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2,920,214

CONDITION RESPONSIVE RELAY MEANS

Filed March 11, 1954

3 Sheets-Sheet 1

FIG. 1

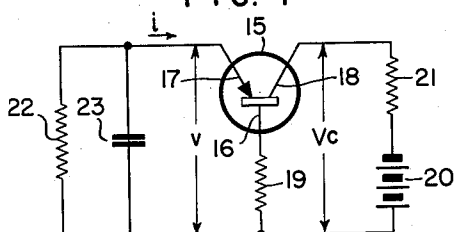


FIG. 2

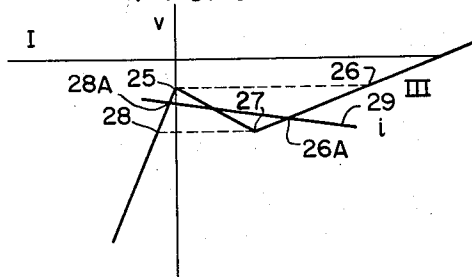


FIG. 3

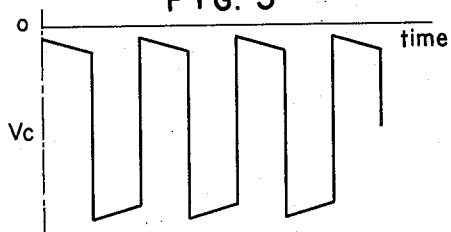


FIG. 4

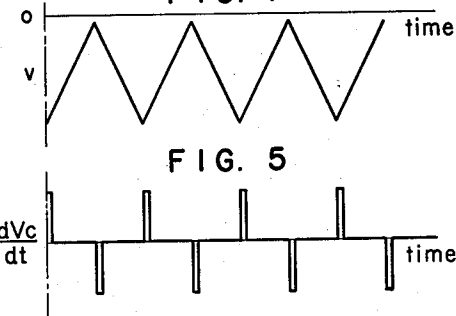
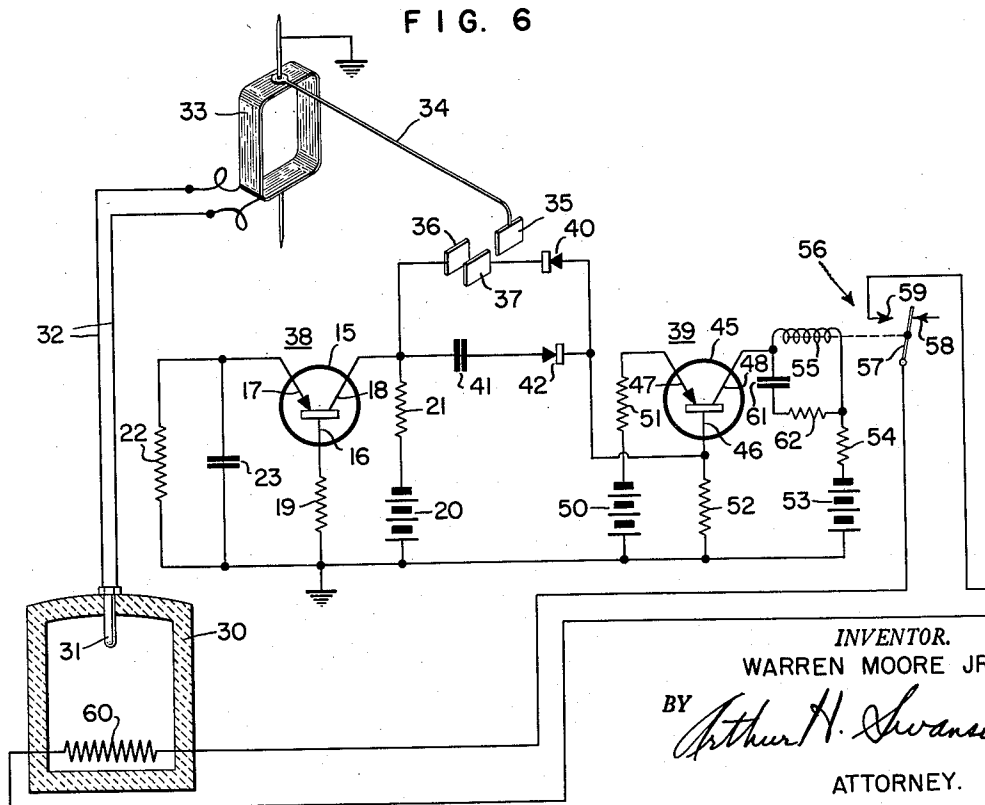


