

July 16, 1946.

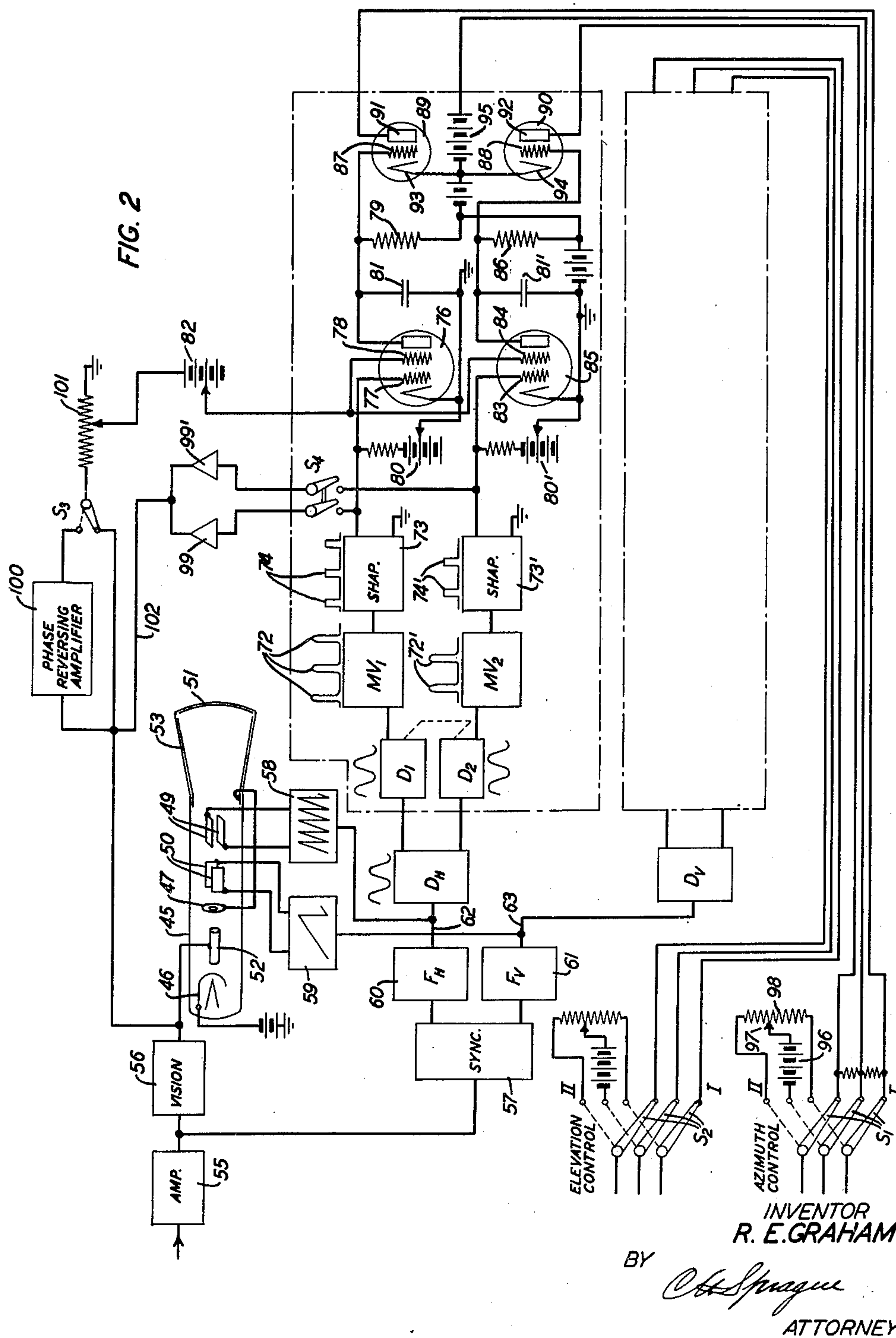
R. E. GRAHAM

2,403,975

AUTOMATIC FOLLOWING SYSTEM

Filed Sept. 24, 1941

4 Sheets-Sheet 2



July 16, 1946.

