

April 21, 1964

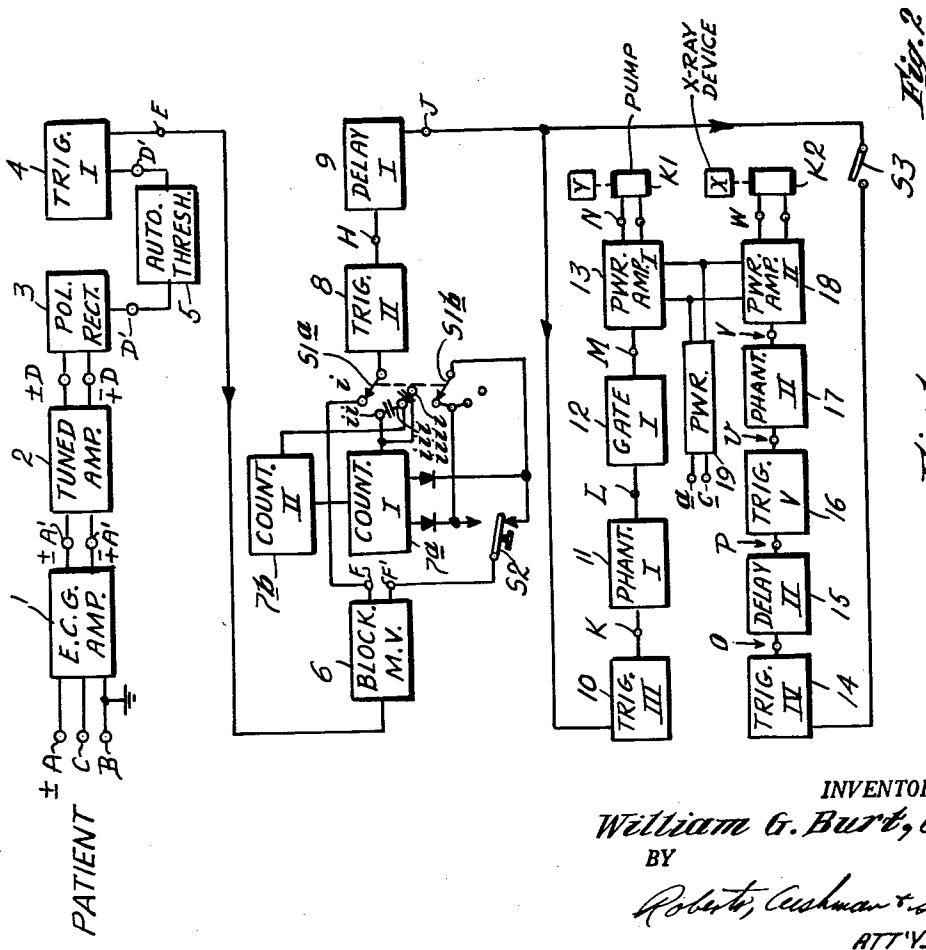
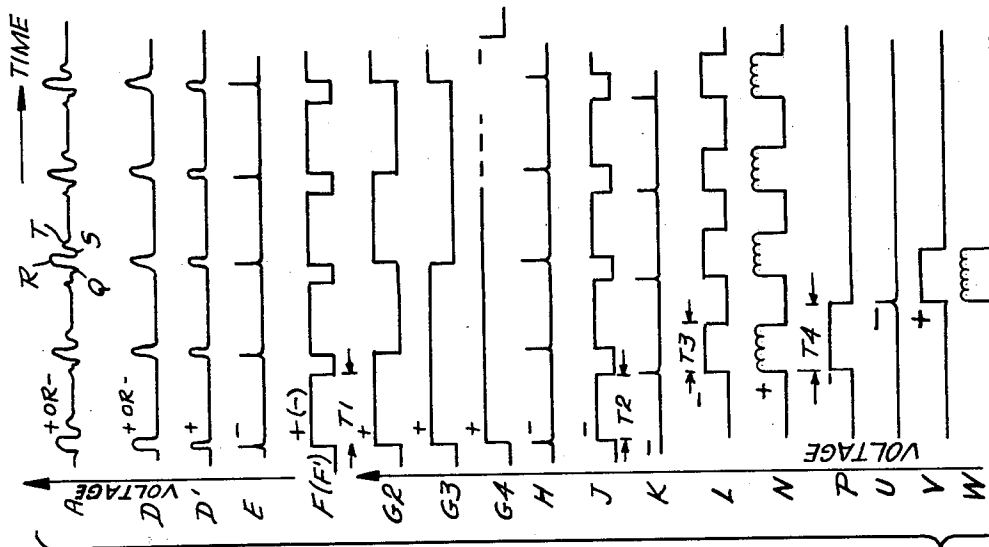
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3,129,704

ELECTRONIC CARDIAC PROGRAMMER

Filed Aug. 25, 1960

6 Sheets-Sheet 1



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ELECTRONIC CARDIAC PROGRAMMER

