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ELECTRONIC CONTROL CIRCUIT FOR CONTROLLING THE RATE OF FIRE OF A MACHINEGUN

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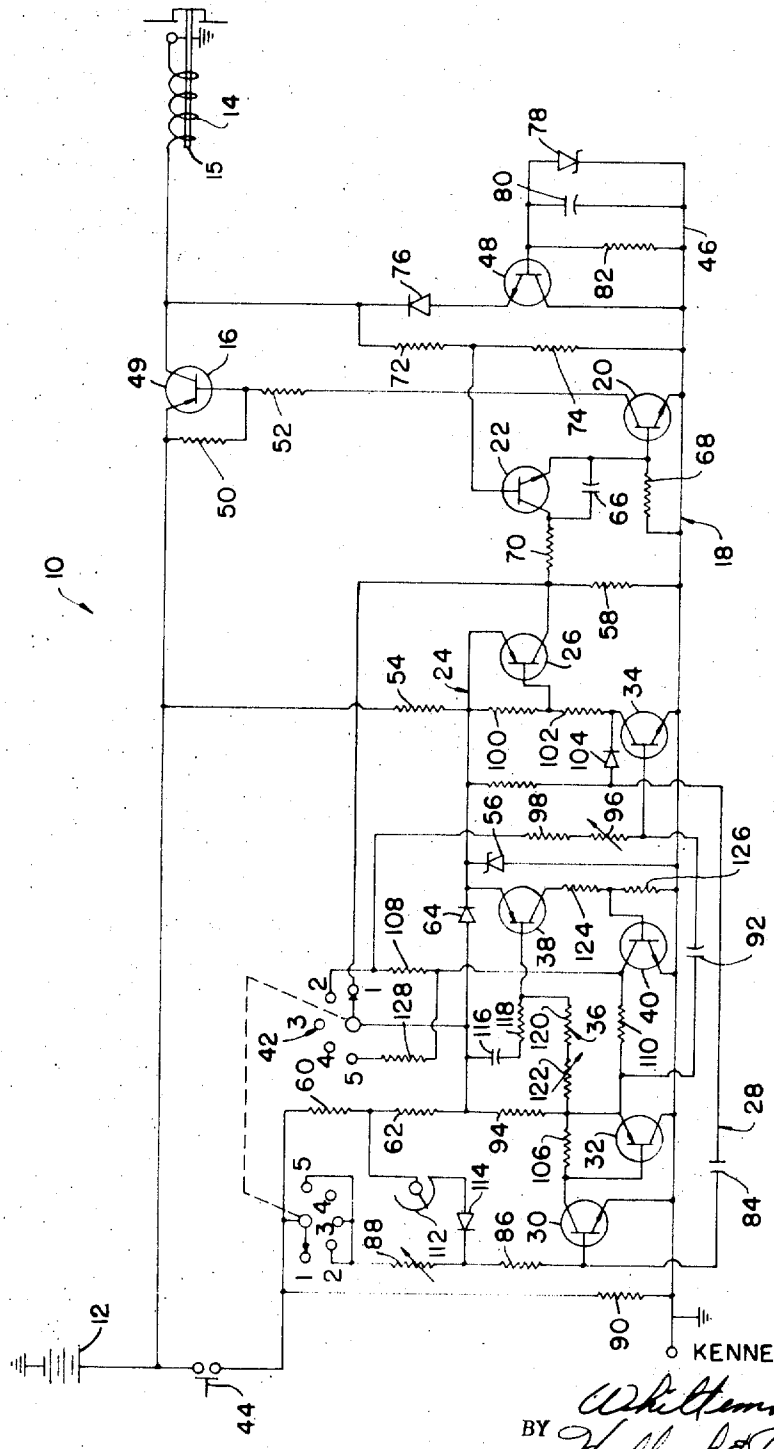

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ELECTRONIC CONTROL CIRCUIT FOR CONTROLLING THE RATE OF FIRE OF A MACHINEGUN

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ABSTRACT OF THE DISCLOSURE

An electronic control circuit for and method of controlling the rate of fire of a machinegun or the like, including means for and the method of selectively providing a full firing rate, a reduced firing rate, one shot at a time, a burst of shots and a selected number of single shots or a slow burst. The control circuit is essentially an output solenoid energized from a source of electrical energy in accordance with the closing of an electronic switch and a multivibrator for selectively closing the electronic switch at controlled intervals; i.e., by means of pulses of electric energy, or for a predetermined time or both.