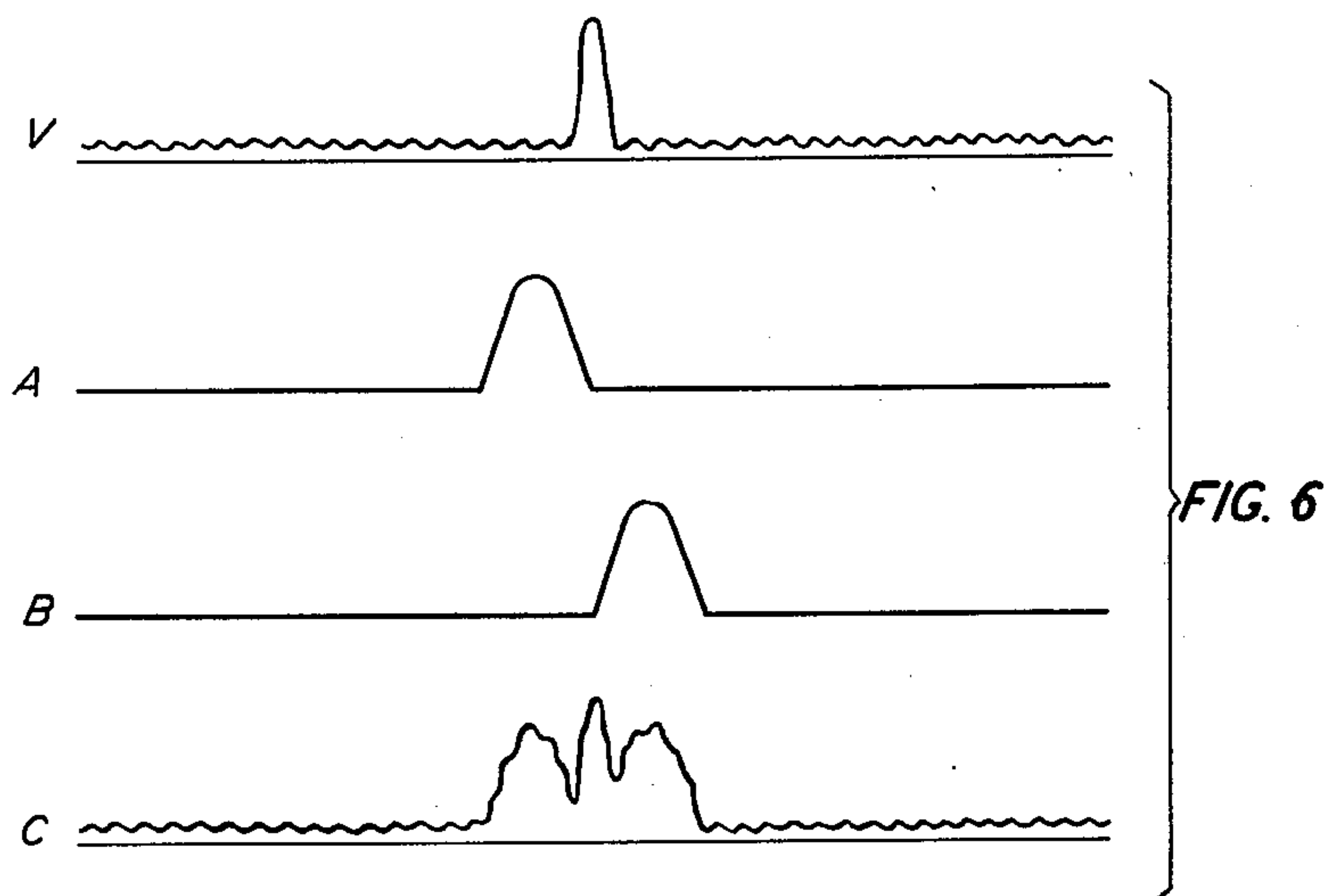
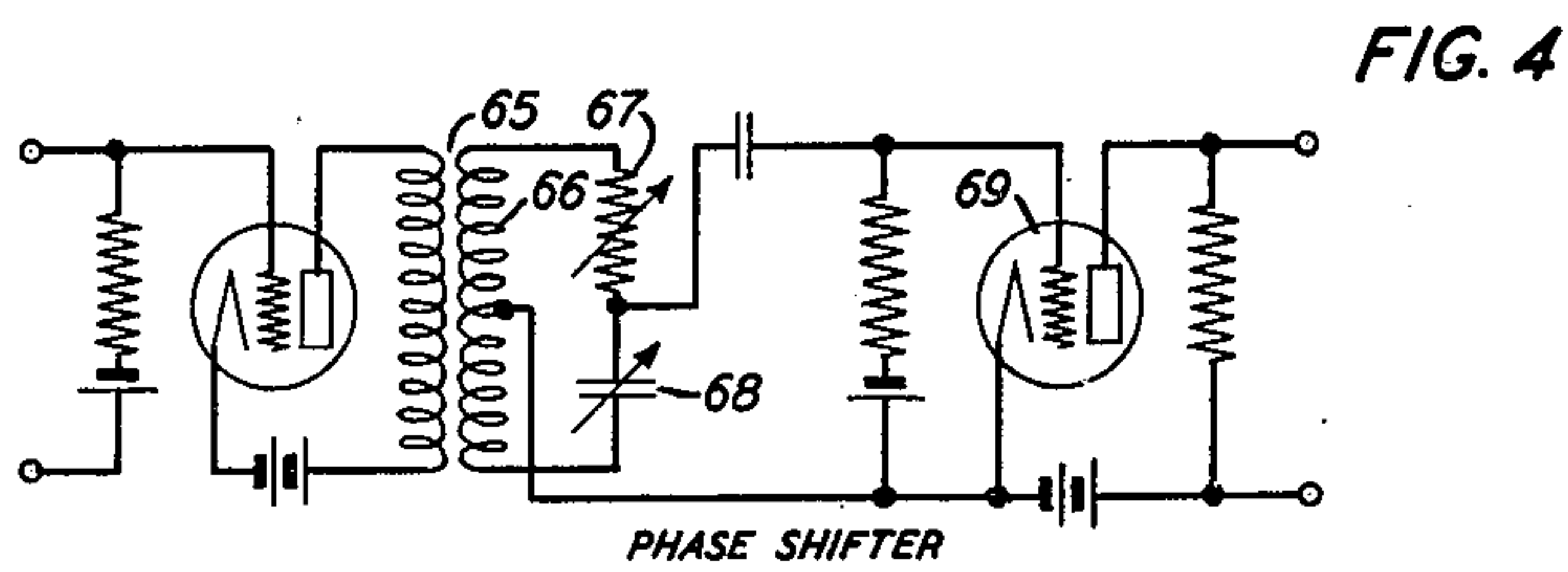
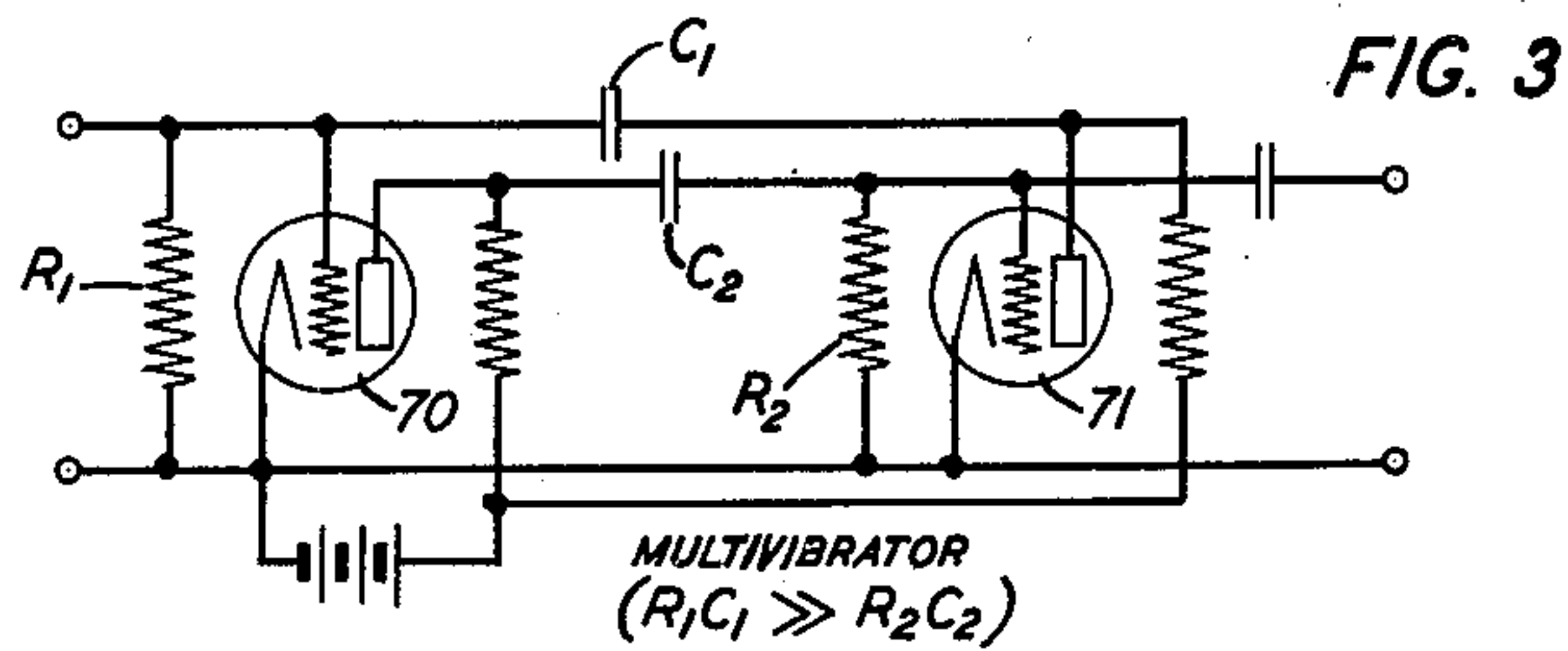
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4 Sheets-Sheet 3