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6 Sheets-Sheet 2

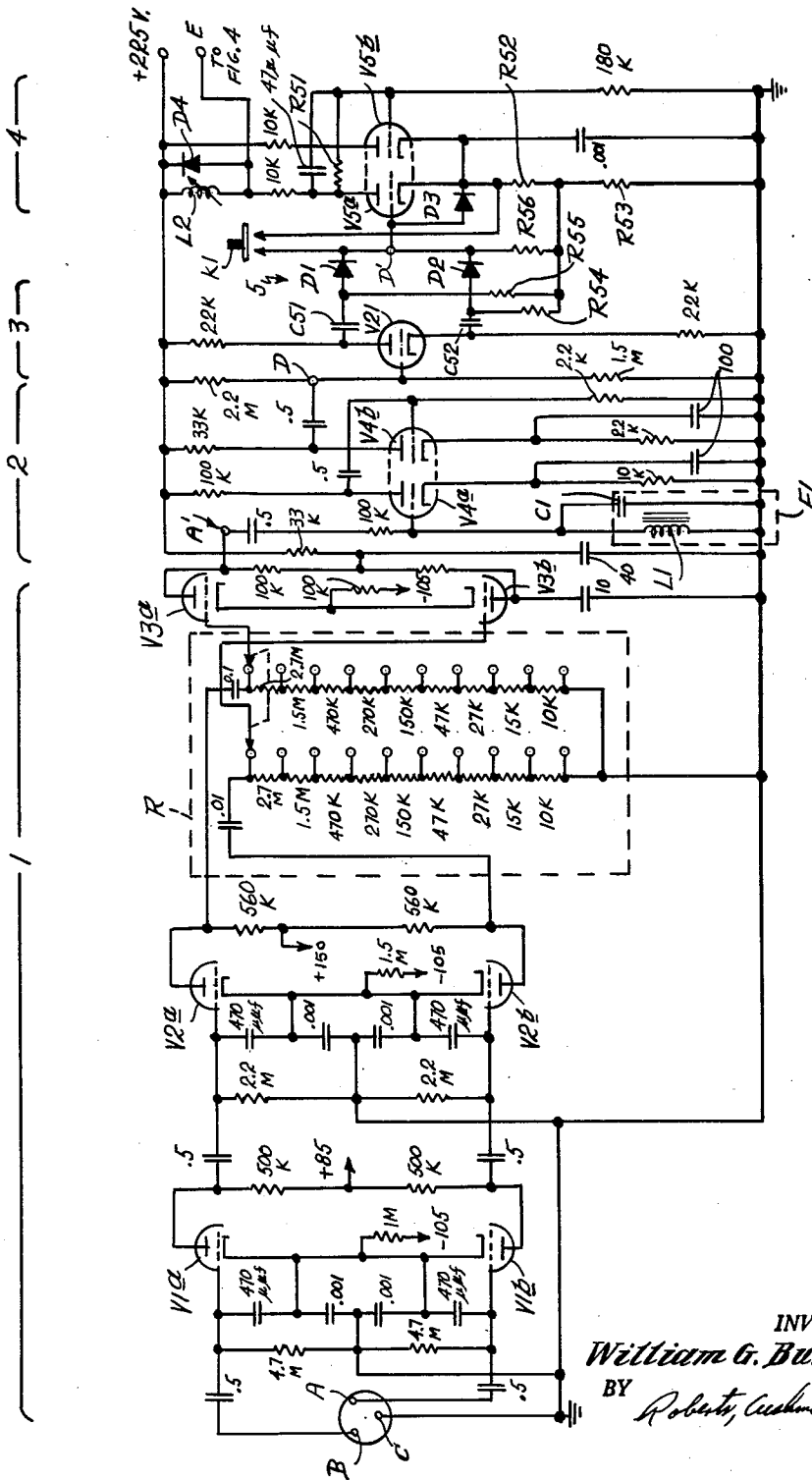


Fig. 3

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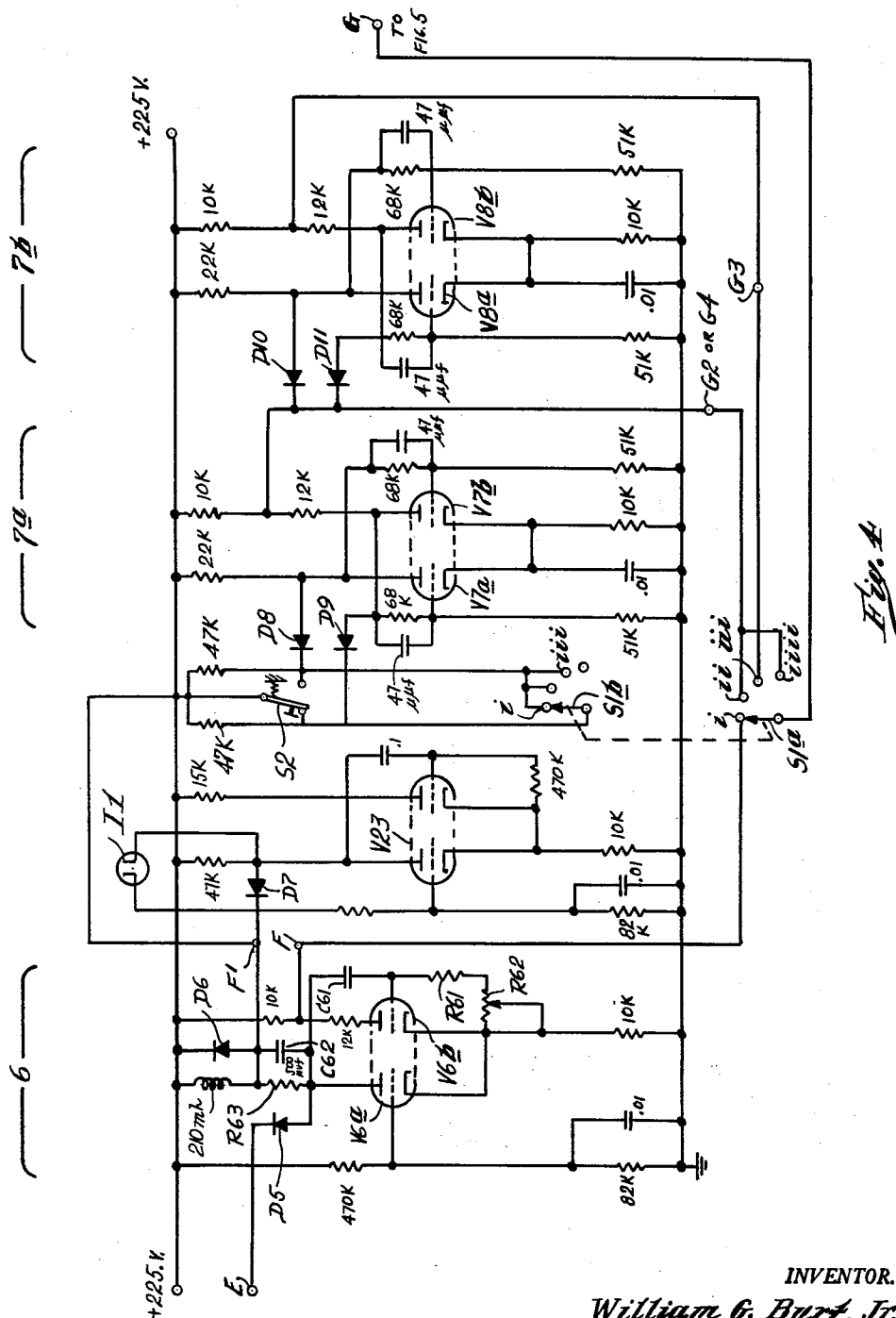
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ELECTRONIC CARDIAC PROGRAMMER

