United States Patent

[11] 3,617,813

[72] Inventor **Charles E. Everest**
Corona Del Mar, Calif.

[21] Appl. No. **62,948**
[22] Filed **Aug. 11, 1970**
[45] Patented **Nov. 2, 1971**
[73] Assignee **William Wahl Corporation**
Los Angeles, Calif.

[54] **INTERVALOMETER AND TIMING OSCILLATOR**
22 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **317/80,** 89/1.814
[51] **Int. Cl.** **F23g 7/02**
[50] **Field of Search** 317/80; 102/70.2, 22; 89/1.814

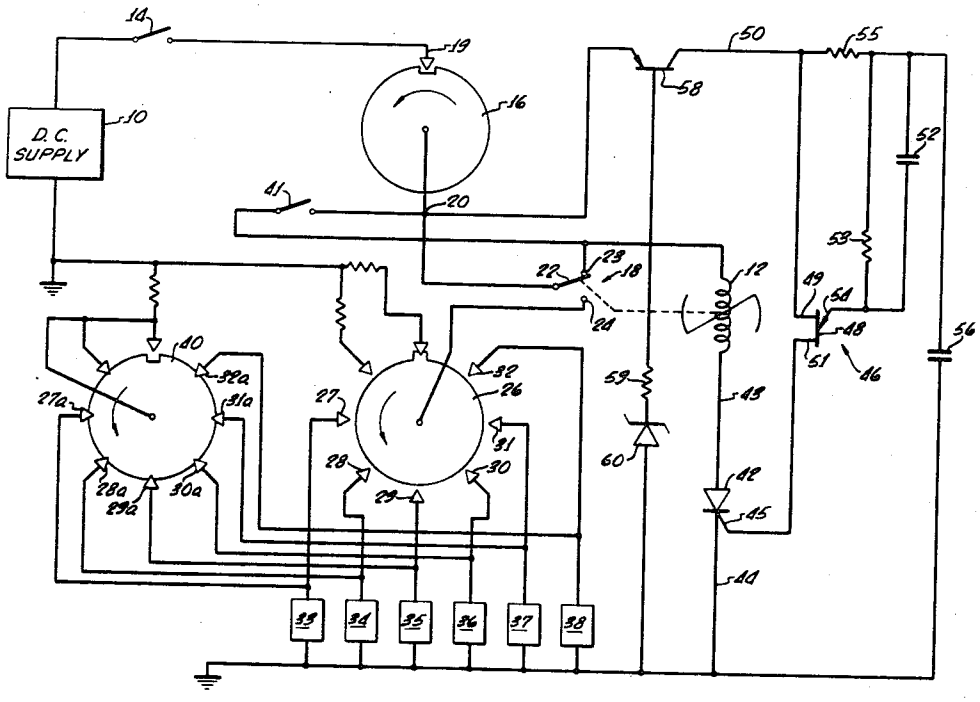
[56] **References Cited**

UNITED STATES PATENTS

2,421,893	6/1947	Lambert et al.	89/1.814 X
2,488,228	11/1949	Nims et al.	317/80
2,794,079	5/1957	Baller et al.	317/80 X
2,832,265	4/1958	Reid et al.	317/80 X
2,853,563	9/1958	Bole et al.	317/80 X
3,064,537	11/1962	Baller et al.	89/1.814
3,453,496	7/1969	Wright et al.	317/80
3,468,255	9/1969	Stryker, Jr.	102/70.2

Primary Examiner—Volodymyr Y. Mayewsky
Attorney—Gausewitz and Carr

ABSTRACT: An intervalometer for firing one or a group of ordnance devices comprises a normally self-stepping electromechanical solenoid-operated switching device and a separate independent timing oscillator. The oscillator is connected to the stepping switch to externally trigger initiation of each step of the switch and is arranged to permit substantially instantaneous actuation of the intervalometer upon receipt of the electrical fire command signal. Although normally instantaneously starting, the oscillator is provided with a delay to accommodate bounce time of pilot-operated firing switches. Continued oscillator operation in the event of temporary power dropout is provided.



