SEQUENTIAL DISCHARGE ELECTRONIC IGNITION SYSTEM FOR BLACKPOWDER FIREARMS

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ABSTRACT
An electronic ignition system for use with a personal firearm utilizing black powder or black powder substitutes, such as a shotgun, rifle, or pistol, is disclosed. The electronic ignition system generates an electric arc in the barrel of the firearm, which ignites the propellant charge in the firearm, discharging it when a firing switch is closed. A sequential discharge of lower and higher capacitance capacitors increases reliability of discharge of the firearm. A multi-switch system may include an arming switch to charge the ignition system, a safety switch to select enable and disable firing, and/or a firing switch for triggering discharge of the firearm, for increased safety in use.

![Diagram of Electronic Ignition Circuit]
Fig. 1
Fig. 3b
Fig. 5

121' are activated by the trigger
121 are activated by the electronic circuit

to weapon breachplug

123
125

107" electronic circuit

microprocessor
SEQUENTIAL DISCHARGE ELECTRONIC IGNITION SYSTEM FOR BLACKPOWDER FIREARMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 10/920,807, filed Aug. 18, 2004; which application claims priority to U.S. Provisional Patent Application Ser. No. 60/547,450, filed Feb. 25, 2004; the entireties of which applications are hereby incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates generally to muzzle-loading firearms, and more particularly to an electronic ignition system that generates an electric arc to ignite the powder charge propellant in a muzzleloading firearm and to a firearm incorporating such an ignition system.

BACKGROUND OF THE INVENTION

[0003] Hunting and shooting with muzzleloading firearms has gained a level of popularity as a sport. In typical embodiments, a muzzleloading firearm is a rifle, shotgun or pistol, based to some degree on primitive firearm designs used during the early days of America. Such firearms typically lack the effective range and speed of recharging enabled by modern center-fire cartridge firearms, adding to the challenge and enjoyment of the sport. Because of their popularity, many states have adopted special muzzleloader seasons for hunting with these weapons to allow sportsmen using them (who generally have to get much closer to their targets and be more sure of their aim than those using modern cartridge rifles) to be able to effectively hunt. And with the creation of these special seasons, more hunters are drawn to muzzleloaders.

[0004] A muzzleloader is also sometimes referred to as a “black powder” firearm due to its use of a different chemical formulation of gunpowder, commonly called black powder (which does not specifically relate to the color). As opposed to a more modern firearm which is typically loaded with a cartridge at the breech, in a muzzleloader loose powder (or powder pellets) and the projectile are loaded into the barrel via the muzzle of the gun and tamped against the breechplug. The powder used is typically a black powder or more modern substitute for black powder such as, but not limited to, Pyrodex™ or Triple 7™ manufactured by the Hodgdon Powder Company. The modern smokeless powder used in cartridges and shotgun shells, however, cannot be safely used with most muzzleloaders.

[0005] Current black powder firearms typically use one of two systems to ignite the powder charge that propels the projectile from the firearm. The more primitive type of muzzleloading firearm ignition system is the flintlock, which utilizes a flint striker that is thrown forward by a spring-driven hammer (which is generally mounted on the side of the firearm) into a piece of steel (the frizzen) to generate a spark. The spark ignites a priming pan of fine black powder. The burning priming powder sends a flash or spark through a touchhole, which is a small hole in the side of the firearm’s barrel. The flash or spark then ignites the main powder charge in the barrel, which discharges the firearm to propel the bullet toward its target.

[0006] A more modern variety of black powder firearm utilizes a caplock ignition system. The traditional caplock still has a spring-driven hammer on the side of the barrel, but the flint, steel and priming pan are eliminated. Instead the hammer is driven against a percussion cap or primer, which typically contains an explosive fulminate of mercury. The percussion cap is typically removably installed on a nipple on the barrel having an opening through which a spark generated by the cap travels to ignite the main propellant charge in the barrel. The in-line caplock is a more modern type of caplock muzzleloader developed to provide more effective discharge. The in-line caplock ignition system operates in much the same manner as a traditional caplock, but instead of having the hammer, nipple and cap on the side of the gun, they are placed in line with the barrel, for example with the priming cap installed in the barrel’s breechplug. The in-line caplock is essentially a modernized muzzleloader that retains the firing and loading profile of a traditional muzzleloader, but with a more modern ignition system.

[0007] By their very nature, most muzzleloaders are essentially primitive firearms, and for many hunters and shooters this primitive nature is part of their appeal. The weapon’s decreased effective range requires the hunter to be a more effective stalker. Further, the time it takes to reload a muzzleloader generally means that the hunter gets only one shot at a game target, requiring the hunter to be sure of their aim before firing. However, there is a degree of polarization among muzzleloading hunters. Some muzzleloading hunters wish to only utilize traditional firearms, and are very interested in the nostalgia. These hunters tend to use flintlocks and sidelocks to more accurately represent primitive hunting. Other muzzleloading hunters are continuously seeking to modernize the “primitive” muzzleloading firearm to provide for improved performance (e.g., better triggering, safety and accuracy), while still loading powder and shot down the muzzle so as to still qualify for the special muzzleloading hunting seasons. These hunters tend to use in-line caplocks that may resemble more modern firearm designs, and are always interested in improving on the design without altering the basic loading and shooting characteristics of the firearm. Many of these improvements relate to modernized projectiles that provide improved flight characteristics, modern propellants that provide improved propulsion and ignition, and the in-line caplock design, which provides for surer ignition.

