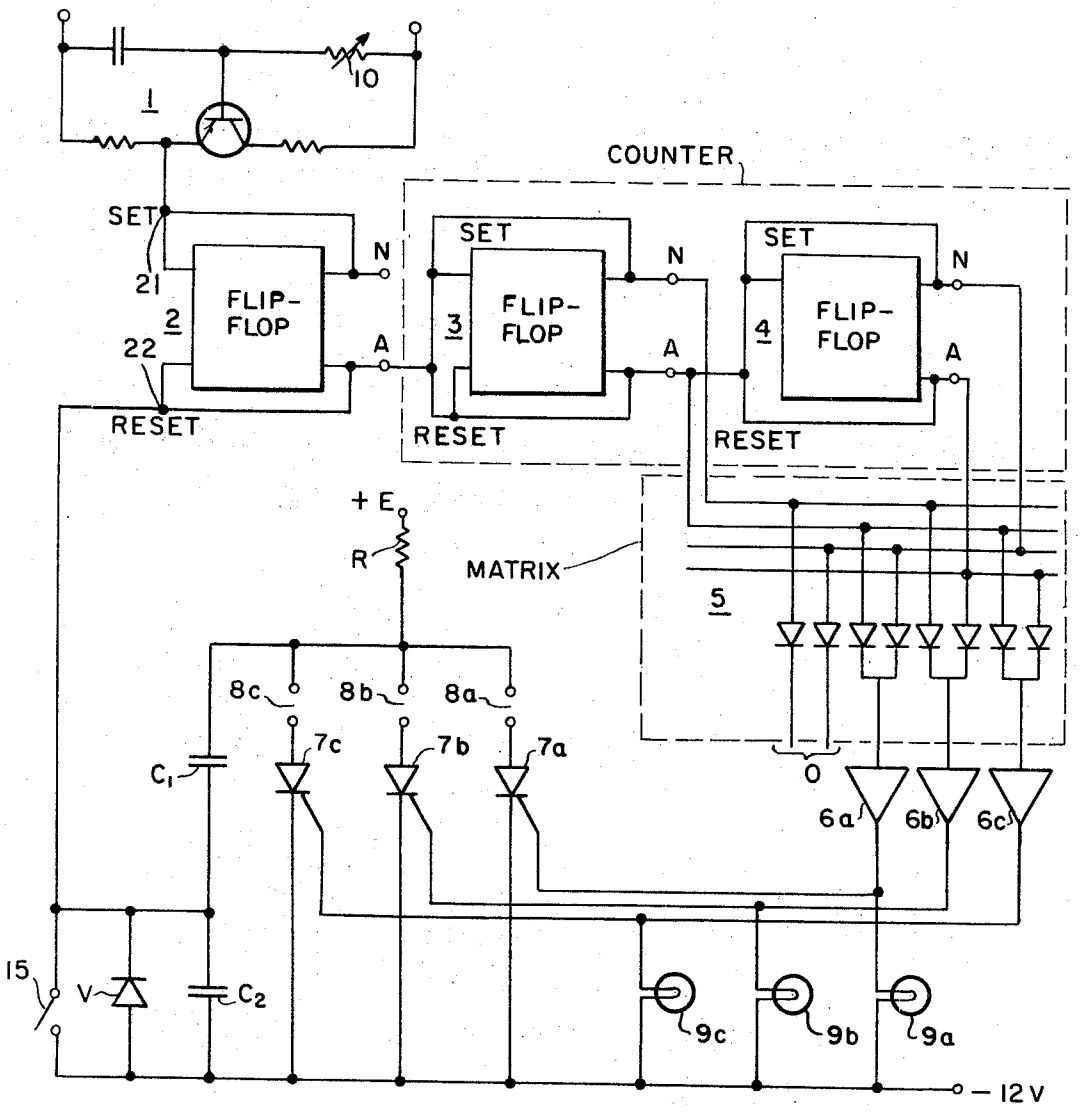
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DETONATOR APPARATUS FOR SERIES FIRING OF EXPLOSIVES

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DETONATOR APPARATUS FOR SERIES FIRING OF EXPLOSIVES

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The invention relates to an electrical firing apparatus with means for timed series firing of a number of explosive charges.

Blasting by means of electrical detonators is usually done with instantaneous detonators or delay detonators. Delay detonators inherently are more expensive than instantaneous detonators. Further, the certainty of a charge being fired is greater with instantaneous detonators. Difficulties in connection with delay shot firing of blasting explosives, and one solution, are described in U.S. Pat. 2,814,991; an apparatus for firing explosive charges is also shown in U.S. Pat. 2,812,711.

It is an object of the present invention to provide a timed firing apparatus which is inexpensive and provides a means to determine if a specific explosive charge did not fire, in order to increase safety to the blasting personnel. When making series shot firings it has been proposed to determine which one of a series of charges did not fire, for example, by counting the noise from the explosion. Difficulties have arisen with such counting and the particular location and thus the particular charge which did not fire, is difficult to determine.