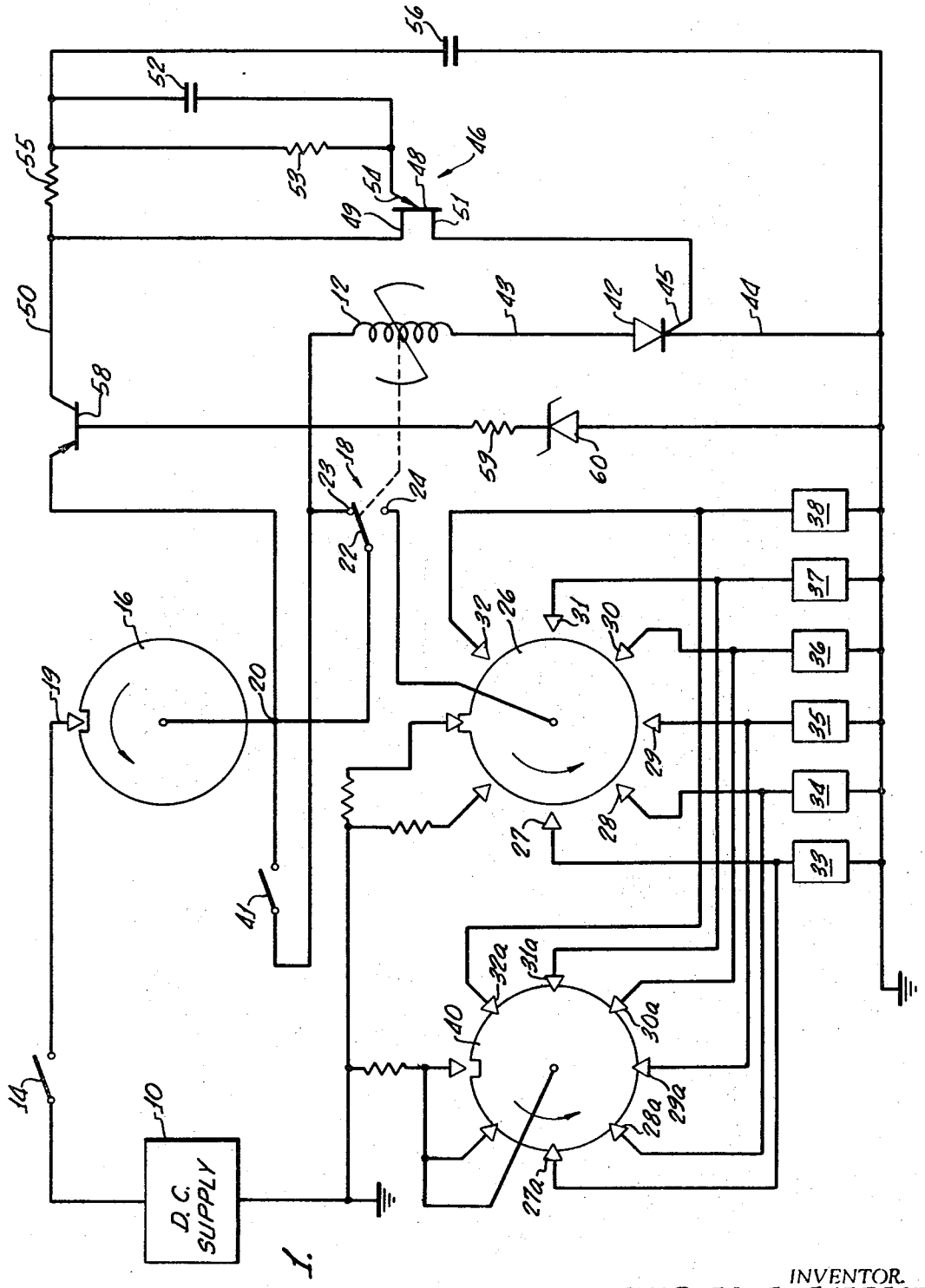


FIG. 1.

INVENTOR.
CHARLES E. EVEREST
BY
Dorsey, Gay & Cass
ATTORNEYS.

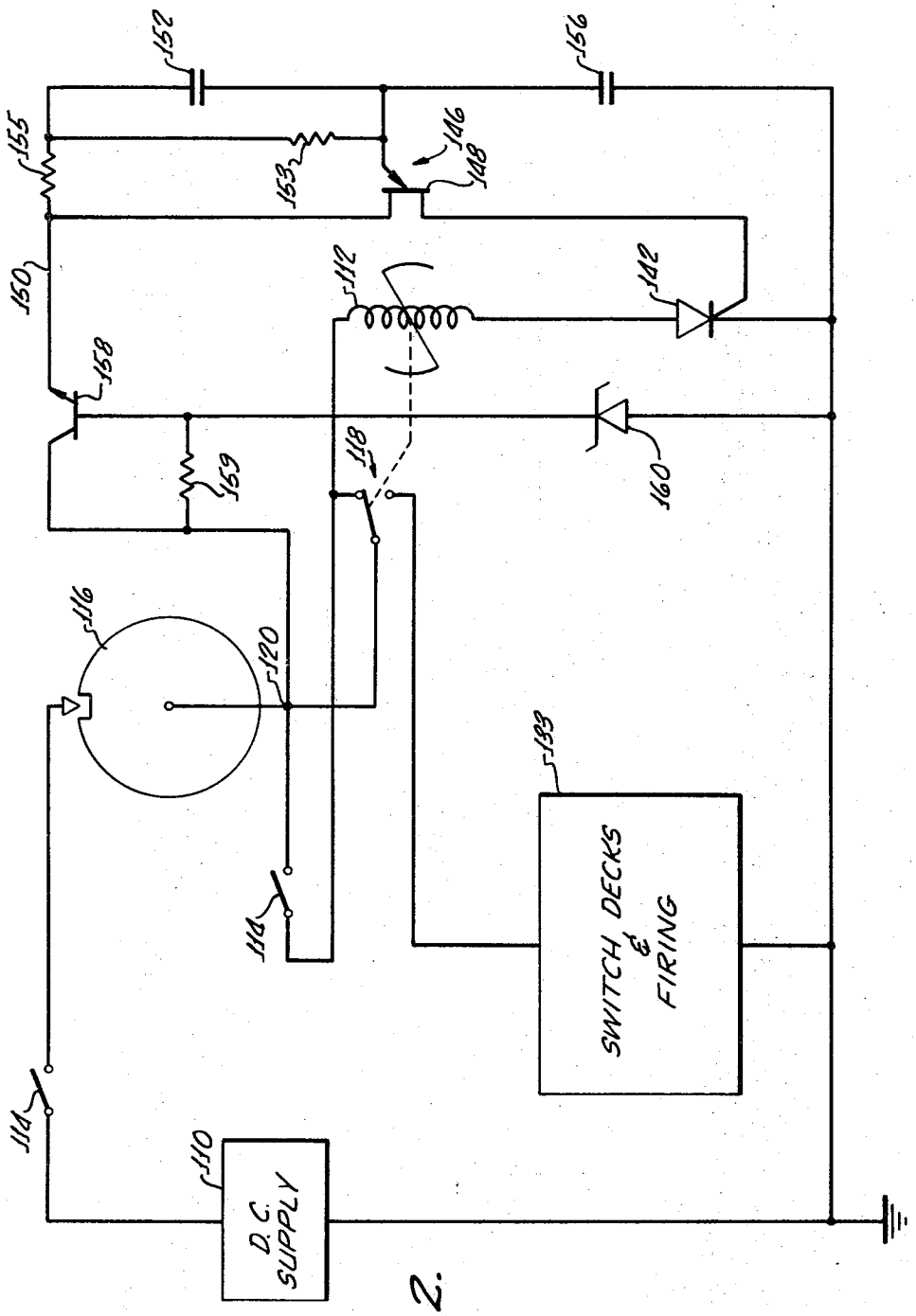


FIG. 2.

INVENTOR.
CHARLES E. EVEREST

BY
Gausewitz & Carr
ATTORNEYS.

INTERVALOMETER AND TIMING OSCILLATOR

BACKGROUND OF THE INVENTION

1. Filed of the Invention

This invention relates to the field of electromechanical devices and associated methods for controlling firing of rockets or other ordinance devices in predetermined sequence and with predetermined times between firings, and more particularly concerns operation of a normally self-stepping firing device by means of an independent all-electronic triggering circuit.

2. Description of Prior Art

Various types of rockets and other ordnance devices such as flares, for example, are conventionally fired from their launching devices either singly or in sequence or in a sequence of pairs. Where the rockets are fired in sequence, it is essential that the sequential ignition and firing be precisely times. Although it is desirable to fire the rockets of a group in as short a time as possible, where the rockets are to be fired individually and not collectively as in a salvo, it is essential that sufficient time between ignition of successively fired rockets be allowed to permit each rocket to clear its launching tube before triggering of the next ignition is begun. Failure to provide adequate periods between successive ignitions may cause one rocket to be fired too closely after a preceding rocket has been fired. This may result in damage to the rockets, bending or destroying fins of one or both. At best, such damage will result in a rocket's failure to strike its target. At worst, such damaged rockets may explode closely adjacent their launch tubes or may be so deflected as to return to strike the launching system.