[0008] Because the powder, projectile and percussion cap are separately loaded for each shot and are not subject to mechanical assembly as in a cartridge rifle, muzzleloaders are particularly vulnerable to conditions known as “hangfire” or “misfire” where the gun does not discharge immediately upon the trigger being pulled. A misfire occurs when the gun does not fire at all. A hangfire occurs when the cap or flint successfully lights and sends sparks toward the main charge, but the main charge does not ignite for a few seconds after the trigger is pulled. A hangfire can be particularly problematic because the action of the hammer may startle the intended target, and the gun may discharge later without the intended target in the field of fire. Further, a hangfire may result in the user positioning the gun unsafely prior to its eventual discharging, thinking the gun has misfired, potentially leading to accidents.
Most of these problems result from imperfect operation of the ignition system of the firearm. In a cartridge firearm, the ignition system and primary propellant are both encased in the cartridge, which allows them to be in direct contact when the gun is fired. Therefore, hangfires are unlikely. In a muzzleloading firearm, however, there is always some distance that the primer spark or flame needs to travel to get from the cap or priming pan to the primary propellant. The travel time of the spark can be undesirably increased if the conditions are wet or if there is powder in the nipple opening or touch hole that must burn, essentially like a fuse, for the spark to reach the primary propellant charge.

Thus it can be seen that needs exist for improved ignition systems for muzzleloading firearms. It is to the provision of improved ignition systems meeting this and other needs that the present invention is primarily directed.

SUMMARY OF THE INVENTION

To improve upon such ignition systems that are known in the art, described herein are example embodiments of electronic ignition systems for use with personal black powder firearms such as muzzleloading rifles, shotguns and pistols. The terms black powder firearm and muzzleloader are used interchangeably in this disclosure to refer to firearms of the same general type—in particular, to firearms wherein the propellant charge is not encased in a cartridge with the projectile and ignition material, but wherein the principal propellant is in contact with the barrel of the firearm.

The electronic ignition systems discussed herein generally provide for a more predictable and reliable ignition of the primary propellant charge in the firearm when the firearm is triggered, which helps to improve safety and reliability of the firearm relative to a similar firearm utilizing a propellant cap. At the same time, the electronic ignition systems described herein do not alter the ballistics of the projectile or dramatically accelerate the reloading time of the firearm. In this way, a black powder hunter can be more certain that his firearm will both discharge safely and discharge when triggered, even in inclement weather, without having to give up the characteristics of a black powder firearm that many hunters particularly seek out.

In an embodiment of the invention described herein, an electronic ignition system for a firearm comprises: an electrode, the electrode being capable of producing an electric arc; a battery electrically connected to said electrode for providing electricity to said electrode; and a firing switch electrically connected between said battery and said electrode such that when said firing switch is closed said electricity from said battery produces an electric arc from said electrode; wherein said electrode is sized and shaped so that said electric arc contacts a propellant charge in said firearm igniting said propellant charge. In example embodiments, the electric arc is generated between a first electrode and a second electrode. In alternate embodiments, the electric arc is generated between a single electrode and a breach plug, barrel portion, or other conductive surface or component supporting or adjacent to the electrode; or between the electrode and an adjacent propellant charge or other material.

In another aspect, the electronic ignition system comprises a capacitor, said capacitor placed between said battery and said firing switch such that said capacitor is charged by said battery and discharges when said firing switch is closed; an arming switch electrically connected between said capacitor and said battery wherein said capacitor cannot charge when said arming switch is open, a safety switch electrically connected between said capacitor and said firing switch wherein said electric arc cannot be generated unless both said firing switch and said safety switch are closed.

In another aspect, the electronic ignition system of the present invention comprises two capacitors, said capacitors placed between said battery and said firing switch such that said capacitors are charged by said battery and discharge when said firing switch is closed; an arming switch electrically connected between said capacitors and said battery, wherein said capacitors cannot charge when said arming switch is open; and a safety switch electrically connected between said capacitors and said firing switch, wherein said electric arc cannot be generated unless both said firing switch and said safety switch are closed. When the two switches are closed, the firing switch of each capacitor is connected in series, the capacitor arc is produced only when both switches are closed, and the capacitor arc is connected in series with the arcing point of the capacitor. The capacitor arc is preferably connected to the electrode where the arc is produced and once the discharge of the first capacitor has been initiated, the resistance between terminals of the capacitor is drastically reduced thus discharging the energy stored in the capacitor through the spark, producing a more powerful electrical arc than the initial one, lasting while the second capacitor discharges and having enough current remaining to maintain the ionization in the air gap between the electrode and the ground. Also preferably included in the embodiment is an indicator, electrically connected to the second capacitor, and serving to indicate when the second capacitor is charged.