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6 Sheets-Sheet 3



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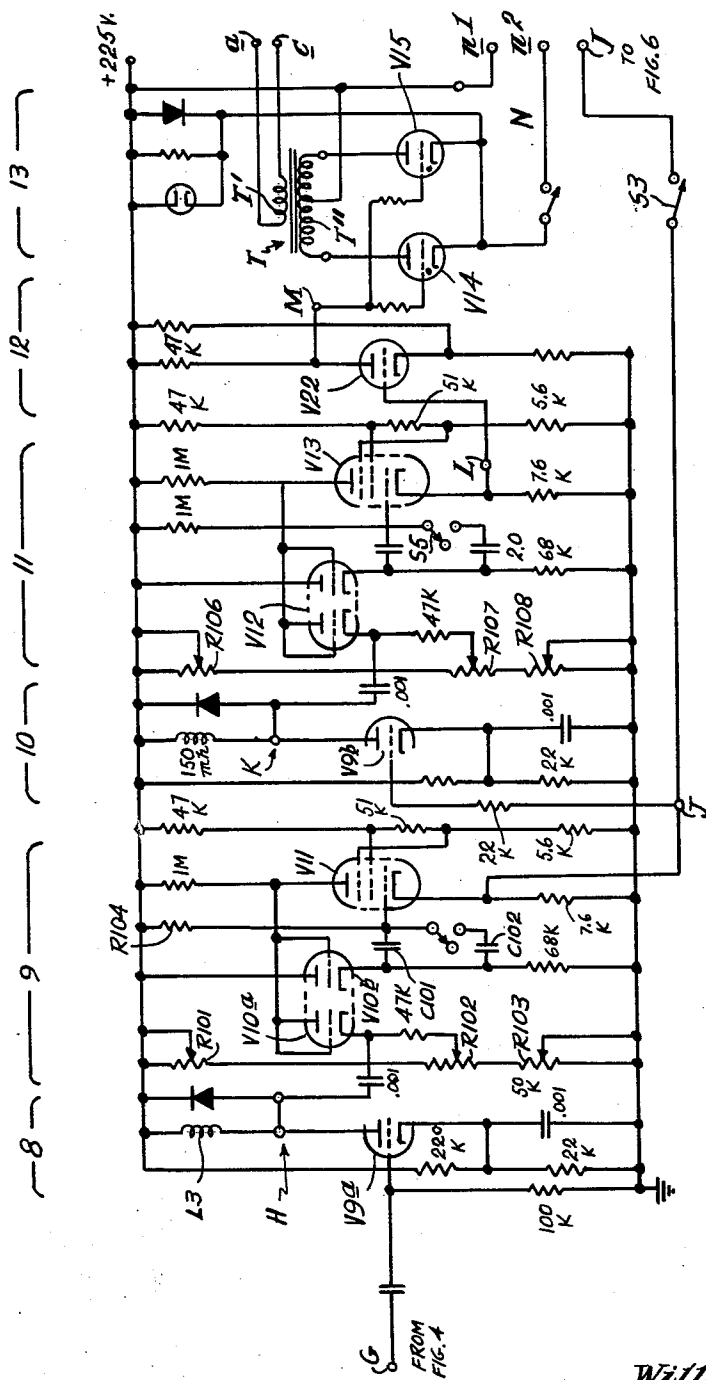
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ELECTRONIC CARDIAC PROGRAMMER

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6 Sheets-Sheet 4



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ELECTRONIC CARDIAC PROGRAMMER