An additional disadvantage of successively fired rockets ignited at short intervals derives from the high shock loads experienced by the launching equipment upon the launch of each rocket. Such shock load may be as high as 500 g's and may have severe and adverse effects upon the firing mechanism itself. In particular, it is highly desirable to avoid motion of mechanical switch and camming parts of the firing mechanism at the time of ignition, when such mechanisms are subjected to the maximum shock load. Accordingly, all of the moving parts of the firing mechanism are preferably in a temporary rest position and firmly retained in such position when the electrical firing pulses are applied to ignite the individual rocket.

Intervalometers most commonly used at present are of two general types. The self-interrupting, self-stepping electromechanical stepping switch has been widely employed for a number of years. Attempting to avoid problems involved with mechanical devices, a second type, the all-electronic firing pulse distributing system, has been designed.

All-electronic intervalometers such as that shown in the U.S. Pat. 3,316,451 issued Apr. 25, 1967 to R. L. Silverman for Intervalometer will, in general, employ a timing oscillator and an all-electronic commutator that provides a number of sequentially timed firing pulses to the rocket igniters. Complexity, reliability, and high cost of manufacture of such all-electronic circuits are among their major disadvantages.

The earlier designed and more widely used self-interrupting stepping switches have been developed over a period of years to a point that has brought the cost of manufacture well below that of equivalent all-electronic apparatuses. Nevertheless, the electromechanical self-interrupting and self-stepping switch suffers from many drawbacks. Typical of such solenoid-operated stepping switches are the devices shown in U.S. Pats. to G. H. Leland, Nos. 2,496,880 and 2,501,950, and the U.S. Pat. to J. R. Davis, No. 3,384,728.

Employing the principles of these patents, C. C. Giese, Jr. et al. in U.S. Pat. No. 3,405,376 describes a stepping mechanism for a driving rotary switch that includes an interrupter cam to cause the device to operate much like a free-running oscillator. It automatically steps from contact to contact as long as power continues to be applied to its solenoid-actuating coil. Briefly, the rotary stepping mechanism of Giese, Jr. et al. comprises a rotary actuator that is driven through a segment of arc upon energization of a solenoid coil. Motion of the solenoid during each step is stopped mechanically during such segmental rotation. Near the end of its travel a cam connected with the actuator temporarily opens a switch that interrupts power to the driving coil. Upon interruption of power, a return spring that is extended during the stepping action returns the actuator to its initial point and the mechanism is cocked, having completed one cycle and begins its next cycle, providing that the main power is still applied. In the course of the segmental rotation of the driven actuator, a ratchet is driven to segmentally rotate or step one or more decks of rotary switch banks which accordingly may sequentially apply power to a group of ordnance devices.

The solenoid operated switch mechanisms of the type described in the Leland and Davis patents are mechanisms of established operation, proven utility, and are available at relatively low cost. Nevertheless, the free-running electromechanical version or self-interrupting switch as described by Giese, Jr. et al. introduces a number of problems that increase its difficulty of manufacture and cost, and, further, seriously degrade reliability and operation of the intervalometer. Because the self-interrupting electromechanical stepping mechanism of Giese, Jr. et al. is largely a mechanical oscillator, the apparatus must be detuned and desensitized to the severe and repetitive shock and vibration of rocket launching and airborne applications in general.

Major problems of the self-interrupting rotary stepping mechanism arise because of its natural frequency. It is found that switches of this type operate at a natural frequency having a natural period in the order of 20 milliseconds. Such frequency is determined to a large extent by the size and mass of the moving mechanical parts. However, since the parts are mass produced to minimize cost, it is exceedingly difficult if not impossible to maintain a natural frequency of such a self-stepping mechanism within any reasonable tolerance limits. In fact, in actual practice, natural frequency of such switches for intervalometer operation have been known to vary as much as 100 percent.

Even the 20 millisecond nominal natural period is too small for optimum operation of a sequentially fired bank of rockets. Accordingly, rockets fired with such apparatus may be subject to inadvertent salvo firing; that is, where all are fired together. Alternatively, the rockets may fire in such rapid sequence that they will physically interfere with each other to thus totally destroy the intended trajectory or as has been known to happen on occasion, to actually damage the firing aircraft itself.

In spite of this problem of relatively short and unpredictably variable natural period of the self-stepping intervalometer switch, the mechanism is so constructed and arranged that it is impossible to significantly increase the natural period of its self-stepping operation. It has long been known that no rocket in a sequence of rocket firing should be ignited until the preceding rocket has cleared the launching tubes. Since ignition and acceleration of rockets are fairly predictable, it is known that ignition of rockets to be fired in a sequence should be spaced by intervals of not less than about 60 milliseconds. Thus, optimum firing intervals are considerably greater than maximum natural periods of the commonly employed self-interrupting stepping switch.

Hybrid devices have been suggested, largely for the purpose of providing greater flexibility and number of control functions and allowing more intensive monitoring of the firing operation by the pilot who can then visually monitor the operation and condition of the apparatus at all times. Such a hybrid arrangement is shown in U.S. Pat. No. 3,453,496 for Fire Control Intervalometer to J. B. Wright, et al. In the arrangement shown by Wright, both electrical and mechanical parts of the stepping switch mechanism itself inherently form parts of the timing oscillator and accordingly, the mechanical parts to some degree control the period of operation. Nevertheless, there is provided by Wright an electronic circuit that does afford additional flexibility of control of timing.

Although Wright provides a separate and selectively operable timing circuit that enables selection of a different number of rockets for firing, the basic timing is provided by an oscillator coil and the self-interrupting switch contacts of the stepping switch itself. Accordingly, this arrangement fails to adequately isolate fundamental frequency defining components from the mechanical parts of the mechanism. Furthermore, the arrangement of Wright suffers from a drawback that is common to all of the previously described electronically controlled intervalometer operations. This is the inability to precisely control the time of firing of the first rocket of a sequence.

According to military requirements, the first rocket of a sequence must be fired within 20 milliseconds of completion of the firing circuit by pilot operation of the firing button.

This requirement for near instantaneous and controlled initial turn-on operation introduces even greater problems and complexity of circuitry in the all-electronic or all-electronically timed intervalometer. As indicated above, the preferably natural period for such an electronic timer is in the order of 60 milliseconds. Although this period is an optimum requirement, it will not meet the military specification that requires a substantially instantaneous firing of the first rocket. Relaxation oscillators, astable multivibrators and other free-running oscillators will provide an output pulse after initial energization that occurs upon completion of a first half cycle of the oscillator. For highly asymmetrical oscillators such as the ordinary unijunction transistor relaxation oscillator, the output pulse occurs only after the timing capacitor has fully charged which may take up to 99 percent of a full complete cycle. Thus, although the conventional oscillator may be readily timed to provide a 60 millisecond natural period, such a period has not been available from an apparatus capable of substantially instantaneous turn on operation.