The ignition system of the present invention can be retrofitted into an existing firearm or originally manufactured as part of a new firearm. For example, in various embodiments, the invention includes the electronic ignition system described herein in combination with a firearm such as a muzzleloading rifle, shotgun or pistol. In alternate embodiments, the invention comprises a retrofit component for a muzzleloading firearm, wherein the retrofit component has a shell or housing with an outer configuration substantially identical to that of an existing component, such as a breechplug, bolt, or other firearm component, and having an ignition system as described herein or portion(s) thereof mounted into and/or onto the shell or housing, for retrofit onto an existing firearm.

In another aspect, the invention is a firearm comprising: a barrel; a breech plug; one or more (preferably at least two) electrode(s) in or on said breech plug; a source of electricity electrically connected to said electrode(s); and a firing switch electrically connected between said electrode(s) and said source of electricity, such that when said firing switch is closed, an electric arc is created between the electrodes or between at least one electrode and an adjacent portion of the breechplug or other component of the firearm, said electric arc being inside said barrel.
In an example embodiment of the firearm, the firearm further comprises: a capacitor, said capacitor electrically connected between said source of electricity and said firing switch such that said capacitor is charged by said source of electricity and discharges when said firing switch is closed; an arming switch electrically connected between said capacitor and said source of electricity, wherein said capacitor cannot charge when said arming switch is open; a safety switch electrically connected between said capacitor and said firing switch, wherein said electric arc cannot be generated unless both said firing switch and said safety switch are closed; and an indicator electrically connected to the capacitor, said indicator indicating when said capacitor is charged.

In another embodiment, the firearm further comprises: a pair of capacitors, said capacitors electrically connected between said source of electricity and said firing switch such that said capacitors are charged by said source of electricity, and they discharge when said firing switch is closed; an arming switch electrically connected between said capacitors and said source of electricity, wherein said capacitors cannot charge when said arming switch is open; a safety switch electrically connected between said capacitors and said firing switch, wherein said electric arc cannot be generated unless both said firing switch and said safety switch are closed; and an indicator electrically connected to the larger of the two capacitors, said indicator indicating when said larger capacitor is charged.

In another aspect of the invention, the firearm further comprises a propellant charge and at least one projectile within said barrel, wherein said electric arc ignites said propellant charge and the explosion of said propellant charge expels said projectile from said barrel.

The firearm of the present invention is preferably a muzzleloading firearm, such as for example a rifle, a shotgun or a pistol.

In yet a further embodiment, there is described herein a firearm comprising: a barrel; means for producing an electric arc in said barrel; and switching means electrically connected to said means for producing said electric arc such that when said switching means is switched from a first state to a second state said electric arc is generated in said barrel.

In another embodiment, the level of safety of the circuitry that controls the electrical spark production is increased using redundant switches. The firing switch accordingly comprises a plurality of switches, some activated by the trigger of the firearm and others activated by the electronic circuit itself, the latter being activated when all of the previous switches (those activated by the trigger) are activated simultaneously. If the simultaneity does not exist, a failure or malfunction in some of the switches activated by the trigger is considered to have occurred, and the switches actuated by the electronic circuit, that constitutes the end switch that should activate to produce the electric arc, will not activate, and no ignition spark is generated.

In another aspect, the invention is an electronic ignition system for a firearm, the ignition system including at least one electrode for igniting a propellant within the firearm, a pair of capacitors for delivering ignition energy to the at least one electrode, and a firing switch for triggering discharge of the pair of capacitors.

In still another aspect, the invention is an improved muzzleloading firearm of the sort having a trigger, and a barrel having a closed breech end and an open muzzle end for receiving a propellant and a projectile. The improvement is an electronic ignition system including at least one electrode at the breech end of the firearm's barrel, at least one capacitor in electrically-conductive contact with the at least one electrode, and a firing switch operated by actuation of the firearm's trigger to discharge the at least one capacitor and ignite the propellant to cause the projectile to be fired from the barrel.

And in another aspect, the invention is a muzzleloading firearm including a stock; a barrel mounted to the stock, and having a bore extending between an open muzzle end and a closed breech end; a trigger; and an electronic ignition system having at least one electrode within the bore at the breech end, at least one capacitor electrically coupled to the at least one electrode, and a firing switch actuated by the trigger to initiate discharge of the at least one capacitor.

These and other aspects, features and advantages of the invention will be understood with reference to the drawing figures and detailed description herein, and will be realized by means of the various elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following brief description of the drawings and detailed description of the invention are exemplary and explanatory of preferred embodiments of the invention, and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an embodiment of an electronic ignition system according to the present invention.

FIG. 2a is a block diagram of another embodiment of an electronic ignition system according to the present invention.

FIG. 2b is a block diagram of another embodiment of an electronic ignition system according to the present invention, having a plurality of firing switches.

FIG. 3a is a schematic diagram of an embodiment of an electronic ignition circuit according to the present invention.

FIG. 3b is a schematic diagram of another embodiment of an electronic ignition circuit according to the present invention.