FIG. 6



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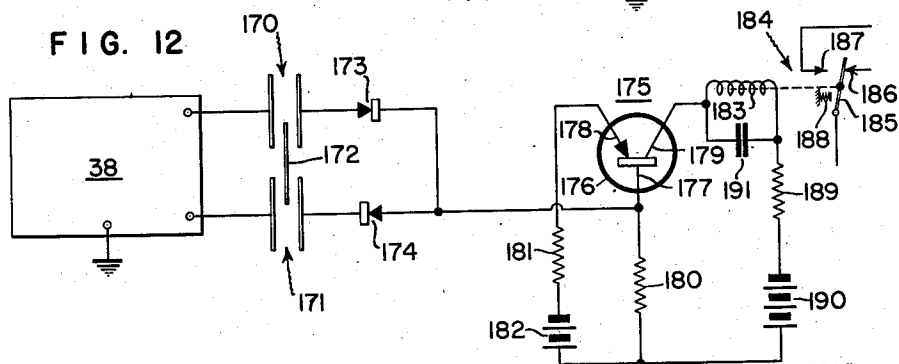
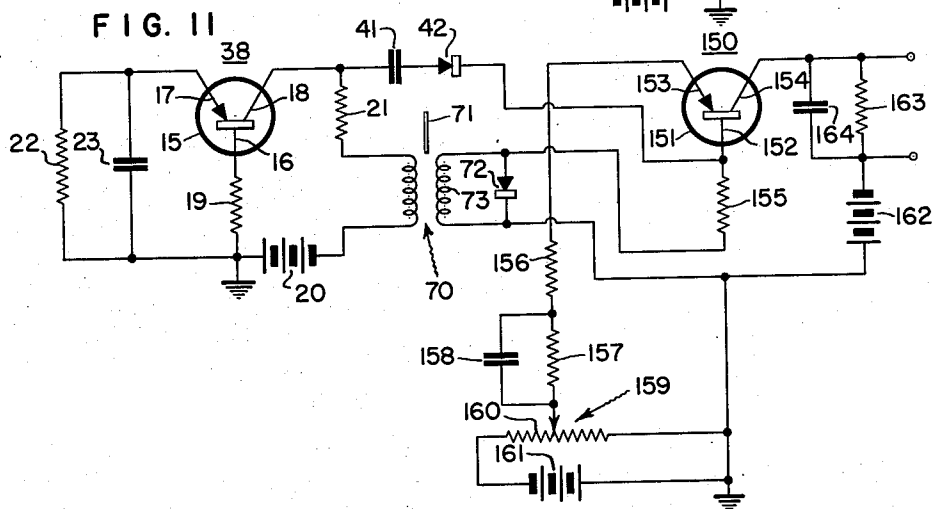
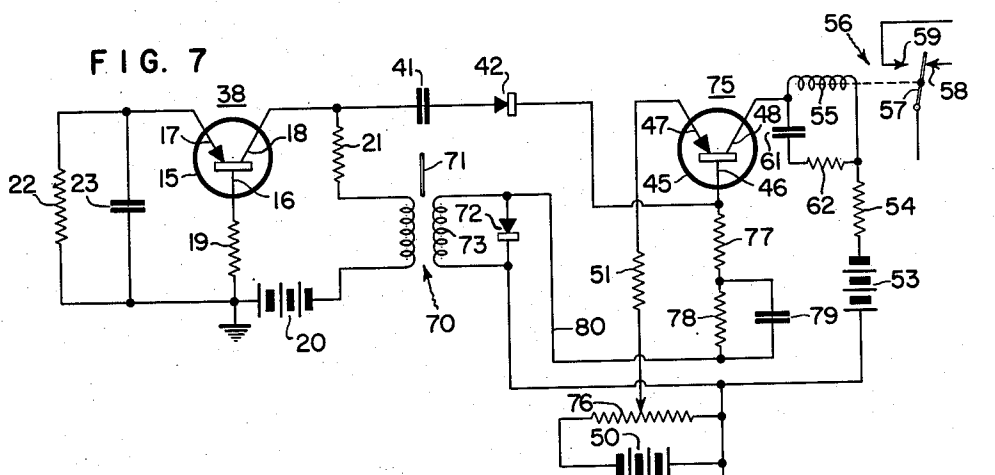
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CONDITION RESPONSIVE RELAY MEANS

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3 Sheets-Sheet 2



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FIG. 8

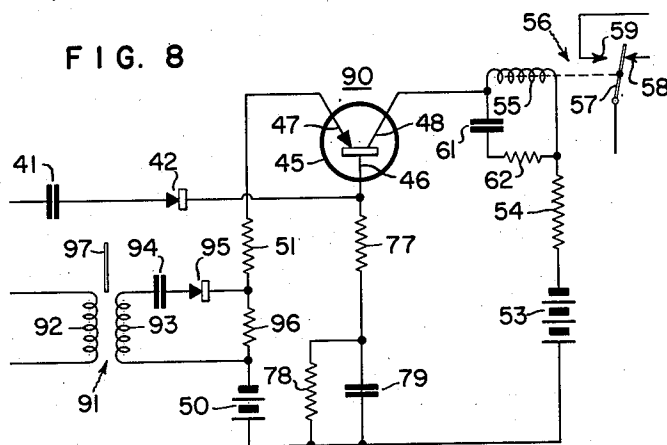


FIG. 9

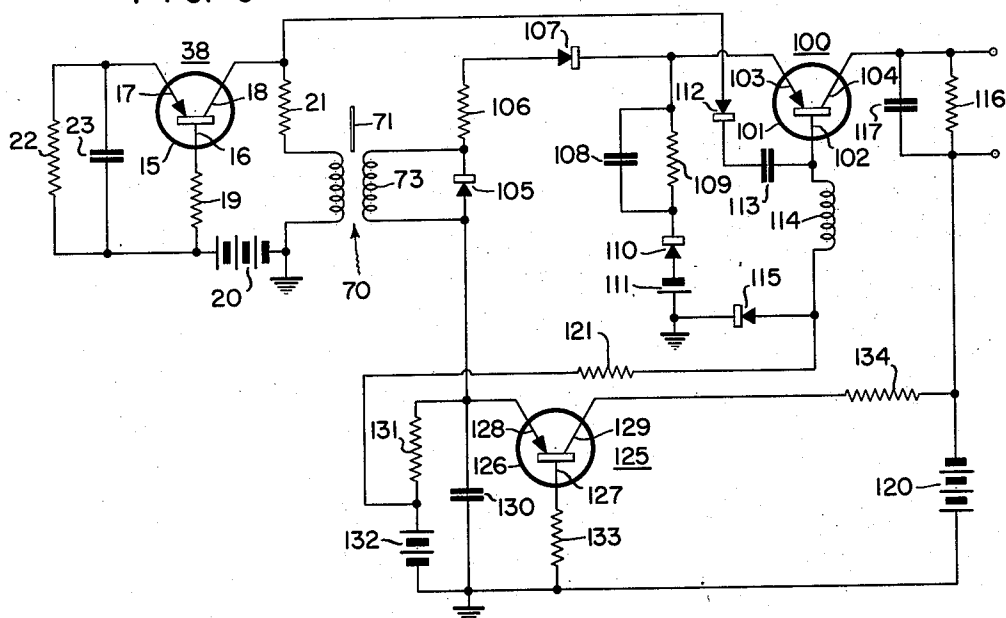
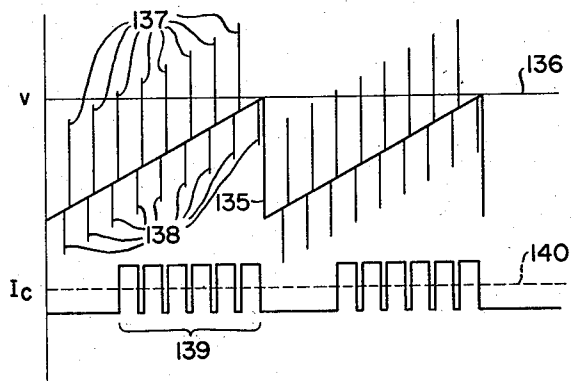


FIG. 10



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CONDITION RESPONSIVE RELAY MEANS

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Application March 11, 1954, Serial No. 415,575

19 Claims. (Cl. 307--88.5)

A general object of the present invention is to provide a new and improved electrical controller which is adapted to be used in the controlling of the magnitude of a variable wherein the magnitude of the variable is indicated by the movement of a movable member. More specifically, the invention is concerned with an electrical type of vane controller wherein the electrical circuits of the controller comprise transistors as the primary elements therein and wherein maximum use is made of the most desirable operating characteristics of the transistors.