Because of the arrangement of the fire control wiring in the ordinary aircraft, there may be as may as 10 to 12 switches and detachable electrical connections between the pilot operated fire control button and the intervalometer itself. Over a period of time and as the apparatus is subjected to repeated and continuous use and vibration of aircraft operation, such switch contacts and connectors wear and become loose whereby ordinary vibration of aircraft operation will induce motion of switch and contact parts. Thus, when the pilot depresses the firing button, one or more of these switches and contacts may be vibrating and be subjected to switch bounce to thereby introduce severe transients into the control signal that may last from 1 to 2 milliseconds. This switch bounce is detrimental to the initial operation that occurs upon the first energization of the solenoid coil of the conventional rotary stepping switch.

Accordingly, it is an object of the present invention to provide a substantially self-stepping electromechanical intervalometer switch with a timing oscillator that will reliably provide the intervalometer with a desired firing interval and at the same time afford a controlled substantially instantaneous turn on of the intervalometer.

SUMMARY OF THE INVENTION

In carrying out the principles of the present invention in accordance with a preferred embodiment thereof a stepping switch having a driving coil connected to be energized by a power supply through a self-interrupting switch in circuit therewith, is provided with an externally triggered coil energizing switch that is arranged to be closed by receipt of an external trigger to initiate energization of the driving coil which has its energization interrupted in a conventional fashion by its interrupter switch. The coil-energizing switch is triggered by an oscillator at the desired intervalometer repetition rate. The oscillator is uniquely arranged to provide its first output trigger pulse to the coil-energizing switch substantially immediately upon application of power to the circuit. A switch bounce delay in operation of the first oscillator trigger pulse is also available.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a preferred embodiment of an intervalometer incorporating a timing oscillator constructed in accordance with the principles of the present invention, and

FIG. 2 comprises an illustration of a modification of circuit of FIG. 1. cDETAILED DESCRIPTION

The present invention in accordance with the preferred embodiment illustrated and described herein basically comprises a self-stepping rotary switch and a timing oscillator for controlling the switch. The rotary switch may be of the type described in the above-identified Leland and Davis patents and, in particular, will include a self-interrupting mechanism for providing self-interrupted power to the solenoid as described in the above-identified U.S. Pat. to C. C. Giese, Jr. et al. No. 3,405,376, the disclosure of which is fully incorporated herein by reference.

Portions of such a stepping switch are schematically shown in FIG. 1. Briefly, the self-interrupting rotary stepping switch of Giese comprises a DC voltage supply **10** that supplies power to a solenoid stepping coil **12** of the electromagnetic actuator via a manual pilot-controlled firing button **14**, a first safety or arming deck **16** and a set of interrupter and firing switch contacts **18**.

Ignoring at this time other elements in circuit with the electromagnetic actuator coil **12**, it will be seen that the firing of the intervalometer is enabled (the device is armed) by manually moving the intervalometer switch through its first two steps, from the illustrated "load" position of first safety deck **16** to an "arm" position by manual means not illustrated. In the illustrated load, or first safety position, first switch deck **16** provides an open circuit in the power supply to the solenoid coil because the switch arm **19** does not make contact in this position with the conductive surface of the deck **16**. In all other positions of the switch and of the deck **16**, the pilot operated closing of firing switch **14** will provide the full 28 volts of the power supply at point **20** for transmission by the interrupter switch **18** to the solenoid actuating coil **12**.

Considering the rotary switch decks to be in "arm" position, closing of firing switch **14** energizes solenoid coil **12** to thereupon initiate the first segmental rotational step of the switch decks. These rotate through about 30° and are mechanically stopped. As more particularly described in detail in the Giese patent, as the actuator travels through its 30° throw the interrupter cam operates to momentarily move an arm **22** of the interrupter switch from its electrically contacting position with contact to momentarily contact with a firing contact **24**. Since this momentary contact of interrupter switch arm **22** and contact **24** occurs at or near the end of the thirty degree actuator throw, the various switch decks have already been stepped to their new position and are preferably at rest. Accordingly, in such switch position, a relatively short firing pulse is provided from the DC supply via the closed fire control button **14** through deck **16**, arm **22** and contact **24** of the interrupter switch, to a fire sequencing switch deck **26**. Switch deck **26** in addition to having a pair of commonly grounded load and arm contacts has six rocket firing contacts in the simplified illustration, identified as **27, 28, 29, 30, 31** and **32**. Each of the latter is connected to ground through a respective one of the schematically depicted rocket ignition circuits **33, 34, 35, 36, 37** and **38**.

A third switch deck **40** provides a second safety operation and has in addition to load and arm positions six contacts designated as **27*a*** through **32*a***, each of which is connected to a correspondingly numbered contact of the second switch deck **26**. The body of third deck **40** is connected to ground whereby all of the input lines to the rocket ignition circuits **33** through **38** are always grounded except when a particular one of the contacts **27*a*** through **32*a*** is adjacent the indented portion of the deck **40**, whereby it is freed of its ground connection.

From this brief description of the stepping switch decks, it will be seen that the cam-operated throw of interrupter switch arm **22** into momentary engagement with contact **24** provides

a firing pulse to that one of the rocket ignition circuits 33 through 38 that is selected by the particular position of the several switch decks at such instant. Accordingly, one rocket and only one rocket will be fired.

The second function of the interrupter switch 22, 24, which occurs simultaneously with the transmission of the rocket-firing pulse therethrough, is the interruption of the power circuit from point 20 of deck 16 to the switch 18 to the solenoid stepping coil 12. When this coil is deenergized, a spring that has been tensioned during the powered rotary throw of the switch actuator returns the latter to a rest or cocked position and the apparatus has completed a single full cycle.

In the absence of any further circuitry or components, and in the absence of the parts of the invention timing circuit that will be described hereinafter, power is still applied from DC supply 10 via the still closed fire command button 14, via safety deck 16, and through arm 22, contact 23 of the interrupter switch which had been immediately returned to its normal position (illustrated). Accordingly, solenoid coil is once again energized, its actuator driven and its switch deck stepped through a 30° segment of rotation. In this new position, a second one of the rocket-firing contacts 27 through 32 is in contact with the firing deck 26 and freed from its safety ground connection of switch deck 40 whereby it is ready to accept a firing pulse. This firing pulse is provided via the interrupter switch 18 and its arm 22 which is momentarily moved during travel of the actuator to engage contact 24. The second rocket is fired, coil 12 is deenergized and returned to its cocked position and arm 22 returns to its normal position whereupon another cycle has been completed.

