

Sept. 20, 1971

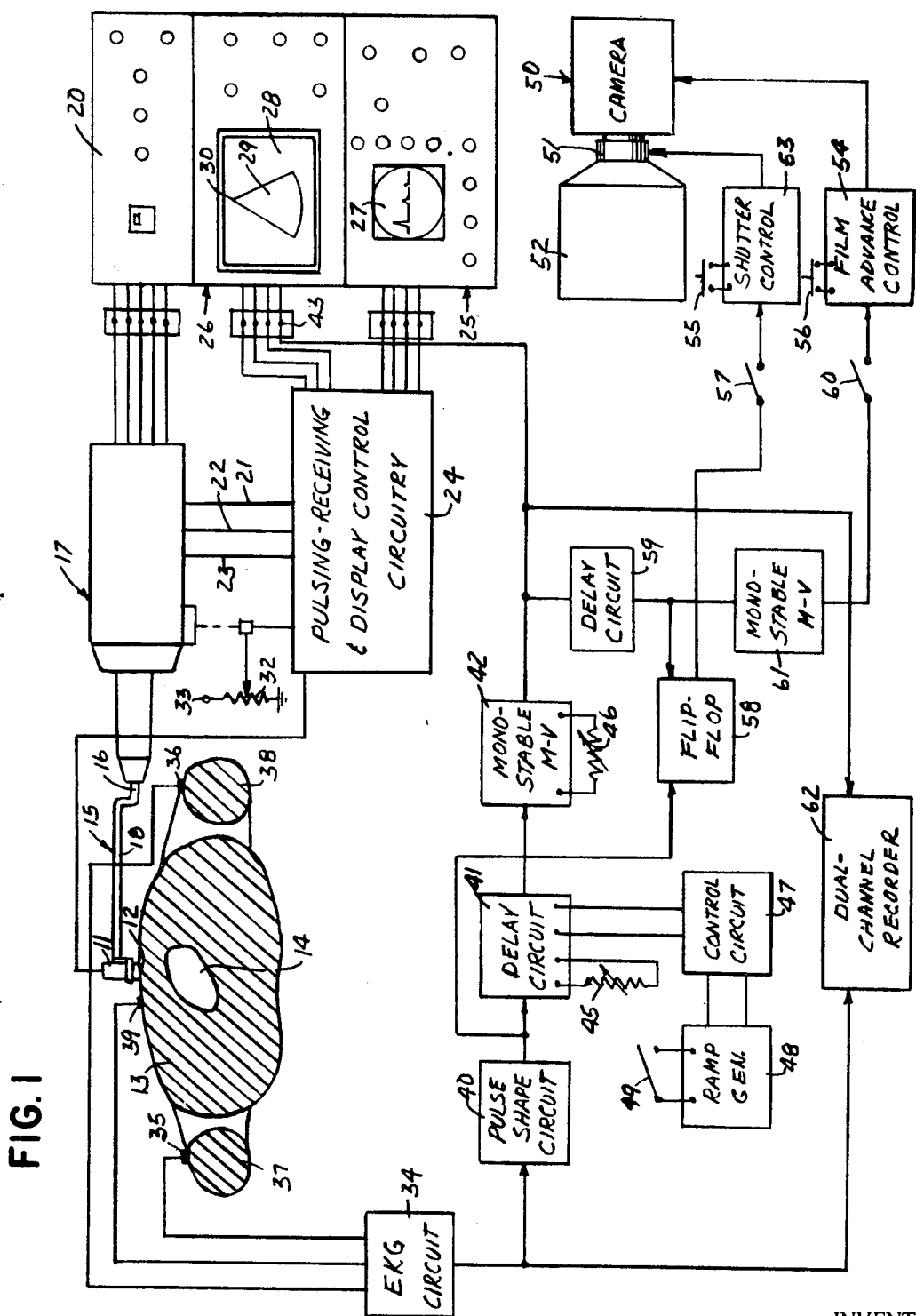
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3,605,724