Means for and a method of absorbing electrical energy from the solenoid on opening of the electronic switch and for protecting the control circuit in case of short circuiting of the solenoid are also disclosed. Provision is also made for extending the initial actuating pulse from the multivibrator to the electronic switch on an initial multivibrator cycle and therefore compensating for lubricating and mechanical rebound of a gun controlled by the control circuit and also for varying the operating parameters of the multivibrator in accordance with the magnitude of the energy source to provide a substantially uniform mechanical operation of the solenoid over a wide range of energy source magnitudes.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates to a means for and method of control of a mechanical structure and refers more specifically to a control circuit for controlling the rate of fire of a machinegun or the like and the method of controlling the rate of fire in accordance with the control circuit.

Description of the prior art

In the past, machineguns and the like have generally been fired or not fired at the single designed rate of fire thereof. Thus, in many instances ammunition has been fired uselessly. In addition, partly due to the rate of firing in the past, machinegun fire has not been as accurate as desired particularly where the firing rate has not been at the natural frequency of the gun support.

Where conservation of ammunition has been necessary in the past, it has been accomplished by individual gunners controlling the pressing of a machinegun trigger to fire the guns in short bursts or possibly in individual shots. In addition, some mechanical methods of controlling the actual rate of fire of a machinegun have been attempted without particular success in the past.

SUMMARY OF THE INVENTION

In accordance with the invention, an electronic control circuit for and method of controlling the rate of firing of a machinegun or the like is provided. The electronic control circuit includes selector switch means for permitting continuous full rate firing of the machinegun, reduced rate firing of the machinegun, firing of one shot at a time, firing of a burst of shots at one time, and for firing a slow burst of shots.

In addition, the electronic control circuit of the invention includes means for absorbing and rapidly dissipating the stored energy in an actuating solenoid connected thereto to assure rapid response of the solenoid and to prevent damage to the electronic control circuit, short circuit protection for the electronic control circuit and structure for compensating the control circuit to provide constant operation of an actuating solenoid connected thereto over a relatively wide range of sources of actuating electrical energy. Means are also included in the control cirsuit for providing compensation during initial firing for operating parameters, such as lubrication and inertia, of a gun controlled thereby and to adjust the firing rate of the gun to the natural frequency of the support therefor to improve the accuracy of the gun.

BRIEF DESCRIPTION OF THE DRAWING

The figure is a schematic diagram of an electronic control circuit constructed in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The electronic control circuit **10** of the invention includes a source of electrical energy **12**, a solenoid output coil **14** and the electronic switch **16** positioned therebetween. The coil **14** is energized from the source of electrical energy **12** on closing of the electronic switch **16**.

The control circuit **10** further includes the relay circuit **18**, including the driver transistor **20** and short circuit protection transistor **22**, the buffer circuit **24**, including the buffer transistor **26**, the multivibrator circuit **28** including the transistors **30** and **32**, and the transistor **34**, the cutoff circuit **36** including the transistors **38** and **40** for stopping the multivibrator **28**, the switching circuit **42** and trigger switch **44**. The electronic control circuit **10** further includes the energy absorbing circuit **46** including the transistor **48**, connected as shown in the figure.

In more detail, the switching transistor **49** of electronic switch **16** is turned on any time the transistor **20** of the relay circuit **18** is energized due to current flowing through resistors **50** and **52** of the switch **16**. The transistor **20** is turned on at different times in accordance with the setting of the switching circuit **42**. Thus, the coil **14** is energized continuously or intermittently at selected rates to provide different firing rates for a machinegun actuated on energizing the coil **14** in accordance with the setting of the switching circuit **42**.

With the switching circuit **42**, as shown in the figure, in the first position and with the battery **12** connected to the control circuit **10** to provide a voltage of approximately six volts across the Zener diode **56** of the voltage divider formed by the resistor **54** and Zener diode **56**, a voltage of approximately six and one-half volts is provided across the resistor **58** in the voltage divider network, including the resistors **60** and **62** through the switching circuit **42** in the first position when the trigger switch **44** is closed. The other half volt between the resistor **62** and the top of the Zener diode **56** is dropped across the diode **64**. The voltage at the resistor **58** will cause the capacitor **66** to draw current through the resistors **68** and **70**, whereby the transistor **20** will be turned on.

The electronic switch **16** will be turned on when the transistor **20** is turned on, as previously indicated, whereby current will be drawn through the resistors **72** and **74** to place the base of the transistor **22** at a potential to provide a bias on the transistor **22** to maintain the transistor **22** in an on condition bypassing the capacitor **66**. Thus, the transistor **20** and therefore the transistor **49** will remain turned on to continuously energize the sole-

noid output coil **14** with the switching circuit **42** in the first position and the trigger switch **44** closed. In the case of a machinegun connected to the solenoid output coil **14** a full rate of fire would thus be produced of, for example 1000 rounds per minute.