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6 Sheets-Sheet 5

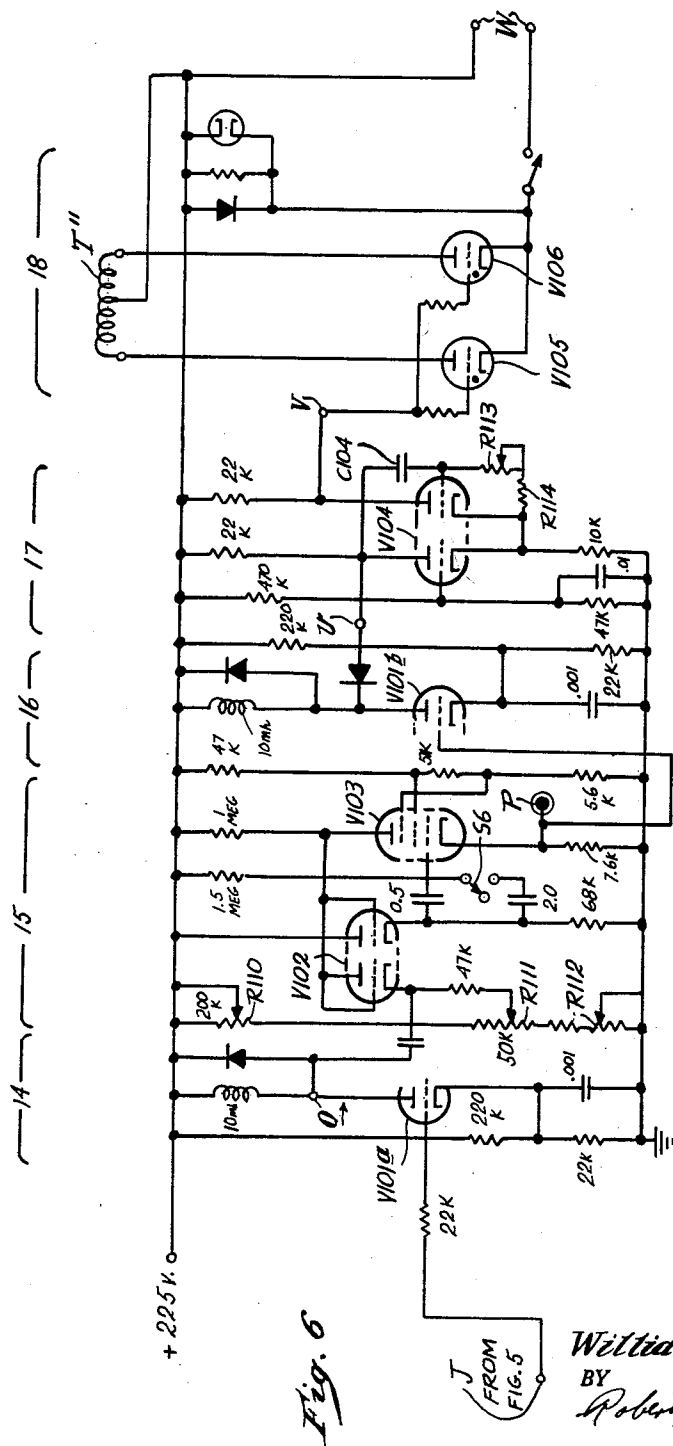


Fig. 6

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6 Sheets-Sheet 6

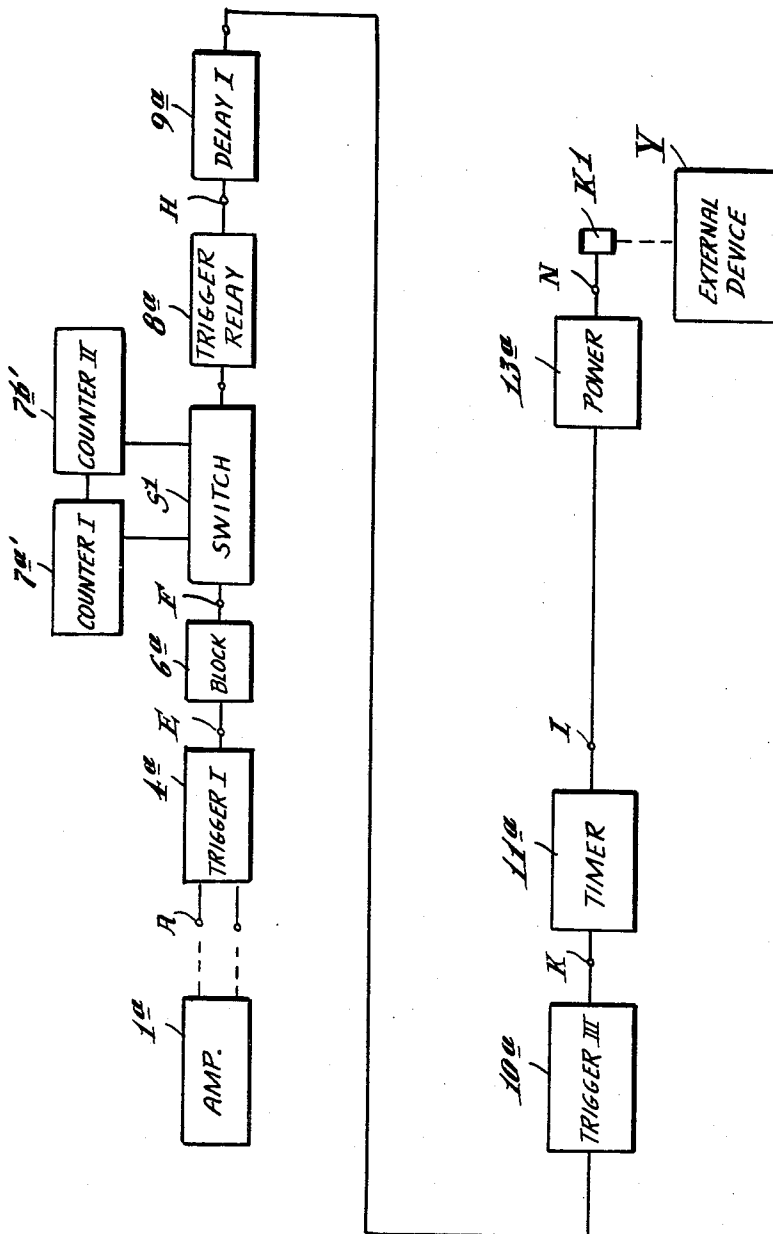


Fig. 7

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ELECTRONIC CARDIAC PROGRAMMER
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20 Claims. (Cl. 128--2.1)

This invention relates to electrical apparatus for monitoring the heart beat of a patient and programming either diagnostic or other treatment of the patient in a precisely timed relation to the heart beat cycle.

Conventional electrocardiograph equipment involves the attachment of three electrodes, usually designated A, B and C, to spaced points of a patient's body. Such electrodes pick up from the patient a cyclically recurrent electrical cardiac signal or voltage waveform having four predominant peaks or components known as the Q, R, S and T pulses which occur during successive cardiac intervals. Of these the R pulse is usually most prominent and its occurrence may be used as a time reference for electrically controlling external apparatus such as a pump or other device for treating the patient either diagnostically or otherwise.

Under ideal conditions it is relatively simple to detect the cardiac signal, generate a trigger pulse in timed relation to the cardiac signal, and use the trigger pulse to produce a control signal for other equipment. The cardiac signal, however, is extremely weak and requires considerable amplification for use as a trigger pulse. In practice, noise from the environment or from related electrical equipment is of such relatively high level that it is difficult to generate a trigger pulse which is consistently related only to the cardiac signal. Frequently the noise will reach such a high level relative to the cardiac signal as to cause generation of a spurious trigger pulse.

Accordingly it is an object of the present invention to generate a control pulse which is reliably and precisely timed in relation to a cardiac signal, and to suppress the effect of environmental noise during and subsequent to the cardiac signal.

A further object is to generate a control pulse which is in precisely timed relation to the cardiac signal regardless of the polarity of the signal picked up from a patient, and to vary the phase relation, frequency and duration of the control pulse with respect to the cardiac signal.

According to the invention electrical equipment comprises a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means for generating an output signal having a predetermined time relation to said cardiac signal, for controlling external equipment, and a channel for coupling said modified signal to said generating means including means for suppressing electrical noise during a substantial portion of the cardiac interval thereby to prevent generation of a spurious output signal unrelated to the cardiac signal.

For the purpose of illustration typical embodiments of the invention are shown in the accompanying drawings in which:

FIG. 1 is a block diagram of electronic control equipment;

FIG. 2 shows the voltage waveforms occurring in the equipment;

FIGS. 3 to 6 are schematic diagrams of the several portions of the equipment of FIG. 1; and

FIG. 7 is a block diagram of electromechanical control equipment.

Referring to FIGS. 1 and 2 the apparatus provides the conventional A, B and C electrocardiograph terminals for connection to electrodes on the patient. The well known cardiac electrical waveform comprising portions Q, R, S and T (at A of FIG. 2) is amplified and

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the R portion or pulse selected. The R pulse is then used to trigger stages in which the R pulse is in effect delayed and modified to form output pulses of variable timing and duration which operate the devices for examining or treating the patient. As one example the apparatus may operate a pump Y, which is connected to the patient's circulatory system. The pump may be used to vary the patient's arterial blood pressure, for example by decreasing pressure during systole to relieve a weakened heart, and increasing pressure during diastole to increase flow to an alternate coronary capillary bed. Or the pump may inject an X-ray opaque dye into the patient's circulatory system so that after a predetermined interval, when the dye has reached a desired region of the systems, an X-ray may be taken of that region. In each case the pumping, to be in natural phase relation with the normal circulation in other parts of the system, should occur at a certain time after the R pulse of the heart beat, and for a duration of time dependent on the type of treatment. The present apparatus controls both the time delay and the duration of pumping.

Referring to FIGS. 1 and 2 in detail the Q, R, S, T signal picked up from the patient is applied to terminals A, B and C. This signal may be of the polarity shown in waveform A of FIG. 2, or of opposite polarity, which cannot be determined in advance. In either case the signal is amplified by the conventional electrocardiograph amplifier 1 at whose output appears a waveform A' like form A but of greater amplitude. The signal at A' is amplified in a tuned circuit 2 which selects the R pulse and discriminates against the Q, S and T portions, so that its output is a waveform D comprising essentially only an amplified R pulse of positive or negative polarity. The signal D is applied to a circuit 3 which produces a pulse D' of, say, positive polarity only, regardless of whether the input pulse D is positive or negative. The waveform D' will be like the waveform D and is used to trip a first trigger stage 4. The first trigger stage has a threshold normally exceeded only when the amplified R pulse is applied. If excessive noise is present at stage 3, an automatic threshold network 5 effectively raises the threshold value of the trigger stage 4 to render the noise for the most part incapable of triggering this stage. In any case the R pulse causes the trigger to produce a standard trigger pulse E.

The trigger pulse E is applied to a blocking or a symmetrical, monostable multivibrator 6, which executes one cycle F following each trigger pulse E. The positive excursion from stable condition, coincident with the trigger pulse E, reaches a level which endures for a major portion T1 of the cycle between R pulses. Then a return excursion to stable condition occurs at the end of the interval T1. During this interval, a spurious triggering of stage 4, due to noise, large amplitude T waves or other causes, can have no effect on the multivibrator 6 since it is fully saturated during the positive excursion. The multivibrator thus blocks spurious triggering of the system during the recovery interval T1, but may be tripped after the interval.

The output F is applied to a contact i of a rotary switch having two contactors S1a and S1b. The multivibrator 6 also has a second output F' of like form but opposite polarity, which is applied through a key S2 either to one input or both inputs of a first 2 to 1 counter 7a depending on the position of contactor S1b. In the first three positions of S1b the signal F' is effectively applied to both inputs of the first counter 7a, causing it to produce the conventional flip-flop action, thereby producing an output pulse of positive polarity only for alternate input pulses. One output of the first counter 7a is connected to switch contacts ii and iii. A second output is connected to a second 2 to 1 counter 7b whose out-

put is connected to switch contact iii. Depending on the positions of switches $S1a-b$ and $S2$ four possible waveforms F, G2, G3 or G4 may appear at the contactor of switch $S1a$, the input to stage 8 as follows:

With $S1a-b$ and $S2$ as shown, waveform F applies a positive excursion or rise to stage 8 for each R pulse. With $S1a-b$ transferred to contact ii a rise G2 appears once for each two successive R pulses. With $S1a-b$ transferred to contact iii a rise G3 appears once for each four successive R pulses. When switch $S1a-b$ is transferred to contact iiii no positively rising signal is produced by the first counter 7a until the key $S2$ is transferred. The first occurrence of a negative rise of signal F' then causes the counter 7a to deliver one rise G4 to contact iiii, but thereafter no further rises occur until the key is released and transferred again, following at least one pulse F' which resets the counter to make it capable of producing further positive pulses.