HEART MOTION IMAGING SYSTEM

Filed Nov. 10, 1969

3 Sheets-Sheet 1



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FIG. 2

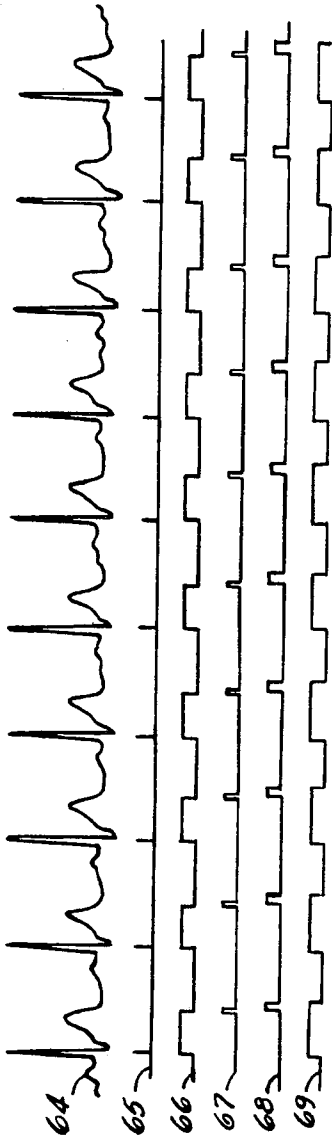
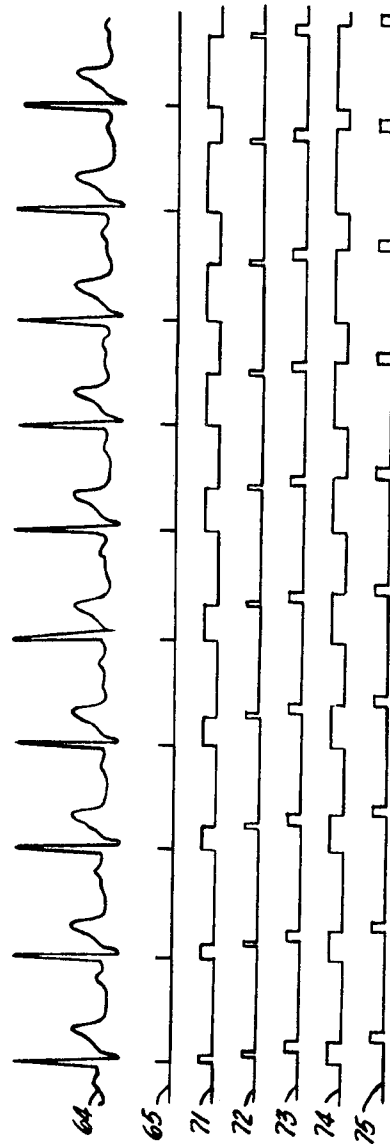


