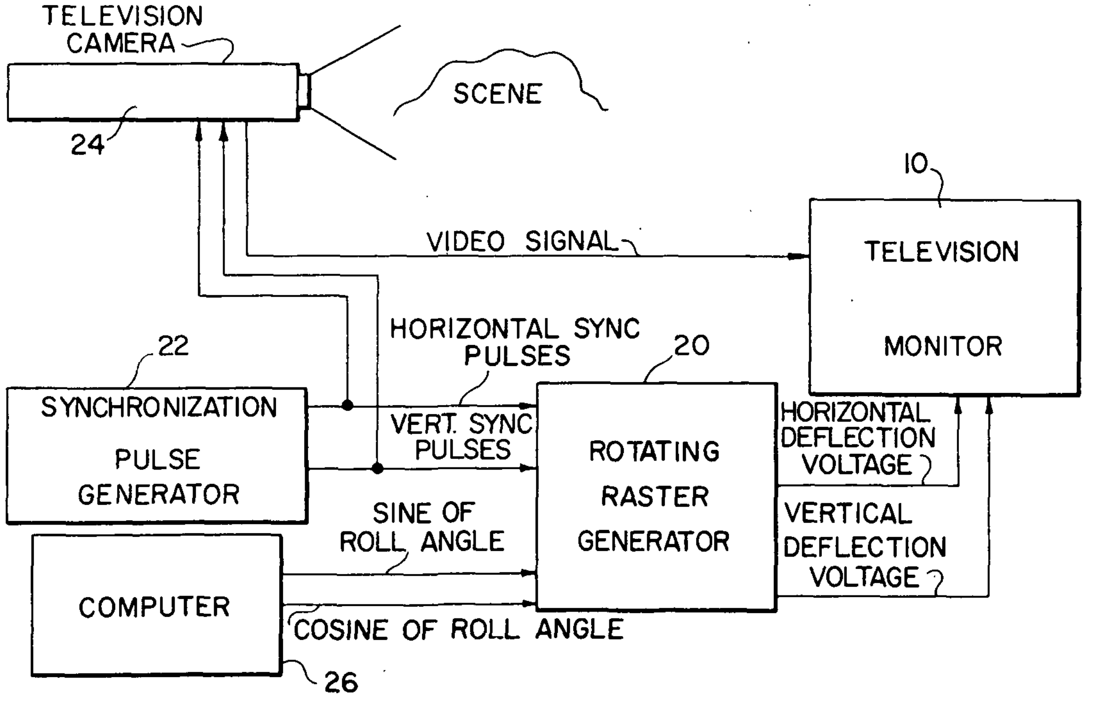
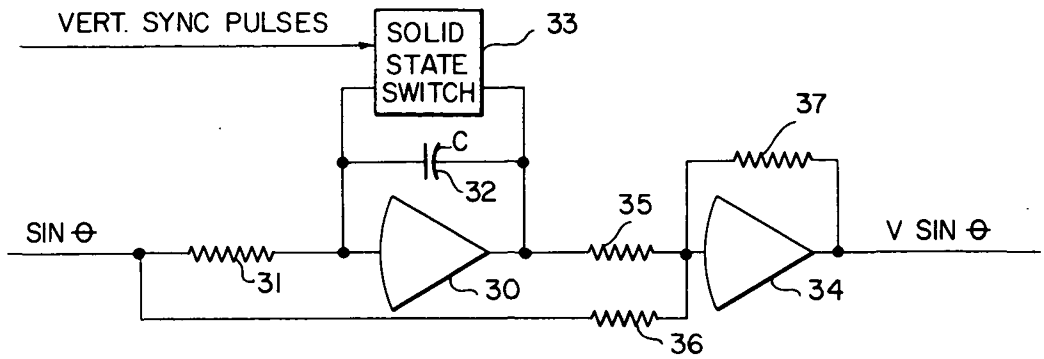
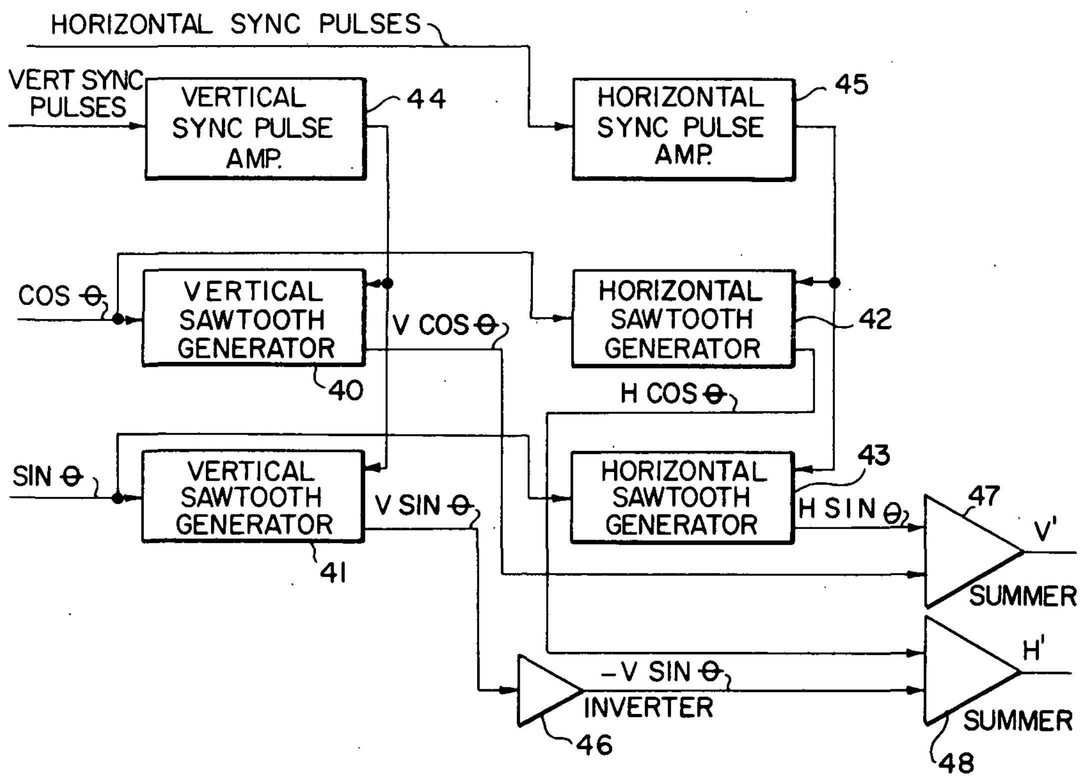