Blasting caps operate on a current of 1.5 amperes or more. The timing of shots is approximately 25 milliseconds, if there are up to ten charges; and about 35 milliseconds in from 10 to 18 shots. The apparatus must therefore be able to furnish pulses of substantial current in intervals of milliseconds. Further, it is desirable that the timing rate is variable and that the apparatus provide an indication for each charge which has actually fired. The apparatus should satisfy the following requirements: (1) in case of a short circuit or break in the electrical connections, automatic stopping of the shots, with further automatic indication which line last line fired, to determine which line did not fire, and (2) permit continuous series blasting without disconnection in case of failure to fire, giving an indication, however, which of the charges did not fire.

Briefly, the invention provides for an electronic counter chain which is controlled by a flip-flop circuit. The individual units of the counter chain provide for a serial discharge of the blasting devices, by means of a diode matrix, coupled to the counting chain. Each blasting cap assigned to a shot is assigned to one group of diodes of the matrix. These groups are connected to the various stages of the counter in such a manner that all diodes of any one group are supplied with a control potential at each step. This potential then controls a gate control rectifier, permitting current to flow from a source to the respective blasting cap. Thus, only if all the diodes have the control potental applied, is the particular gate control rectifier enabled. Additionally, each charge causes an impulse which is fed back to the flip-flop, to permit the counter to be advanced to the next stage and thereby permit enabling of the next group of diodes of the matrix. The control pulses are supplied by means of an impulse oscillator which controls the flip-flop. The impulse oscillator is operative at a variable frequency.

An indication system is also provided which may utilize lamps or the like, and shows how the firing of charges progresses; failure of any lamp to light will then indicate if any shot did not fire and on which number the charge has failed to fire. If a charge does not fire, the counter is not advanced, and the lamp assigned to the last fired charge remains lit.

A manual override is provided to advance the counter if one shot proves a dud and the blasting operator still wishes to continue with the remaining series.

The structure, organization, and operation of the invention will now be described more specifically in the following detailed description with reference to the accompanying single drawing, which shows, in schematic form, apparatus for series blasting. For reference to details of the circuit shown schematically, attention is directed to, for example, the "Transistor Handbook" published by General Electric Company, Syracuse, N.Y., which shows suitable flip-flop, counter, oscillator, and other transistorized circuits; and to "High-Speed Computing Devices," Engineering Research Associates, McGraw-Hill Book Co., 1950.

Referring now to the drawing, an impulse generator **1**, which may be in the form of a relaxation oscillator, is schematically indicated only, and detail circuits may be obtained by referring to the literature mentioned. It is supplied from a source of power, not shown. As soon as the power source is connected, a series of pulses will be supplied, the frequency of which is adjustable by changing the resistance of the adjustable resistor **10**. Thus the delay of firings between shots can be adjusted. The impulses are supplied to SET terminal **21** of flip-flop circuit **2**, which may have as active elements, vacuum tubes, transistors or the like. When the output terminal A of the flip-flop **2** changes from negative to positive, a binary counter consisting of flip-flops **3**, **4**, etc., begins to count. In the drawing, two stages only are shown, for firing of three shots. The counter, of course, may contain as many stages as are desired. Each one of the counter stages themselves may consist of flip-flops similar to the flip-flop **2**. Means not shown, and known per se in the electronic counter art, are provided to prevent undesired progression of counting impulses without proper timing from pulse generator **1**. Each of the flip-flops **2**, **3** and **4** has a pair of outputs, one of which is normally positive N and the other normally negative A, reversing polarity when the counting stage is activated.

The N and A outputs of counter stages **3**, **4**, etc., are connected to a diode matrix generally indicated at **5**. Each explosive charge is assigned a group of diodes. A group of diodes marked **0** is connected in the ZERO position and may be used for checking the circuit. These diodes are connected to the outputs N and A of the counter stages, in such a manner that with continuous counting by the counting stages, as the control flip-flop **2** furnishes pulses, first the diodes for the first charge both become negative, then the diodes for the second shot both become negative, and so on. When one of the counter stages **3**, **4**, is not activated, line N furnishes a negative output and line A a positive one; in other words, there is a reversal and the diode matrix **5** decodes the binary progression of the counting stages **3**, **4**, as is well known in the art. For each count there is one, and only one, group of diodes which have a negative potential applied.

Each one of the diodes is connected to an inverter **6***a*, **6***b*, **6***c*, and supplies a control pulse to a gate controlled rectifier **7***a*, **7***b*, **7***c*. A source of current supply from E, with a current limiting resistor R in series, is connected to the respective explosive charge lines which are connected to the terminals **8***a*, **8***b*, **8***c*. When one of the gate controlled rectifiers **7***a*, **7***b*, **7***c* fires, the circuit through the charge line will be completed to fire the respective explosive charge. The power itself is not supplied by the impulse source, but rather by the main power supply, and the amount of power to fire the respective charge is only limited by the current carrying capacity of the gate controlled rectifier. Since present commercially available silicon controlled rectifiers are able to carry

electrical currents greatly in excess of the requirements of explosive charges, certainty of firing is assured.