Electrical vane type controllers have been widely used in industry wherever an inexpensive and accurate type of control unit is required. The most common form of controller is one utilizing a vane carried by an element movable in accordance with the magnitude of a variable, said member taking the form of a galvanometer or some other similar type of device. The movement of the vane is generally effective to tune or vary the impedance of a circuit associated with an oscillator to change the current flow in the oscillator or in an auxiliary circuit associated therewith. This change in current is sensed by a control relay or some other like device.

When electrical vane controllers are used with relays, it may be desirable that the controlling action be effectively snap acting in its operation which means that when electrical conditions in the circuit indicate the need for relay operation, the current flow through the relay should immediately change to a value which will insure positive action of the relay.

Vane controllers may also be readily useable with load devices requiring current flow changes which vary proportionally with the changes in magnitude of an input variable. This is preferably accomplished by arranging the circuit so that the output current will vary proportionally to the positioning of a movable vane.

The circuit principles of the present invention are well adapted to either proportional control, or snap acting, on-off control. By using common circuit principles in both types of control, the manufacture is simplified and there is a minimizing of the total number of components needed for a wide variety of controllers. Transistors have been found to be very useful in circuits of the type used in the present invention primarily because of their effectiveness when operating as the primary elements in an oscillator, a multivibrator, a monostable or a bistable trigger circuit. The point contact type of transistor is particularly useful in that it exhibits negative impedance characteristics which render it very adaptable for use in this type of circuit. The present invention uses particularly the ability of the transistor to operate in a multivibrator type circuit and as a trigger circuit.

It is accordingly a more specific object of the present invention to provide a new and improved electrical type vane controller using a trigger circuit wherein the trigger circuit is adapted to have either a multi-position type

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of output or an output whose current is proportional to the positioning of a control vane.

It is a characteristic of a bistable circuit that it will generally have two stable points of operation with either point remaining effective once the circuit has been rendered operative at that point. By appropriate circuitry, as utilized in the present invention, it is possible to cause the bistable circuit to be operative in either one or the other of its stable points or to cause the circuit to proportionally divide its operating time between the two stable points in accordance with the positioning of a vane or other movable member relative to control circuitry therefor. The control circuitry may generally take the form of a pulse differentiating circuit with the differentiating circuit output signals being effective to cause the bistable circuit to operate in one or the other of its two stable operating conditions. The pulses for this differentiating circuit may be conveniently generated by a free running multivibrator which may also be of the transistor type.

It is accordingly a further more specific object of the present invention to provide an improved electrical vane controller comprising a trigger circuit whose state of operation is adapted to be controlled by a vane controlled circuit.

Still another more specific object of the present invention is to provide an electrical controller which includes a pulse generator having its output connected to a trigger circuit wherein the connection is adapted to be controlled by a vane movable in accordance with the magnitude of a variable.

A still further more specific object of the present invention is to provide a new and improved vane controller utilizing a bistable trigger circuit whose operation is controlled by a movable element wherein the output of the circuit is adapted to vary proportionally with the movement of the movable member.

A further more specific object of the present invention is to provide an improved electrical vane controller wherein a bistable circuit has applied thereto a slowly varying control signal and a vane controlled pulse signal.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its advantages, and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described preferred embodiments of the invention.

Of the drawings:

Fig. 1 is a representative circuit of a transistor multivibrator;

Fig. 2 shows a representative characteristic curve for a transistor circuit of the type used in Fig. 1 showing its negative impedance characteristics;

Fig. 3 shows a representative output signal from the circuit of Fig. 1 taken across the load resistor thereof;

Fig. 4 shows a representative saw tooth wave taken from the emitter circuit resistor of Fig. 1;

Fig. 5 shows the pulses of Fig. 3 differentiated;

Fig. 6 shows a representative vane type controller using the principles of the present invention;

Fig. 7 shows a modified form of circuit incorporating a vane controlled inductive element as a control element for the circuit;

Fig. 8 shows a circuit modification of the circuit shown in Fig. 7;

Fig. 9 shows the electrical circuit modified for proportional action;

Fig. 10 shows diagrams representing the operation of the circuit of Fig. 9;

Fig. 11 shows a modified form of controller producing an output current which is proportional to the position of the movable vane of the circuit; and

Fig. 12 shows a modification of the circuit of Fig. 6 wherein three position control may be obtained.

Referring first to Fig. 1, the numeral 15 represents a transistor which is preferably of the contact type. This transistor includes a base electrode 16, an emitter electrode 17, and a collector electrode 18. Connected to the base electrode 16 is a resistor 19 whose opposite end is connected to the positive terminal of the supply battery 20. The negative terminal of the battery 20 is connected by way of a resistor 21 to the collector electrode 18. Also connected to the lower end of resistor 19 is a resistor 22 which is connected at its opposite end to the emitter electrode 17. In parallel with the resistor 22 is a condenser 23.

The circuit of Fig. 1 may be classed as a multivibrator or a square wave generator. If a point contact transistor is used in this circuit, the operating characteristic curves will be of the type shown in Fig. 2. The abscissa of the graph of Fig. 2 represents the emitter current while the ordinate represents the emitter voltage. Initially, the circuit will start operating in region I and the circuit of Fig. 1 will be conducting current in the base and collector electrode circuits. This circuit may be traced from the positive terminal of the battery 20 through resistor 19, base electrode 16, collector electrode 18, and resistor 21 back to the negative terminal of the battery 20. As the current flow will produce a voltage drop across the base resistor 19, there will be a tendency for current to flow in the emitter circuit and this current flow may be traced from the positive end or lower end of resistor 19 through resistor 22, emitter electrode 17, base electrode 16 to the upper terminal of resistor 19.