TELEVISION CAMERA
SCENE
24
10
VIDEO SIGNAL
TELEVISION MONITOR
HORIZONTAL SYNC PULSES
22
20
SYNCHRONIZATION PULSE GENERATOR
VERT. SYNC PULSES
ROTATING RASTER GENERATOR
HORIZONTAL DEFLECTION VOLTAGE
SINE OF ROLL ANGLE
VERTICAL DEFLECTION VOLTAGE
COMPUTER
COSINE OF ROLL ANGLE
26

FIG. 2



SAWTOOTH GENERATOR

FIG. 3



BLOCK DIAGRAM OF ROTATING RASTER GENERATOR

FIG. 4

FIG. 5a

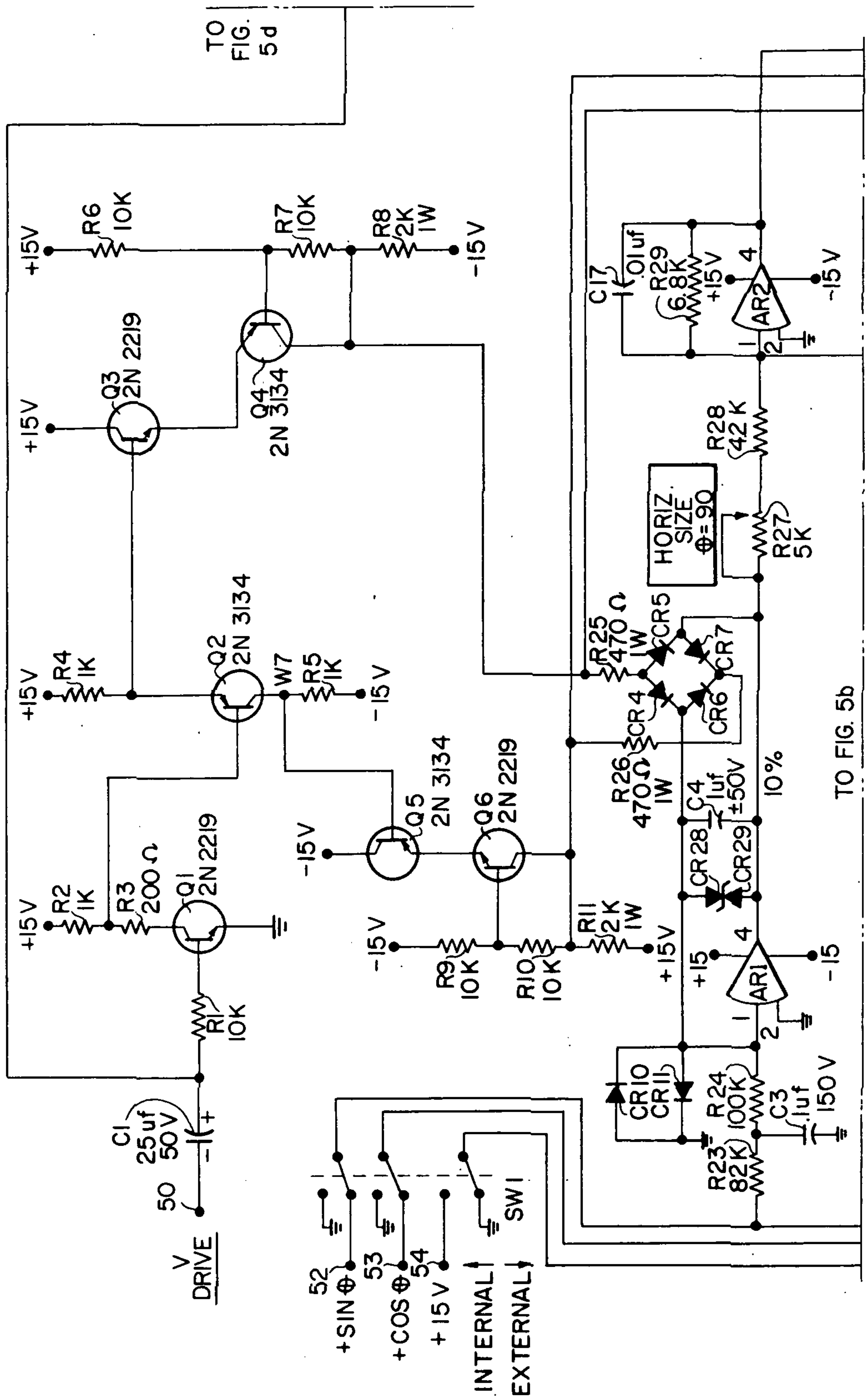

TO FIG. 5d
TO FIG. 5b
V DRIVE
50
C1 25uf 50V
R1 10K
Q1 2N 2219
R2 1K
R3 200Ω
Q2 2N 3134
W7
R4 1K
R5 1K
Q3 2N 2219
Q4 2N 3134
R6 10K
R7 10K
R8 2K 1W
Q5 2N 3134
Q6 2N 2219
R9 10K
R10 10K
R11 2K 1W
R25 470Ω 1W
R26 470Ω 1W
CR4
CR5
CR6
CR7
C4 1uf ±50V
CR28
CR29
10%
HORIZ. SIZE Φ=90
R27 5K
R28 42K
R29 6.8K
C17 .01uf
AR1
AR2
R23 82K
R24 100K
C3 .1uf 150V
CR10
CR11
SW1
52 +SIN Φ
53 +COS Φ
54 +15V
INTERNAL
EXTERNAL
+15V
-15V