In parallel to the gate controlled rectifiers 7*a*, 7*b*, 7*c*, a pair of condensers C_1, C_2 are provided, connected in series as shown. Across condenser C_2 there is a rectifier V. So long as none of the gate controlled rectifiers 7*a*, 7*b*, 7*c* are conducting, condenser C_1 is essentially charged to the potential of the source E. This condenser discharges through rectifier V and the conducting gate controlled rectifiers 7*a*, 7*b*, 7*c*. Condenser C_2 bridged by the rectifier V is provided to supply a reset impulse to RESET terminal 22 of control flip-flop 2, when a charge is fired. This reset impulse resets the control flip-flop 2 to permit a new pulse from the pulse generator 1 to set flip-flop 2 again. If one of the charges does not fire, condenser C_2 will not recharge and thus not send a pulse to reset terminal 22 and permit resetting of flip-flop 2 and thus no further automatic counting and further explosions, will result. Similarly, any interruption in the network controlling the charges will likewise prevent further counting, and thus application of current to further explosive charges.

Indicators, shown as lamps 9*a*, 9*b* and 9*c*, are provided in parallel to the control electrodes of gate controlled rectifiers 7*a*, 7*b*, 7*c*. If there is an interruption in the counting, potential continues to remain on the particular line from the diode matrix 5 assigned to the next shot and that particular lamp will remain lit. Thus a dud will be indicated.

If it is desired to continue firing a series of shots in spite of a dud in the series, then an artificial, manually applied reset pulse can be furnished to the reset terminal, for example, by momentary closing of switch 15. It is also possible to provide a manually controlled alternate connection from the impulse generator 1 to the RESET terminal 22, for example, by means of a spring-controlled, single pole, double throw switch.

Before starting a series of firing, flip-flop 2 and the electronic counter must be reset. This can be done by impressing a potential, manually, on the RESET, and on all terminals A, for example, in a known manner and not specifically shown in the drawing.

The present firing apparatus for serial firing of explosive charges essentially comprises an electronic counter having a plurality of counting stages, 3, 4. Means shown as the diode matrix 5, inverters, and gate controlled rectifiers 7*a*, 7*b*, 7*c* are provided for connecting the explosive charges to discrete stages of the counter and for causing explosion of the charge. The counter 3, 4 is enabled by application of a pulse to the SET terminal of flip-flop 2. This pulse not only causes a single count, but also changes the condition of the flip-flop 2 so that, unless flip-flop 2 is re-set, further pulses to the SET terminal will not cause any further counting. Supplying power to cause an explosion of the charge is sensed by means of the combination of condensers C–1, C–2 and diode V; upon recharging of the circuit, a pulse is supplied to the counter enabling means, i.e. the flip-flop 2, to re-set the same and permit application of further pulses and thus further explosions. If an explosion has not been sensed, then the flip-flop 2 is not re-set and thus further counting and further explosions are inhibited. Means are preferably provided to manually re-set flip-flop 2.

I claim:

1. Firing apparatus adapted for communication to a source of electrical power, for serial firing of explosive charges comprising a pulse source, an electronic counter having a plurality of counting stages connected to said pulse source and advancing a count each time a pulse is received; firing control means for the explosive charges connected to discrete stages of the counter, said firing control means causing selectively application of power to said charges and thus causing explosion thereof; means enabling the counter to count, one stage at a time upon application of pulses thereto, and means sensing operation of the firing control means and connected to said enabling means to inhibit said enabling means if an explosion has not been sensed.

2. Firing apparatus as claimed in claim 1 further including manually operating means connected to said enabling means for manually overriding said sensing means and to permit said enabling means to enable the counter to advance, even if an explosion upon a prior count has not been sensed.

3. Firing apparatus as claimed in claim 1 wherein said pulses source is a pulse generator connected through said enabling means to said counter; said counter advancing, one stage at a time, at the rate of pulses from the pulse generator and only if the enabling means does not inhibit application of pulses to said counter.

4. Firing apparatus as claimed in claim 1, said enabling means comprising a bistable element having a SET and RESET input; said counter being advanced only if the SET terminal is enabled; said pulse source being connected to, and applying a pulse to said SET terminal, whereby

(a) the counter will advance one stage and

(b) the bistable element will change its state, and said sensing means being connected to said RESET input and supplying a RESET pulse thereto, whereby said bistable element will again change its state to accept a subsequent pulse if, and only if, a RESET pulse is applied.

5. Firing apparatus as claimed in claim 1 further including indicator means operatively connected to the firing control means for indicating the particular charge being, or last having been, fired.

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