FIG. 3



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3 Sheets-Sheet 3

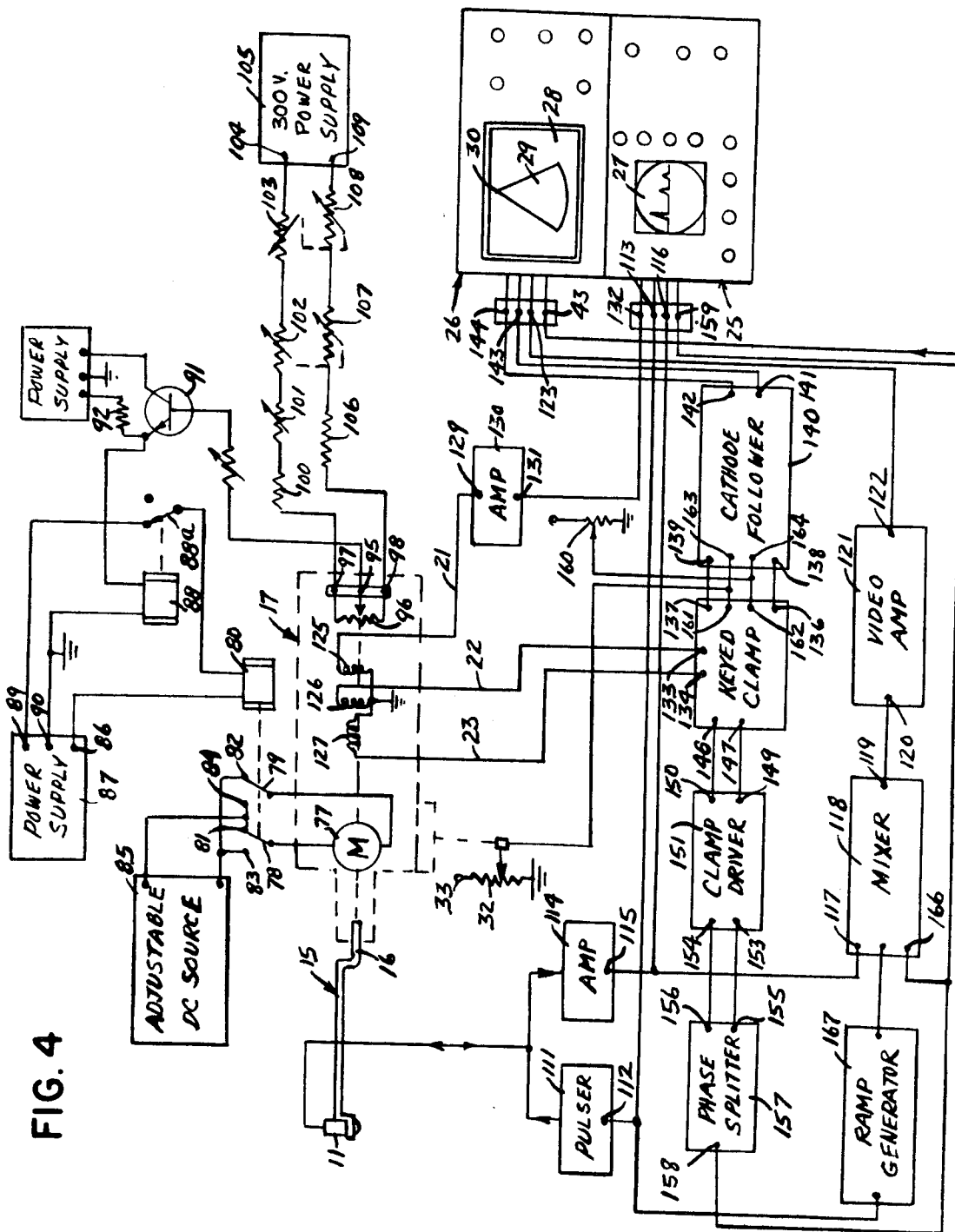


FIG. 4

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HEART MOTION IMAGING SYSTEM

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15 Claims

ABSTRACT OF THE DISCLOSURE

Heart motion imaging system in which a rapidly moving ultrasonic beam transversely scans a beating heart and in which a complete image corresponding to a cross-section of the beating heart is produced on an oscilloscope screen during a time interval which is a small fraction of the duration of the heart cycle and which corresponds to a specific portion of the heart cycle, the time and duration of the time interval being continuously variable. In one mode of operation, a single image is produced during a specific portion of one heart cycle, which may be recorded on film. In a second mode, multiple images are produced during the same specific portions of successive heart cycles to produce images which are integrated on the oscilloscope screen and/or on a single section or frame of film. In this mode, compound scanning may be used. In a third mode, multiple images are produced during progressively different portions of successive heart cycles to produce a slow motion showing of movement of the heart and valves thereof. Such multiple images may be recorded on successive frames of film to be projected at a desired speed for examination.

This invention relates to a heart motion imaging system and more particularly to an ultrasonic scanning system for producing and recording images corresponding to the cross-section of a beating heart. The system operates with a high degree of reliability to produce and record high resolution images in a manner such as to facilitate diagnosis, and the system is very versatile.

Ultrasonic systems have heretofore been developed for scanning a heart to produce cross-sectional indications on an oscilloscope screen and have been used with a great deal of success to obtain diagnostic information not otherwise available and without the dangers of X-ray examinations. However, the images obtained have not always been as clear as would be desirable and the study of the action of heart valves has been difficult because of the relatively rapid movement thereof. It has been proposed to use a signal from an electrocardiograph to control imaging in an ultrasonic system but the arrangements as proposed would not produce a clear image or allow the thorough study of heart valve action.

This invention was evolved with the general object of overcoming the disadvantages of prior art arrangements and of providing a system in which clear images of heart operation are obtained to facilitate accurate diagnosis.

According to this invention, an ultrasonic B-scan arrangement is provided in which transverse scanning movements of an ultrasonic beam and synchronized transverse scanning movements of a trace on an oscilloscope screen are produced at a rapid rate while an unblanking signal is applied to the oscilloscope means from circuitry responsive to a heartbeat signal produced at a certain point in the cycle of beating movement of the heart, the unblanking signal having a duration equal to a small fraction of the duration of a cycle of movement of the heart. Preferably, the duration of the unblanking signal is on the order of less than 0.1 second and with the transverse scanning movements being effected at a

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rapid rate, it is possible to effectively "stop" the action of a human heart.

The transverse scanning movements are preferably effected at a rate such that at least one scanning movement is effected in a time interval equal to the duration of the unblanking signal and with the unblanking signal having a duration on the order of less than 0.1 second, the transverse scanning movements are effected at a rate equal to at least ten per second.

According to a further feature, camera means are provided for photographically recording the image produced on the oscilloscope screen during application of the unblanking signal, preferably with shutter opening means for the camera means being operated from a time preceding to a time following the unblanking signal.

According to another feature of the invention, a series of unblanking signals are produced during consecutive heartbeats, each unblanking signal occurring at the same point in each cycle. With this arrangement, an integrating effect can be obtained on the oscilloscope screen, or on a single section or frame of film on which the successive images are recorded. With compound scanning being used in conjunction with this feature, it is possible to further enhance the resolution obtained.

A further feature of the invention is in the provision in the unblanking circuitry of controllable delay means for changing the timing of the unblanking signal relative to the heartbeat signal. The controllable delay means may be manually controlled to select the portion of the heart cycle in which the image is produced. Also, means may be provided for progressively changing the delay during a series of consecutive heart cycles to produce a slow motion representation of the action of the heart on the oscilloscope screen. In addition, the camera means are arranged to photographically recording on a series of frames of film the images produced on the oscilloscope screen during the series of consecutive heart cycles. The frames of films, or prints thereof may be examined at a later time for diagnostic purposes, or may be projected at a desired speed to show the action of the heart.