FIG. 5b

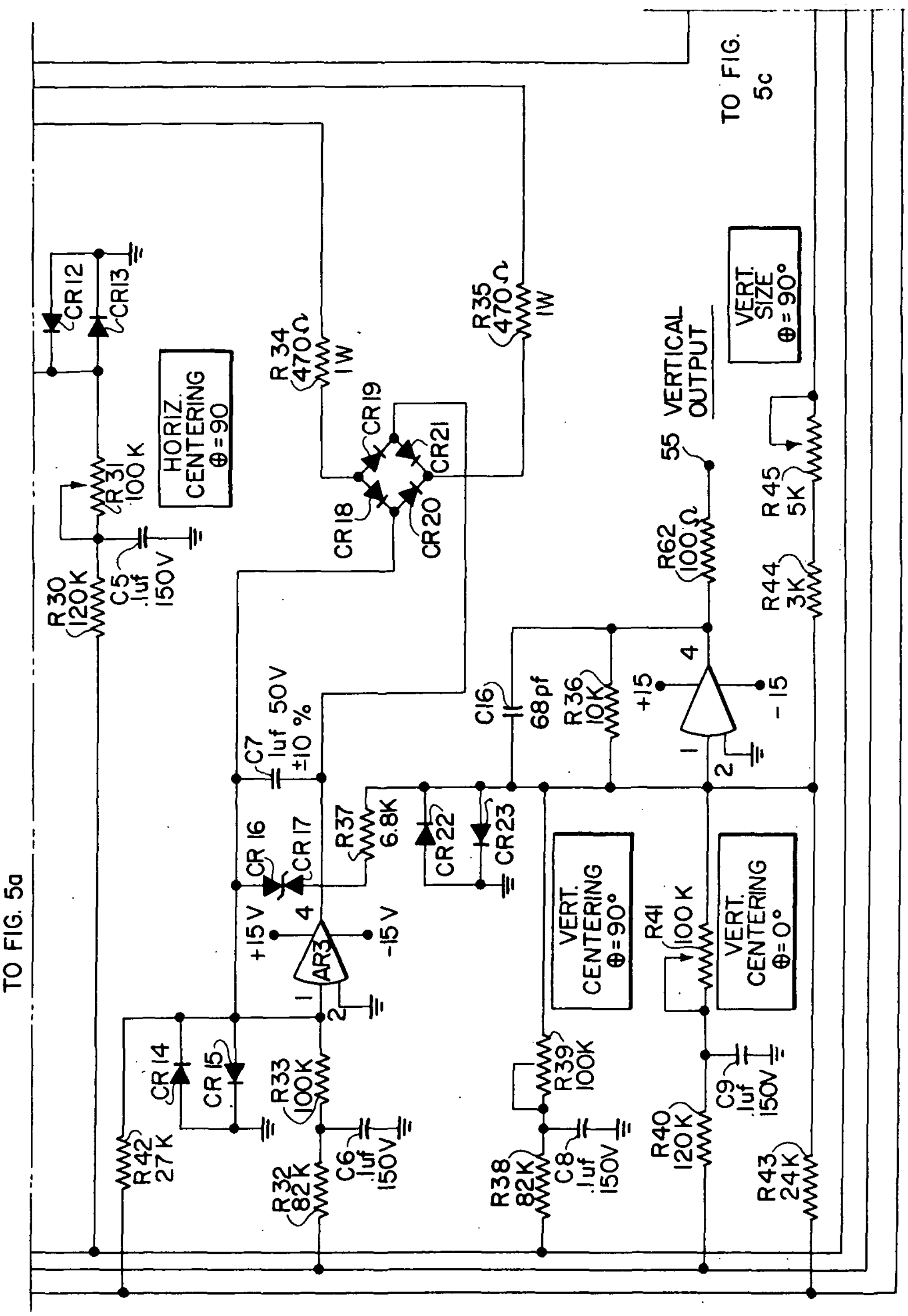
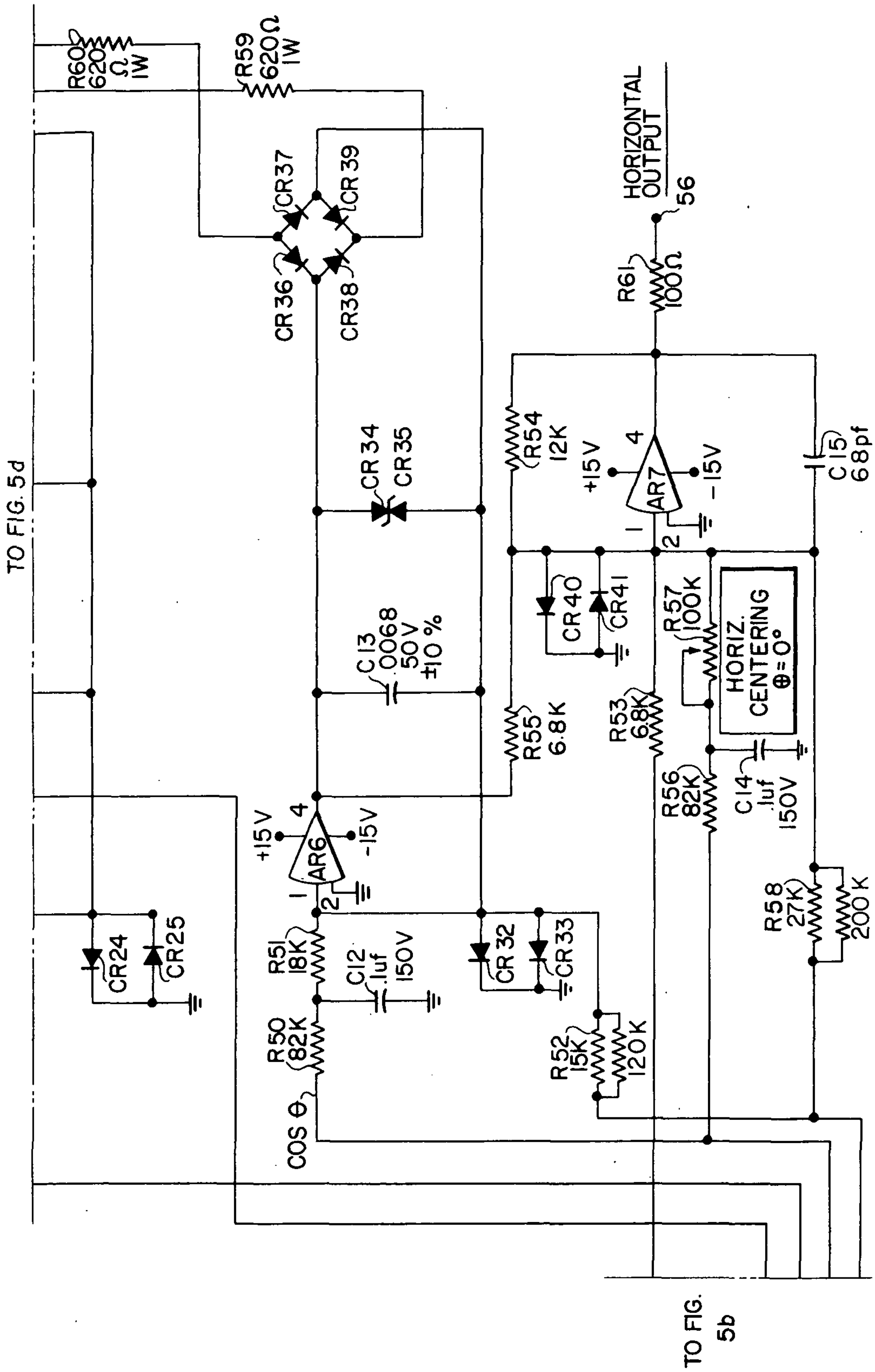