Whichever waveform F, G2, G3 or G4 is applied to a succeeding, second trigger stage 8 it causes the trigger stage to deliver one short negative pulse for each positive rise in the applied signal. As shown at H one negative pulse is produced for each positive excursion of waveform F, such positive excursions being substantially coincident with the occurrence of an R pulse.

The trigger signal H is then applied to a first delay stage 9 which executes a square wave cycle J for each negative trigger pulse H received. The cycle J comprises a negative excursion substantially coincident with a trigger pulse, followed after a delay interval $T2$ determined by the delay circuit, by a negative voltage drop. The delayed negative drop is used to trip a third trigger stage 10, and also a fourth trigger stage 14, if a switch $S3$ is closed as will be more fully explained.

The third trigger stage 10 is in a channel 10-13 controlling a solenoid K1 and its valve or pump Y. As shown in wave form K, the trigger 10 produces one negative pulse delayed an interval $T2$ after the trigger pulse H of the second trigger stage 8. The delay trigger pulse K is applied to a first generator 11 of square waves L whose duration $T3$ is determined by the generator circuit. The square wave L is coupled by a gate 12 to a power amplifier 13, the gate serving to raise the D.C. level of the signal L to the high voltage reference level of the power amplifier, as will be explained more fully hereinafter. The output M of the gate 12, which is like the waveform L, causes the power amplifier to draw from a power supply 19 a high current control signal for the duration of the square wave L. This signal N controls a solenoid K1 and its associated pump or valve Y.

The circuit so far described may be used to pump blood on every heart beat. The start of pumping is delayed after the heart beat a time interval determined by the first delay stage 9, and the interval during which blood is pumped is determined by the duration phantatron square wave generator 11. If two or more operations are desired an additional channel 14-18, connected to the switch $S3$, is used. For example, if the first channel 10-13 controls dye injection from pump Y at a certain interval after a heart beat, the second channel 14-18 may initiate an X-ray exposure of the area in which the dye is circulated. An additional delay after dye injection is necessary to allow some circulation of the dye before triggering the exposure. Since X-ray exposure should be minimized, the switch $S1a-b$ is transferred to contacts iiii so that only when key $S2$ is closed is a single pulse G4 transmitted to the second trigger stage 8, only one negative drop occurs in the waveform J, and subsequent stages produce only one pulse or square wave for each transfer of the key $S2$.

The second channel comprises fourth and fifth trigger stages 14 and 16 like trigger 10, a delay stage 15 like delay 9, a duration square wave generator 17 of multivibrator configuration and a power amplifier 18 like amplifier 13.

The power amplifiers 13 and 18 are furnished current from a common power supply 19, comprising a transformer T shown in FIG. 5.

When switch $S3$ is closed, the delayed negative drop of signal J trips trigger 14, whose output O is like waveform K but comprises only one pulse delayed an interval $T2$ after the first occurrence of an R pulse following transfer of switch $S2$. The single delayed pulse initiates a single square wave cycle P in a second delay stage 15. At the end of this square wave cycle which represents a delay $T4$, a trigger stage 16 produces one pulse U which is now delay an interval $T2+T4$. The delayed pulse U causes the generator 17 to produce one square wave V which triggers the desired X-ray exposure. The square wave causes the power amplifier to deliver a high current signal W of duration suitable for triggering an X-ray device X and its associated timer for example.

FIG. 3 shows schematically preferred circuits of the electrocardiograph amplifier 1, tuned amplifier 2, polarity rectifier 3, automatic threshold 5 and first trigger 4.

The input terminals A and B of electrocardiograph amplifier 1 are capacitatively connected respectively to the control grids of a first balanced differential amplifier $V1a$ and $V1b$, each one half of a type 12AY7 tube. As previously mentioned the cardiac signals are opposite in polarity, but cannot be determined in advance whether terminal A or C carries a signal with a positive rising R pulse. The first stage amplifiers $V1a$ and $V1b$ are individually capable of amplifying a signal of either polarity, as are the succeeding amplifier stages $V2a$, $V2b$, and $V3a$, $V3b$.

The anodes of amplifier $V2a$ and $V2b$ are respectively coupled to a step attenuator R comprising two banks of nine resistors decreasing from 2.7 megohms to 10 kilohms. The wipers for respective banks are mechanically ganged to that cardiac signals of substantially the same signal level can be selected for application to the respective control grids of the succeeding balance amplifiers $V3a$ and $V3b$, type 12AX7. The three balanced amplifier stages are designed to amplify the oppositely phased cardiac signals in the parallel channels while tending to cancel in-phase noise components, or alternating voltages picked up by the input leads to terminals A, B, and C from other electrical equipment.

A single phase signal A' appears at the anode of tube $V3a$. This signal, of undetermined polarity, is coupled to a two-stage, voltage amplifier 2 including stages $V4a$, $V4b$, type 12AU7. At the grid of stage $V4a$ is a parallel-tuned circuit F1 comprising an inductance L1 (500 henries) and a capacitance C1 (0.168 microfarad) whose resonant frequency is approximately that of the principal frequency component of the R pulse in the cardiac signal A'. The strength of the R pulse is accentuated, while that of the Q, S and T portions and of 60-cycle and other noises is attenuated, so that the R pulse is principally amplified by stage $V4a$, as shown by voltage D in FIG. 2. The R pulse is further amplified by stage $V4b$ and coupled to a two-phase output stage $V21$, type 6C4.

At the anode and cathode of stage $V21$ appear amplified and accentuated R pulses of approximately equal voltage amplitude and in opposite, but still undetermined, polarity. Both phases are coupled through 0.5 microfarad capacitors C51 and C52 to the anodes of diodes D1 and D2 (types 1N628) of the polarity rectifier 3, whose cathodes in turn are connected to the control grid of the succeeding stage $V5a$. Whether the positive R pulse appears at the anode or cathode of stage $V21$, only the positive R pulse, and not the negative R pulse will be passed by one of the diodes D1 or D2 to the grid of stage $V5a$. Thus regardless of the polarity of the signals applied to the input terminals A and C only a signal of positive polarity is selected.

Stages $V5a$ and $V5b$ comprise a trigger circuit 4, known as a Schmidt trigger. The second stage $V5b$ is normally held conducting by positive biasing of its control grid, as

a result of connection of the grid through a resistor R51 (220 kilohms) to the positive anode supply voltage for the first stage V5a. Current drawn by the first stage V5a through resistors R52 (1.2 kilohms) and R53 (8.2 kilohms) provides a bias voltage of about 80 volts for the cathode of stage V5a and 70 volts for the grid. A positive pulse raising the grid approximately 10 volts will cause the first stage to conduct and lower its anode voltage. This anode voltage drop will be reflected in a drop at the grid of stage V5b, causing this stage to cease conduction for the period during which the pulse at the grid of stage V5a continues. The transfer of conduction from the second to the first stage is abrupt and produces a short negative going pulse E at the anode of the first stage regardless of the length of the triggering R pulse D'. The pulse E is limited in duration by a choke coil L2 (210 millihenries) paralleled by a diode D4 (type 1N96) which prevents ringing of the coil.