In this connection it will be noted that if the solenoid output coil **14** is shorted to ground, that no current will be drawn through the resistors **72** and **74** so that the transister **22** will not be biased on after the capacitor **66** has been charged so that the transistor **20** would be turned off. Short circuit protection for the control circuit **10** is thus provided since the transistor **49** will not be maintained in a conducting condition if the coil **14** is short circuited.

When the switch **16** is opened the voltage at the emitter of the transistor **49** substantially immediately goes from the value of the positive source of electrical energy **12** to zero volt. This decline in voltage can occur in, for example, five microseconds. A substantial negative potential then appears at the collector of the transistor **49** due to the decaying voltage in the solenoid output coil **14**. It is desired to absorb this negative voltage from the output coil **14** to prevent it from damaging the transistor **49**.

To absorb the current from the coil **14** on opening of the switch **16**, the transistor **48** of the energy absorbing circuit **46** conducts through the diode **76** when the voltage of the diode **76** is slightly negative. When the transistor **48** conducts, a voltage which is regulated by the Zener diode **78** is built up on the capacitor **80** and across resistor **82**. The negative voltage due to the decaying of the energy stored in the output solenoid coil **14** is thus allowed to build to a level allowed by the voltage established by the Zener diode **78** over a period of, for example, one hundred microseconds and remains at this level which the transistor **49** can withstand without damage while still allowing the stored energy in the inductance of the solenoid to dissipate quickly until the energy in the coil **14** has been dissipated at which time the transistor **48** ceases to conduct.

The mechanical actuator **15** is provided in conjunction with the coil **14** to effect the physical firing of, for example, a machinegun controlled by the control circuit **10**. The mechanical time of response of the actuator varies inversely with voltage across the coil **14** and is more rapid at higher values of supply voltage. Also, the amount of energy stored in the inductance of coil **14** is proportional to the current flowing in the coil or if the resistance remains constant, proportional to the voltage. Circuit **46** causes the stored energy of coil **14** to discharge at a fixed voltage, the release time of the actuator **15** is thus proportional to the supply voltage. The response of the actuator **15** is thus compensated to maintain the sum of the actuating and release times relatively constant over the operating voltage range of the control circuit **10**.

With the switching circuit **42** in the second position thereof, illustrated in the figure, and with the source of electrical energy **12** connected to the control circuit **10**, the initial voltage on the right side of capacitor **84** will be approximately the six volts across the Zener diode **56**. Before the trigger switch **44** is closed the voltage on the left side of the capacitor **84** is substantially zero volt since the left side of capacitor **84** is grounded through resistors **86** and **88**, the switching circuit **42** and the resistor **90**.

Also, at this time the charge on the left hand side of the capacitor **92** will be zero volt since the left hand side of the capacitor **92** is also grounded through the resistors **94**, **62**, **60** and **90**. The right hand side of capacitor **92** is likewise grounded through the resistors **96** and **98**, the switching circuit **42** and the resistors **62**, **60** and **90** when the trigger switch **44** is open.

On closing of the trigger switch **44** the voltage on the lieft side of the capacitor **92** substantially immediately rises to 6.5 volts, causing a positive bias on the transistor **34** due to a positive five-tenths of a volt on the right hand side of the capacitor **92** and consequently conduction of the transistor **34**.

Conducting of the transistor **34** also places the right hand side of the capacitor **84** at approximately five-tenths of a volt positive through the diode **104**, whereby the left hand side of the capacitor **84** is caused to go approximately 5.5 volts negative to insure that the transistor **30** remains turned off. The transistor **30** has been urged toward conduction on closing of the trigger switch **44** due to the application of the source of energy **12** to the base thereof through the switching circuit **42** and resistors **88** and **86**.

Also, conduction of the transistor **34** provides a positive bias for the buffer transistor **26** across the resistor **100** to cause conduction of the transistor **26**. When the transistor **26** conducts the six-volt signal from the Zener diode **56** it is applied to the resistors **58** and **70**, as shown, to produce closing of the switch **16** through transistor **20**, as previously indicated.

As the transistor **34** conducts, the negative 5.5 volts now on the left side of the capacitor **84** rises toward the voltage of the source of electrical energy **12** in accordance with the time constant provided by capacitor **84**, the resistance **86** and to a lesser extent the variable resistor **88**. After a predetermined time the left hand side of the capacitor **84** will go positive to, for example, .5 volt and the transistor **30** will be caused to conduct. On conducting of the transistor **30** a bias is applied across the resistor **106** to the transistor **32** to produce conduction of the transistor **32**. Conducting of the transistor **32** will place the left hand side of the capacitor **92** at approximately five-tenths of a volt positive and cause the right hand side of the capacitor **92** to substantially immediately assume a negative 5.5 volts charge.