TO FIG. 5a
TO FIG. 5c
CR12
CR13
HORIZ. CENTERING Θ=90
R31 100K
R30 120K
C5 .1uf 150V
R34 470Ω 1W
R35 470Ω 1W
CR18
CR19
CR20
CR21
C7 1uf 50V ±10%
CR16
CR17
R37 6.8K
AR3
+15V
-15V
4
1
2
CR14
CR15
R42 27K
R33 100K
R32 82K
C6 .1uf 150V
CR22
CR23
C16 68pf
R36 10K
VERT. CENTERING Θ=90°
R41 100K
VERT. CENTERING Θ=0°
R39 100K
R38 82K
C8 .1uf 150V
R40 120K
C9 .1uf 150V
R43 24K
+15
-15
55 VERTICAL OUTPUT
R62 100Ω
R44 3K
R45 5K
VERT. SIZE Θ=90°

FIG. 5c


R60 620 Ω 1W
R59 620Ω 1W
CR37
CR39
CR36
CR38
HORIZONTAL OUTPUT
56
R61 100Ω
CR 34 CR 35
R54 12K
4
+15V
AR7
-15V
1
2
C 15 68pf
CR 40
CR41
R 57 100K
HORIZ. CENTERING Θ=0°
C 13 .0068 50 V ±10 %
R55 6.8K
R53 6.8K
C14 .1uf 150V
R56 82K
TO FIG. 5d
+15V
4
AR6
-15V
1
2
R58 27K
200 K
CR24
CR25
R51 18K
C12 .1uf 150V
CR 32
CR 33
R50 82K
R52 15K
120K
COS Θ
TO FIG. 5b

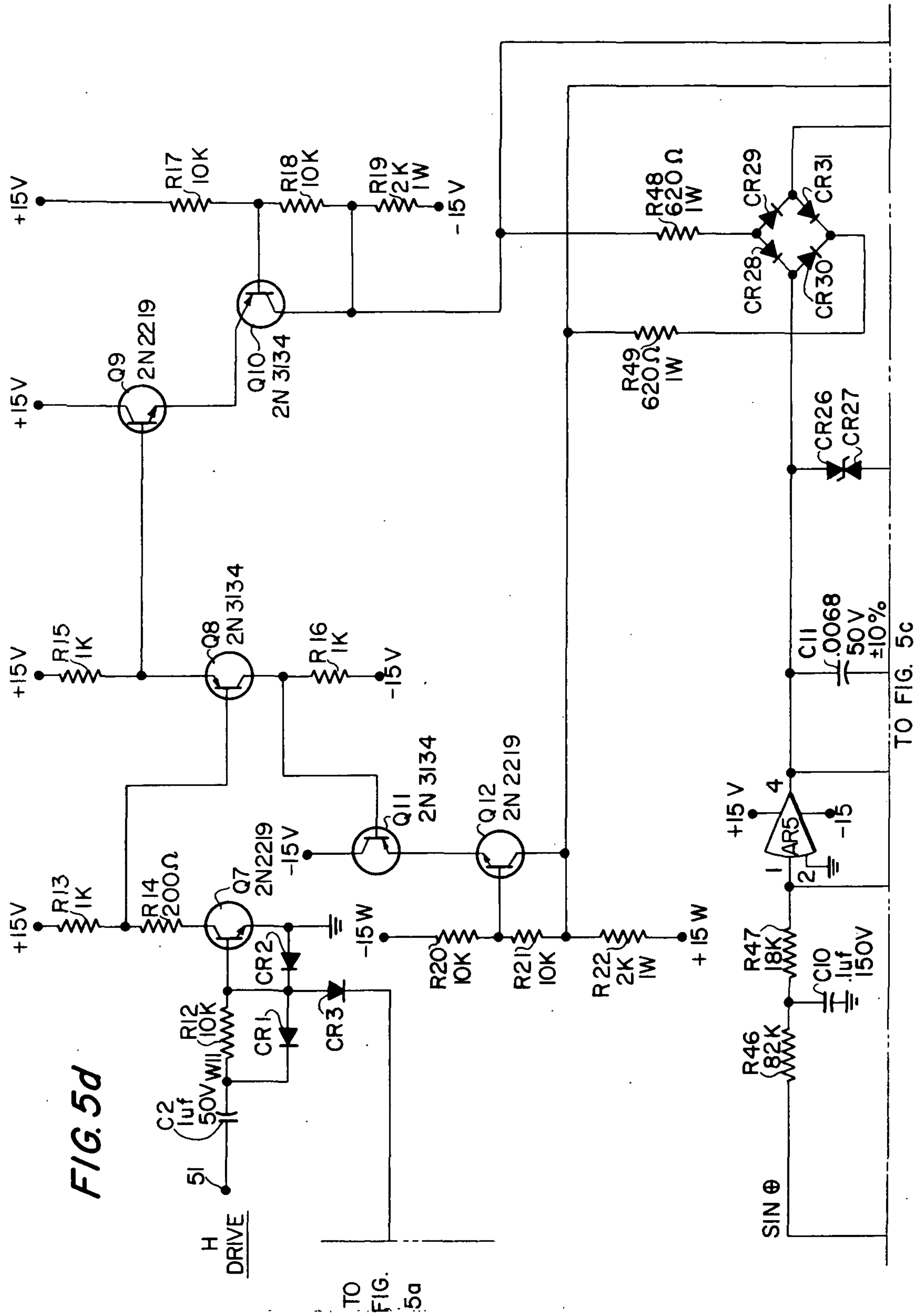

+15V
R17 10K
R18 10K
R19 2K 1W
-15 V
Q9 2N2219
Q10 2N 3134
R15 1K
Q8 2N 3134
R16 1K
-15V
R13 1K
R14 200Ω
Q7 2N2219
R12 10K
W11
CR2
CR1
CR3
C2 1uf 50V
51
H DRIVE
TO FIG. 5a
Q11 2N 3134
Q12 2N 2219
-15W
R20 10K
R21 10K
R22 2K 1W
+15W
R48 620Ω 1W
R49 620Ω 1W
CR28
CR29
CR30
CR31
CR26
CR27
C11 .0068 50V ±10%
TO FIG. 5c
AR5
-15
R47 18K
C10 .1uf 150V
R46 82K
SIN θ

FIG. 5d

ROTATING RASTER GENERATOR

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

FIELD OF THE INVENTION

The present invention relates to generators which produce television rasters which can be displayed at an angle with respect to horizontal and visual simulation systems incorporating such generators.