As previously described, the natural period of the above-described repetitive and cyclic switch operation is in the order of 20 milliseconds and furthermore, may vary with normal manufacturing tolerances by as much as 100 percent. This 20 millisecond period is considerably less than the desired 60 millisecond interval between firing of successive rockets and cannot be significantly increased in a rotary stepping switch of any reasonable size or of any reasonable degree of compactness. Consequently, even if the high degree of variation of the natural period could be tolerated, the short period and high frequency of operation is still unacceptable.

In accordance with principles of the present invention, maximum use is made of the highly developed mechanical arrangement of the electromechanical self-interrupting stepping switch, described herein. At the same time its most serious disadvantages are eliminated. To these ends there is provided a second switch, a coil-energizing switch 42, in series circuit with the coil 12, its interrupter switch 18, and the power supply 10. Coil-energizing switch 42 is illustrated in the form of a silicon-controlled rectifier (SCR) having an anode 43 connected to one side of coil 12 and having a cathode 44 connected to ground which forms the other side of the power supply 10. Coil-energizing switch 42 has a triggering electrode, the SCR control electrode 45, that is arranged to receive a trigger pulse from an oscillator 46 that defines and provides the overall timing of the illustrated intervalometer. Frequency of the oscillator is considerably less than the natural frequency of the stepping switch.

Coil energizing switch 42 is a conventional SCR that provides a normally open circuit between its anode 43 and cathode 44 until it has been actuated or turned on. It is actuated by a receipt of a trigger pulse at its control electrode 45. Once it has been actuated and even though all signals are withdrawn from its control electrode 45, it provides a substantially low-resistance circuit between its anode 43 and cathode 44 to thereby, in effect, connect the lower end of coil 12 to ground. This low-resistance circuit continues to connect the coil to ground unless and until anode current to the SCR 42 is interrupted.

Consequently, once triggered by a signal at control electrode 45, SCR 42 continues to ground the lower end of coil 12 until power to the coil is interrupted by operation of interrupter switch 18. Thus, each cycle of the stepping switch is terminated by the interrupter switch 18 just as if the stepping switch was entirely free-running and independent of any external control. The difference is, however, that once any cycle has terminated, the next cycle does not and cannot commence until the coil-energizing switch 42 has been once again triggered.

Each stepping switch cycle is initiated by an external trigger signal and terminated by internal mechanisms. The external trigger signal for initiating operation of each stepping switch cycle is provided by oscillator 46 comprising a unijunction transistor 48 having a base one electrode 49 connected to a positive supply line 50 and a base two electrode 51 connected to the control electrode 45 of the coil-energizing switch 42. A primary RC timing circuit of the oscillator comprises a capacitor 52 and a resistor 53 that are connected as a parallel RC circuit between the emitter electrode 54 of the unijunction transistor and the positive supply line 50. Interposed between the RC timing circuit 52, 53, and line 50, is a second resistor 55. A bounce delay and power storage capacitor 56 is connected between ground and the power line 50 through resistor 55.

The illustrated oscillator arrangement provides a uniquely timed relaxation oscillator having an oscillator switch formed by transistor 48 that will provide an output pulse substantially immediately upon receipt of power thereto. Although primary timing of the oscillator cycle, that is, the length of each of its periods, is controlled by RC timing circuit 53, 52, delay of the first pulse, and only of the first pulse, is achieved by use of the switch bounce capacitor 56. The latter effects a delay only of the first oscillator cycle and, therefore, in effect, achieves a phase delay of an entire series of successive oscillator cycles.

Power is supplied to oscillator 46 via power line 50 and a PNP transistor 58 having its collector connected to the oscillator power supply line 50 and its emitter connected to point 20 at which a positive DC voltage is supplied from source 10.

Connected to the base of transistor 58 is a series connected resistor 59 and a zener diode 60. The anode of zener diode 60 is connected to ground. This circuit, comprising resistor 59 and zener diode 60, protects the oscillator 46 from inadvertent operation that may be caused by stray or spurious voltages, in the order 149 138 volts or less where a standard 28 volt source 10 is sued. Zener diode 60 is chosen so that it will fire and conduct only when a voltage somewhat less than the chosen level of 18 volts is provided thereacross. Accordingly, unless and until the voltage at the emitter of transistor 58 rises to a point at least one diode drop, (about one-half volt) above the voltage established by the zener diode 60, the latter will not conduct and the base of transistor 58 will draw no current. Transistor 58 is and remains cut off until voltage at its emitter rises above 18 volts. With this arrangement, the circuit is particularly arranged for operation with the conventional 28 volt DC military supply source and protected against inadvertent operation in the presence of stray voltages of 18 volts or less.

In operation, when the pilot closes firing button 14, power is supplied via deck 16 and point 20 through transistor 58, through resistor 55, to one side of the primary timing capacitor 52. However, since the voltage across the capacitor cannot change instantaneously, this primary timing capacitor will instantaneously (assuming for this part of the description that capacitor 56 is not connected) transmit to the emitter electrode 54 of the unijunction transistor 48, the high level of DC voltage that suddenly occurs upon closing of the firing button 14. It should be noted at this point that the conventional relaxation oscillator and the conventional unijunction transistor version of the relaxation oscillator ordinarily has its primary timing capacitor connected between the transistor or oscillator-switching device control electrode and ground. Thus, in a conventional oscillator no instantaneous voltage-transmitting circuit such as primary timing capacitor 52 is connected between the power supply and the transistor control electrode. Accordingly, with such a conventional device, the transistor control electrode will not see a voltage sufficient to cause it to conduct unless and until its timing capacitor

becomes fully charged. In the ordinary relaxation oscillator, this time for fully charging the main timing capacitor is a significant portion and often well over 90 percent of the entire total period of the oscillator. For this reason, if one were to use the usual relaxation oscillator as a timing device for generating trigger pulses to actuate coil-energizing switch 42, coil 12 could not begin to be energized until nearly 60 milliseconds after operation of fire control button 14, and because of the built-in and inherent delay of the electromagnetic stepping mechanism itself, the firing of the first rocket would be still further delayed. Such delay does not comply with military specifications.

A simple, reliable and inexpensive circuit to avoid this undue delay is the illustrated arrangement of connecting the main timing capacitor between the unijunction transistor emitter and the power line 50. Thus, as power line voltage steps up immediately upon closing of the firing button 14, the emitter 52 reaches a voltage sufficient to trigger conduction of the unijunction transistor whereby current flows from the power line via main timing capacitor 52 through the emitter base one electrodes of unijunction transistor and to the control electrode 45 of silicon-controlled rectifier 42. The latter thereupon goes into conduction and the current path through coil 12 is then completed through the cathode of the SCR to ground.

As the SCR conducts the lower end of solenoid coil 12 is grounded and, accordingly, a path is completed through the coil 12 through the interrupter switch 18 in its normal position, through switch deck 16, and firing button 14 to the power supply 10. Thus, the first cycle of the electromagnetic stepping switch is initiated immediately upon closure of the fire control button 14.