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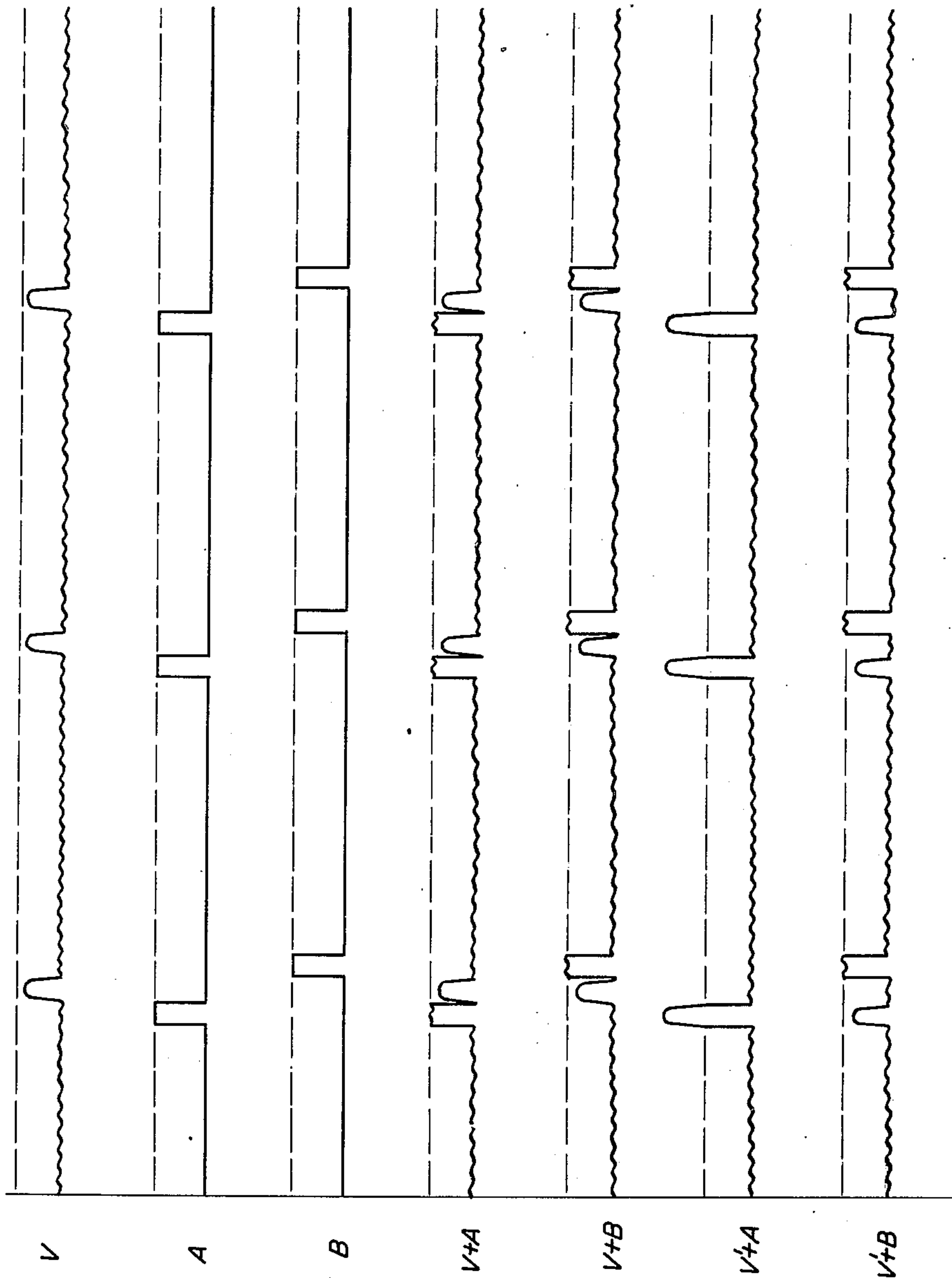
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AUTOMATIC FOLLOWING SYSTEM

Filed Sept. 24, 1941

4 Sheets-Sheet 4

FIG. 5



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UNITED STATES PATENT OFFICE

2,403,975

AUTOMATIC FOLLOWING SYSTEM

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Application September 24, 1941, Serial No. 412,074

24 Claims. (Cl. 178—6.8)

1

This invention relates to automatic following systems and particularly to a system for controlling the direction of aim of a television pick-up device or camera in a manner to cause it automatically to follow an object moving in an object field so as to hold the synthesized image substantially stationary on the receiver screen.

It has been proposed to equip a television camera with auxiliary apparatus, for example, paired photoelectric cells and prisms, from which are derived auxiliary signals whose characteristics vary in dependence on the displacement of a selected object in the object field from a central position. These signals may then be utilized to reorient the camera so as to restore the object to a central position in the camera field. The precision required of such apparatus for correct operation makes it both delicate and costly. Furthermore, difficulties are encountered in adapting it to following very small objects and objects of various sizes and also in causing it to be responsive only to a desired selected object which may be but one of a number of objects in the camera field.

It is an object of the invention to provide improved automatic following means which shall be sensitive and flexible in action as well as widely and simply adjustable at the will of an observer. A related object is to provide automatic following means which are wholly electrical in their nature and which operate without the assistance of auxiliary optical apparatus such as photoelectric cells, prisms, and the like. Another object is to provide automatic following means which are responsive to television signals and which are thus peculiarly appropriate for directing the television camera from which such signals are derived.

In pursuance of these and other objects and in a preferred embodiment there are produced at the television receiver station two trains of short, square-topped voltage or current pulses which are preferably alike, one train being delayed with respect to the other. The pulses of both trains are in synchronism with a regularly recurrent component of the received signals, for example, the conventional line and frame synchronizing signals and bear a definite phase relation to these signals. For example, the pulses of each train may occur once for each line scan while the phase relation may be such that the pulses of the first or leading train, which may be termed the "A" train, occur just before the scanning spot has reached the center of the line, while the pulses of the lagging or "B" train occur just after the

2

spot has passed the center of the line. Thus, a vision signal peak which in the synthesis operation is represented by a bright spot at the center of the line scan intervenes, or is bracketed in time, between these two pulses. The pulses and the vision signal are applied to circuit apparatus which responds only to a signal of magnitude in excess of that of the original pulses or of the vision signal alone, so that the output current of this circuit consists of composite pulses whose time of occurrence is determined by the phasing of the original pulses and whose magnitude is determined by the vision signal peaks which happen to coincide in time with the original pulses. Thus, if a vision signal peak representative of an object field portion which is intended to be centrally located on the screen occurs ahead of its proper time, it will coincide with pulse A, and if it is retarded with respect to its proper time it will coincide with pulse B, whereas if the object field portion which it represents is correctly centered, the representative signal peak will occur between pulses A and B. The resulting composite pulses are then utilized to reorient the television camera in a sense to equalize their averaged amplitudes and so aim the camera squarely at the object represented by the particular image signal peak and bring its image to the center of the scanning line.

For holding the camera aim on a rising or falling object and so centering its image vertically of the screen, similar "C" and "D" pulse trains are provided in synchronism with another regularly recurring signal component, for example, the vertical synchronizing signals. These are similarly combined with the vision signals to produce composite pulses which, in turn, are utilized to change the elevation of the camera.

Preferably, means are also provided for controlling the phase relation of the pulses both with respect to the synchronizing signals and with respect to each other, so as to accommodate objects of various sizes and maintain their images in desired positions on the receiver screen.

For automatically following a bright object moving on a dark background the pulses should evidently be voltage or current excursions in the "bright" direction. For a dark object on a light background the opposite is true. To accommodate both conditions a switch is provided for reversing the polarity of the vision signals with respect to the pulse trains.