The current flowing through the resistor 22 will be effective to slowly charge the condenser 23 so that the voltage v will increase along the line of region I until the point 25 is reached on the characteristic curve. At this instant, any further increase in voltage v causes the emitter current to suddenly jump to region III of the characteristic curve at point 26. At this instant, the current flow in the emitter circuit will have effectively reversed and the condenser 23 will be slowly discharging and will follow along the curve of region III until point 27 is reached. At this point, the operating point will suddenly shift to point 28 on the curve of region I. With the condenser 23 in the circuit, the apparatus will repeat its operation in the above manner and there will be a resultant output signal of the general wave form, represented by Fig. 3, in the form of a square wave.

Fig. 4 shows the emitter voltage which is actually the voltage across the condenser 23 and this is represented by a saw tooth voltage.

It will be readily apparent that by changing the circuit constants of the circuit of Fig. 1 it is possible to vary the repetition rate of the square waves shown in Fig. 3 or the frequency of the waves. In addition, it is possible to vary the length of the positive pulse with respect to the negative pulse. In the same way, it is possible to vary the slopes of the saw tooth voltages produced in the emitter circuit as shown in Fig. 4.

Fig. 5 shows the wave forms of Fig. 3 after they have been passed through a suitable differentiator circuit which will be used in a manner hereinafter to be described in controlling the operation of a further circuit of the type shown in Fig. 1.

Should the circuit of Fig. 1 be modified by the omission of the condenser 23, it is possible to have a bistable circuit. In such a bistable circuit, the circuit will operate in a stable manner either at a point 26A on the curve shown in Fig. 2, or at point 28A, the latter points falling on the emitter circuit load line 29. The circuit may be switched to one or the other of the operating points by a suitable control pulse. Once the circuit has

been switched to one of its stable operating points, it will continue to operate at that point until such time as some external signal is applied thereto to cause the circuit to move to its other stable operating point.

For example, if the circuit of Fig. 1 without the condenser 26 connected thereto is operating at the point 28A, it will continue to operate at that point until such time as some external voltage is applied thereto to cause it to move to some new point. Thus, if a positive pulse is applied to the emitter electrode 17, and if the magnitude of this pulse is sufficient to carry it above the point 25, the circuit will be switched to point 26A on the curve shown in region III. The circuit will continue to operate at this point until such time as a negative pulse is applied to the emitter electrode 17 which is of sufficient magnitude to cause the circuit to move back to point 28A.

Referring now to Fig. 6, there is shown here a representative form of the present invention used in a millivoltmeter type of vane controller. In this figure, the numeral 30 represents a furnace or other similar device wherein the temperature is to be controlled. For sensing the temperature within the furnace, there is provided a thermocouple 31 having output leads 32. These output leads are connected to a deflection coil 33 of a conventional galvanometer or millivoltmeter controller. This coil 33 carries an arm 34 which arm may cooperate with an indicating scale, not shown, and also carry a movable vane 35.

The vane 35 cooperates with a variable impedance element shown in Fig. 6 as a condenser formed by a pair of plates 36 and 37. The vane 35 in this figure is used to block the flow pulses between plates 36—37 when placed between the plates.

The electrical control portion of the circuit of Fig. 6 comprises a free running multivibrator or pulse generator 38 which is essentially the same as the multivibrator shown in Fig. 1. Corresponding components between Figs. 1 and 6 carry corresponding reference numerals.

The output of the pulse generator 38 is coupled to a bistable trigger circuit 39. This coupling circuit includes the variable condenser 36—37, and a diode 40. In parallel with this first coupling circuit is a further coupling circuit including a condenser 41 and a further diode 42, the latter of which is effectively conductive in a direction opposite to that of the diode 40. Both the diodes have sufficient back leakage to permit their associated condensers to discharge between pulses.

The bistable trigger circuit 39 comprises a transistor 45 having a base electrode 46, an emitter electrode 47, and a collector electrode 48. A battery 50 is connected in the emitter circuit in series with a resistor 51. A resistor 52 is connected as the base electrode resistor. Power is supplied to the collector electrode by a battery 53 by way of a load resistor 54 and a relay coil 55 of a relay 56. The relay 56 includes a switch blade 57 which is normally biased into engagement with a contact 58 when the relay coil 55 is deenergized. When the coil is energized, the blade 57 is moved into engagement with an associated contact 59. Switch blade 57 and contact 59 are connected in the control circuit for an electrical heater 60 associated with the furnace 30. The coil 55 is shunted by a pulse by-pass circuit and relay holding circuit including a condenser 61 and a resistor 62.

In considering the operation of Fig. 6, it is first assumed that the pulse generator 38 is operating to produce square waves in a manner corresponding to the way in which the generator of Fig. 1 operates. The positive swing of the wave is differentiated by the condenser 41 and resistor 52 in a circuit that may be traced from the collector electrode 48 through condenser 41, diode 42, and resistor 52 back to the generator 38. Since the output square wave is differentiated, a positive pulse is applied to the base 46 of the bistable trigger circuit 49. This positive pulse has the effect of lowering the emitter voltage on the bistable trigger circuit 39 and causing the

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trigger circuit to be switched to its low current operating point which may be represented by the point 28A, in Fig. 2.

When the square wave reaches the point where it swings in a negative direction, the wave will not pass through the last traced circuit because the diode 42 will appear as a high resistance. The low resistance circuit for this pulse is through the variable condenser 36—37, diode 40, and resistor 52. This circuit forms a further differentiating circuit which will normally differentiate the negative portion of the wave when the impedance of the condenser 36—37 is low. With the apparatus in the position shown with the vane 35 being separated from the plates 36—37, the impedance of the condenser 36—37 is sufficiently low that the negative pulses normally produced by this circuit will appear across the base resistor 52 in the bistable trigger circuit 39. When the negative pulse is applied to the base resistor 52 of bistable trigger circuit 39, this will have the tendency of shifting the operating point of the bistable circuit to its highly conductive state as represented by the point 26A in Fig. 2. This increased current flow will be of sufficient magnitude to energize the coil 55 so that the relay 56 will be in an energized position with the blade 57 engaging contact 59.