The transistor **34** is thus cut off when the transistor **30** conducts. Cutting off of the transistor **34** will cause the right hand side of the capacitor **84** to again assume approximately six volts positive, while the left hand side will return to approximately five-tenths of a volt positive since five-tenths of a volt is dropped across the conducting transistor **30**.

The transistor **34** will remain cut off for a period determined by the time constant of the capacitor **92**, the variable resistor **96** and the resistor **98**. When the charge on the right hand side of the capacitor **92** has again reached a positive five-tenths of a volt, the transistor **34** will again conduct to cut off the transistor **30** and close the electronic switch **16**.

It will thus be seen that the transistor **34** will be energized at the frequency of the multivibrator circuit **28** to close the electronic switch **16** at the frequency of the multivibrator circuit **28** on closing of the trigger switch **44** with the switching circuit **42** in the second position thereof. Thus, a reduced firing rate of a machinegun connected to be actuated by the solenoid coil **14** of, for example, 200 rounds per minute may be provided.

Referring to the frequency of operation of the multivibrator circuit **28**, it will be understood that the transistor **34** is always energized first so that immediately on pressing the trigger switch **44**, firing of a machinegun energized by the coil **14** will begin.

The operation of the control circuit **10** is stabilized over large changes in supply voltage by the Zener diode **56**. However, the time during which the solenoid **14** is energized or the off time of the transistor **30** will vary with the magnitude of the electrical energy from the source of electrical energy **12**. The off time of the transistor **30** may be initially adjusted for a particular value of voltage source by selection of the resistor **88**.

With the switching circuit **42** in the third position thereof, the solenoid **14** is energized with one pulse of electrical energy, whereby a machinegun actuated thereby will fire a single shot. Thus, with the right hand portion of the selector switch **42** in the third position, the multivibrator circuit **28** is converted into a single shot multivibrator.

That is to say, the transistor **34** is maintained in an off

condition once the transistor **30** conducts since the right hand side of the capacitor **92** is connected through resistors **96, 98, 108** and **110** to the left hand side of the capacitor **92** which is connected to ground through the conducting transistor **32**. With such a connection, the base of the transistor **34** is not permitted to go positive a sufficient amount to turn the transistor **34** on after the initial pulse of energy provided therethrough.

With the switching circuit **42** in the fourth position, again the multivibrator circuit **28** is a single shot multivibrator. However, the single pulse through the transistor **34** and therefore the length of time that the switch **16** is closed is considerably longer since the time constant for discharge of the capacitor **84** now includes the diode **114** and the relatively large resistance of the potentiometer **112**.

Also, the voltage supply for potentiometer **112** is reduced by the voltage divider including resistors **60** and **62**, and this voltage is more constant because of the stable voltage at the junction of resistor **62** and diode **64** produced by action of Zener diode **56**. Thus, the amount of compensation for mechanical delay of actuator **15** is the same as with the switching circuit **42** in the second and third conditions although the percentage of compensation is reduced. The net result is that the single pulse will allow a burst of approximately five rounds from a machinegun controlled by the circuit **10**.

The potentiometer **112** allows a field adjustment to permit exactly five rounds to be fired per burst whenever the trigger switch **44** is pressed by varying the time constant of the capacitor **84**, resistor **86**, and resistance of potentiometer **112**, as will be understood by those in the art.

Additionally, it will be seen that in the operation of the multivibrator circuit **28**, initially the left hand side of capacitor **92** is at a zero voltage as is the left hand side of capacitor **84**. After the first cycle of operation of the mulivibrator, the voltage of the left side of both the capacitors **92** and **84** vary to .5 of a volt. As the result of this difference in the voltage on the capacitors **84** and **92**, the initial energizing of the solenoid coil **14** is for a longer period by approximately ten percent. This difference in time of operation of the multivibrator circuit **28** compensates for lubricants which may initially be somewhat sticky and for the mechanical rebound found in the operation of many machineguns which will not be initially present.

With the switching circuit **42** in the fifth position, it is desired to put the multivibrator through five cycles of operation thereof and then stop the operation of the multivibrator. Thus, the coil **14** will be energized to provide a slow burst of five single shots from a machine gun actuated thereby on continuous pressing of the trigger switch **44**.