This invention contemplates other objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate preferred embodiments and in which:

FIG. 1 is a schematic diagram of a heart motion imaging system according to the invention;

FIG. 2 shows the waveforms at various circuit points in one mode of operation;

FIG. 3 shows the waveforms at various circuit points in another mode of operation; and

FIG. 4 is a schematic diagram illustrating circuits used in controlling movement of a transducer of the system and in displaying indications therefrom.

Reference numeral 10 generally designates a heart motion imaging system constructed in accordance with the principles of this invention. In the system 10, an ultrasonic transducer 11 has an end face 12 from which bursts of ultrasonic energy are transmitted in a beam into a body echo signals being generated from energy reflected from interfaces within the body and impinged on the face 12. As diagrammatically illustrated, the face 12 is engaged with the chest 13 of a patient's body to transmit energy into and receive energy from the region of the patient's heart 14. The transducer 11 is affixed to one end of a shaft 15 having an opposite end 16 journaled in a drive unit 17 for oscillatory movement about an axis which is approximately aligned with the face 12 of the transducer 11. Preferably, the shaft 15 may have an offset portion 18 intermediate the transducer 11 and the end 16.

The drive unit 17 includes a motor for mechanically oscillating the shaft 15 and transducer 11 at a rapid rate, for example 10 oscillations per second and further includes a potentiometer unit coupled to the motor and to the shaft, the motor and potentiometer unit being connected to a control unit 20. The drive unit 17 further includes a resolver which is connected through lines 21-23 to pulsing-receiving and display control circuitry 24. The circuitry 24 is connected to the transducer 11 and to display units 25 and 26. The display unit 25 includes an oscilloscope having a screen 27 on which an A-scan indication is produced, a spot of light produced on the screen 27 being deflected horizontally by a sawtooth wave synchronized with the pulsing of the transducer 11 while received echo signals are used to deflect the spot in a vertical direction to produce "pips" on the screen 27. The position of such pips, measured from the left side of the screen 27, are measures of the depths within the body of the interfaces producing the echo signals.

The display unit 26 includes an oscillograph having a screen 28 on which a pie-shaped indication 29 is produced, as diagrammatically shown, which consists of traces originating from an apex 30, the angulation of the traces being synchronized with the angular oscillatory movement of the transducer 11. Received echo signals are used to brighten the spot on the screen 28 and, as a result, a cross-sectional indication of the structure of the heart 14 is obtained.

The circuitry 24 is further connected to the movable contact of a potentiometer 32, shown connected between ground and a power supply terminal 33, the movable contact of the potentiometer 32 being mechanically connected to the drive unit 17 and being responsive to movement of the drive unit 17 in a direction transverse to the axis of oscillation of the transducer 11 and parallel to the surface of the body engaged by the face 12. The electrical signal developed from the potentiometer 32 is so applied as to cause the image 29 to move across the screen 28 in synchronism and in proportion to the movement of the drive unit 17. With this arrangement a form of compound B-scan operation is obtained.

It is noted that the circuitry of the control unit 20 and the pulsing-receiving and display control circuitry 24 are shown in FIG. 4, described hereinafter.

This invention involves the use of circuitry which functions to produce the image 29 on the screen 28 only during certain selected and relatively short portions of the cycle of beating movement of the heart 14. Means are provided for supplying a heartbeat signal occurring at a certain point in the cycle of beating movement of the heart 14 and in the illustrated arrangement, such means comprise an electrocardiogram unit 34, shown connected to electrodes 35 and 36 on the arms 37 and 38 of the patient's body and to an electrode 39 positioned on the chest 13 adjacent the heart 14. Additional electrodes are connected to the unit 34 and may be positioned on the patient's legs or at other points of the body.

The EKG unit 34 functions to produce a signal having a waveform corresponding to electrical signals at the heart 14, which signal is applied to a pulse shaping circuit 40 operative to develop a short pulse at a certain point in the cycle of movement of the heart 14. The output pulse from the circuit 40 is applied through a delay circuit 41 to a monostable multivibrator 42 which develops a pulse which is applied to an unblanking terminal 43 of the display unit 26. Terminal 43 is connected directly or through a suitable amplifier to an intensity control electrode of the cathode ray tube of the unit 26, either to the control grid or to the cathode.

In accordance with important features of the invention, the delay circuit 41 is adjustable by means of a variable resistor 45 to obtain a selected amount of delay and the monostable multivibrator 42 is adjustable by means of a variable resistor 46 to obtain an unblanking pulse having a desired duration. In addition, the delay circuit 41 may

be controllable through a control circuit 47 from a ramp generator 48 controlled by a switch 49, such circuits being operative to progressively change the amount of delay of the delay circuit 41 through a series of consecutive heart cycles, when the switch 49 is closed.