FIG. 4 shows a portion of a firearm including an embodiment of an electronic ignition system according to the present invention.

FIG. 5 is a block diagram of an electronic ignition circuit that incorporates a microprocessor and a plurality of switches, including firing switches activated by a trigger and other firing switches activated by the ignition circuit.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

The present invention may be understood more readily by reference to the following detailed description of the invention taken in connection with the accompanying
drawing figures, which form a part of this disclosure. It is to be understood that this invention is not limited to the specific devices, methods, conditions or parameters described and/or shown herein, and that the terminology used herein is for the purpose of describing particular embodiments by way of example only and is not intended to be limiting of the claimed invention. Also, as used in the specification including the appended claims, the singular forms “a,” “an,” and “the” include the plural, and reference to a particular numerical value includes at least that particular value, unless the context clearly dictates otherwise. Ranges may be expressed herein as from “about” or “approximately” one particular value and/or to “about” or “approximately” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another embodiment.

[0036] The embodiments of the invention discussed herein are principally shaped and designed for use to replace the firing mechanism of a modern in-line caplock muzzleloading rifle. However, one of ordinary skill in the art would understand how the electronic ignition systems discussed herein can be used to replace the firing system on a side-lock or flintlock simply by reshaping components. Further, while the ignition system is also principally discussed herein for use on a rifle, the ignition system can be used on a shotgun, pistol or any other style of personal black powder firearm without undue experimentation. Still further, while the systems discussed herein are described to be retrofit into an existing in-line caplock rifle, replacing the in-line caplock mechanism, this is done simply to show comparison to existing systems; and the ignition system will often be built into an originally constructed black powder firearm providing a completely new class of black powder firearm.

[0037] FIG. 1 is a block diagram of a first embodiment of an electronic ignition system (100) for use in connection with a firearm. In FIG. 1 there is shown a breach plug (101) insulating a positive electrode (103) therein. The electrode (103) is preferably an electrically conductive wire or similar component arranged so that at least a portion of the electrode (103) is unshielded and extends from the front end (111) of the breach plug (101). Generally, electrical discharge from the electrode (103) will be an electric arc or spark generated between the electrode (103) to the breach plug (101) or to another component or material which acts as an opposing electrode. The breach plug (101) will be used to replace the existing breach plug on a muzzleloading firearm substantially of the type known to the prior art with the front end (111) placed toward the barrel (401) of the firearm, as shown in FIG. 4, and the rear end (113) placed toward the stock (403) or handle of the firearm. The electrode (103) is electrically connected to wire (105) toward the rear end (113) of the breach plug (101). The wiring (105) will preferably be insulated so as to decrease the risk of electric shock or short in the system (100). The breach plug (101) is preferably made of metal and can act as a ground for the electrode (103).

[0038] The wiring (105) is in turn connected to a printed circuit board (PCB), integrated circuit (IC), or other circuit arrangement that comprises an electronic ignition circuit (107). Example embodiments of electronic ignition circuits are shown in FIGS. 3a and 3b, discussed below. The electronic ignition circuit (107) will typically be a circuit to allow discharge of one or more capacitors included within the electronic ignition circuit (107). While particular examples of electronic ignition circuits (107) are shown in FIGS. 3a and 3b, one of ordinary skill in the art would recognize that this circuit is merely exemplary. For this reason only the most basic function of the circuit will be discussed.

[0039] Attached in a manner to provide power to the electronic circuit (107) is a source of electricity such as, but not limited to, a battery (151). The battery (151) is preferably a standard 1.5 volt alkaline or rechargeable (e.g., nickel—cadmium) battery preferably of a smaller size, such as those classified as AA or AAA or used as photo batteries. However, any sized battery of any voltage and amperage could be used, as would be understood by one of ordinary skill in the art, to drive an appropriately laid out electronic circuit. The battery (151) will serve to charge up the capacitor(s) in the electronic ignition circuit (107) when the arming switch (125) is closed.

[0040] The electronic ignition system of FIG. 1 can be used to replace the caplock mechanism of an existing in-line caplock firearm in the following manner as shown in FIG. 4. The caplock firing mechanism is removed from the firearm by removing the existing bolt, hammer system/firing pin, nipple, and breach plug. The breach plug of the caplock is then replaced with the breach plug (101) with the electrode (103) projecting into the barrel (401) of the firearm (400). The wiring (105), electronic circuit (107), and battery (151) are then placed into the space the bolt was removed from. Some or all of the bolt assembly (405) can be used to cover the electronic ignition system (100) to protect it from the elements, depending on the construction of the device, or a new cover is installed to protect the system (100) or any portion of the system. The safety switch (123) can be wired in a manner to allow the existing safety in the firearm (400) to be used to open and close the safety switch (123), and the firing switch (121) can be wired to the existing trigger (407) to allow the trigger (407) to be used to close the firing switch (121) in the traditional manner of most firearms. The arming switch (125) can be placed anywhere to make it accessible to the user, and will generally be provided in a custom location in the breech area or in the stock, for example adjacent the trigger guard or gripping areas of the stock.