As soon as the next positive differentiated pulse is received from the pulse generator 38, as produced across the base resistor 52, the bistable trigger circuit will again switch to the low current operating point as represented by the point 28A in Fig. 2. The circuit will remain in this low conducting state until the next negative pulse is produced across the resistor 52 at which time the output current will again be switched to a high current level. This switching of the bistable trigger circuit 39 will continue so long as the vane 35 is not between the condenser plates 36—37. This will mean that the average current flow through the coil 55 of the relay 56 will be sufficient to maintain the relay in an energized position so that heater 60 will be energized.

It will be readily apparent that the circuit controlling energization of the relay 56 may be very sensitive in that the bistable circuit 39 is switched from the low operating current point to a point where it has a relatively high average value as soon as a predetermined position of vane 35 is realized. This high average value may be increased by changing the timing of the input pulses from the pulse generator 38 by decreasing the time length of the positive portion of the square wave from the generator and increasing the time length of the negative portion of the square wave from the generator, as shown in Fig. 3. This will mean that the negative pulses shown in Fig. 5 will be closer in time to the positive pulses so that when the positive pulse turns the bistable trigger current low, the negative pulse will effectively shift the circuit back to a high level substantially immediately.

When the temperature within the furnace 30 rises, this will be sensed by the thermocouple 31 which will cause the coil 33 to move so that the vane or blade 35 will be between the condenser plates 36—37. When this occurs, the impedance presented by the condenser 36—37 will be relatively high due to the blocking or shunting effect of vane 35 and the circuit will no longer function as a differentiating circuit for the square wave output from the pulse generator 38 on the negative portion of the square waves. Consequently, only the positive pulses will be fed to the bistable trigger circuit 39 and this will insure that the trigger circuit will be maintained in its operating point wherein the output current from the trigger circuit flowing through the relay coil 55 is low. When the current flow to the relay coil 55 is low, the blade 57 will be biased into engagement with the contact 58 and the heater for the furnace 30 will remain de-energized.

By proper selection of the circuit constants of the foregoing circuit it is possible to substantially eliminate the

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effects of temperature changes in the circuit in that the circuit is operating either in an effective cut off point for the relay or in a high current state which will permit relatively wide selection of the output control relay for the device to insure that it will operate only when the desired operating conditions are present. In addition, the use of pulses controlled by the vane prevents undue loading of the vane which might affect the accuracy of the complete controller.

Referring now to Fig. 7, there is here shown a modified form of the apparatus shown in Fig. 6 with the present figure incorporating the same operating principles. The circuit of Fig. 7 includes the basic pulse generator circuit 38 shown in Fig. 6 and corresponding reference numerals are used on corresponding components. Added to the output circuit of the pulse generator 38 is a vane controlled transformer coupling circuit 70 whose coupling effect is effectively varied by a vane 71. A rectifier 72 is connected across the secondary 73 of the transformer 70.

The pulse generator is coupled to a bistable trigger circuit 75 which is basically similar to the bistable circuit 39 of Fig. 6. The circuit 75 includes an output control relay 56 and other components which correspond to the components of Fig. 6 and these components carry corresponding reference numerals. Connected to the emitter electrode circuit is an adjustable emitter bias adjusting potentiometer 76. Connected to the base electrode 46 is a base resistor 77 and a further base resistor 78 having a condenser 79 in parallel therewith.

In operation, the apparatus of Fig. 7 operates substantially the same as that of Fig. 6. The square wave generator 38 produces pulses and these pulses are differentiated and applied to the bistable trigger circuit 75. The positive pulses are coupled from the pulse generator circuit through condenser 41, diode 42, resistor 77, to the bistable trigger circuit. These positive pulses will cause the trigger circuit to operate at its low current condition. This will mean that the current flow through the relay 56 will be insufficient to energize the relay.

When the vane 71 is between the coils of the transformer 70, there will be no negative pulse produced or applied to the bistable trigger circuit to turn it to its high operating state. However, when the vane 71 moves to the position shown so that there is coupling between the coils of the transformer 70, the negative pulse produced by the differentiating action of the transformer 70 will be applied to the base electrode 46 by way of lead 80, resistor 78 and resistor 77. This negative pulse will cause the bistable circuit 75 to be triggered to its high operating state so that the relay 56 may be energized. With the vane 71 out of the coils of the transformer 70, the pulse recurring rate from the pulse generator 38 will be sufficient to maintain the current level through relay 56 of a sufficient magnitude to maintain the relay in its energized state. It will be readily apparent, however, that the bistable circuit 75 will be alternately switched between the high conductive and low conductive state.

During each period of high conduction a current flows through the base impedance in such a direction as to cause the base electrode to be negative with respect to the emitter. The condenser 79 tends to store part of this negative voltage from one period of high conduction to the next. Because of this the size of the negative turn on pulse required to trigger the circuit from its low current to its high current state is reduced by the amount of the voltage remaining across capacitor 79. The net effect of this is to introduce a dead spot or hysteresis in the operation of the unit which contributes a desirable positiveness of operation and reduces the probability of relay chatter due to vane vibrations or other random disturbances.

It will be readily apparent that the circuit of Fig. 7 is well adapted for use in an apparatus such as shown in Fig. 6 or any other suitable control circuit wherein the magnitude of a variable may be used to control the

position of the vane 71 and the relay 56 may be used to affect the magnitude of the control variable or any other associated variable.

The circuit of Fig. 8 shows a modified form of bistable trigger circuit whose operating characteristics are the same as the trigger circuits of Figs. 6 and 7. The modification in this circuit involves the manner in which the negative pulses are produced and applied to the trigger circuit. In this circuit, corresponding components are represented by corresponding reference numerals.

More specifically, the bistable trigger circuit 90 has an input through the condenser 41 and through a coupling transformer 91 having a primary winding 92 and a secondary winding 93. The secondary winding 93 is connected in series with a condenser 94 and a diode 95 to a resistor 96 which is in series with the emitter resistor 51 and battery 50.