In the preferred system above described it is the inner edges of the pulses and the space between them which are effective in operation,

3

When the apparatus is following a single moving object, the outer edges of the pulses do not come into operation at all, so their shapes are not of importance. However, pulses of short duration are helpful in rendering the apparatus insensitive to the presence in the field of other objects, moving or still, than the one it is desired to follow. Furthermore, if the object moves always in the same direction, only the inner edge of one of the pulses comes into operation. Lastly, the steep slope of the inner edge of the pulse and its square top contribute to the positiveness of the operation of the apparatus but are not essential. Therefore, in a broader aspect, it may be stated that the invention comprises the production of auxiliary signals having a prescribed phase relation to a received signal and the mingling of said auxiliary signals with a selected part of said received signal to produce a composite signal for actuating control means in a sense to maintain the character of the composite signal invariant. In another aspect the invention comprises the production of an auxiliary signal having a prescribed phase relation to some regularly recurring component of television signals and the comparison of the phase of a vision signal peak with the phase of said auxiliary signal to produce a restoring signal for actuating camera aim-altering means in a sense to hold the camera aimed at a selected object in an object field, independently of movements of the object.

The invention will be more fully understood from the following detailed description of a preferred embodiment thereof taken in connection with the appended drawings, in which:

Fig. 1 is a schematic showing of a television pick-up device or camera and associated apparatus for altering its aim under control of auxiliary signals;

Fig. 2 is a schematic diagram, partly in block form, of television receiver apparatus including a preferred circuit arrangement for producing control signals to be delivered to the apparatus of Fig. 1. Fig. 2 also shows means for initially aiming the television camera of Fig. 1 toward a desired part of an object field under manual control of an observer;

Fig. 3 is a circuit diagram of a multivibrator which may serve for some of the blocks of Fig. 2;

Fig. 4 is a circuit diagram of phase shifting apparatus which may serve for others of the blocks of Fig. 2;

Fig. 5 is a group of diagrams illustrating the mode of operation of the invention; and

Fig. 6 is a group of diagrams illustrating the mode of operation of the invention in a modified form.

Referring now to Fig. 1, a housing 10 is mounted for rotation in a vertical plane about a pivot 11 on a pedestal 12 which pedestal is, in turn, mounted for rotation in a horizontal plane about another pivot 13 on a base 14. Rotation of the housing 10 in the vertical plane is effected by a motor M_2 fixed to the housing and driving a worm 15 which engages with a worm gear 16 fixed to the pedestal 12. Similarly, rotation of the pedestal 12 about the base 14 may be effected by a motor M_1 fixed to the pedestal 12 and driving another worm 17 which engages with a worm gear 18 fixed to the base 14. The armatures of the motors M_1 and M_2 may be energized by the output voltages of generators G_1 and G_2 , respectively, which may be driven at constant speed as by a synchronous motor M_3 energized by a constant frequency source 19. The generators are

4

preferably provided with center-tapped field windings 21, 23 to which are supplied the control currents as hereinafter described.

The housing 10 may contain a television camera of any suitable type. For example, the camera may comprise an evacuated vessel 25 containing a cathode 26 for projecting an electron beam, anodes 27, 28 for accelerating and focussing the beam and means such as plates 29, 30 for deflecting the beam in the course of the scanning operation in transverse lines across a metal-backed mosaic screen 31 on which is formed an image of an object field 32 as by an objective lens 33. As is well-known with devices of this type, a current may be drawn from the conductive backing plate of the mosaic screen 31 which returns through a load resistor 34 to produce a voltage drop which may be amplified by any suitable apparatus for transmission to a receiver station where it may be reconstituted as an image. Apparatus for this purpose, which is well-known per se, forms no part of the invention and is indicated merely by a block 35. Likewise, horizontal beam deflection control and vertical beam deflection control may be supplied to the horizontal and vertical deflecting elements 29, 30 of the pick-up device by any suitable apparatus such as sweep generators 36, 37. Synchronizing pulses may likewise be provided by any suitable means such as a generator 38 which controls the synchronism of the horizontal and vertical deflections, the synchronizing pulses being likewise fed to the transmitter through a conductor 39 for transmission to the receiver.

Referring now to Fig. 2, the receiver apparatus proper may be of any suitable type, for example, it may comprise a cathode ray tube 45 containing a cathode 46, an anode 47 for accelerating and focussing the cathode beam, vertical and horizontal beam deflecting plates 49, 50, and a fluorescent beam-receiving screen 51. It may also include a control electrode 52 to which are fed vision signal components representative of the light-tone values of the field of view at the transmitter. In accordance with common practice, the received signal which contains synchronizing pulses, both horizontal and vertical, may be amplified by any suitable apparatus indicated by a block 55, and the vision components separated from the synchronizing components by suitable devices such as amplitude discriminators 56, 57. The vision signal components may then be applied to the control electrode 52 and the synchronizing pulses to the horizontal and vertical deflection control apparatus, respectively. Horizontal deflection of the beam may be effected by a line frequency saw-tooth voltage generator 58 held in synchronism with the horizontal synchronizing signals and vertical deflection may be effected by a frame frequency saw-tooth generator 59 held in synchronism with the vertical synchronizing signals, separation between line synchronizing signals and frame synchronizing signals being effected in any appropriate manner, as by filters 60, 61.

In accordance with the invention, further use is made of the horizontal and vertical synchronizing pulses, respectively, in connection with the production of control signals to be delivered to the camera aim-altering means. To this end, the synchronizing pulse separation filters 60, 61 are preferably tuned sharply to the fundamental components of the horizontal synchronizing voltage and vertical synchronizing voltage, respectively, so that the output voltages of these filters con-

sist substantially of a pure sine wave of line scanning frequency on the line 62 and another sine wave of frame scanning frequency on the line 63.

The vertical control apparatus of the invention is substantially the same as the horizontal control apparatus, and only the latter will be described in detail. The horizontal synchronizing sine wave is first passed through a delay network D_H and is then split into two parallel paths, designated A and B, respectively, in each of which another delay network D_1 or D_2 , respectively, is included. The reason for the inclusion of these delay networks will be apparent hereinafter. Each of the delay networks may be of any suitable type. As shown in Fig. 4 it may comprise, for example, a transformer 65, having a center-tapped secondary winding 66 to which are connected a resistor 67 and a reactance element, for example, a condenser 68 in series, the junction point between the resistor and the condenser and the center tap of the secondary winding constituting the output terminals of the device. If the transformer load impedance is high compared with the impedance seen looking back into the secondary terminals of the transformer and if, in turn, the impedance of the load connected to the device as a whole is high compared with the self-impedance of the device, as will be true when, as shown in Fig. 4, the output terminals are connected to the control grid and cathode, respectively, of an electron discharge device 69, then, as is well-known, variations either of the capacitance or the resistance as may be preferred, result in phase variations of the output voltage of the device with respect to its input voltage without any change in its magnitude. For a full description of the mode of operation of such a device, reference may be made to "Electrical Engineers Handbook of Electric Communication and Electronics" by Harold Pender and Knox McIlwain, 3d edition, section 16, page 11, and particularly Figs. 24, 25 and 26.

In practicing the invention the three delay devices D_H , D_1 , D_2 may be adjusted to suit the taste of the observer. For example, the delay device D_H which is common to both the A and B paths may be set so that its output voltage, constituting the input voltages of the delay devices D_1 , D_2 , at instants when the horizontal deflecting saw-tooth voltages of the generators 35 and 50 are about half-way between their minima and their maxima on the rise, so that the delayed voltage peaks occur when the cathode beams are approximately at the center of the mosaic screen 31 and the fluorescent screen 51, measured horizontally. The A delay device D_1 and the B delay device D_2 are preferably adjusted for a slight difference in delay so that the peaks of the output voltage in the A path occur slightly earlier than the peaks of the output voltage in the B path. For simplicity of operation the controlling elements of the devices D_1 and D_2 may be arranged for joint operation as by a single control knob which alters the phases of their output voltages by equal amounts and in opposite senses.