With the circuitry as thus far described, the delay circuit 41 may be adjusted to select the portion of the heart cycle during which the monostable multivibrator 42 is operative to develop an unblanking pulse while the duration of the unblanking pulse is adjustable by means of the resistor 46. Preferably, the delay circuit 41 is adjustable over a range at least equal to the duration of one heart cycle so that any desired portion of the cycle may be selected. The monostable multivibrator 42 is adjustable to produce a pulse having a duration which is a small fraction of the duration of one heart cycle, preferably on the order of one-tenth or less. By way of example, the delay circuit 41 may be adjustable to provide a delay of from 0 seconds to 40 milliseconds while the multivibrator 42 is adjustable to produce a pulse having a duration of from 25 to 200 milliseconds.

With proper adjustment of the circuits in accordance with the rate of beating of the heart, it is possible to effectively "stop" the action of the heart on the oscilloscope screen 28, at any desired point of the heart cycle.

With the switch 49 closed to cause the ramp generator 48 to control the delay through the control circuit 47, the amount of the delay is progressively changed through a series of consecutive heart cycles to produce an effect a slow motion representation of the heart action on the screen 48.

Further important features of the invention relate to the provision of means for photographically recording the images produced on the screen 28 for later examination and to provide a record of the operation of a patient's heart. As diagrammatically illustrated, a camera 50 is provided including a lens and shutter assembly in a housing portion 51, which may be positioned to record an image on the screen 28, preferably with a suitable light shroud 52 being provided the end of which may be positioned against the face of the unit 26 around the screen 28. The shutter of the camera 50 is solenoid-operated and controlled from a shutter control circuit 53. Film-advancing means of the camera 50 are also solenoid-actuated and are controlled from a film-advancing circuit 54. Circuits 53 and 54 may be manually operated from push button switches 55 and 56 or may be automatically controlled. For automatic control, an input of the shutter control circuit 53 is connectable through a switch 57 to a flip-flop 58 having one input connected to the output of the pulse shape circuit 40 and having a second input connected to the output of a delay circuit 59, connected to the output of the monostable multivibrator 42. The flip-flop 58 is set in response to a pulse from the circuit 40 and reset in response to a pulse from the delay circuit 59, so that the shutter of the camera 50 may be opened prior to the unblanking pulse developed by the multivibrator 42 and closed after the unblanking pulse.

The film-advancing control 54 has an input connectable through a switch 60 to the output of a monostable multivibrator 61 the input of which is connected to the output of the delay circuit 59. With switch 60 closed, the film is advanced at a time following the unblanking pulse.

To provide a record of the relative timing of the heartbeat signal developed from the EKG circuit 34 and the unblanking pulse developed by the monostable multivibrator 42, the outputs of such circuits are connected to a dual channel recorder 62.

FIG. 2 shows the waveforms produced at various circuit points in one mode of operation. The waveform of the output of the EKG circuit 34 is indicated by reference numeral 64 and normally includes, in each heart cycle, an amplitude pulse which is very large, designated as the "R" wave and two smaller pulses or signals designated as the "S" wave and "T" wave. The pulse shaping circuit

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40 may preferably respond to the trailing edge of the R wave to develop a waveform comprising a series of short pulses, designated by reference numeral 65.

Each pulse from the circuit 40 triggers the delay circuit 41, which is preferably in the form of a monostable multivibrator, to develop a squarewave of controllable duration, the waveform being designated by reference numeral 66. At the trailing edge of each squarewave pulse from the delay circuit 41, the monostable multivibrator 42 is triggered to produce a relatively short pulse, the unblanking waveform being designated by reference numeral 67. The delay circuit 59, which may also comprise a monostable multivibrator, operates in response to the trailing edge of each pulse from the multivibrator 42 to develop a pulse having a certain duration, the waveform at the output of the delay circuit 59 being indicated by reference numeral 58.

The waveform of the output of the flip-flop 58 is designated by reference numeral 69, consisting of a series of squarewave pulses, each having a leading edge initiated by the pulse from the circuit 40 and each having a trailing edge following the trailing edge of each pulse developed by the delay circuit 59.

In the mode of operation as depicted in FIG. 2, the delay of the delay circuit 61 is constant and each of the unblanking pulses is produced at the same point in the heart cycle. With the film advancing mechanism of the camera 50 inoperative, a series of images are recorded on one section or frame of film each produced at the same point of a heart cycle. With this operation, an integrating effect is obtained and a clearer picture with higher resolution and more discrimination against noise results. In this mode of operation, the drive unit 17 may be moved linearly while the transducer 11 is oscillated, the position of the image 29 being also shifted linearly in accordance with the linear movement of the drive unit 17. A form of compound scan results in which, with respect to each reflecting point or interface in the body, the ultrasonic beam is impinged at difference angles. With the integrating effect, even higher resolution and greater picture clarity is obtained.