The pulse input to the circuit of Fig. 8 will correspond to that of the preceding Figs. 6 and 7. A positive pulse is applied to the base electrode 46 by a circuit including the condenser 41 and diode 42. The positive pulse will trigger the bistable circuit 90 into its low conducting state. The input pulse to the transformer 91 is effective to apply a positive pulse to the emitter 47 which takes the place of the former negative pulse applied to the base electrode 46 of the preceding figures. The positive pulse produced across the resistor 96 will be the pulse resulting from the negative swing of the pulse produced by the pulse generator and will be differentiated in its form. When the vane 97 is between the coils 92 and 93 so that the transformer 91 has low coupling, there will be no pulse produced across the resistor 96 and as a consequence, only the positive pulse applied to the base electrode 46 will be effective to trigger the bistable circuit 90 into its low current level conducting state. When the vane 97 moves out from between the coils 92 and 93, the pulse from the pulse generator will be coupled to the transformer 91 and the positive pulse will appear upon the resistor 96 to trigger the circuit into its highly conducting state. The relay 56 will accordingly be rendered operative or inoperative depending upon the position of the vane 97 with respect to the transformer coils 92 and 93. The circuit may likewise operate in any combination such as shown in Fig. 6.

The circuit of Fig. 9 shows a form of the apparatus wherein an output current proportional to vane position will be attained. The circuit of Fig. 9 includes the pulse generator 38 of Fig. 7 and carries corresponding reference characters. The output of this pulse generator is coupled to a further bistable trigger circuit 100 which includes a transistor 101 having the base electrode 102, an emitter electrode 103, and a collector electrode 104. The input emitter circuit includes a diode 105 connected across the secondary 73, a resistor 106, and a diode 107. Also connected to the emitter 103 is a condenser 108 in parallel with a resistor 109 and a diode 110 connected in series with a battery 111. Connected to the input of the base electrode 102 is a diode 112 and a condenser 113. Also connected to the base electrode 102 is a coil 114 and an isolating diode 115. The output circuit for the transistor 101 includes a load resistor 116 having a condenser 117 in parallel therewith. Power is supplied to the transistor 101 by a suitable battery 120.

Also associated with the bistable trigger circuit 100 is a further multivibrator circuit 125. The multivibrator circuit 125 comprises a transistor 126 having a base electrode 127, an emitter electrode 128, and a collector electrode 129. Connected to the emitter electrode 128 is a condenser 130 and a resistor 131 having a battery 132 in series therewith. The battery 132 is connected through a current limiting resistor 121 to the end of the coil 114. Connected to the base electrode 127 is a base resistor 133. A collector load resistor 134 is connected between the battery 120 and the collector electrode 129.

In considering the operation of Fig. 9, it should first be

noted that the pulse generator 38 operates in the manner explained in connection with Figs. 6 and 7 and the output square waves are differentiated by the circuits associated therewith tending to switch the bistable trigger circuit 100 between its high and low current operating conditions. The differentiated pulses from this circuit are combined with a saw tooth wave generated by the multivibrator 125.

It will be recalled with reference to Fig. 1 that the voltage across the resistor 22 is a saw tooth wave as represented by Fig. 4. By changing the time constants of the circuit it is possible to vary the slopes of the respective wave portions so that the wave form may be changed from that of Fig. 4 to the saw tooth wave form represented by the numeral 135 in Fig. 10. This is in effect the wave form which will appear across the resistor 131 and battery 132 or across the condenser 130 of the multivibrator circuit 125. This saw tooth voltage is applied to the emitter electrode 103 of the bistable circuit 100 by a circuit that may be traced from the upper terminal of the condenser 130 through diode 105, resistor 106, diode 107, to the emitter electrode 103. The magnitude of the saw tooth voltage 135 shown in Fig. 10 is adjusted so that it approaches the switching point of the bistable circuit 100 as represented by the line 136. However, the magnitude of the saw tooth wave 135 is insufficient to trigger the bistable circuit 100 into its highly conductive operating state. By superimposing the differentiated pulses from the pulse generator 38 on top of the saw tooth wave 135, as represented by the pulses 137 in Fig. 10, it is possible to cause the pulses to become more effective as the magnitude of the saw tooth voltage increases. As soon as one of the pulses 137 crosses the bistable circuit trigger line 136, the trigger circuit 100 will be rendered operative in its highly conductive state. This high current state will continue until a low current state is again created by the application of a pulse 138 which will trigger the bistable circuit 100 so that the emitter voltage will be below the trigger line 136.

The resultant output wave will be represented by the curve I_c shown in Fig. 10 and this will be the current flowing in the collector electrode circuit 104. The resultant current flowing through the resistor 116 will be averaged out by the condenser 117 and this may be represented by the line 140 in Fig. 10.

As the vane 71 changes its position relative to the coil of the transformer 70, the amplitude of the positive pulses 137 will be varied and the time length of the pulses 139 will accordingly be varied. As a consequence, the average D.-C. level of the line 140 will shift to represent the time length of the pulses 139 so that this current level will follow proportionally the movement of the vane 71 between the coils of the transformer 70.

It will be readily apparent that a circuit of the type shown in Fig. 9 is well adapted for use in any type of controller wherein it is desired that the magnitude of the variable produce a current which varies proportionally with the changes in the magnitude of the variable. Controlling devices well adapted to use in this type of apparatus are controllers incorporating saturable reactors wherein the control windings of the saturable reactors may be varied by varying the current flow through the control winding.

The circuit of Fig. 9 is also adapted to time proportional control action. Thus, if the period of the saw tooth wave is increased sufficiently and a relay is connected to the output of the trigger circuit 100, the relay may be rendered operative for timed periods which vary proportionally with the magnitude of the measured variable.

Referring now to Fig. 11, there is shown a further form of controller whereby a current proportional to the positioning of a vane may be produced in the output of the apparatus. In this figure, the pulse generator 38 corresponds to the pulse generators of the preceding figures and carry corresponding reference characters. A bistable trigger circuit 150 is included in the present apparatus

and this includes a transistor 151 having a base electrode 152, an emitter electrode 153, and a collector electrode 154. A resistor 155 is connected to the base electrode 152.

Connected to the emitter electrode 153 is a resistor 156, a second resistor 157 having a condenser 158 in parallel therewith, and an adjustable emitter biasing source 159 including a potentiometer 160 and a battery 161. Power is supplied to the transistor 151 by a battery 162 which is connected to the collector electrode 154 by way of a load resistor 163. A condenser 164 is connected to bypass the load 163.

In considering the operation of Fig. 11, it should first be noted that the pulse generator 38 operates in a manner corresponding to the manner explained above and produces a series of recurring pulses which are used to control the operation of the trigger circuit 150. The trigger circuit 150 is normally rendered operative in its low current conducting state by the pulses produced by the pulse generator passing through the condenser 41 and diode 42 to the base resistor 155.