[0041] The electronic ignition system (100) of FIG. 2a is essentially the same as that of FIG. 1; however, instead of using a single positive electrode (103) with a ground in the breach plug (101), whereby the electric arc therebetween triggers the propellant charge, the breach plug (201) of this embodiment includes both a positive electrode (203a), and a negative electrode (203b) (sometimes referred to in combination herein as electrodes (203)), closely spaced, and both of which extend from the front (211) of the breach plug (201). When the capacitor(s) of the electronic ignition circuit (107) discharge, the electrodes (203) will produce an electrical arc across the air gap between them, and this electrical arc starts the ignition of the main propellant charge (411), which fires the projectile (413). With embodiments of the electronic ignition circuit having two capacitors, the initial electrical arc are between electrodes (203a, 203b) generated by the first capacitor induces the discharge of the second capacitor, thus increasing the initial electrical arc energy,
and more robustly ignites the main propellant charge (411), which fires the projectile (413).

[0042] The electronic ignition system of either embodiment (100, 100') preferably includes numerous features to help improve safety. The clearest is in the reliability of discharge. The main propellant charge (411), when loaded, will be preferably placed in contact with the electrode(s) (103) or (203a, 203b). Therefore, there is no need for a spark to be transferred through a nipple or flash hole, which as discussed above can suffer the disadvantages of increased lock time, misfire and/or hangfire.

[0043] In particular, the main propellant (411), when loaded in the barrel (401) of the firearm (400) will rest, at least partially on the breach plug (101) and will lie immediately adjacent to, or within, the air gap through which the electric arc will pass. Alternatively, a shaped powder charge may be used, placing the propellant in a similar arrangement. The electrical spark generated by the arcing electrodes is preferably in direct contact with the main propellant charge (411) when generated. Because there is no need for the transfer of a spark to the main propellant charge (411), as it is generated in sufficiently close proximity to not require transfer, there is a decreased risk of hangfire resulting from a small amount of powder in the hole that acts as a fuse, or the spark being otherwise delayed on its way to the propellant charge (411). This generally decreases the risk of a hangfire situation and makes the firing of the weapon more reliable.

[0044] The electric arc ignition also is preferable for use in inclement weather. In inclement weather conditions, particularly damp conditions, traditional black powder firearms are generally more prone to hangfires or misfires, as the traveling spark can be extinguished or have problems traveling. In an electric arc ignition system, however, the entire ignition structure is protected from the elements by being internal to the firearm. This will protect it from the weather conditions. Further, with appropriate insulation, protection, and design, electric systems may be shielded from the elements to provide for reliable discharge and arc generation, which results in both more reliable and safer firing characteristics.

[0045] Also preferably included are three switches in the electric ignition system (100), acting as safety switches and helping prevent unintended discharge of the firearm (400), which system is generally more effective than traditional mechanical safeties. Firstly, there is included an arming switch (125). The arming switch (125) is electrically connected in the system to serve to prevent the capacitor(s) from charging from the battery (151) until the user arms the firearm (400). The arming switch (125) can be placed as shown in FIG. 3a, or as shown in FIG. 3b, or in various other positions wherein it can be switched to prevent the capacitor(s) from charging. In this way, when the firearm (400) is not armed it is highly unlikely that the ignition system (100) will accidentally discharge the firearm (400), as the capacitor(s) lack the necessary charge to send an electrical current of sufficient strength to the electrode (103 or 203) to create the electric arc.

[0046] In preferred embodiments, the arming switch (125) and capacitor(s) are connected to an LCD light, LED, display, or similar indicator (421) that indicates if the capacitor(s) is/are fully charged or not. The indicator may optionally also signal the user of a low-battery condition or other accessory functions. In this way, the user of the firearm (400) can load the firearm (400) with the ignition system (100) disarmed to decrease the danger of the firearm (400) firing during loading. Also, in preferred embodiments the arming switch (125) will automatically open after firing of the firearm (400) (or triggering of the electronic ignition system (100) even if the firearm (400) hangfires or misfires). In this way, when the one or more capacitor(s) discharge(s), they will not be able to recharge prior to the user rearming the ignition system (100).

[0047] If the arming switch (125) is open, but the capacitor(s) is/are already charged, there is still a possibility of the firearm (400) firing, as the capacitor(s) still have sufficient charge to generate an electric arc as they slowly discharge. By opening the arming switch (125) when the capacitor(s) is/are discharged, the capacitor(s) have no chance to recharge until the arming switch (125) is purposefully re-engaged.

[0048] In another embodiment, there is also included a further system for safely discharging the capacitor(s), bypassing the electrode (103) or discharging them through an electronic switch (transistor, thyristor or so on) when the arming switch is opened, so that the user may discharge the capacitor(s) without generating an arc from the electrode (103, 203) or firing the firearm (400), even if the firearm (400) is loaded. The arming switch (125) effectively acts to safe the firearm (400) and prevent discharge by eliminating the ability of the ignition system (100) to ignite the main propellant (411). In this way, the firearm (400) may be safely carried even while loaded.