These output voltages of D_1 and D_2 are then fed in accordance with the invention into separate pulse generators MV_1 and MV_2 , respectively, there to serve as synchronizing voltages. These pulse generators may be of any suitable type, for example, they may be multivibrators comprising two discharge devices 70, 71 cross-coupled as shown in Fig. 3, whose mode of operation is well-known, being described in the Pender-McIlwain Handbook above referred to in section 7, page 126. Re-

ferring to Fig. 3, when the time constant R_1C_1 is large in comparison with the time constant R_2C_2 , the wave form of the output of the device may consist of a succession of comparatively narrow peaks 72 or impulses of one polarity with intervening periods of the opposite polarity of comparatively long duration. Likewise, as is well-known, the frequency of oscillation, within limits determined by the circuit parameters which may easily be adjusted to suit, may be held in synchronism by the injection of a small voltage input to the control electrode and cathode of one of the two discharge devices 70, 71. In such case, and since each of the multivibrators is supplied with a synchronizing voltage from its delay circuit D_1 or D_2 , the synchronizing voltage of the B path being slightly delayed with respect to that of the A path, the pulses in the output of MV_1 will occur slightly in advance of those in the output of MV_2 .

Though not essential to the practice of the invention, it is preferred that the A and B pulses before being utilized shall be short, sharp square-topped pulses. Any suitable shaping circuit may be employed to give to the outputs of the multivibrators the desired shape. For example, the shaping circuit 73 may comprise an amplifier followed in cascade by any suitable amplitude limiting device such as a triode biased to reach its anode current saturation with a comparatively small input voltage, and the shaper 73' in the B path may be entirely similar.

Thus, there are produced by the apparatus so far described two trains of short, sharp square-topped pulses 74, 74' the A train in one path and the B train in another path, the A train pulses 74 occurring slightly in advance of the B train pulses 74'. The gain of the system may be so adjusted that the pulses 74 are substantially equal in amplitude to the largest vision signal peaks to be expected, and they should be of the same polarity as these peaks. This result may be secured by proper selection of the number of stages in the amplifiers of the shapers 73 and 73', or in any other manner, as desired.

In accordance with the invention, the A train pulses are now "mixed" with the vision signals themselves to produce composite pulses. The mixer circuit may be of any suitable type, the mixing (whenever it occurs) being preferably linear in character. For this purpose there may be provided an electron discharge device 76 having two or more control electrodes 77, 78 to one of which 77 the voltage of the A pulse train is applied while the vision signals are applied, through potentiometer 101 and bias battery 82, to the other control electrode 78. Both of the control electrodes 77 and 78 may be biased as by adjustment of batteries 80 and 82 to a point such that neither an auxiliary A pulse nor a vision signal peak alone is sufficient to produce a voltage across the load impedance 79, while the presence of both pulse and properly phased vision signals together does produce such an output voltage. The high frequency components of the output may be by-passed to ground through a condenser 81.

The path which brings the vision signals to the mixer should preferably allow the passage of direct current, in order that the magnitude of vision signal peaks as they appear at the control electrode 78 may be independent of the background light level of the object field as a whole.

The B train of pulses appearing at the output of the B limiter is similarly "mixed," preferably in additive relation, with the vision signals, the pulses being impressed on one control grid 83 and

the vision signals on a second control grid 34 of an electron discharge device 85 so that, as in the case of the A path, the voltage which appears across the load impedance 86 contains a composite signal when and only when a vision signal peak coincides in phase with a B pulse.

In accordance with the invention the resulting composite A signals and B signals are differentially mixed to produce restoring signals for actuating the aim-altering motor M₁ at the camera station. To this end they may be impressed on push-pull connected control electrodes 87, 88 of discharge devices 89, 90 whose anodes 91, 92 are connected through a switch S₁ to the end terminals of the generator field winding 21 of the generator G₁ and whose cathodes 93, 94 are connected together and through an anode supply source such as a battery 95 of the center tap of the generator field winding 21. The control electrodes 87 and 88 are so biased that both tubes are normally conducting and the directions of winding of the two parts of the generator field winding are such that a flow of current in one of them toward the center tap produces a flux of opposite polarity to a flow of current in the other toward the center tap. Thus, in the absence of signals on these tubes, plate currents will flow which are balanced in the generator field windings and therefore produce no net magnetic flux.

The vertical control circuit may be similar to the horizontal control circuit above described. Starting with the vertical synchronizing pulses, these are first passed through a narrow band-pass filter 61 tuned to the fundamental component of the vertical synchronizing pulses to deliver a substantial sine wave output. The latter is then delayed to suit the observer's taste by a delay circuit D_v which, again, may be as shown in Fig. 4, whereupon it is split into two paths containing relative delay circuits, multivibrators, shapers or limiters, means for mixing the resulting pulses trains with the vision signals to provide composite signals, and means for differentially mixing the two composite signal trains to provide control signals which appear at the output terminals of the apparatus which, as in the case of the horizontal control, may be the anode terminals of two discharge devices. As in the case of the horizontal control these terminals may be connected through a switch S₂ similar to the first-named switch S₁ to the field windings 23 of the elevation control generator G₂ at the transmitter station.

In order that the television camera may be aimed at the will of the observer at a desired part of the object field, it is also preferred to provide means for disconnecting the automatic control apparatus above described and supplying manual control signals to the aim-altering motors. Any suitable apparatus may be employed for this purpose and simple and convenient apparatus is shown in the lower part of Fig. 2. A three-pole switch S₁ is provided, the center pole being connected in the position II to the negative terminal of a battery 96 whose positive terminal is connected to a moving contact or wiper 97. The two outer poles are connected to the respective ends of a resistor 98 along which the moving contact 97 is arranged to slide. When the switch is thrown to the position II, movement of the contact 97 along the resistor 98 will actuate the two halves of the field winding 21 of the camera generator G₁ in a manner to vary the field currents differentially. For example, when the contactor is at the center of the resistor, the field currents

in the two halves of the field windings will be equal and opposite so that there will be no net flux in the generator and, therefore, no generated voltage. When the contactor is moved away from this central neutral position to one side or to the other, the net flux of the generator G₁ will be positive or negative and greater or less in magnitude depending on the sense and magnitude of the contact movement, so that the generated voltage delivered to the azimuth control motor will vary in magnitude and in sign under control of the observer who moves the contacting element 97.