The pulses from the pulse generator 38 tending to trigger the trigger circuit into the high conducting state are applied to the base electrode 152 by the secondary 73 and tend to cause the current flow through the load resistor 163 to increase to the high value of current flow to the trigger circuit. When this high current is flowing, there is a current flow in the emitter circuit that may be traced from the ground through the potentiometer 160, resistor 157, resistor 156, emitter electrode 153, base electrode 152, resistor 155, secondary 73 back to ground. This emitter current flow will produce a voltage drop across the resistor 157 which will tend to be stored there by the condenser 158. The charge on the condenser 158 will be sufficient to hold the trigger circuit 150 in a non-conductive state for a period of time. The time length of this period will be dependent upon the time constant of the R-C network formed by resistor 157 and condenser 158 as well as the magnitude of the turn on pulse. With this circuit, the average direct current flowing in the load resistor 163 may be made to proportionally follow the movement of the vane 71.

The circuit of Fig. 12 shows a form of the apparatus whereby three position control may be readily achieved. In this figure, the pulse generator 38 is shown in block diagram form and may take the form shown in the above mentioned figures. The output of the pulse generator is fed through a pair of condensers 170 and 171. The magnitudes of the condensers 170 and 171 are adapted to be controlled by a movable vane 172, the vane in this circuit acting as an impedance lowering element when placed between the condenser plates of condensers 170 and 171. In series with the condenser 170 is a diode 173 while in series with the condenser 171 is a diode 174.

Also included in this circuit is a bistable trigger circuit 175 which includes a transistor 176 having a base electrode 177, an emitter electrode 178, and a collector electrode 179. Connected to the base electrode 177 is a resistor 180 while connected to the emitter electrode 178 is a resistor 181 in series with a battery 182. Connected to the collector electrode is a coil 183 of a relay 184. The relay 184 includes a switch blade 185 normally engaging the contact 186 when the relay is deenergized, a contact 187 when the coil 183 has a high state of energization, and a spring 188 which will cause the blade 185 to assume a mid position between the contacts 186 and 187 when the energization of the coil 183 is at an intermediate state. In series with the coil 183 is a resistor 189 and a battery 190.

With the circuit in the position shown, the vane 172 is serving to maintain the impedance of both the condensers 170 and 171 at a relatively low value inasmuch as the vane is between the respective plates of the condensers 170 and 171 to increase the capacity thereof. As a consequence, when the square wave pulse from the pulse generator 38 is differentiated, there will be produced a

positive pulse through the condenser 170, diode 173, and resistor 180 which will cause the bistable trigger circuit to be actuated to its low conducting state. When the negative pulse is differentiated, this pulse will pass through the condenser 171, diode 174, and resistor 180 to trigger the bistable trigger circuit 175 to its high conducting state. If a symmetrical square wave pulse is produced by the pulse generator 38, the time that the bistable trigger circuit 175 will be conducting in its high state will be equal to the time that the trigger circuit is conducting in its low state. This will mean that there is an intermediate value of current flowing through the relay coil 183 which when averaged by the condenser 191 will cause the relay coil to pull the blade 185 up against the spring 188 so that the blade 185 will be centered between the contacts 186 and 187 at its intermediate position.

If the magnitude of the variable affecting the positioning of the vane 172 changes so that the vane moves in an upward direction between the plates of the condenser 170 and out from between the plates of the condenser 171, the impedance of the condenser 170 will remain sufficiently low that the pulses from the output of the generator 38 will still be applied through the condenser 170, diode 173, to the base electrode 177. On the other hand, the condenser 171 will have a sufficiently high impedance to prevent the passage of any pulses there-through. This will mean that only the positive pulse will be applied to the bistable trigger circuit 175 and this pulse will maintain the trigger circuit operating in its low current state. This will mean that the relay 184 will be deenergized so that the blade 185 engages contact 186.

If the vane 172 should be moved in the direction opposite to that assumed above, that is where the vane 172 is between the plates of the condenser 171, this latter condenser will now have a low impedance and the condenser 170 will have a high impedance. This will mean that only the turn on pulses from the generator 38 will be applied to the bistable trigger circuit and it will remain in its highly conductive state. When in this state, the relay coil 183 will be effective to move the blade 185 into engagement with the contact 187 against the force of the spring 188 and the relay will remain in that position until such time as the vane moves back to its center position.

It will be readily apparent that the circuit of Fig. 12 thus forms a three position controller having an on position, an off position, and an intermediate position. It will be readily apparent that the coupling impedances between the pulse generator 38 and the bistable trigger circuit 175 may well take the form of transformers or a combination of transformers and condensers with the vane being effective to vary the magnitudes of the pulses effective upon the bistable trigger circuit 175.

From the foregoing description, it will be readily apparent that the circuits of the present invention are well adapted to be used in two position controllers, proportional controllers, and three position controllers. It will further be readily apparent that the basic components in each of the various forms of the controllers are very similar with only minor circuit modifications being necessary in order to effect a wide variety of control actions. While a bistable trigger circuit has been shown, other types of trigger circuits such as monostable trigger circuits may be used.

While, in accordance with the provisions of the statutes, there has been illustrated and described the best forms of the embodiments of the invention known, it will be apparent to those skilled in the art that changes may be made in the form of the invention as set forth in the appended claims and that in certain cases, certain features of the invention may be used to advantage without a corresponding use of other features.

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

1. An electric vane controller comprising, a pulse producing means, a bistable circuit adapted to assume a first

operating state or a second operating state in accordance with the polarity of input pulses applied thereto, circuit means connecting said pulse producing means to said bistable circuit, a movable vane for varying an electrical impedance characteristic of the circuit means coupling the pulses from said pulse producing means to said bistable circuit to affect the operation thereof, and a process condition responsive means coupled to control the movement of said movable vane.

2. An electrical controller comprising, a pulse producing means, said means having pulses which are alternately positive and negative, a bistable trigger circuit adapted to assume a first operating state or a second operating state in accordance with the polarity of input pulses applied thereto, circuit means connecting said pulse producing means to said bistable circuit, a movable element comprising a variable electrical impedance in said last named circuit means for regulating the effect of said pulses on said bistable circuit, a process condition responsive means coupled to control the movement of said movable element, and circuit operational responsive means being rendered operative in accordance with the operating state of said trigger circuit.