BACKGROUND OF THE INVENTION

A number of techniques are known which are capable of producing television rasters which can be displayed at an arbitrary "roll angle," that is, at an arbitrary angle with respect to a horizontal reference as viewed on a television monitor. One application of such a technique is in the field of flight simulation. Specifically, where a flight simulator includes a television display to represent the view through the windshield to the pilot trainee, by introducing a roll angle into the display, banking of the aircraft can be simulated.

Raster rotation has been accomplished by physically rotating the deflection yoke around the neck of the cathode ray tube using a servo motor. Further, in one type of visual flight simulator which utilizes a television projector, raster rotation is accomplished by physically rotating the entire projector assembly with a large servo motor. It will be appreciated that these mechanical techniques suffer a number of disadvantages and, in particular, cannot produce roll motions which are sufficiently fast, smooth and free from lag so as to be suitable for the more demanding types of flight simulation problems.

A further television raster generator that merits attention here is that disclosed in U.S. Pat. No. 3,379,833 (Hecker et al.). The purpose of the controllable raster generator disclosed in the Hecker et al. patent is to produce raster signals that are externally controllable in position, size, shape and display, i.e., roll angle. The raster generator disclosed in the Hecker et al patent operates in response to an analog voltage proportional to roll angle and is, therefore, limited in the magnitude of roll angle that can be produced, the generator apparently being intended to provide relatively small adjustments in the raster roller angle. Structurally, the raster generator of the Hecker et al patent includes integrators which receive appropriate pulses from which sawtooth waveforms are generated. The roll angle control signals are produced by adding field rate pulses and line rate pulses in a single integrator for X-deflection and by performing a similar addition in another integrator for Y-deflection.

SUMMARY OF THE INVENTION

In accordance with the present invention, a rotating raster generator is provided which electronically generates a television raster which can be displayed at any arbitrary roll angle and can produce continuous roll angles of any magnitude. The rotating raster generator also overcomes the disadvantages of the mechanical techniques discussed above. For example, the roll motions produced thereby are inherently perfectly smooth and the roll rate can be so high that the eye cannot follow the motion. Further, there is no lag between the roll command and the roll angle of the display. The rotating raster generator of the invention can be used equally well with both television projectors and television monitors with the proviso discussed below that the projector or monitor have a non-resonant deflection circuit.

According to a presently preferred embodiment thereof, the rotating raster generator of the invention comprises first, second, third and fourth integrators each of which receives a first voltage input corresponding to the sine or cosine of the desired roll angle and a second input comprising conventional horizontal or vertical sync pulses. The integrators convert these inputs into outputs which are added to produce horizontal or X-deflection and vertical or Y-deflection control signals in a manner described hereinafter.

The integrator circuits actually serve to multiply the sine or cosine inputs thereto with the conventional sawtooth voltages, using integration techniques, each circuit advantageously comprising an operational amplifier with a capacitor and an electronic switch connected thereacross. Considering the integrator circuit which receives vertical sync pulses and sinc θ voltage input (where θ is the roll angle), the sine θ input is applied to the operational amplifier which together with the capacitor acts as integrator having a rate of integration proportional to sin θ and hence produces a corresponding ramp. The sync pulses control switching of the electronic switch which, when triggered, discharges the capacitor and resets the integrator to zero. At the end of a sync pulse, the integrator again produces the ramp so that a sawtooth is generated. To center this ramp around zero, a variable bias is supplied by using a summer to add the sin θ signal to the output of the operational amplifier so as to produce a resultant zero-centered sawtooth equal to $V \sin \theta$, where V is the conventional vertical sawtooth corresponding to a non-rolled raster. The remaining integrator circuits produce $V \cos \theta$, $H \sin \theta$ and $H \cos \theta$ outputs and as explained hereinbelow suitable algebraic addition of pairs of these signals produces horizontal and vertical deflection control signals.

Other features and advantages of the invention will be set forth in or apparent from the detailed description of a preferred embodiment found hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a schematic representation of a television monitor, used in illustrating the term "roll angle;"

FIG. 2 is a block diagram of a television visual simulation system incorporating the rotating raster generator of the invention;

FIG. 3 is a schematic circuit diagram of a sawtooth generator utilized in the rotating raster generator of the invention;

FIG. 4 is a block diagram of the rotating raster generator of the invention; and

FIGS. 5*a* to 5*d*, taken together, are a schematic circuit diagram of the rotating raster generator of the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

As stated hereinabove, the rotating raster generator of the invention is capable of electronically generating a television raster which can be displayed at any arbitrary roll angle. To aid in familiarizing the reader with the term "roll angle," reference is made to FIG. 1 which schematically depicts a television monitor generally denoted **10.** The normal raster presented by the monitor **10** is indicated in solid lines at **12** whereas a rolled or rotated raster is indicated in dashed lines at **14.** The roll angle, i.e., the angle between the normal raster **12** and the rolled raster **14,** is denoted θ.

Referring to FIG. **2,** the raster generator of the invention, which is represented by block **20,** is shown as a component in an exemplary television system capable of utilizing the raster generator. This system includes a synchronization pulse generator **22** which provides precision timing pulses for controlling the scans of a television camera **24** and the display device, and assuring that these scans remain synchronized with one another. Camera **24,** of course, provides the video signal which ultimately modulates the brightness of the picture on the face of the picture tube or CRT (not shown) of television monitor **10,** as is indicated by the connection between camera **24** and monitor **10.** The horizontal and vertical pulses produced by pulse generator **22** are also applied to rotating raster generator **20** which, in addition, receives signals corresponding to the sine and cosine of the roll angle from the device in the system which produces the roll angle command signals and which is shown here as a computer **26.** As described in more detail hereinbelow, raster generator **20** electronically generates first and second voltage signals which control horizontal and vertical deflection and, in particular, command the scan on the CRT face of monitor **10** in such a manner that the picture appears at the desired roll angle θ.