[0049] Preferably, there are also two more switches included in the ignition system (100). The second or safety switch (123) acts similarly to a mechanical safety for a firearm. As the safety switch (123) is in the path between the electrode (103, 203) and one or more of the capacitor(s), if the safety switch (123) is open, the electronic circuit (107) is designed not to discharge through the electrode (103, 203). The safety switch (123) therefore acts to protect against accidental discharge of the firearm (400) once the electronic circuit (107) has been armed. The use of a safety switch (123) is preferred, but by no means required, and the safety switch (123) acts in many ways like, and may even be connected to, the existing safety switch (123) of a muzzle-loading firearm.

[0050] The third switch is the firing switch (121). The firing switch (121) closes the electronic circuit (107) and, in the intended manner of operation, if the safety switch (123) is closed and the capacitor(s) is/are charged, triggers the electrical arc at the electrode(s), ignites the main propellant (411), and fires the firearm (400) to propel the projectile (413) at the target. The firing switch (121) is effectively the firearm’s trigger (407). Depending on the preference of the user, the firing switch (121) may be linked to a mechanical trigger of the type known to those of ordinary skill in the art, or may replace the trigger with an electronic switch. The firing switch (121) will preferably be a type of switch that will default to an open position whereby the user must hold the firing switch (121) closed to place it in the closed position.

[0051] It would be apparent to one of ordinary skill in the art, that the use of an electronic switch to either replace or
supplement the existing mechanical trigger has particular advantages. It is well known in shooting that one of the difficulties in shooting a firearm accurately is that pulling the trigger requires a particular amount of force, and applying that force can cause the firearm to be moved off target. In the black powder case, due to the inaccuracies and single shot limitation commonly inhering in such firearms, such movement is more likely to result in a missed target and lost opportunity. Also, it is almost always safer to have the projectile hit the intended target, so easier controlled and accurate discharge of the firearm is generally a safety improvement.

[0052] Because the firing switch (121) is electronic, even if a traditional trigger is used, the trigger can require little to no strength to activate, which can help to eliminate inaccuracy due to trigger pull force. Further, the mechanical trigger can be replaced with a purely electrical switch, which can provide further benefits. For instance, the electrical switch can incorporate computer chips, scanners or similar devices to determine, before triggering the firearm (400), that the user is the owner of the firearm (400) (such as by, but not limited to, scanning a fingerprint from the surface of the switch). The firing switch (121) can also be customized for the intended application. For instance, in a hunting situation, the firing switch (121) may be placed in a manner to allow for triggering without noise, so in the unlikely event of a misfire the target is not spooked by the firing mechanism being activated. The firing switch (121) may also be able to supply different amounts of pull depending on the need of the user and may be switchable or variably adjustable. For instance, the user may be able to set the trigger to a very high pull strength when transporting the firearm (400) and approaching the target, but lower the pull strength once the hunter is ready to fire. Used in conjunction with the safety switch (123) and/or arming switch, this can make it very difficult to accidentally discharge the firearm (400). The amount of pull strength may be based on a force feedback or other electronic or electromagnetic resistance device, which may be controlled by the user of the firearm (400) by a dial or similar control (not shown). Any or all of the switches may be electronic, electric, electromechanical, or mechanical switches in various embodiments of the invention.

[0053] FIG. 3a shows a first example embodiment of an electronic ignition circuit (107) suitable for use in connection with the electronic ignition system (100, 100') of a firearm (400), according to the present invention, which includes a plurality of capacitors including C2 and C3, an inverter transformer T1, and a high-voltage transformer T2, configured as shown and as described above. The capacitors are charged by the battery (151) when the arming switch (125) is closed, and discharge when the firing switch (121) is closed. The indicator lamp 421 is preferably electrically connected to capacitor C2, serving to indicate when capacitor C2 is charged. The capacitors cannot charge when the arming switch (125) is open. The safety switch (123) prevents firing unless both the firing switch (121) and the safety switch (123) are closed.

[0054] When the two switches 121 and 123 are closed, a sequential discharge of capacitors C2 and C3 takes place. Capacitor C3, which is a lower capacitance capacitor (for example between 22 nF and 100 nF), discharges on the primary winding of the high voltage transformer T2, whereby the high voltage generated on the secondary wind-
firearm (400) and ignition system (100). The projectile (413) is then loaded as normal onto the propellant (411). Any type of propellant or projectile, known now or later discovered, which can be ignited by an electric arc and safely discharge the firearm may be used as the propellant (411) and projectile (413) as understood by those of ordinary skill in the art. In an alternate form of the invention, the arming switch (125), safety switch (123), and firing switch (121) are open at the time of loading, and the one or more capacitors will preferably be discharged. The user may verify discharge of a capacitor by determining that the "armed" indicator (421) indicates that a capacitor is no longer charged. If there is an indication that the capacitor is charged, the user should either safely discharge the capacitor by dry firing the firearm (400) (firing with no propellant or projectile in a safe direction and into a safe backstop), waiting for the capacitor to discharge over time or using a safe discharge mechanism bypassing the electrode(s) (103, 203), or discharging the capacitor through an electronic switch (transistor, thyristor, etc.) if the firearm (400) is provided with such a mechanism. After verifying that the weapon is not armed, the user will load the main propellant (411) into the barrel (401) of the firearm (400), and proceed generally as outlined above.