It is noted that in the operation as depicted in FIG. 2, the shutter is operated during each heart cycle. If desired, the shutter can be simply left open for a series of heart cycles, as by opening the switch 57 and closing the switch 55 for the desired time interval.

FIG. 3 depicts the waveforms produced in another mode of operation. Waveforms 64 and 65 are again produced by the circuits 34 and 40, in the same manner as described above. However, the ramp generator 48 is brought into operation by closing the switch 49 to cause the delay produced by the delay circuit 41 to progressively increase during a number of consecutive heart cycles, the waveform at the output of the circuitry 41 being indicated by reference numeral 71. The change in the delay from one heart cycle to another is somewhat exaggerated in the illustration, for the purpose of clarity and normally it is desirable that the amount of the delay be shifted only slightly from one cycle to another. The waveform at the output of the monostable multivibrator 42 is indicated by reference numeral 72, the position of the unblanking pulses being progressively shifted with respect to the signal from the EKG circuit 34.

The waveforms at the output of the delay circuit 59 and at the output of the flip-flop 58 are designated by reference numerals 73 and 74, being similar to that waveforms 68 and 69 except that they are shifted in accordance with the progressive delay introduced.

The waveform at the output of the monostable multivibrator 61 is designated by reference numeral 75 and consists of a series of pulses each occurring at a time following the closure of the shutter.

It is important that the oscillatory scanning movements of the transducer 11 be effected at a rapid rate such that at least one scanning movement is effected at a time inter-

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val equal to the duration of the unblanking signal. FIG. 4 shows the circuit of the control unit 20 as well as the pulsing-receiving and display control circuit 24, which facilitates such rapid scanning movements as well as the display of indications therefrom. It is noted that these circuits are disclosed in U.S. Pat. No. 3,403,671 of John J. Flaherty and Peter J. Rosauer and in Pat. No. 3,448,606 of John J. Flaherty, John W. Clark and Peter J. Rosauer, in more complete detail. With the combination of the oscillating mechanism and control and the display circuitry disclosed in said patents and as shown in FIG. 4, and the unblanking control and photographic recording arrangement of FIG. 1, it is possible to obtain high resolution images of the operation of the heart at any selected point in the cycle of operation thereof.

Referring to FIG. 4, the unit 17 includes a DC motor 77, the rotor of which is preferably directly coupled to the end 16 of the shaft 15, the motor being connected through relay contacts 78 and 79, operated by a relay coil 80, either to contacts 81 and 82 or to contacts 83 and 84, contacts 81 and 84 being connected to one terminal of a DC source 85 while contacts 82 and 83 are connected to the other terminal of source 85. One terminal of the coil 80 is connected to a negative terminal 86 of a power supply 87 while the other terminal thereof is connected through a contact 87, operated by a relay coil 88, to a positive terminal 89 of the power supply 87. One terminal of the relay 88 is connected to ground and to a neutral terminal 90 of the power supply 87 while the other terminal thereof is connected to the emitter of a transistor 91 and through a resistor 92 to a negative terminal of a power supply 93 having a positive terminal connected to the collector of the transistor 91 and having a neutral terminal connected to ground. The base of the transistor 91 is connected through an adjustable resistor 94 to a terminal 95 connected to a movable contact of a potentiometer 96 having end terminals connected to terminals 97 and 98. The movable contact of the potentiometer 96 is mechanically coupled, directly to the rotor of the motor 77.

The relay coil 88 which controls the relay coil 80 and thereby controls the direction of rotation of the rotor of the motor 77 has characteristics such that a certain negative voltage is required at the emitter of the transistor 91 to move contact 87 to one position while a certain positive voltage is required to move it to its other position. Transistor 91 operates as an emitter-follower with the emitter voltage corresponding to the base voltage thereof which, in turn, is controlled by the position of the movable contact of potentiometer 96. When the potential of the potentiometer contact reaches a certain positive level due to rotation of the motor rotor in one direction, the voltage of the emitter of transistor 91 reaches a level which is sufficiently positive to energize the relay coil 88, causing contact 87 to be connected to the terminal 89 and to energize relay coil 80 to move the contacts 78 and 79 to positions opposite those shown in FIG. 4. The switching of relay contact 87 causes a reversal of polarity of the motor current and a reversal of the motor. When the rotor of the motor rotates far enough in the opposite directions, the negative potential of the contact of the potentiometer 96 becomes sufficiently high to cause switching of the relay contact 87 to deenergize the relay coil 80 and to again reverse the direction of rotation of the motor 77.