As indicated above, the stepping switch terminates its own cycle by operation of interrupter contacts 18 whereby power to the anode 43 of SCR 42 is interrupted and the latter goes into its nonconducting state.

During the driven segmental rotation of the stepping switch actuator and before interrupter switch 18 was actuated to disconnect the SCR anode from power supply, the instantaneous initial surge of current provided via primary timing capacitor 52 to the emitter electrode 54 of unijunction transistor 48, decreased rapidly below the value of the holding current required to maintain unijunction transistor 48 in its conducting state. Accordingly, the unijunction transistor 48 is turned off and conducts no further current to the gate electrode 45. Consequently, the latter, when its anode current is shot off by interrupter switch 18, remains nonconducting.

Thus, the first external trigger has been supplied substantially instantaneously (except for the switch bounce delay to be described), a stepping switch cycle has been initiated and has been self-terminated. Coil energizing switch 42 is open and the circuit now must wait for the next trigger pulse from the oscillator 46, even though firing button 14 remains closed.

At the end of this first cycle, emitter 54 of the unijunction transistor 48 is at a low voltage, being above ground by an amount only equal to the relatively small voltage drops across the several electrodes of the unijunction transistor 48 and the SCR 45. When transistor 48 stops conducting, capacitor 52 beings to charge via main timing resistor 53, the latter having a relatively large value in the order of 124,000 ohms, whereby the junction of capacitor 52 and emitter 54 of transistor 48 begins to rise. After lapse of the time period of the oscillator 46, which is established at 60 milliseconds as previously described, the junction of capacitor 52 and emitter 54 has been raised to a voltage level that is about 60 percent of the base one to base two voltage of the unijunction transistor. This is the voltage at which the latter will conduct, whereupon a second trigger signal is fed from the base two electrode of the unijunction to the control electrode 45 of the SCR. The SCR conducts to once again initiate energization of coil 12 and a second full cycle of the stepping switch.

Thus, it will be seen that the first cycle of the stepping switch is almost instantaneously triggered upon turn on of the apparatus and the subsequent triggering pulses are received at 60 millisecond intervals.

Because of the many switches and contacts that are wired into the conventional aircraft between the pilot's fire control button and the intervalometer, the power supply signal fed to the oscillator and to the intervalometer is subject to 1 to 2 milliseconds of startup transients as previously described. If the oscillator circuit should be turned on instantaneously and start its operation, and thereafter during the next 1 to 2 milliseconds the power line transients due to switch bounce should momentarily withdraw power, operation and timing of the mechanism will be seriously hampered. Accordingly, full instantaneous application of energizing power to the oscillator is not desirable. A small amount of delay, in the order of 1 to 2 milliseconds to allow transients caused by switch bounce to settle out, is accordingly provided by the use of capacitor 56 connected between ground and power line 50. Capacitor 56 cooperates with resistor 55 to provide the relatively small amount of delay in the initial rise of voltage at emitter 54. The time constant of the circuit including resistor 55 and capacitor 56 is relatively small since resistor 55 may be in the order of 2,200 ohms, a value considerably less than the value of the primary timing resistor 53. Thus, upon initial operation of the firing button 14, switch bounce capacitor 56 provides a short delay but is rapidly charged to the voltage required to fire the unijunction transistor 48. With the illustrated arrangement, switch bounce capacitor 56 has a negligible affect upon operation of the circuit subsequent to the generation of the first oscillator trigger signal except for its storage function, to be described below.

Provision is made for firing the rockets singly to thereby override the ripple or sequence firing previously described. This operation is achieved by actuation of a ripple switch 41. In the illustrated open position of this switch, all of the rockets connected to the sequencer stepping switch will be fired in sequence by the described cyclic operation. When ripple switch 41 is closed, interrupter switch contacts 22, 23, are bypassed, whereby only a single rocket will fire as long as pilot button 14 is held in closed position.

With ripple switch 41 closed, the power is supplied directly to the top end of coil 12 to FIG. 1 to thereby bypass interrupter switch 18 in the power application line. Accordingly, even though interrupter switch 18 will be thrown momentarily to fire a single rocket, when it does throw, it will not interrupt power to the coil 12. The latter will remain energized and cannot be returned to its cocked position until power thereto is disconnected by release of firing switch 14.

Military specifications allow relatively wide variation in airborne DC power supplies. In addition to transients and fluctuations in power supply level, the specifications permit momentary loss of power from the supply. Obviously, a loss of power, even if momentary, could seriously disrupt any ongoing timing sequence of rocket firing. To compensate this temporary loss of power to the oscillator 46, switch bounce capacitor 56 is connected as illustrated in FIG. 1 and made as large as is possible within the space limits of the intervalometer apparatus.

Accordingly, in addition to its operation to provide a 1 or 2 millisecond delay in cooperation with delay resistor 55, capacitor 56 will charge to the voltage on line 50 during any firing sequence and maintain such charge. Should there be a momentary dropout in line power, such that power is no longer supplied from the DC supply 10 to the relaxation oscillator transistor 48, such power may be provided by the charge stored in capacitor 56. This capacitor remains charged because of the unidirectional characteristics of the spurious and transient voltage protection transistor 58. The latter acts as a diode to prevent any charge on capacitor 56 from being discharged back through the power supply in the event of momentary dropout of the latter. To retain this unidirectional isolating function of transistor 58 in those arrangements where its spurious or transient voltage protection functions are not required, the transistor 58 may simply be replaced with a

suitably poled diode in order to ensure retention of sufficient charge on capacitor 56.

It may be noted that this operation of capacitor 56 to retain an oscillator driving charge in the event of power supply dropout in no way compromises or adversely affects its other function, which is to provide the desired switch bounce delay.

Modified Circuit:

Illustrated in FIG. 2 is an externally triggered electromechanical intervalometer that is substantially identical to the arrangement illustrated in FIG. 1. The circuit of FIG. 2 does not employ the stray voltage protection arrangement provided by transistor 58, resistor 59, and zener diode 60 of FIG. 1. In its stead, a voltage regulating circuit comprising substantially similar components, but connected for a different function, is employed. Further, a different connection for the switch bounce capacitor is employed.

Electromechanical portions of the self-interrupting stepping switch, as schematically illustrated in FIG. 2 and corresponding to similar parts of FIG. 1, are designated by corresponding reference numerals prefixed by the number 1. Thus, coil 112 of FIG. 2 is equivalent to coil 12 of FIG. 1 and switch deck 116 of FIG. 2 is equivalent to switch deck 16 of FIG. 1.