Reverting to the input of stage V5a, the diodes D1 and D2, in addition to selecting only a positive R pulse, perform a noise suppression function in an automatic threshold circuit 5, described as follows. The noise background of the accentuated R pulse at the anodes of the diodes D1 and D2 will have an undetermined level. But positive swings of the noise will draw current through the diodes D1 and D2 tending to cause a negative shift of the potential at the anodes, this shift occurring across coupling condensers C51 and C52. The negative shift reduces the potential at the anodes of the diodes below the bias potential at the diode cathodes so that positive noise swings are insufficient to draw further current through the diodes and cause spurious triggering of stages V5a and V5b. The anodes tend to return to the bias potential of the anodes by conduction through resistors R54 and R55. These resistors are, however, of high value (2.2 megohms) and tend to maintain the potential shift so long as the same noise level occurs. As the noise level varies, the potential shift across the anodes will vary, thus automatically suppressing transmission of noise to the trigger stages. The accentuated R pulse, however, need be in the order of only 10 volts higher than the noise level, and the corresponding potential shift, in order to be passed by one of the diodes D1 or D2 to the grid of stage V5a. The grid of stage V5a is prevented from going positive relative to the cathode by a diode D3 (type 1N628). The operation of the trigger stages may be tested by closing a key k1.

The trigger pulse E is applied through a type 1N628 coupling diode D5 to a monostable multivibrator 6 (FIG. 4) comprising stages V6a and V6b, each one half of a type 12AU7 tube. Stage V6a is normally non-conducting while stage V6b is normally held conducting by positive bias. The negative trigger pulse drives the control grid of stage V6b sufficiently negative to cut off this stage and lower the voltage of the cathode of stage V6a to the point where it conducts, producing a sharp negative excursion at its anode. As shown in waveform F of FIG. 2 a corresponding positive excursion occurs at the anode of stage V6b. The respective negative and positive excursions at the two anodes are maintained for a period T1 determined by a time constant network including a capacitor C61 (0.5 microfarad), a resistor R61 (100 kilohms) and a variable resistor R62 which can be adjusted between values of zero to 1 megohm to vary the steady D.C. period T1. After this period the voltages at the anodes of V6a and V6b return to their stable level until the occurrence of another trigger pulse, as shown by waveform F of FIG. 2. During the delay period T1, the multivibrator 6 blocks itself from responding to any signal or noise passed by the Schmidt trigger 4. For this reason the variable resistor is set such that the period T1 of the multivibrator cycle extends for the greater part of the normal cardiac period between R pulses.

From the anode of stage V6b, waveform F is applied to contact i of a switch S1a, from the anode of stage V6a

the square wave opposite in polarity to waveform F is coupled through a network comprising a capacitor C62 (500 micro microfarads) and a resistor R63 (22 kilohms) which pass only a short negative pulse F' (similar to waveform E).

The short negative pulse F' is applied to a conventional monostable multivibrator stage comprising tube V23, type 12AU7, and its associated circuit including a type NE51 neon tube, I1. Each negative pulse F' causes the multivibrator V23 to execute one cycle and flash the neon tube I1 thus giving a visual indication that an R pulse is being picked up and transmitted through previous stages, or, on closing of the key k1 in the Schmidt trigger stage 4, that the Schmidt trigger 4 and blocking multivibrator 6 are operating. The multivibrator V23 is isolated from the previous trigger stage 6 by a diode D7 (type 1N628).

The negative pulse F' is applied also through a switch S2 to the input of a first counter 7a. The first counter 7a comprises a conventional bistable flip flop or Eccles-Jordan circuit with two stages V7a and V7b, each one half a type 12AU7 tube, to whose control grids the negative pulse F' is applied through two diodes D8 and D9, each type 1N628. Either stage V7a or V7b may be conducting and holding the other stage cut off. A negative pulse at the switch S2 will be coupled through diode D9 to the grid of stage V7a, and through switch S1b (when at contacts i, ii or iii) and diode D8 to the grid of stage V7b. Whichever stage is conducting at the instant of arrival of a negative pulse F' will be cut off, and conduction transferred to the other stage. On each transfer of conduction from stage V7b to V7a the positive rise of square waveform G2 (FIG. 2) will appear at the anode of V7b. The next following negative pulse F' will effect only an opposite transfer of conduction and a drop in waveform F'. The transfer of conduction from V7b to V7a and the positive rise of waveform G2 occurs only every second occurrence of the negative input pulse F'. The waveform G2 is applied to contacts ii and iii of switch S1a, and also through coupling diodes D10 and D11 to the input of a second counter 7b.

The second counter, comprising stages V8a and V8b, like the first counter just described, executes one complete cycle (G3, FIG. 2) for each two cycles of its input, and hence one cycle for each four negative pulses F' from the blocking oscillator 6. The waveform G3 is applied to contact iii of switch S1a. There are thus available at contact i of switch S1a, a signal F having one cycle for each R pulse of the cardiac signal; at contact ii, a signal G2 having one cycle for each two R pulses; and at contact iii a signal G3 having one cycle for each four R pulses.

In addition a signal G4 is supplied to contact iii of switch S1a when switch S2 is transferred. When ganged switches S1a and S1b are transferred to their respective contacts iii switch S1b breaks the direct connection from switch S2 to the diode D8 and the grid of the first counter stage V7b. The next occurring negative pulse F' can only transfer conduction from stage V7a to V7b. Subsequent pulses do not cause a change in the conducting state, and hence produce no output signal G2 from the first counter 7a. Then transfer of switch S2 will directly connect the negative pulse F' through diode D8 to the grid of the first counter stage V7b causing transfer of conduction from this stage and producing a single positive excursion of the voltage at the anode of stage V7b synchronously with the occurrence of an R pulse (waveform G4, FIG. 2). No further excursions will occur in the cycle until the switch S2 is returned to its position as shown and a subsequent negative pulse F' occurs. At that undetermined time, conductance will be transferred back to stage V7b and the anode voltage of stage V7b will drop, completing the cycle. There is thus provided at contact iii of switch S1a a single cycle signal G4 whose positive rise occurs at the same relative time in the cardiac period as the positive rises of the signals F, G2

and G3. The selected one of these signals is connected by switch S1a through a terminal G to a succeeding trigger 8.

The second trigger 8 comprises a triode V9a, one half a type 12AU7 tube, with an anode load inductance L3. Stage V9a is normally cut off by positive cathode bias. The initial positive excursion of the selected one of signals F, G2, G3 and G4 causes stage V9a to conduct for a very short period, and produce at its anode a negative pulse H which is peaked and shortened in duration by the anode inductance L3. The negative pulse H, which is substantially simultaneous with the R pulse, is applied to the input of a delay circuit 9.