With the obvious exception of the raster generator **20,** the devices shown by the various blocks can take conventional forms and suitable devices for performing the functions discussed are readily available on the market. However, it should be noted that the monitor **10** is different from conventional monitors insofar as the deflection system is concerned. Specifically, conventional television monitors utilize resonant deflection systems wherein the deflection yoke and deflection amplifier constitute a tuned circuit that oscillates at the appropriate scanning frequency and which cannot oscillate at frequencies off resonance. It will be appreciated that such a deflection system will not follow an arbitrary input and hence, as perhaps will become more clear later, will not work with the rotating raster generator of the invention. Hence, monitor **10** incorporates a non-resonant deflection circuit. Monitors incorporating non-resonant deflection systems which are suitable for displaying television rasters are also commercially available.

Before proceeding with a discussion of the specific embodiment of the rotating raster generator of the invention, it might be helpful to investigate background equations associated with the operation of the generator of the invention. A television raster can be characterized in terns of the vertical and horizontal coordinates of the scanning spot. If the origin of the coordinate system is taken to be the center of the raster, a scanning spot tracing out a conventional raster, i.e., one that has zero roll angle, has vertical and horizontal position coordinated which vary in a sawtooth fashion. Thus, in a standard 525 line television, the vertical coordinate is a 60 Hz sawtooth and the horizontal coordinate is a 15,750 Hz sawtooth. For purposes of discussion, the conventional vertical coordinate sawtooth is denoted V and the conventional horizontal coordinate sawtooth is denoted H. If the scanning spot is tracing out a raster which is rolled through an angle θ such as shown in FIG. **1,** the corresponding vertical and horizontal coordinates, denoted V' and H', are no longer of simple sawtooth form and may be described by the following equations:

$$V' = V \cos \theta + H \sin \theta$$

$$H' = H \cos \theta - V \sin \theta$$

The rotating raster generator of the invention computes V' and H' by using a multiplying by integration technique. This technique can be understood by referring to FIG. **3,** which shows a sawtooth generator including an integrator circuit formed by a first operational amplifier **30** connected in series with an input resistor **31** and in parallel with a capacitor **32,** the circuit so formed providing a rate of integration proportional to the sin θ input. For all practical purposes, the signal sin θ can be considered to be constant over a period of one vertical field, i.e., 1/60 seconds, and thus the voltage at the output of amplifier **30** is a linear ramp which starts at zero. A solid state switch **33** is connected parallel with capacitor **32** and is triggered at the end of the vertical field by a vertical sync pulse as indicated. When triggered, switch **33** discharges capacitor **32** and resets the integrator circuit to zero. At the end of the sync pulse, the integrator repeats the production of the ramp. The output of operational amplifier **30** is a sawtooth but one which is not centered around zero. Further, because the amplitude of the sawtooth so produced varies, the amount of bias necessary to center the sawtooth around zero also varies. The required variable bias is provided by the sin θ input signal itself, this signal being added to the output of amplifier **30** in the summing circuit or summer formed by a second operational amplifier **34** and three resistors **35, 36** and **37** connected as shown. Thus, the output of operational amplifier **34** is a zero-centered sawtooth voltage whose amplitude is proportional to sin θ. This voltage, as indicated in FIG. **3,** is the desired V sin θ signal in the second equation set forth above. It should be pointed out that the circuitry of the invention does not form V (or H) separately but rather the product V (or H) times the appropriate trigonometric function.

Referring to FIG. **4,** a block diagram of the rotating raster generator of the invention is shown, the raster generator including four sawtooth generators **40, 41, 42** and **43** generally corresponding to and functionally similar to the sawtooth generator of FIG. **3.** Sawtooth generators **40** and **41** are vertical sawtooth generators and are connected to a vertical sync pulse amplifier **44** which simply amplifies the vertical sync pulses from generator **22** of FIG. **2** so that these pulses can operate the solid state switches in generators **40** and **41** corresponding to switch **33** of FIG. **3.** Similarly, a horizontal sync pulse amplifier **45** amplifies the horizontal sync pulses forming the input thereto so that these pulses can operate the solid state switches in horizontal sawtooth generators **42** and **43.** As shown in FIG. **4,** sawtooth generators **40, 41, 42** and **43** produce outputs *V* cos θ, *V* sin θ, *H* cos θ, and *H* sin θ, respectively. An inverter **46** inverts the output of sawtooth generator **41** to produce a −*V* sin θ signal and first and second summers **47** and **48** add the outputs of generators **40** and **43** and generator **42** and inverter **46**, respectively. As indicated in FIG. **4** and in accordance with the equations set forth above, the outputs at summers **47** and **48** are the desired *V'* and *H'* sawtooth signals.

Referring to FIGS. **5**a to **5**d, collectively referred to as FIG. **5**, a circuit diagram of one embodiment of the overall rotating raster generator system of FIG. **4** is shown. It is noted that the embodiment shown in FIG. **4** is designed to be compatable with a particular visual simulation system and such features as the available sync pulses, the deflection requirements of the monitor and the scale factors of the sine and cosine of the roll angle will, of course, affect the particular design of the generator, and the values shown in FIG. **5** are tailored to this design. For example, as set forth hereinbelow, the vertical and horizontal sync pulses are of a particular waveform and frequency in the exemplary embodiment under consideration. Further, each axis of the deflection system of the monitor **10** has a 5,000 ohm input impedance and requires at least five volts to move the spot from the center to the edge of the screen. Each axis is equipped with an attenuator which can reduce the deflection sensitivity to one half the maximum, thus requiring 10 volts for a half-screen deflection. The sine and cosine of the roll angle are scaled to have maximum values of ± 100 volts.