[0057] Once loaded, the user will prepare to shoot. It is preferred, but not required, that the user not arm the ignition system until he is ready to take his shot. However, the user may arm the ignition system before being ready to shoot in an alternate embodiment. The firearm (400) is only considered to be "safe," once loaded with propellant (411) and projectile (413), when the capacitors are discharged and the arming switch (125) is open.

[0058] When the user is ready to discharge the firearm (400), he will first arm the firearm (400) by closing the arming switch (125). At this time, the capacitor(s) will charge from the battery (151) and, once charged, will be so indicated by the armed indicator (421). The user can then set their desired trigger pull weight if such functionality is included. The user will then close the safety switch (123) readying the firearm (400) to fire. They will then fire the firearm (400) by closing the firing switch (121) either by pulling trigger (407) to close the firing switch (121), or by triggering any other mechanism. When the firing switch (the firing switch (121)) is closed, the ignition process commences with the capacitor(s) discharging. The electric arc will ignite the primary propellant charge (411) whose explosion in turn shoots the projectile (413) from the barrel (401). Upon capacitor discharge, the user will release the firing switch (121) allowing it to open. However, even if the firing switch (121) is held down after firing, the firearm (400) will preferably not discharge again as it has not yet been loaded. Further, even if the arming switch (125) remains closed while the firing switch (121) is closed, the capacitor(s) will generally not recharge, as the electricity will flow into the electrode and safely to ground.

[0059] The arming switch (125) will preferably automatically open upon firing of the firearm (400) or the generation of the electric arc. Alternatively, the arming switch (125) may remain closed after firing, with the safety switch and the firing switch providing redundant safety against unintended discharge of the firearm; or the arming switch (125) may be manually opened and the capacitors discharged, for additional redundancy. Opening of the arming switch (125) preferably occurs upon the closing of the firing switch (121), as the firearm (400) will fire so long as the capacitor(s) is/are charged and the safety switch (123) and firing switch (121) are both closed, even if the arming switch (125) is open. Alternatively, the arming switch (125) may open upon opening of the firing switch (121) or when another specified event occurs. The safety switch (123) preferably also automatically opens upon firing of the firearm (400). The user will then wait to make sure there is no residual burning of propellant (411) in the barrel (401) and that all switches (121, 123 and 125) are open. The user may also alter the pull or type of the trigger mechanism, if such functionality is provided. The user can then repeat the above steps to prepare the weapon to fire again.

[0060] The high level of reliability and safety achieved through the use of the arming switch (125), the safety switch (123) and the firing switch (121), can be increased even further through the use of redundant switches in any of the arming, safety or firing switches, as shown by way of example embodiments of the ignition system 100 in FIG. 2b and of the ignition circuit 107 in FIG. 5. In these more sophisticated embodiments, the firing switch (121) comprises serially or cascade-connected switches, which may be of a different type (whether one of them be electromechanical and the other semi-conductor, either an IGBT, transistor, thyristor or any other semiconductor device used as a switch), with the electromechanical switch(es) (121) being activated by the firearm trigger (407) and the other switch(es) (121) being activated by the electronic ignition circuit (107, 107, 107) (once the activation of the first switch has been detected) with a slight delay with respect to the first switch, so as to produce the electric arc when the bounces or oscillations that are usually produced on activating the mechanical switch and in order to guarantee that the electric arc is cleaner and stronger, have disappeared.

[0061] The firing switch (121) optionally also comprises a set of or various switches that may be of different types (electromechanical, reed switch, semiconductor or proximity sensors), so that some of them (121) are activated by the firearm trigger (407) and another (or others, preferably semiconductor switches) (121) are activated by the electronic circuit (See FIG. 5). The electronic circuit can detect when one of the switches actuated by the trigger is activated. Therefore all the switches connected to the trigger are also activated within a certain time interval, so that if said activation is not produced simultaneously, there is considered to be a malfunction or the failure of some switch, and the circuit does not activate the semi-conductor switches. As a result, the firearm does not fire. Additionally the electronic circuit can optionally include other safety measures, such as discharging the capacitors that produce the arc, which would make the unforeseen firing of the firearm substantially impossible.

[0062] In a more sophisticated embodiment, two switches can be serially connected or a set of various switches carrying out the function of a safety switch (123) can be provided, as was explained before for the firing switch (121).

[0063] In addition to the function described above, the electronic circuit can optionally be further optimized so that the battery disconnection or the opening of the arming switch (125) provokes the capacitor(s) to discharge as a
precautionary measure, to avoid unforeseen firing, thereby making it substantially impossible to produce an accidental electrical arc.