The mechanical stepping switch of FIG. 2 includes a DC supply 110 providing voltage through a fire control button 114 and a switch deck 116 to an interrupter switch 118 which also connects with and provides firing signals to a group of switch decks and firing circuits collectively illustrated at 133 and constructed and arranged just the same as corresponding parts of the embodiment of FIG. 1.

An SCR 142 is provided in series circuit with the coil 112 and arranged to receive a trigger signal from a unijunction transistor relaxation oscillator 146. All of the elements thus far identified in FIG. 2 are identical in construction, arrangement and operation to the corresponding elements of the embodiments of FIG. 1.

In the embodiment of FIG. 2, the transistor 158 is interposed between the oscillator power line 150 and the power line provided at the output 120 of the first safety switch deck 116. This transistor is an NPN transistor and its position is reversed in order to allow it to perform its operation as a voltage regulator. Its emitter is connected to the oscillator and its collector is connected to receive power from the supply line at point 120. Transistor 158 has its base connected to ground via a zener diode 160. A resistor 159 is connected between the transistor base and collector.

Zener diode 160 is chosen with such rating that it will not conduct via resistor 159 as long as the power supply provided to the collector of NPN transistor 158 is substantially at or not greatly above the 20 volt supply level. However, should the notoriously fluctuating aircraft supply source provide higher voltage, such higher voltage is transmitted to the zener via resistor 159 and the zener will conduct to maintain the base of transistor 158 at a substantially maximum level above ground. In other words, high-level transient signals at the transistor collector are shunted to ground via the zener. Accordingly, the power supply provided to the oscillator at the emitter of transistor 158 is regulated and oscillator frequency and stability thereby greatly enhanced.

In the embodiment of FIG. 2 there is shown a variation in connection of the switch bounce capacitor 156. This capacitor now performs solely the initial time delay and participates with timing capacitor 152 in the steady-state cyclic timing of the oscillator. Initial step-up of voltage, upon turn on, at the power side of capacitor 152 is stored in capacitor 156. Consequently, rise of voltage at the emitter of transistor 148 is delayed for 1 to 2 milliseconds by the action of resistor 155 and capacitor 156.

With the capacitive divider connection of capacitors 152, 156, as shown in FIG. 2, both control voltage on the emitter of the unijunction transistor, and both are charged through resistor 153 to control the oscillator period.

It will be understood that the connection of timing capacitors of either FIG. 1 or FIG. 2 can be used with either of the voltage regulator or spurious voltage protection transistors 158, 58, or vice versa.

There has been described a new and unique intervalometer that employs a long developed electromagnetic self-interrupting stepping switch together with a novel control circuit that makes optimum use of desirable features of the stepping switch and avoids its major disadvantages. The control circuit operates to initiate energization of the stepping switch driving coil at precisely controlled and independently variable repetition rate, independent of the mechanical switch elements. The timing control circuit is arranged to permit substantially instantaneous turn on of the stepping switch energization, to allow the intervalometer to meet the military requirement of firing a rocket within 20 milliseconds of the firing command, and at the same time provide sufficient delay to avoid deleterious effects of switch bounce.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

I claim:

1. An intervalometer for providing electrical firing signals in a selected sequence and at a selected frequency to a group of ordnance devices, said intervalometer comprising:
- a power supply,
- a solenoid-operated stepping switch for sequentially supplying electrical pulses from said power supply to said ordnance devices,
- a solenoid-coil-energizing switch for controlling application of energizing electrical power to said solenoid-operated switch, and
- a timing oscillator for operating said solenoid-coil-energizing switch with a controlled turn on delay and thereafter with a preselected steady-state repetition rate, said oscillator comprising
  - an oscillator switch having an output connected to actuate said solenoid-coil-energizing switch, and having a triggering input,
  - an oscillator storage device for initially effecting a substantially instantaneous transmission of power supply voltage to said triggering input of said oscillator switch when said power supply is turned on, said storage device including
    - means for effecting a charging thereof at a selected rate and to a value sufficient to again trigger said oscillator switch,
    - said oscillator storage device being connected to be discharged by said oscillator switch when the latter is operated,
  - means for effecting a controlled initial delay of the application of a voltage from said power supply to said oscillator switch through said storage device, whereby said oscillator switch is triggered after a relatively short interval following initial turn on of the power supply and is thereafter triggered at relatively longer intervals each determined by the time required to charge said storage device, and whereby said solenoid-coil-energizing switch is actuated each time said oscillator switch is triggered.

2. The intervalometer of claim 1 wherein said oscillator switch comprises
- a unijunction transistor having an emitter, and wherein said oscillator storage device comprises a parallel resistance capacitance circuit connected between the power supply and said emitter.

3. The intervalometer of claim 2 wherein said solenoid-coil-energizing switch comprises
- a silicon-controlled rectifier having an anode connected with a coil of the solenoid, having a cathode connected to a common line, and having a control electrode, and wherein said unijunction transistor includes a base one electrode connected to said power supply and a base two electrode connected to said control electrode of the silicon-controlled rectifier.

4. The intervalometer of claim 3 wherein said means for effecting a controlled delay of the first application of said supply voltage to the oscillator-switching device comprises a delay capacitor connected between said common line and one side of said parallel resistance capacitance circuit.

5. The intervalometer of claim 4 wherein said delay capacitor is connected between said common line and the emitter of said unijunction transistor.

6. The intervalometer of claim 4 wherein said delay capacitor is connected between said common line and the junction of said power supply with said resistance capacitance circuit, and wherein a unidirectional device is connected between said power supply and said delay capacitor, whereby in the event of temporary power supply dropout, said delay capacitor will retain a charge sufficient to continue operation of said oscillator.

7. An electronically timed mechanical intervalometer for sequentially firing a group of ordnance devices, said intervalometer comprising:

a plurality of banks of switches,

a solenoid connected to drive said banks of switches,

said solenoid having an energizing coil and a set of self-interrupting contacts therefor,

a coil-energizing switch for repetitively energizing said solenoid coil, and

an oscillator for repetitively closing said coil-energizing switch, said oscillator comprising

a unijunction transistor having

a base one electrode connected to said power supply, having a base two electrode connected to a controlling terminal of said solenoid-coil-energizing switch, and having an emitter electrode,

a main timing capacitor having one side thereof connected to said emitter electrode of said unijunction transistor,

a first resistor connected between one side of said power supply and the other side of the timing capacitor, a second resistor connected in parallel with said capacitor, and

a delay capacitor connected between the other side of said power supply and one side of said main timing capacitor.

8. The intervalometer of claim 7 wherein said capacitors comprise a capacitive voltage divider connected between a junction of said first and second resistors and said other side of the power supply,

said voltage divider having a tap connected to said emitter electrode of the unijunction transistor.

9. The intervalometer of claim 7 wherein said delay capacitor is connected between said other side of said timing capacitor and said other side of said power supply.