To cut off the multivibrator **28** after five cycles of operation thereof, the transistor **38** of the cutoff circuit **36** is caused to conduct after a stepped time delay selected by the value of the capacitor **116**, resistor **118**, resistor **120** and resistor **122**. Turning the transistor **38** on provides a bias on transistor **40** through the resistors **124** and **126** sufficient to turn the transistor **40** on which will again place the base of the transistor **34** at something less than one-half volt above ground through the resistors **96, 98, 108** and **128** and the conducting transistor **40**.

Thus, initially the capacitor **116** is at zero volt at the top and six volts on the bottom thereof since transistor **38** is conducting with the switch **44** open. On pressing of the trigger switch **44** a 6.5 volt potential is present on the top of the capacitor **116** and approximately twelve and one-half volts are provided on the bottom of the capacitor **116** to cut the transistor **38** off. During the five subsequent cycles of the multivibrator circuit **28**, the capacitor **116** discharges toward a positive six volts at the base of the transistor **38** through a stepped time delay caused by the periodic conduction of transistors **30** and **32** which permits conduction of transistor **38** again after five cycles of operation of the multivibrator circuit **28**.

Thus, it will be recognized that there is provided in the control circuit **10** a simple, economical and efficient control for firing a machinegun or the like at different selected rates. Further, it will now be obvious how protection is provided in the control circuit **10** against excessive voltage from the solenoid **14**, how the circuit **10** is protected against short circuiting of the solenoid **14**, and how lubrication and mechanical rebound compensation and compensation for actuation and release time of the actuator **15** is provided.

I claim:

1. An electronic control circuit for controlling the rate of fire of a machinegun or the like, comprising a source of electrical energy, an actuating transducer, a first electronic switch for energizing the actuating transducer from the source of electrical energy and means for selectively closing the first electronic switch on command to provide continuous energizing of the actuating transducer or a selected pulsed energizing of the transducer, including a second electronic switch connected to the first electronic switch operable on being closed to close the first electronic switch and means including a trigger switch and a third electronic switch in series for closing the second electronic switch on closing of the trigger switch.

2. Structure as set forth in claim **1**, wherein the trigger switch is connected to the source of electrical energy and the third electronic switch includes multivibrator means for closing the second electronic switch at a predetermined frequency on closing of the trigger switch.

3. Structure as set forth in claim **2**, and further including means operably associated with the multivibrator means for opening the second electronic switch a predetermined time after closing of the trigger switch.

4. Structure as set forth in claim **2**, and further including means operably associated with the multivibrator means for selectively rendering the multivibrator means a single shot multivibrator.

5. Structure as set forth in claim **4**, and further including means operably associated with the multivibrator means for varying the length of the single pulse of energy to vary the time during which the second electronic switch is closed.

6. Structure as set forth in claim **1**, and further including an energy absorbing circuit connected between the first electronic switch and electromechanical actuating transducer for absorbing energy from the transducer on opening of the first electronic switch.

7. An electronic control circuit for controlling the rate of fire of a machinegun or the like, comprising a source of electrical energy, an actuating transducer, a first electronic switch for energizing the actuating transducer from the source of electrical energy, means for selectively closing the first electronic switch on command to provide continuous energizing of the actuating transducer or a selected pulsed energizing of the actuating transducer and means connected between the first electronic switch and the actuating transducer for preventing continued closing of the first electronic switch on a short circuit occurring at the actuating transducer.

8. An electronic control circuit for controlling the rate of fire of a machinegun or the like, comprising a source of electrical energy, an actuating transducer, a first electronic switch for energizing the actuating transducer from the source of electrical energy, means for selectively closing the first electronic switch on command to provide continuous energizing of the actuating transducer or a selected pulsed energizing of the actuating transducer, and means operably associated with the means for closing the first electronic switch for extending the length of the initial pulse of energy through the output transducer by extending the length of time the electronic switch is closed during the first pulse in pulsed energizing of the transducer.

9. Structure as set forth in claim 8 and further including separate means operably associated with the means for closing the first electronic switch for regulating the length of the pulses through the transducer in accordance with the magnitude of the electric energy supplied from the source of electrical energy to assure substantially constant mechanical operation of the transducer.

10. An electronic control circuit for controlling the rate of fire of a machinegun or the like, comprising a source of electrical energy, an actuating transducer, a first electronic switch for energizing the actuating transducer from the source of electrical energy, means for selectively closing the first electronic switch on command to provide continuous energizing of the actuating transducer or a selected pulsed energizing of the actuating transducer and means operably associated with the means for closing the first electronic switch for regulating the length of the pulses through the transducer in accordance with the magnitude of the electric energy supplied from the source of electrical energy to assure substantially constant mechanical operation of the transducer.

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