The angular velocity of rotation of the motor rotor is determined by the DC voltage applied thereto, which, in turn, is controlled by the voltage of the DC source 85 which is preferably adjustable. The angle between the limit positions, at which the motor is reversed, and the attitude are determined by the voltages applied to the terminals 97 and 98. Terminal 97 is connected through a resistor 100, variable resistor 101, a variable resistor 102 and a variable resistor 103 to a terminal 104 of a power supply 105. Terminal 98 is connected through a

resistor 106 and variable resistors 107 and 108 to a second terminal 109 of the power supply 105. Resistors 102 and 107 are ganged together and controlled from a suitable adjustment knob such that the resistances thereof are changed in the same direction to vary the angle between the limits of the oscillatory movement of the motor rotor while maintaining an equal distance between such limits and a neutral position, to maintain a constant attitude. Variable resistors 103 and 108 are also ganged together and controlled by a suitable adjustment knob but the arrangement is such that the resistances are changed in opposite directions to change the attitude of the oscillatory movement. Resistor 101 is adjustable to obtain proper balance and it is noted that resistor 94 may also be adjusted to control the angle between the limits of movement.

To produce indications on the oscilloscope screens 27 and 28, the transducer 11 is energized from a pulser 111 which has an input terminal 112 connected to a terminal 113 of the unit 25 which includes timing and sweep generating circuitry of a type conventional in the oscilloscope art. Such circuitry generates a timing signal at the terminal 113 which is applied to the input terminal 112 of the pulser 111 to cause the transducer 11 to transmit a burst of ultrasonic waves. Echo signals generated by the transducer 11 are applied to the input of an amplifier 114 having an output terminal 115 connected to a terminal 116 of the unit 25 to be applied through amplifier circuits of the unit 25 to vertical deflection plates of a cathode ray tube thereof and to produce pips on the screen 27 in response to such echo signals. The output terminal 115 of the amplifier 114 is also connected to an input terminal 117 of a mixer 118 having an output terminal 119 connected to an input terminal 120 of a video amplifier 121 which has an output terminal 122 connected to a terminal 123 of the unit 26. Terminal 123 is connected either directly or through an amplifier in the unit 26 to the grid of the cathode ray tube therein to intensify the electron beam and brighten the spot in response to echo signals produced by the transducer 11.

The drive unit 17 includes a resolver which is directly coupled mechanically to the rotor of the motor 77 and to the end portion 16 of the shaft 15, effective to translate angular movement into electrical signals for correlating indications on the screen 28 with the oscillatory movement of the transducer 11. The resolver includes a stator coil 125 and a pair of rotor coils 126 and 127 located at right angles to each other and inductively coupled to the stator coil 125 to generate signals having sine and cosine functions of a signal applied to the stator coil 125.

Stator coil 125 is connected through the line 21 to an output terminal 129 of an amplifier 130 having an input terminal 131 connected to a terminal 132 of the unit 25. An internal sweep circuit of the unit 25 operates to generate a sawtooth signal at the terminal 132 which is amplified by the amplifier 130 and applied to the stator coil 125. The rotor coils 126 and 127 then develop corresponding sawtooth signals, having amplitudes which are sine and cosine functions of the angular position of the transducer 11.

Rotor coils 126 and 127 are respectively coupled through the lines 22 and 23 to input terminals 133 and 134 of a keyed clamp circuit 135 having a pair of output terminals 136 and 137 connected to input terminals 138 and 139 of a cathode follower circuit 140 which has output terminals 141 and 142 connected to terminals 143 and 144 of the unit 26. Terminals 143 and 144 are connected directly or through amplifier circuits in the unit 26 to horizontal and vertical deflection plates or coils of the cathode ray tube therein. In the system as illustrated, the terminal 143 is connected to the horizontal deflection circuit and is controlled from a signal developed by coil 126 while terminal 144 is connected to the vertical deflection circuit and is controlled by the signal from coil 127.

The system may be operated in a manner such that with the axis of the transducer 11 in a vertical position, the coil 126 is at right angles to the stator coil 125 so that no signal is applied to the horizontal deflection input terminal 144, while the coil 127 is aligned with the stator coil 125 to generate a maximum signal which is applied to the vertical deflection input terminal 144. A vertical trace is then developed on the screen 28 starting at the apex 30 and moving downwardly under control of the sawtooth sweep signal.

With the transducer moving away from the vertical position signals are applied to the horizontal deflection circuit in proportion to the sine of the angle of such movement while the signal applied to the vertical deflection circuit is reduced in proportion to the cosine of the angle of such movement. As a result, when the transducer 11 is oscillated, the trace on the screen 28 is caused to sweep through a certain arc about the apex 30 to produce a sector scan indication corresponding to the oscillatory movement of the transducer 11.