10. In an intervalometer having a stepping switch connected to fire a group of ordnance devices in sequence, said stepping switch having a solenoid and solenoid-energizing coil adapted to be energized through a coil-energizing switch from a power supply for incrementally rotating the switch, the improvement comprising a timing oscillator for periodically energizing said solenoid coil at a selected repetition rate in a sequence of energizations that begins substantially instantaneously on application of power from said power supply, said timing oscillator comprising

an oscillator switch having an output connected to operate said coil-energizing switch and having a triggering electrode connected to be substantially isolated from steady-state levels of said power supply and to respond to sharply rising increases thereof as occur upon turn on of the power supply,

an RC timing circuit connected to be charged from said power supply and to provide a triggering signal to said triggering electrode upon attainment of a predetermined voltage level, said timing circuit connected to be discharged by actuation of said oscillator switch, whereby said oscillator switch and said coil energizing switch are actuated substantially instantaneously upon turn on of the power supply and intermittently thereafter each time said timing circuit attains said predetermined charge.

11. In an intervalometer having a stepping switch connected to fire a group of ordnance devices in sequence, said stepping switch having a solenoid-energizing coil adapted to be energized through a coil-energizing switch, the improvement comprising a timing oscillator for periodically initiating energization of the solenoid coil at a selected repetition rate in a sequence of energizations that begins substantially instantaneously upon application of power from said power supply, said oscillator comprising

an oscillator switch having an output electrode connected to actuate said coil-energizing switch, and having an input electrode arranged to trigger said oscillator switch upon attainment of a predetermined signal level at said input electrode,

a capacitor connected in series circuit with said power supply and said input and output electrodes of said oscillator switch, whereby a sudden increase in voltage of said power supply, as occurs upon turn on of the circuit, is transmitted to said input electrode of the oscillator switch substantially instantaneously, and said capacitor is discharged by current conducted from said input to said output electrodes of said oscillator switch, and

a charging circuit connected to charge the capacitor from said power supply when said oscillator switch is nonconducting, whereby after the first actuation of the oscillator switch that occurs substantially instantaneously upon turn on of the power supply, the oscillator switch will be operated periodically upon recharging of the capacitor through said charging circuit.

12. The intervalometer of claim 11 including a second capacitor connected with said first-mentioned capacitor to form a capacitive voltage divider connected across said power supply and having a tap thereof connected to said input electrode of said oscillator-switching device.

13. The intervalometer of claim 11 including a second capacitor connected to momentarily delay the sharp rise of voltage transmitted through said first capacitor to said input electrode of the oscillator-switching device upon turn on of the power supply, said second capacitor being connected between said input electrode of the oscillator-switching device and ground.

14. The intervalometer of claim 11 including a second capacitor connected to momentarily delay the sharp rise of voltage transmitted through said first capacitor to said input electrode of the oscillator-switching device upon turn on of the power supply, said second capacitor being connected between ground and said power supply, and a unidirectional conducting device series connected between said second capacitor and said power supply to enable said second capacitor to store and retain a charge sufficient to power said oscillator in the event of temporary dropout of said power supply.

15. An intervalometer for providing electrical firing signals at a selected frequency and in a selected sequence that starts substantially instantaneously upon a firing command for firing a group of ordnance devices, said intervalometer comprising:

a power supply and a firing switch connected thereto,

a stepping switch including

a driving coil connected to be energized by said power supply through said firing switch,

an interrupter switch in circuit with said coil between said firing switch and the coil for momentarily disconnecting the coil from the power supply after the coil has been energized and upon substantial completion of one step of the stepping switch,

an externally actuated coil energizing switch connected in series circuit with said coil and power supply to initate energization of the coil upon actuation of said coil-energizing switch and to maintain such energization until said interrupter switch is operated to disconnect said coil from said power supply and firing switch, whereby the coil is energized by each actuation of said coil-energizing switch

and is self deenergized by operation of said interrupter switch.

16. The intervalometer of claim 15 including an oscillator connected to be energized from said power supply and fire control switch for providing a cyclically repetitive output trigger at the beginning of each cycle of the oscillator and for providing a first output trigger signal substantially immediately upon application of power to the oscillator from the power supply and fire control switch, the output of said oscillator being connected to actuate said coil-energizing switch into conductive condition to thereupon initiate energization of said solenoid coil.

17. The intervalometer of claim 16 wherein said oscillator has a natural frequency considerably less than the natural frequency of said stepping switch whereby after each energization of the stepping switch coil that occurs upon actuation of the coil energizing switch, the coil is self deenergized by operation of the interrupter switch and remains deenergized until the coil-energizing switch is once again actuated by the output of said oscillator.

18. The intervalometer of claim 17 wherein said coil-energizing switch comprises

a silicon-controlled rectifier having an anode and cathode connected in series circuit with said solenoid coil and having a control electrode, and wherein said oscillator comprises a unijunction transistor relaxation oscillator that includes a base two electrode connected to the control electrode of the silicon-controlled rectifier.

19. The intervalometer of claim 17 wherein said coil energizing switch comprises

a silicon-controlled rectifier having an anode and cathode in series circuit with the solenoid coil and having a control electrode, and wherein said oscillator comprises a unijunction transistor having a base one electrode connected to said power supply and fire control switch, and having a base two electrode connected to said control electrode of the silicon-controlled rectifier and having an emitter electrode,

a capacitor connected between said emitter electrode and the power supply and firing switch, and

a charging resistor connected across the capacitor.

20. The intervalometer of claim 19 including

a second capacitor connected between said power supply and ground, and

a second resistor series connected between said second capacitor and said power supply and firing switch, whereby the sharp rise in voltage occurring upon closing of the firing switch is applied to said emitter electrode substantially instantaneously across said first capacitor, but is momentarily delayed in application to the emitter by means of the delaying action of the second resistor and second capacitor so as to prevent operation of said unijunction transistor for a short period in the order of the time required for switch bounce.

21. The intervalometer of claim 20 including a voltage-regulating transistor connected between said s second resistor and said firing switch,

said voltage-regulating transistor having a base electrode, a zener diode connected to said base electrode for establishing a substantially constant voltage level at such base electrode, and

a third resistor connected across the collector and base electrodes of the voltage-regulating transistor.

22. The intervalometer of claim 20 including

a spurious voltage protection circuit connected between the said oscillator and said power supply and firing switch, said protection circuit comprising

a protection transistor having emitter and collector electrodes connected between said second resistor and said firing switch and having a base electrode, and

a zener diode connected between the base electrode and ground, whereby said protection transistor will not conduct until a signal at one of said collector and emitter electrodes rises above a predetermined potential level established by said zener diode and the voltage drop across said protection transistor.

* * * * *