The operation of the automatic aim-altering apparatus will be clear from a consideration of the diagrams of Fig. 5. The switch S₁ being thrown to the position I, vision signals will be received and synthesized to form an image on the screen of the cathode ray tube 45. In Fig. 5 the curve V shows vision signals representative of a bright object on the center of a dark background for three successive line scans. At the same time the multivibrators MV₁ and MV₂ in the A and B paths will deliver trains of pulses in synchronism with the horizontal synchronizing voltage. The A and B pulses will be spaced apart more or less depending on the relative delay provided by the delay circuits D₁ and D₂. The position in the scanning cycle of both pulses taken together is determined by the setting of the common delay device D_H. The curves A and B of Fig. 5 show the resulting pulse trains phased to occur just before and just after the vision signal peak representing the selected object. The linear additive "combination" of the A and B pulses with the vision signals is shown in curves V+A and V+B. It will be observed that the vision signals, the pulses of the A and B trains and resulting composite signals are at all times approximately at the cut-off level of the mixing apparatus indicated by the broken lines. Therefore, neither of the discharge devices 76, 85 will be rendered conductive by the arrival of a pulse alone or of any vision signal peak alone so that no current flows in either half of the generator field winding 21 and no torque is delivered to the motor M₁ unless and until a vision signal peak happens to coincide either with the A pulse or the B pulse. When this occurs, the cumulative effect of the pulse and the vision signal peak being sufficient to swing one or the other of the mixer tubes 76, 85 past its cut-off point in the conductive direction, a current flows in the plate circuit of that tube during the short interval throughout which the pulse exists. This correspondingly modifies the current flow in one or other of the field windings of the generator and so produces a torque in the motor M₁ in a direction to rotate the camera housing 10 to left or to right in dependence on whether the field winding current originated with the A pulse or the B pulse. This condition is illustrated in curves V'+A and V'+B which show the "addition" of the A and B pulses to a vision signal of which the selected peak has been slightly advanced in phase.

If now, it is desired to follow an object moving in the object field, for example, a single small bright object on a dark field, the camera may first be aimed directly at the object by manipulation of the moving contact 97, the switch S₁ being thrown to the position II. When the image, assumed to be stationary, is brought to a desired position, for example, the center of the screen 51, the switch S₁ may be thrown to the position I

which permits the automatic following apparatus to take control.

As long as the object remains stationary in the center of the field, the image signal peaks which are representative of it occur at instants just following the A pulses and just preceding the B pulses in the manner shown in Fig. 5. As a result, since the mixer tubes 76, 85 are biased below the maximum excursion of either the pulses or the brightest vision signal peak to be expected, these devices remain below cut-off at all times and equal currents are delivered to the generator field winding 21. But if the object should start to move in the object field, for example, to the left, its image will move to the left across the receiver screen and the image signal peak which represents it will advance in phase relatively to the vision signals generally and to the horizontal synchronizing pulses in particular. As shown in curve V'+A of Fig. 5, this will bring the vision signal peaks representative of the bright object into phase with the A pulses so that the mixer tube 76 will be raised above its cut-off point to deliver a composite signal to the tube 89 of the differential mixer and the latter will, therefore, deliver pulses of current, one for each line scanned, to one of the windings of the generator G₁ which are wound and poled in a direction such that the resulting movement of the camera is to the left, or in a direction to overtake the moving object. Similarly, movement of the object to the right produces composite pulses in the B path coinciding in time with the original B pulses, which are great enough to raise the B mixer tube 85 above its cut-off point and produce in the output circuit of the differential mixer tube 90 a succession of pulses in such a direction as to move the camera in a right-hand direction.

In the above description of the operation of the apparatus it was assumed that the object to be followed was a single, small, bright object on a dark field, that it had been centered manually, and that the delay devices D₁ and D₂ were so adjusted that the A and B pulses occurred just before and just after the vision signal peak representative of the object, so that the signal peak is in effect bracketed between the pulses. The invention is equally applicable to large objects as well as small, in which case the same bracketing is of course desirable. Provision is therefore made to advance the phase of the A pulses and retard the phase of the B pulses by manipulation of the control elements of the delay devices D₁ and D₂ as described in connection with Fig. 4. By such manipulation the A pulses may be caused to occur just before the start of the vision signal representative of the extended object and the B pulses just after its termination.

To assist the operator in making these adjustments it may be of assistance to have an immediate visual indication of the pulse phases. This is accomplished in accordance with the invention by feeding the pulse voltages themselves to the vision signal reconstituting device so that the object to be followed appears bracketed in space between two bright spots which are fixed with respect to the field of view. To this end the pulse voltages themselves, as they appear at the output terminals of the shapers 73 and 73' may be fed through a switch S₄, buffer amplifiers 99, 99' and conductor 102 to the control electrode 52 of the cathode ray receiver 45. Precautions should, of course, be taken in the construction of the amplifiers 99, 99' to assure that they shall not alter the phase relations of the pulse volt-

ages. The brightness of the auxiliary bracketing spots may be adjusted by providing the amplifiers 99, 99' with manual gain control.

Once having made the bracketing adjustment visually, the operator may prefer to remove the auxiliary bracketing spots from his field of view. The switch S₄ is provided for this purpose.

Depending on the visual characteristics of the object to be followed, of the background in which it appears, the number and light values of neighboring objects and the like, improved positiveness of action or sensitivity or both may be secured by varying the relative magnitudes of the vision signal voltages and the pulse voltages at the mixer tubes 76 and 85, and also by varying the cut-off point of these tubes. The latter may be varied by adjustment of the bias voltages 80, 80', and 82 and the former by adjustment of the potentiometer 101.

In case it is desired to utilize the apparatus for following a dark object on a light background, it is only necessary that the relative polarity of the pulses and the vision signals be reversed. This is for the reason that in the case of a dark object on a light background, the average value of the vision signals is a steady positive value whereas the peaks representing the object are excursions in the negative direction. In order to accommodate dark objects on a light background, there is provided means for reversing the polarity of the vision signals relatively to the A and B pulses. To this end there is provided an additional stage 100 of unity amplification which, as is well-known, serves to reverse the polarity of its voltage input. Accordingly, to accommodate the apparatus to a dark object on a light background, it is only necessary to throw the switch S₃ which introduces this additional amplifier stage in the line which carries the vision signals to the tubes 76 and 85. This reinverts the phase of the vision signal peaks so that, though the image signal peaks proper are excursions in the negative direction, the signal peaks which are "combined" with the A and B pulses, respectively, to produce composite pulses are inversions of the image signal peaks and, therefore, voltage excursions in the positive direction.

It will now be understood that by adjustment of the setting of the common delay device D_H the apparatus of the invention may be caused to follow an object while holding its image in any desired portion of the receiver screen 51 which may be far from the center thereof.

The sharp, initial rise of the A pulse and the sharp fall of the B pulse do not contribute to the operation of the invention. Alternatively, the A pulse may have a gradual rise of random slope and the B pulse may tail off gradually. However, it is desirable that the period during which each of these pulses rises close to its maximum value and approaches or exceeds the conduction threshold of the mixer apparatus shall be of short duration, in order that the apparatus may clearly distinguish between the object sought to be followed and other objects which may exist in the field.

In operation it is evident that the transfer factor of the apparatus as a whole, that is to say, the ratio of camera speed response to the composite signal as a stimulus shall be such that the camera movement may keep up with the fastest motion of a moving object to be expected, and this with an object which is differentiated from its background by a light-tone difference which is as small as may reasonably be expected.

11

Serious hunting, however, will be prevented by electrical damping and losses of the system so that, for practical purposes, the camera movement will be comparatively steady.

It will be noted that the system is inherently stable in operation, since the current in the generator field winding and, therefore, to a first approximation the camera restoring speed, is proportional to the time integral of the vision signal peak over the period throughout which it overlaps the auxiliary pulse, while this period is, in turn, proportional to the phase displacement of the image signal peak from its proper bracketed position.