The keyed clamp circuit 135 operates to fix the signal level at the output terminals 136 and 137 during time intervals between the applied sawtooth signals. To control operation of the keyed clamp circuit 135, input terminals 147 and 148 thereof are connected to output terminals 149 and 150 of a clamp driver circuit 151 having input terminals 153 and 154 connected to output terminals 155 and 156 of a phase splitter circuit 157 which has an input terminal 158 connected to an output terminal 159 of the unit 25. The timing and sweep circuitry of the unit 25 generates an unblanking pulse at the terminal 159 which is applied to the phase splitter 157 to cause the phase splitter 157 to apply squarewave signals of opposite polarity to the clamp driver circuit 151 which in turn operates the keyed clamp circuit 135 to fix the levels during time intervals between sawtooth signals.

The levels at which the signals are fixed are controllable to control the position of the trace or sector scan produced on the screen 28. In particular, the potentiometer 32 and a manually adjustable potentiometer 160 are connected to terminals 161 and 162 of the keyed clamp circuit 135 and terminals 163 and 164 of the cathode follower circuit 140. The potentiometer 32 is controlled by movement of a suitable carriage supporting the drive unit 17 and it operates to shift the base level of the horizontal deflection signal so that the trace or the sector scan indication is moved horizontally on the screen 28 in response to movement of the unit 17.

The mixer 118 has an input terminal 166 to which the unblanking signal from terminal 159 is applied. An additional input terminal of the mixer 118 is connected to the output of a ramp generator 167 having an input connected to the terminal 113 of the unit 25. Ramp generator 167 is of a type known in the radar art and applies a signal to increase the amplification of echo signals in proportion from the distance from the transducer so as to compensate for attenuation of signals and also to compensate for the fact that with the sector scan, the separation of trace lines increases in proportion to the distance from the transducer.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention.

I claim as my invention:

1. In a medical diagnostic system for the examination of a living body having a beating heart therewithin, including transducer means for transmitting bursts for ultrasonic energy in a beam into the body and for receiving energy reflected from interfaces within the body to generate echo signals, oscilloscope means having a screen, means for producing a spot on said screen, and means for deflecting said spot in synchronism with the pulsing of said transducer means to produce a trace on said screen, means for controlling the intensity of said spot in response to said echo signals, and means arranged to

produce transverse scanning movements of said ultrasonic beam and synchronized transverse scanning movements of said trace at a rapid rate, means for supplying a heart-beat signal at a certain point in the cycle of beating movement of said heart, unblanking signal means responsive to said heartbeat signal for supplying an unblanking signal having a duration equal to a small fraction of the duration of a cycle of movement of said heart, and means for applying said unblanking signal to said oscilloscope means.

2. In a system as defined in claim 1, said transverse scanning movements being effected at a rate such that at least one scanning movement is effected in a time interval equal to the duration of said unblanking signal.

3. In a system as defined in claim 2, the duration of said unblanking signal being on the order of less than 0.1 second.

4. In a system as defined in claim 3, said transverse scanning movements being effected at a rate equal to at least ten per second.

5. In a system as defined in claim 1, camera means for photographically recording the image produced on said screen during application of said unblanking signal.

6. In a system as defined in claim 5, shutter control means for opening the shutter of said camera from a time preceding to a time following said unblanking signal.

7. In a system as defined in claim 1, said unblanking signal means being operative to produce a series of unblanking signals during consecutive heartbeats each occurring at the same point in each cycle.

8. In a system as defined in claim 7, camera means for photographically recording on one section of film a series of images produced on said oscilloscope screen during said consecutive heartbeats.

9. In a system as defined in claim 1, said unblanking signal means including controllable delay means for changing the timing of said unblanking signal relative to said heartbeat signal.

10. In a system as defined in claim 9, said controllable delay means being continuously adjustable over a range at least equal to the duration of one heart cycle.

11. In a system as defined in claim 9, means for progressively changing the delay of said controllable delay means through a series of consecutive heart cycles to produce a slow motion representation of the action of said heart on said oscilloscope screen.

12. In a system as defined in claim 11, camera means for photographically recording on a series of frames of film the images produced on said oscilloscope screen during said series of consecutive heart cycles.

13. In a system as defined in claim 1, said transverse scanning movements of said ultrasonic beam being in the form of oscillatory movements about a certain axis and said synchronized transverse scanning movements of said trace being effected as arcuate sweeping movement about an apex point.

14. In a system as defined in claim 13, means for shifting said apex point transverse in synchronism with linear movement of the axis of oscillatory movement of said ultrasonic beam.

15. In a system as defined in claim 14, said unblanking signal means being operative to produce a series of unblanking signals during consecutive heartbeats each occurring at the same point in each cycle.

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ALDRICH F. MEDBERY, Primary Examiner

U.S. Cl. X.R.

128—2.05R, 2.06R