3. An electrical controller comprising, a source of electrical pulse signals, a trigger circuit having bistable characteristics adapted to operate in a first or second state in accordance with the polarity of the pulse signals applied thereto, a coupling circuit between said source and said trigger circuit, said circuit including a movable electrical impedance element for varying the magnitude of the signals coupled into said trigger circuit to determine the state in which said trigger circuit will operate, and a process condition responsive means coupled to control the movement of said movable element.

4. An electrical controller comprising, a source of electrical pulses, a trigger circuit having bistable characteristics adapted to operate in a first, second, or intermediate state in accordance with the pulses applied thereto, a coupling circuit between said source and said trigger circuit, said coupling circuit comprising a pair of coupling impedances and a movable element adapted to vary the coupling effect thereof to determine whether said trigger circuit will operate in said first, second, or intermediate state, and a process condition responsive means coupled to control the movement of said movable element.

5. An electrical controller comprising, a square wave generator, a bistable trigger circuit, circuit means coupling said generator to said bistable circuit, said circuit means comprising a pair of differentiating circuits, a movable vane which is operable to render one of said differentiating circuits effective or ineffective, and a process condition responsive means coupled to control the operation of said vane.

6. An electrical controller comprising, a square wave generator, a bistable trigger circuit, circuit means coupling said generator to said bistable circuit, said circuit means comprising a pair of differentiating circuits, a movable vane arranged to control the relative effectiveness of both of said differentiating circuits, and a process condition responsive means coupled to control the operation of said vane.

7. An electrical controller comprising, a free running pulse generator, means for differentiating the output pulses of said generator to form positive and negative pulses, a bistable trigger circuit adapted to be operative in a first state when a negative pulse is applied thereto and in a second state when a positive pulse is applied thereto, circuit means coupling said differentiated pulses to said bistable trigger circuit, said circuit means including a vane controlled element for varying the magnitude of one of the pulses applied to said trigger circuit, and a process condition responsive means coupled to control the operation of said vane.

8. An electrical controller comprising, a pulse generator comprising, a first transistor having a base elec-

trode, emitter electrode, and collector electrode, a source of power having two terminals, a first resistor connecting said source of power to said base electrode, a parallel connected resistor and condenser connecting said emitter electrode to said source of power, and a second resistor connecting said source of power to said collector electrode, a bistable trigger circuit comprising a second transistor having a base electrode, emitter electrode, and collector electrode, a second source of power, circuit means including a third resistor connecting said second source of power to the base electrode of said second transistor, circuit means including a fourth resistor connecting said second source to the emitter electrode of said second transistor, a fifth resistor connecting said second power source to the collector electrode of said second transistor, a variable responsive impedance circuit means coupling said pulse generator to said bistable trigger circuit, said impedance circuit means including a movable vane for varying the electrical impedance characteristic of said impedance circuit means and a process condition responsive means coupled to control the operation of said variable circuit means.

9. Apparatus as defined in claim 8 wherein said impedance circuit means includes a condenser and an asymmetrically conductive device connected in series.

10. Apparatus as defined in claim 8 wherein said impedance circuit means includes a pair of condensers, each of which has an asymmetrically conductive device in series therewith, said vane being adapted to vary the impedance of one of said condensers.

11. Apparatus as defined in claim 8 wherein said impedance circuit means comprises an inductive element.

12. Apparatus as defined in claim 8 wherein said impedance circuit means comprises a pair of signal circuits, one of which is inductive and the other of which is capacitive, and a vane for varying the impedance of one of said signal circuits.

13. Apparatus as defined in claim 8 wherein said impedance circuit means comprises a pair of vane controlled impedance coupling elements.

14. An electrical controller comprising, a source of electrical pulses having a first recurrence rate, a trigger circuit having bistable characteristics adapted to operate in a first or a second state in accordance with the pulses applied thereto, a coupling circuit including a movable vane connecting said source of pulses to said trigger circuit, a process condition responsive means coupled to control the operation of said movable vane, a second cyclically operating signal source having a recurrence rate less than that of said pulse source and having a sloping characteristic, and means connecting said second signal source to said trigger circuit to vary the effect of said pulses on said trigger circuit.

15. An electrical controller comprising, a source of electrical pulses having a first recurrence rate, a trigger circuit having bistable characteristics adapted to operate in a first or a second state in accordance with the pulses applied thereto, a circuit coupling said pulse circuit to said trigger circuit, said coupling circuit including a vane to vary the amplitude of an applied pulse signal from said pulse source, a process condition responsive means coupled to control the operation of said vane, a pedestal signal source, said pedestal signal having a sloping characteristic and a recurrence rate less than that of said first recurrence rate, and means connecting said pedestal signal source to said trigger circuit to vary the effect of said pulse source on said trigger circuit in accordance with the sloping characteristics of said pedestal signal.

16. Apparatus as defined in claim 15 wherein said trigger circuit comprises a transistor having a base electrode, emitter electrode and collector electrode, and means connecting said source of electrical pulses and said pedestal signal source in series with the emitter electrode of said transistor.

17. An electrical controller comprising, a source of

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control pulses, a bistable trigger circuit including a transistor having an emitter electrode, circuit means connecting said pulse source to said trigger circuit, a movable vane in said last named circuit for varying the amplitude of said pulses on said trigger circuit, a process condition responsive means coupled to control the operation of said movable vane, and a parallel connected resistor and condenser connected in the circuit of said emitter electrode to maintain an average voltage on said emitter electrode proportional to the amplitude of the pulses applied through said circuit means.

18. A vane controlled apparatus comprising, a source of signal pulses, first circuit means for differentiating the leading edge of said pulses, second circuit means for differentiating the trailing edge of said pulses, a movable vane for varying the amplitude of the differentiated pulse from one of said circuit means, a process condition responsive means coupled to control the operation of said movable vane, a trigger circuit comprising a transistor having a base electrode, emitter electrode, and collector electrode, means connecting one of said circuit means to said base electrode, and means connecting the other

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of said circuit means to an impedance element connected to said base electrode.

19. Apparatus as defined in claim 18 wherein said first circuit means comprises a condenser and a rectifier in series, and said second circuit means comprises a transformer having a secondary winding with a rectifier in parallel therewith.

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