[0064] The stated functions can be carried out with traditional analog-digital circuitry or more preferably with a microprocessor that supervises the state of the switches that require inspection and, depending on their state, actuates the switches that provoke the spark production and the consequent ignition of the gunpowder (or if not applicable actuate the switches that provoke the capacitors discharge), through the use of the corresponding microprocessor input and output gates and in accordance with the appropriate software. Therefore, the electronic circuit of the ignition system can optionally comprise analog circuitry, a combination of digital-analog circuitry, digital circuitry as by a circuit based on a microprocessor or microcontroller, and/or by an ASIC circuit or by a circuit utilizing onboard or external software.

[0065] While the invention has been disclosed in connection with certain preferred embodiments, this should not be taken as a limitation to all of the provided details. Modifications and variations of the described embodiments may be made without departing from the spirit and scope of the invention as defined by the following claims, and other embodiments should be understood to be encompassed in the present disclosure as would be understood by those of ordinary skill in the art.

What is claimed is:

1. An electronic ignition system for a firearm, said ignition system comprising at least one electrode for igniting a propellant within the firearm, a first capacitor and a second capacitor, and a firing switch for triggering discharge of the first and second capacitors, wherein the first and second capacitors discharge sequentially and discharge of the first capacitor provokes discharge of said second capacitor to deliver ignition energy to the at least one electrode.

2. The electronic ignition system of claim 1, wherein the first capacitor has a lower capacitance than the second capacitor.

3. The electronic ignition system of claim 2, further comprising a transformer, and wherein the first capacitor discharges on the transformer to generate arcing at the at least one electrode to provoke discharge of the second capacitor.

4. The electronic ignition system of claim 1, wherein the firing switch is linked to the trigger of the firearm.

5. The electronic ignition system of claim 1, wherein the firing switch has an adjustable release force.

6. The electronic ignition system of claim 1, further comprising an indicator light that indicates whether the capacitors are fully charged.

7. The electronic ignition system of claim 1, further comprising a battery for charging the capacitors.

8. The electronic ignition system of claim 7, further comprising an arming switch switchable between a first state for permitting charging of the capacitors and a second state for preventing charging of the capacitors.

9. The electronic ignition system of claim 1, further comprising a safety switch, and wherein both the safety switch and the firing switch must be actuated to fire the firearm.

10. The electronic ignition system of claim 1, wherein the firing switch comprises a plurality of redundant switches.

11. The electronic ignition system of claim 10, wherein at least one of the plurality of redundant switches is a mechanically actuated switch, and at least one of the plurality of redundant switches is an electronically actuated switch.

12. The electronic ignition of claim 11, wherein the electronically actuated switch has a slight delay with respect to mechanically actuated switch.

13. The electronic ignition system of claim 1, in combination with a muzzleloading firearm.

14. The electronic ignition system of claim 1, housed within a retrofit component for use in combination with a muzzleloading firearm.

15. The electronic ignition system of claim 14, wherein the retrofit component takes the place of the breechplug of the muzzleloading firearm.

16. In a muzzleloading firearm comprising a trigger and a barrel having a closed breech end and an open muzzle end for receiving a propellant and a projectile, the improvement comprising an electronic ignition system, said electronic ignition system comprising at least one electrode at the breech end of the firearm's barrel, a high-capacitance capacitor in electrically-conductive contact with the at least one electrode, a low-capacitance capacitor for initiating discharge of the high-capacitance capacitor, and a firing switch operated by actuation of the firearm's trigger to discharge low-capacitance capacitor.

17. The improvement to a muzzleloading firearm as claimed in claim 16, wherein said electronic ignition system further comprises a transformer, and wherein the low-capacitance capacitor discharges on the transformer to generate arcing at the at least one electrode and provoke discharge of the high-capacitance capacitor.

18. A muzzleloading firearm comprising:

   a stock;

   a barrel mounted to said stock, and having a bore extending between an open muzzle end and a closed breech end;

   a trigger; and

an electronic ignition system having at least one electrode within the bore at the breech end, a higher capacitance capacitor and a lower capacitance capacitor each electrically coupled to the at least one electrode, and a firing switch actuated by the trigger to initiate discharge of the capacitors.

19. The muzzleloading firearm of claim 18, wherein discharge of the lower capacitance capacitor provokes discharge of the higher capacitance capacitor.

20. The muzzleloading firearm of claim 19, wherein the lower capacitance capacitor discharges onto a transformer to generate arcing at the at least one electrode, thereupon provoking discharge of the higher capacitance capacitor to generate increased arcing at the at least one electrode.

21. The muzzleloading firearm of claim 18, wherein the stock houses a battery to charge the capacitors.

22. A muzzleloading firearm comprising a barrel having a bore for receiving a propellant, at least one electrode for igniting the propellant within said bore, an energy source coupled to said electrode, and a switching system comprising a plurality of switches operable to deliver ignition energy from said energy source to said electrode.
23. The muzzleloading firearm of claim 22, wherein the plurality of switches of the switching system comprise a firing switch and a safety switch.

24. The muzzleloading firearm of claim 22, wherein the plurality of switches of the switching system comprise a firing switch and an arming switch.

25. The muzzleloading firearm of claim 24, wherein the plurality of switches of the switching system comprise a redundant array of switches.

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