Referring to FIG. **5** and more particularly to FIG. **5***a*, the vertical sync pulses, referred to as the *V*-drive, are applied to an input terminal **50.** The V-drive is a 60 Hz voltage waveform that remains at 0 volts during the vertical sweep and changes to −10 volts for about 1 ms at the end of the vertical sweep. The V-drive pulse at terminal **50** is applied to the negative side of a capacitor C1 which is connected to a vertical sync pulse amplifier which corresponds to amplifier **44** of FIG. **4** and which is formed by transistors Q1 to Q6 and the resistors R1 to R11 associated therewith. Capacitor C1 is also connected to a horizontal sync pulse amplifier which corresponds to amplifier **45** of FIG. **4** and which is formed by transistors Q7 to Q12 and resistors R12 to R22 associated therewith (see FIG. **5***b*). A diode network including diodes CR1, CR2 and CR3 is connected between capacitor C1 and the input to transistor Q7 to, as set forth below, prevent transistor Q7 from turning on during the V-drive pulse. Since diodes CR2 and CR3 will not permit the positive side of capacitor C1 to go more than about 1.5 volts negative, the voltage waveform at the terminal common to diode CR3 and resistor R1 is essentially a V-drive varying from about +8.5 volts to −1.5 volts. When this voltage goes to +8.5 volts, transistor Q1 gets base current through resistor R1 and turns on. This causes the voltage at the base of transistor Q2 to drop from +15 volts to about +2.5 volts as a result of the voltage divider action of resistors R2 and R3. Transistor Q2 is connected as an emitter follower which produces two voltage waveforms that are equal in amplitude and opposite in direction. When voltage on the base of transistor Q2 is at +2.5, the emitter thereof is at about +3 volts. Substantially all of the current through resistor R4 also goes through resistor R5 since transistor Q2 draws very little base current. Therefore, when the emitter of transistor Q2 is at +3 volts, the collector current, which very nearly equals the emitter current, passing through resistor R5 causes the collector of transistor Q2 to be at −3 volts. When the voltage on the base of transistor Q2 is at +15 volts, the voltage on the base of transistor Q3 is at +15 volts and the voltage on the base of transistor Q5 is −15 volts. Transistor Q3 which is connected to the emitter of transistor Q2 is an emitter follower that supplies current gain to transistor Q4, transistor Q4 being a common base amplifier with a voltage gain of approximately 2. Transistor Q4 converts the input thereto, which has a peak-to-peak range of 11.5 volts, into an output having a peak-to-peak range of about 20 volts. The operation of transistors Q5 and Q6 is similar to that of transistors Q3 and Q4 although transistor Q5 is connected to the collector transistor Q2 and hence these transistors operate on the negative portion of the signal from transistor Q2.

The vertical sync pulse amplifier discussed above thus produces two output waveforms that are identical except for sign. Specifically, during the period of the V-drive pulse, the voltage at the collector of transistor Q4 is at +8 volts and that at the collector of transistor Q6 is at −8 volts whereas during the portion of sweep when the V-drive pulse is off these voltages are −12 volts and +12 volts respectively. As explained in connection with FIG. **4**, the voltages produced are used to operate the solid state switches in the vertical sawtooth generators described in more detail hereinbelow.

The horizontal sync pulse amplifier formed by transistors Q7 to Q12 operates in the same manner as the vertical sync pulse amplifier just described except for two features. Firstly, the horizontal sync pulse signal, called the H-drive and applied at terminal **51**, operates this section, the H-drive being a 15,750 Hz voltage waveform that remains at 0 volts during the horizontal sweep and changes to −10 volts for about 8.5 ms at the end of the horizontal sweep. Secondly, as described above, the common junction of diodes CR1, CR2 and CR3 is connected to the base of transistor Q7 and prevents transistor Q7 from turning on during the V-drive pulse. Thus, horizontal sweeps are not generated during vertical retrace, as the horizontal sawtooth generators remain at zero volts during this period. The principle purpose of this feature is to make the integrators, described hereinbelow and formed by operational amplifiers AR5 and AR6, self-unsaturating. If a transient should occur that causes the operational amplifiers of either of these integrators to saturate, the period of the H-drive pulse is too short to permit them to recover. The V-drive pulse, however, is long enough to permit such recovery and thus if saturation should occur during a vertical field, there will be recovery at the end of the field.

It is noted that the H-drive is also capacitively coupled to the horizontal sync pulse amplifier through capacitor C2. The capacitive coupling of the drive pulses to the sync pulse amplifiers effectively blocks the inputs if the sync pulses are lost, regardless of the D.C. levels remaining in the inputs.

The amplifiers described above are designed to keep the solid state switches, mentioned in connection with FIG. **4** and described below, closed when no sync pulses are present. Thus, the integrators described below all remain at zero volts until sync pulses are applied.

The circuit of FIG. 5 also includes four sawtooth generators corresponding to those discussed above in connection with FIG. 4. From the discussions hereinabove in connection with FIGS. 3 and 4, it will be appreciated that seven summing or inverting operations must be performed for the raster generator of the invention to function since each sawtooth generator includes a summer as shown in FIG. 3 and the circuit of FIG. 4 includes two additional summers and an inverter. However, by utilizing each amplifier for as many operations as possible, only three summing amplifiers are actually required.

Turning to a consideration of these sawtooth generators, the integrators formed by operational amplifiers AR1, AR3, AR5 and AR6 and the circuitry associated therewith, all operate in generally the same way, the only difference being that the integrators tied to the H-drive operate much faster than those tied to the V-drive and hence have smaller feedback capacitors and different input resistors. Because of this similarity, only the integrator which is formed by operational amplifier AR1 and the circuitry associated therewith will be described.

Operational amplifier AR1 is connected to the sin θ input at terminal 52 through a switch SW1 and input resistors R23 and R24. A capacitor C4 in parallel with operational amplifier AR1 serves as the feedback capacitor described above regarding FIG. 3 whereas a capacitor C3 connected between resistors R23 and R24 and ground serves as a filter capacitor designed to eliminate high frequency noise from the input. The exemplary valves given for the resistors R23 and R24 and capacitor C4 were chosen so that the integrator will reach a peak of about 8 volts during one sweep when the input is 100 volts. First and second diodes CR10 and CR11, connected from the feedback loop to ground as indicated, prevent the voltage at the summing junction from reaching more than about ± 0.7 volts. This arrangement protects operational amplifier AR1, and the other circuitry associated therewith, from high voltages if the 100 volts is present with the power supply turned off. First and second oppositely poled or back-to-back zener diodes CR8 and CR9 are also connected in parallel with operational amplifier AR1 and provide overload protection therefor. A diode bridge formed by diodes CR4, CR5, CR6 and CR7 and also connected in parallel with operational amplifier AR1 together with associated resistors R25 and R26 form the SOLID STATE switch referred to above in connection with FIG. 3, the switch so formed serving to reset the integrator during the negative portion of the V-drive pulse. When the V-drive is at zero volts, the input voltage from the collector of transistor Q4 is at −12 volts and the input voltage from the collector of transistor Q6 is at +12 volts and under these conditions the bridge does not conduct and acts as an open switch. When the V-drive is at −10 volts, the voltages at the collectors of transistors Q4 and Q6 reverse polarities, the former going to +8 volts and the latter to −8 volts. At this time diodes C4 to C7 conduct and the switch formed thereby is effectively closed. If, for example, the output of the integrator is positive, diodes CR5 and CR6 are cut off and capacitor C4 will discharge through diode CR7 and resistor R26, the return current passing through resistor R25 and diode CR4. The rate of discharge of capacitor C4, which essentially determines the current capacity of the switch, is dictated by the voltage at the collector of transistor Q4 and the resistance of resistor R25.