Still further stability may, if desired, be secured at the expense of some sensitivity by the use of pulses having sloping inner edges. Curve C of Fig. 6 shows how a vision signal peak, V, may be bracketed between two such pulses, A and B. All of the circuit arrangements may be the same as those above described with the exception of the shaping apparatus. The operation will be the same as that described above, with the exception that the restoring camera speed response increases as a higher power than the first of vision signal phase displacement.

It is within the contemplation of the invention that the apparatus above-described may be duplicated or otherwise modified to provide two or more camera speeds to accommodate fast or slow objects. For example, a remotely operated manually controlled speed change gear may be provided so that a composite signal of given magnitude may produce fast or slow camera movement as desired. Again, the gain of the system as a whole may be varied to suit various conditions and such gain changes may be manually controlled by the observer or automatic gain control may be provided, for example, to be actuated by a photoelectric cell responsive to the average light values of the field of view. Again, the single A and B pulses may be replaced by pulses of more complex wave form and the apparatus may be modified to have two or more different threshold values in such a way that passing the first threshold value produces a low camera speed and passing the second threshold value in the same direction produces an increase in camera speed.

Still other modifications will occur to those skilled in the art which may be practiced without departing from the spirit of the invention.

While the synchronizing signals of conventional television systems provide a convenient reference for adjustment of the phases of the auxiliary A and B pulses, it is evident that the invention may be employed without these conventional synchronizing signals, as long as some signal or signal component is available which is invariant with respect to the character of the object field and therefore independent of movements of objects or their images in the image field. Since, whatever may be its function apart from the invention, its function with reference to the invention is to provide a reference for synchronization and phase adjustment of the auxiliary pulses, it may properly be termed a synchronizing signal. This term is used in the appended claims in this broad sense, the terms "line synchronizing signals" and "frame synchronizing signals" being employed to indicate conventional television synchronizing signals in distinction thereto.

What is claimed is:

1. In a television system of the type in which

12

a pick-up device produces signals having a vision component which is representative of the light-tone values of an object field and another component which is independent of said values, said device being under control of aim-altering means, apparatus for holding stationary an image synthesized from said vision signal component which comprises means for producing an auxiliary signal pulse having a controlled time relation to said other component, and means responsive to the elapsed time between said auxiliary signal pulse and a selected part of the wave form of said vision component for producing control energy for actuating said aim-altering means in a sense to hold said pick-up device aimed at a part of said object field which is represented by said selected part of said vision signal component.

2. In a television system of the type in which a pick-up device produces signals having a vision component which is representative of the light-tone values of an object field and another component which is independent of said values, said device being under control of aim-altering means, apparatus for holding stationary an image synthesized from said vision signal component, which comprises means for producing an auxiliary signal pulse having a controlled time relation to said other component, and means responsive to the elapsed time between said auxiliary signal pulse and a selected part of the wave form of said vision component for producing control energy for actuating said aim-altering means in a sense to restore said elapsed time to a preassigned value.

3. In apparatus for controlling the aim of a pick-up device for producing signals having at least two components, which components are subject to relative time delay variations in dependence on the orientation of said pick-up device, means for producing an auxiliary signal pulse having a controlled time relation to one of said components, and means responsive to time delays between said auxiliary signal pulse and the other of said components for producing control energy for reorienting said pick-up device in a sense to maintain said time delays at a desired value.

4. In a system for receiving and utilizing signals having at least two components which are subject to relative time delay variations, means for producing an auxiliary signal having a controlled time relation to one of said components, means for combining said auxiliary signal with the other of said components to produce a composite signal dependent on the instant of occurrence of said second component, and means for utilizing said composite signal for maintaining invariant the elapsed time between said two components.

5. In a television system of the type in which a pick-up device for producing vision signals and synchronizing signals is under the control of aim-altering means, said vision signals being representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing an auxiliary signal having a controlled time relation to said synchronizing signals, means for additively combining said auxiliary signal with said vision signals unmodified, to produce a composite signal, and means for deriving control energy from said composite signals for actuating said aim-altering means in a sense to maintain the character of said composite signal invariant.

6. In a television system of the type in which

a pick-up device for producing vision signals and synchronizing signals is under the control of aim-altering means, which vision signals are representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing two auxiliary signals of like magnitude having a controlled time separation and a controlled time relation to said synchronizing signals, means for additively combining said auxiliary signals with said vision signals to produce two composite signals of magnitudes dependent on the light-tone values of two parts of said object field, and means for deriving control energy from said composite signals for actuating said aim-altering means in a sense to equalize the magnitudes of said composite signals.

7. In a television system of the type in which a pick-up device for producing vision signals and synchronizing signals is under control of aim-altering means, which vision signals are representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing two auxiliary signals of like magnitude having a controlled time separation and a controlled time relation to said synchronizing signals, means for additively combining said auxiliary signals with said received vision signals to produce two composite signals of magnitudes dependent on the light-tone values of two parts of said object field, means for differentially mixing said composite signals to provide a control signal dependent in magnitude and polarity on the difference between said composite signals, and means for actuating said aim-altering means in a sense to equalize the magnitudes of said composite signals.

8. In a television system of the type in which a pick-up device for producing vision signals and synchronizing signals is under control of aim-altering means, which vision signals are representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing an auxiliary voltage having a controlled time relation to said synchronizing signals and having a magnitude substantially equal to a stipulated threshold value and in excess of the magnitudes of all peaks of said vision signal, means for combining said auxiliary voltage with a voltage of said vision signals to produce a composite voltage signal which exceeds said threshold value by an amount dependent on that portion of said vision signal which coincides in time with said auxiliary voltage and is representative of a particular part of said object field, said composite voltage coinciding in time with said auxiliary voltage, a network responsive to voltages in excess of said threshold value, means for impressing said composite voltage on said network, and means for utilizing the output current of said network to actuate said aim-altering means in a sense to reduce the magnitude of said composite signal to said threshold value.

9. In a television system of the type in which a pick-up device for producing line-by-line vision signals representative of the light-tone values of an object field and containing a horizontal synchronizing component and a vertical synchronizing component is under control of means for altering its aim in azimuth and in elevation, apparatus for holding stationary an image synthesized from said vision signals, which comprises

means for producing an auxiliary signal having a controlled time relation to said horizontal synchronizing component, means for producing another auxiliary signal having a controlled time relation to said vertical synchronizing component, means for separately combining said auxiliary signals with said vision signals to produce separate composite signals of characters dependent on the light-tone values of a particular part of said object field in the horizontal and vertical directions, respectively, and means for deriving separate control currents from said composite signals for actuating said azimuth aim-altering means and said elevation aim-altering means, respectively.

10. In a television system of the type in which a pick-up device for producing vision signals and synchronizing signals is under control of aim-altering means, which vision signals are representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing an auxiliary signal having a controlled time relation to said synchronizing signals and a polarity like that of vision signal peaks representative of relatively light-toned portions of said object field, means for combining said auxiliary signal with said vision signals to produce a composite signal of a character dependent on a particular light-toned part of said object field, means for reversing the polarity of said vision signal with respect to said auxiliary signal to cause the character of said composite signal to be dependent on a particular dark-toned part of said object field, and means for deriving control energy from said composite signal for actuating said aim-altering means in a sense to maintain the character of said composite signal invariant.