The delay circuit 9 comprises a conventional phantatron circuit including stages V10a, V10b, type 12AU7 and V11, type 6AS6. As indicated by waveform J, the phantatron circuit executes a cycle which, at the cathode of stage V11 comprises a sharp negative excursion followed after a delay period T2 by a positive excursion. The negative excursion is coincident with each negative pulse H which is coupled through stage V10a, connected as a diode, to the grid of V10b. The duration of the delay period T2 is determined by the variable resistances R101 (0 to 200 kilohms), R102 (0 to 50 kilohms), R103 (0 to 15 kilohms), fixed resistance R104 (1 megohm) and capacitors C101 (0.5 microfarads) and C102 (2 microfarads) which couple the cathode of stage V10b to the control grid of stage V11. A switch S4, when transferred from the position shown to a position connecting capacitor C102 in circuit, multiplies the delay period by a factor of five, thus providing two ranges of delay T2. Within each range the delay may be continuously varied by the variable resistances R101, R102 and R103. R101 sets the maximum length of delay and R103 the minimum. Resistance R102 selects a delay length within the limits. As will be explained more fully, the delay period T2 is terminated by the positive excursion of waveform J.

Preferably resistances R101 and R103 are set for a delay in the shorter of the two ranges which has a minimum length of 0.01 second and a maximum of 0.31 second. Resistance R102 may be an accurately calibrated potentiometer which is adjusted according to the treatment to be given a patient. For example, the time in the cardiac cycle in which a patient's arterial blood pressure is to be varied may be chosen by adjustment of resistance R102. The operating characteristic of the phantatron circuit permits a linear potentiometer R102 to be used. That is the potentiometer R102 may vary linearly and be calibrated linearly to afford accurate selection of the delay period.

The positive excursion in voltage J following the delay period T2 is coupled from the cathode of tube V11 to the control grid of tube V9b, type 12AU7 in a third trigger stage 10. This trigger stage 10, like stage 8 produces a negative pulse K in response to the positive excursion of voltage J. The negative pulse K delayed for the time T2 following pulse H triggers a first duration phantatron stage 11 comprising tubes V12 (12AU7) and V13 (6AS6), substantially like stage 9, and producing a voltage waveform L similar to voltage J. Variable resistors R106 and R108 select the maximum and minimum limits of duration T3 of voltage L, and resistance R107 selects the actual delay within these limits. A capacitor switch S5 multiplies the duration T3 by a factor of five.

The negative waveform L appearing at the cathode of tube V13 is inverted by a gate stage 12 to produce a like positive control voltage M (not shown). Stage 12 comprises tube V22 (type 6C4) normally held in conducting state and cut off by the negative voltage L for the duration of period T3.

The positive control voltage M is applied to the control grids of two thyratrons V14 and V15, each type 884, or like controlled rectifiers of a power amplifier 13. The anodes of tubes V14 and V15 are supplied by a transformer T (Triad type N67A) whose primary T' is con-

nected to a 115 v. A.C. power line. The secondary T'' is center tapped and connected so that alternating voltages are applied to the anodes of the controlled rectifier tubes in opposite phase. Power output terminals n1 and n2 are connected respectively to the center tap of transformer T2 and the cathodes of the rectifier tubes.

Across the terminals n1 and n2 appears a full wave rectified voltage N during the period T3 in which the gating tube V22 supplies the positive voltage M to the grids of the rectifiers. The output voltage N is of sufficient power to operate the solenoid K1 of a valve, pumping or dye injection device Y as explained with reference to FIG. 1.

As shown in FIGS. 1 and 5, the voltage J may also be applied to a second output channel comprising stages 14 to 18. The first stage 14 in this channel comprises a fourth trigger tube V101a (one half a type 12AU7 tube) and is connected and functions like the third trigger stage 10, to produce a negative trigger pulse O (not shown but like voltage K). The trigger pulse O is applied to a second delay phantatron stage 15 comprising tubes V102 (12AU7) and V103 (6AS6) which corresponds to the first delay phantatron stage 9, and which produces a negative square wave voltage P whose positive return excursion is delayed for a period T4. The period T4 may be limited and varied by potentiometers R110, R111 and R112 and switch S6, as in the first delay stage 9.

The positive going excursion of voltage P causes the subsequent stage 16 comprising tube V101b (one half a type 12AU7 tube) to produce a negative trigger pulse U as stage 10 produces the trigger pulse K.

The negative trigger pulse U causes a second duration stage 17 to produce a control voltage V. This stage 17 comprises tube V104 (type 12AU7) connected as a conventional one-cycle or monostable multivibrator. The duration of its square wave, control voltage output V is determined by capacitor C104 (0.1 microfarad), resistor R114 (100 kilohms) and potentiometer R113 which can be varied from zero to two million ohms. The duration of V is in the order of 0.1 second, for example.

The control voltage V is applied to the grids of control rectifier tubes V105 and V106, each type 884, of a second power amplifier stage 18. The anodes of these tubes are supplied by the same transformer secondary T'' as supplies tubes V14 and V15 of stage 13. Similarly the rectified output voltage W is taken respectively from the center tap of the transformer secondary T'' and the cathodes of tubes V105 and V106.

In FIG. 7 is shown an alternate, electromechanical embodiment of the invention, adapted to be connected to a conventional electrocardiograph amplifier 1a producing the cardiac signal A. The signal is applied to a trigger relay 4a, for example of the sensitive galvanometer type, which makes a contact when it receives a positive or negative R pulse exceeding a predetermined threshold above the Q, S or T levels. This relay 4a supplies a trigger pulse E to a dash pot relay 6a which closes its contacts for a period T1 determined by its dash pot. After this period, opening of its contacts transmits a voltage change, such as the negative excursion of waveform F, to a switch S1 like that shown at S1a and S1b of FIG. 1. In a similar manner switch S1 interconnects the dash pot relay 6a, and one or both of two connecting relays 7a' and 7b' to a succeeding trigger stage 9a. The connecting relays may be conventional bistable devices, each having one pulse output for each two pulse inputs, analogously to the flip flops 7a and 7b. Thus waveforms F, G2, G3 or G4 may be applied to the trigger relay 8a.

The trigger relay 8a, like relay 4a, transmits a sharp pulse H to a delay timer 9a. The timer 9a comprises a conventional constant speed motor with a solenoid clutch energized on receipt of a pulse H and de-energized by a limit switch after a predetermined angle of rotation of the motor, in a time interval T2. The limit switch also has ganged contacts which transmit a pulse K to a dura-

tion timer 11a at the end of the interval T2. The duration timer is like the delay timer, except that its ganged contacts supply control current to a power relay 13a for a period T3 determined by its dash pot. The power relay 13a controls the solenoid or relay K1 of an external device Y. Also analogously to the diagram of FIG. 1 a second channel may control a second external device X after a further delay period T4.

It will be understood that the present disclosure is for the purpose of illustration only and that various electronic and electromechanical devices and modifications falling within the scope of the appended claims are included within the scope of the invention.