As stated hereinabove, the circuit of FIG. 5 utilizes three summing amplifiers or summers and these are formed by three operational amplifiers AR2, AR4 and AR7 and the attendant circuitry associated therewith. The summing amplifiers are of conventional form and include appropriate input and feedback resistors which need not be referred to in detail. A capacitor 17 connected across operational amplifier AR2 serves as a high frequency noise filter and two capacitors C15 and C16 serve the same function. First and second resistors R61 and R62 connected in series with the output lead of operational amplifiers AR4 and AR7 prevent any instability caused by the capacitance of the output cable.

Switch SW1, referred to above, together with associated resistors R42, R43, R52 and R58, is used to produce a test function so that a raster at zero roll angle can be generated without the presence of external sine and cosine inputs. With switch SW1 in the second, "internal" position, the sine θ and cos θ inputs at terminals 52 and 53 are disconnected and a +15 volt input at terminal 54 is connected into the circuit through the named resistors.

As shown in FIGS. 5*a* to 5*d* and as discussed above, the circuitry described operates from *a* ± 15 volt power supply. Since these voltages supply both reference levels and power to the operational amplifiers, the power supply should be well regulated and should be provided with tracking between the positive and negative outputs. A current output of about 0.5 amperes on each output is adequate for the raster generator hereindescribed.

The raster generator of FIG. 5 is calibrated using six potentiometers R27, R31, R39, R41, R45 and R57. Assuming that sine and cosine inputs are present which correspond to or represent a zero roll angle, the raster is centered using potentiometers R41 and R57 as indicated. Under these circumstances the size of the raster is controlled by the gain control of monitor 10. Changing the roll angle θ to 90° permits adjustment of potentiometers R27, R31, R39 and R45 to obtain the proper raster size and centering. It is noted that the raster can be properly centered and will have the proper center of rotation even if the unblanked portion is smaller than the total raster. Such a situation will arise if the raster blanking pulses are wider than the drive pulses. However, this situation does not present problems as long as the raster adjustments are made using the unblanked raster for reference.

The operation of the circuit of FIG. 5 is the same as that described regarding FIG. 4 with V' and H' signals provided at the output terminals 55 and 56 which are marked "Vertical Output" and "Horizontal Output" respectively. Hence, this description will not be repeated here. Further, the components which have not been specifically referred to correspond to those described above or perform conventional functions in the circuit and are included only for the sake of completeness. Hence, further specific description of these components will also be dispensed with.

As stated hereinabove it will be understood that substitutions can be made for the various components shown in FIG. 5. For example, the transistors used merely need to have adequate voltage and current ratings and be of reasonably high speed operation. Similarly, the diodes must be capable of high speed switching on the order of a few nanoseconds. The amplifiers must provide high gain, have a fairly high input impedance and reasonably stable. Perhaps most important is that the amplifiers must have a high slew rate preferably on the order of 100 volts per microsecond. It will be understood by those skilled in the art that modifications and variations in the exemplary embodiment discussed above, other than those merely concerning particular component values, can also be effected without departing from the scope and spirit of the invention.

I claim:

1. A rotating raster generator for generating horizontal and vertical deflection control voltages for producing any desired roll angle comprising first, second, third and fourth sawtooth generator circuits each comprising a *horizontal or vertical sync pulse signal* and a second input voltage corresponding to a trigonometric function of the desired roll angle and for producing an output voltage corresponding to the second input voltage, multiplied by a conventional vertical or horizontal sawtooth voltage waveform, derived from said first input, means for algebraically adding the outputs of a first pair of said sawtooth generators to produce a horizontal deflection control voltage and for algebraically adding the outputs of the remaining pair of said sawtooth generators to produce a vertical deflection control voltage, said first sawtooth generator comprising a first integrator circuit for receiving a first cos θ input voltage, where θ is the desired roll angle, said first integrator circuit also receiving a vertical sync pulse input and producing an output voltage proportional to $V \cos \theta$ where V comprises a conventional vertical sawtooth signal, said second sawtooth generator comprising a second integrator circuit for receiving a sin θ input voltage and a horizontal sync pulse input for producing an output voltage proportional to $H \sin \theta$ where H comprises a conventional horizontal sawtooth signal, said third sawtooth generator comprising a third integrator circuit for receiving said cos θ voltage and said horizontal sync pulse for producing an output voltage proportional to $H \cos \theta$, said fourth sawtooth generator comprising a fourth integrator circuit for receiving said sin θ voltage and said vertical sync pulse for producing an output voltage proportional to $V \sin \theta$, said adding means comprising a first summer means for adding said $V \cos \theta$ and $H \sin \theta$ voltages to produce said vertical deflection control voltage and a second summer means for adding said $H \cos \theta$ output voltage and the inverse of said $V \sin \theta$ output voltage to produce a horizontal deflection control voltage, each of said integrator circuits comprising an operational amplifier and a capacitor connected across said operational amplifier for producing a ramp voltage whose rate of change is proportional to the trigonometric input, each of said sawtooth generators further comprising an electronic switch responsive to said sync input for resetting said integrator circuit, sync pulse amplifier means connected to the sync inputs of said sawtooth generator for amplifying the sync pulse input signals to levels suitable for triggering said electronic switches, said sync pulse amplifier means *comprising a vertical sync pulse amplifier for receiving* vertical sync pulses and a horizontal sync pulse amplifier for receiving horizontal sync pulses, each of said amplifiers including a capacitor connected to receive the sync pulse signal for blocking the input to the amplifier during loss of the sync pulse signal, a first transistor having the base thereof connected to said capacitor, a first transistor emitter follower connected to said first transistor, a second transistor emitter follower connected to the emitter of said first emitter follower, a first common base amplifier connected to the emitter of said second emitter follower, a third transistor emitter follower connected to the collector of said first transistor emitter follower and a second common base amplifier connected to the emitter of said third transistor emitter follower, the outputs of said first and second common base amplifiers being respectively connected to the inputs of the electronic switches of two of said sawtooth generators and a diode network being connected between the point on the connection between said capacitor and the base of the first transistor of the vertical sync pulse amplifier, and the base of the first transistor of the horizontal sync pulse amplifier to prevent the latter transistor from turning on during the vertical sync pulse signal.

2. A rotating raster generator as claimed in claim 1 wherein said electronic switches each comprise a diode bridge.

* * * * *