11. In a television system of the type in which a pick-up device for producing vision signals and synchronizing signals is under control of aim-altering means, which vision signals are representative of the light-tone values of an object field, apparatus for holding stationary an image synthesized from said vision signals, which comprises means for producing two auxiliary signals of like magnitude having a controlled time separation and a controlled time relation to said synchronizing signals, means for combining said auxiliary signals with said vision signals to produce two composite signals of magnitudes dependent on the light-tone values of two parts of said object field, means for deriving control energy from said composite signals for actuating said aim-altering means in a sense to equalize the magnitudes of said composite signals to cause a vision signal peak representative of an intermediate part of said object field to be bracketed between said auxiliary signals, whereby the aim of said pick-up device is automatically held on a moving object, and means for adjusting the time separation between said auxiliary signals to accommodate vision signals representative of objects of various sizes.

12. In a television system of the type in which a pick-up device for producing signals having a synchronizing component and a vision component representative of the light-tone values of an object field is under control of aim-altering means, apparatus for holding stationary an image synthesized from said vision component which comprises means for producing an auxiliary signal having a controllable time relation to said synchronizing component, means responsive to the elapsed time between said auxiliary signal and a

15

selected part of said vision signal component for producing control energy for actuating said camera aim-altering means in a sense to restore said elapsed time to a preassigned value, whereby an image of a selected moving part of said object field appears stationary, and means for controlling the instant of occurrence of said auxiliary signal relatively to said synchronizing component to cause said stationary image to appear in a desired position.

13. In combination with a television pick-up device having means for scanning an object field in transverse elemental lines to produce vision signals representative of the light-tone values of a field of view, means for varying the direction of aim of said pick-up device, means at a receiver station for receiving said vision signals and synthesizing an image therefrom, means for generating an auxiliary signal synchronized with said scanning means, means responsive to the time delay between said auxiliary signal and a selected part of said vision signal for producing a control signal, and means for orienting said pick-up device under control of said control signal in a sense to hold said pick-up device aimed at a part of said object field which is represented by said selected part of said vision signal.

14. In a system for receiving and utilizing signals having at least two components which are subject to relative time delay variations, a network for carrying one of said signal components, said network being biased to render it opaque to said signals, means for periodically removing said bias at instants dependent on the instant of occurrence of the other of said components to permit transmission of parts of said first-named component which occur at said instants, and means under control of energy transmitted by said network for automatically readjusting the relative time delays of said two components.

15. In combination with a television pick-up device for scanning an object field along successive transverse elemental lines to produce vision signals representative of the light-tone values of an object field, a network constructed to deliver auxiliary signals dependent upon said vision signals only at certain instants which regularly recur in pairs, one pair for each line scan, and means for reorienting said pick-up device under control of said auxiliary signals in a sense to cause a vision signal peak representative of a selected object to occur between the two members of each of said pairs of instants.

16. In the art of television, the method of holding a camera aimed at a selected moving object in an object field to cause an image of said object synthesized from television signals derived from said camera to remain stationary, which comprises the steps of receiving said television signals, generating an auxiliary signal in a controlled time relation to a synchronizing component of said television signals, adding said auxiliary signal to the vision component of said television signals to produce a composite signal whose peaks exceed a preassigned threshold only when a vision signal peak is substantially coincident in time with said auxiliary signal, and deriving control energy from said composite signal for reorienting said camera in a sense to maintain invariant the time relation between said auxiliary signal and a vision signal peak representative of said moving object.

17. In combination with a rotatable television pick-up device for repeatedly scanning an object field to derive a signal including a vision com-

16

ponent having a wave form whose amplitude at each instant of a stipulated scanning period is representative of the light tone value of a particular elemental area of said object field and a synchronizing component which is independent of the light tone values of said field, means for holding said scanning apparatus directed toward a desired movable part of said object field independently of movements thereof which comprises means for deriving from said original signal within said scanning period a pulse which occurs at an instant which lags said synchronizing signal by a controlled time delay, whereby the elapsed time between said pulse and each particular peak of said vision signal is dependent on the orientation of said scanning device with respect to that part of said object field which is represented by said peak, and means responsive to variations of said elapsed time from period to period for restoring the same to a desired value.

18. In combination with a rotatable television pick-up device for repeatedly scanning an object field to derive a signal including a vision component having a wave form whose amplitude at each instant of a stipulated scanning period is representative of the light tone value of a particular elemental area of said object field and a synchronizing component which is independent of the light tone values of said field, means for holding said scanning apparatus directed toward a desired movable part of said object field independently of movements thereof, which comprises means for deriving from said original signal within said scanning period a pulse which occurs at an instant which lags said synchronizing signal by a controlled time delay, whereby the elapsed time between said pulse and each particular peak of said vision signal is dependent on the orientation of said scanning device with respect to that part of said object field which is represented by said peak, means for additively combining said pulse with said vision signal component to produce a composite signal whose maximum amplitude peak coincides in time with said pulse, the amplitude of said composite peak being dependent on the amplitude of that portion of said vision signal which coincides in time with said pulse, and means responsive to variations from period to period in the magnitude of said composite signal for restoring the same to a desired value.

19. In combination, means for producing a train of signal pulses, means for producing two trains of auxiliary pulses, means for applying said signal pulses and said two auxiliary trains of pulses to the same circuit so that a signal pulse in said circuit coincides in part at least with one of said auxiliary pulses but is not centered with respect to any two adjacent ones of said auxiliary pulses, and means controlled by said circuit for automatically shifting in time a succeeding train of said signal pulses in a direction tending to cause said centering to occur.

20. In combination, means for forming a number of trains of signals, the time spacing of the signals in each train being at least somewhat similar to that of its predecessor, means for producing during the occurrence of each train of signals a pair of pulses comprising a first pulse having an abrupt trailing edge and a second pulse having an abrupt leading edge the ending of which is displaced in time from the beginning of the corresponding train at least as much as the beginning of the trailing edge of said first pulse, the pulses of each of said pairs occurring

17

at such times with respect to a selected signal in the corresponding train that the latter is substantially symmetrically spaced with respect to the times of maximum intensity of the corresponding pair of pulses, and means responsive to any departure from said symmetrical relationship for controlling means tending to restore said relationship.

21. In combination, means for forming a series of trains of signals of equal duration, each train terminating in a steep-sided pulse, means for filtering said trains to produce a sine wave of a frequency equal to the number of trains per second, and means controlled by said sine wave for producing a series of short pulses, the repetition frequency of which is equal to the frequency of said sine wave.

22. In combination, means for forming an electrical sine wave, means for dividing the energy of said wave into two paths, means for shifting the phase of the wave in one of said paths with respect to that in the other, means for utilizing the waves in the two paths after said phase shifting to control the formation respectively of two trains of pulses regularly recurring at the same frequency, the pulses of one train being displaced in time from the corresponding pulses in the other train, and means under joint control of said pulse trains.

18

23. The combination with a cathode ray tube having a target and beam modulating means, means for deflecting said beam across said target, means for generating a train of electric waves and applying them to said deflecting means, means for generating a second train of waves at a wave frequency having an integral relationship to the frequency of said first train, means for applying said second train of waves to said beam modulating means, and means for delaying by any desired amount one of said trains with respect to the other.

24. The combination with means for producing a series of signal elements or pulses and simultaneously therewith a series of pairs of pulses, each of a plurality of pulses of said first series occurring at least partly within the time span of a corresponding one of said pairs, two circuit control means each acted upon conjointly by one only of the pulses of each pair and any concurring portion or portions of the corresponding pulse of said first series, and means under the joint control of said two circuit control means for automatically varying the time relations between a pulse of said first series and the pulses of its corresponding pair.

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