I claim:

1. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal having a predetermined time relation to said cardiac signal for controlling an external device for treating a patient, a channel for transmitting said modified signal to said generating means including means to delay the occurrence of the output signal for a predetermined interval after the modified signal and including means to suppress noise during a substantial portion of the time between the occurrence of said modified signal and the occurrence of said output signal, said delay means having a time constant means limiting said delay to a fraction of the cardiac interval.

2. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal having a predetermined time relation to said cardiac signal for controlling an external device for treating a patient, a channel for transmitting said modified signal to said generating means including means to delay the occurrence of the output signal for a predetermined interval after the modified signal and including means to suppress noise during a substantial portion of the time between the occurrence of said modified signal and the occurrence of said output signal, said delay means having time constant means determining said delay with respect to the cardiac interval, and means to vary the time constant of said time constant means.

3. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, first means generating a first output signal having a predetermined time relation to said cardiac signal for controlling one external device for treating a patient, a channel for transmitting said modified signal to said generating means, second means generating a second output signal for controlling another external device for treating a patient including means to delay the occurrence of the second output signal for a predetermined interval after the first output signal.

4. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, first means generating a first output signal having a predetermined time relation to said cardiac signal for controlling one external device for treating a patient, a channel for transmitting said modified signal to said generating means, second means generating a second output signal for controlling another external device for treating a patient including means to delay the

occurrence of the second output signal for a predetermined interval after the first output signal, said delay means having time constant means determining said delay with respect to the cardiac interval.

5. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, first means generating a first output signal having a predetermined time relation to said cardiac signal for controlling one external device for treating a patient, a channel for transmitting said modified signal to said generating means, second means generating a second output signal for controlling another external device for treating a patient including means to delay the occurrence of the second output signal for a predetermined interval after the first output signal and including means to suppress noise during a substantial portion of the time between the occurrence of said modified signal and the occurrence of said output signal, said delay means having time constant means determining said delay with respect to the cardiac interval, and means to vary the time constant of said time constant means.

6. Apparatus for treating a patient in accordance with the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising means to pick up the patient's cardiac signal, a channel for modifying said cardiac signal so as to produce a modified signal having a prominent portion, means responsive to the modified signal for generating an output signal having a predetermined time relation to said cardiac signal, a channel for transmitting said modified signal to said generating means including means introducing a time delay between the occurrence of said modified signal and said output signal, and means responsive to said output signal to apply treatment to said patient, said generating means including means to suppress noise during a substantial portion of the time between the occurrence of said modified signal and the occurrence of said output signal thereby to prevent a spurious response of the means to apply treatment to the patient.

7. Apparatus according to claim 6 wherein said means to suppress noise comprises a monostable multivibrator blocking transmission of any signal for said substantial portion of time.

8. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal having a predetermined time relation to said cardiac signal for controlling external equipment, and a channel for transmitting said modified signal to said generating means including means responsive to the output of the modifying channel for suppressing electrical noise during a substantial portion of the cardiac interval thereby to prevent generation of a spurious output signal unrelated to the cardiac signal.

9. Apparatus according to claim 8 wherein said transmitting channel includes a counter responsive to a multiplicity of modified signals to produce a single trigger pulse, said generating means being responsive to each trigger pulse to produce one output pulse.

10. Apparatus according to claim 8 wherein said transmitting channel includes a two stage, bistable flip flop having input means to each stage, a switch normally transmitting successive modified signals to each stage thereby to cause said flip flop to make opposite changes between two stable conditions and to produce at its output a trigger signal in timed relation to said cardiac signal upon one change, said switch having a second position in which said modified signals are applied only to one stage, thereby to cause the flip flop to make only

said one change and produce only a single trigger signal on each transfer of said switch to said second position, said trigger signal being applied by said transmitting channel to said generating means to cause said generating means to produce only one output signal for each transfer of said switch to said second position.

11. Apparatus according to claim 8 wherein said transmitting channel includes means responsive to a modified cardiac signal to produce a trigger signal, a phantatron oscillator for converting said trigger signal into a control signal of predetermined length, and a linearly calibrated linear potentiometer at the input of said oscillator for varying the voltage at said input thereby to select the length of said control signal.

12. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal when the signal is of undetermined polarity, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, said channel having two output terminals respectively carrying said modified signals of opposite polarity, means for generating an output signal of predetermined polarity for controlling external equipment, and a channel for transmitting said modified signals to said generating means including means for selecting one of said modified signals in a predetermined polarity and for suppressing electrical noise during a substantial portion of the cardiac intervals, thereby to prevent generation of a spurious signal unrelated to the cardiac signal.

13. Apparatus according to claim 12 wherein said transmitting channel includes electronic valve means having an input terminal and said selecting means includes two diodes coupling respective output terminals of the modifying channel to the input terminal of said valve means, said diodes being connected in the same polarity whereby only a modified signal of the desired polarity is transmitted by said valve means through said coupling channel.

14. Apparatus according to claim 13 wherein said electronic valve includes means biasing said terminal, and a relatively high resistance is connected across said diodes such that continuous electrical noise causes said diodes to conduct and change the bias of said terminal above the noise level, thereby to prevent transmission of noise to said valve means while passing a modified signal higher than said noise level.

15. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal when the signal is of undetermined polarity, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, said channel having two output terminals respectively carrying said modified signals of opposite polarity, means for generating an output signal of predetermined polarity for controlling external equipment, and a channel for transmitting said modified signals to said generating means including means for selecting one of said modified signals in a predetermined polarity.

16. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for amplifying said cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal having a predetermined time relation to the cardiac signal for controlling external equipment, and a channel for transmitting said modified signal to said generating means including a circuit disabling transmission for at least a substantial portion of said cardiac interval following transmission of said modified signal, thereby to prevent generation of a spurious output signal during a cardiac interval.

17. Apparatus according to claim 16 wherein said disabling circuit comprises a one cycle multivibrator responsive to said modified signal and having a half cycle enduring at least a substantial portion of the cardiac interval following said modified signal, said multivibrator being unresponsive to noise during said substantial portion.

18. Electronic apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal recurring in successive cardiac intervals, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal for controlling external equipment, and a channel for transmitting said modified signal to said generating means including means for suppressing electrical noise during a substantial portion of the cardiac interval thereby to prevent generation of a spurious output signal unrelated to the cardiac signal, said transmitting channel including an oscillator producing a control signal of predetermined length, and said generating means including a pair of controlled rectifier tubes each having at least a control electrode, anode and cathode, means coupling said control signal to respective control electrodes, transformer means including a center tapped secondary for supplying alternating current in opposite phase to respective rectifier anodes, and output terminals connected respectively to the center tap of said transformer secondary and said rectifier cathodes.

19. Electrical apparatus for controlling external equipment for treatment of a patient in timed relation to the patient's electrical cardiac signal occurring in a cardiac interval, said apparatus comprising a channel for modifying the cardiac signal so as to produce a modified signal having a prominent portion, means generating an output signal having a predetermined time relation to said cardiac signal for controlling an external device for treating a patient, a channel for transmitting said modified signal to said generating means including means to delay the occurrence of the output signal for a predetermined interval after the modified signal and including means to suppress noise during a substantial portion of the time between the occurrence of said modified signal and the occurrence of said output signal.

20. Apparatus according to claim 19 wherein the predetermined interval of said means to delay is longer than the cardiac interval.

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