

ELECTRONIC DISABLING DEVICE

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FIELD OF THE INVENTION

The present invention relates to devices for disabling an animal or human target; and to methods for providing an electric current through electrodes and the target in a circuit having an air gap between an electrode and the target.

The original stun gun was invented in the 1960's by Jack Cover. Such prior art stun guns incapacitated a target by delivering a sequence of high voltage pulses into the skin of the target such that the current flow through the target interferes with the target's neuromuscular system. Lower power systems cause a stun effect. Higher power systems cause involuntary muscle contractions. Electronic disabling devices, such as stun guns, have been made in two designs. A first design has electrodes fixed to the gun. In operation the user establishes direct contact of the electrodes to the target. A second design operates on a remote target by launching a pair of darts. Each dart includes an electrode that typically includes a barbed point. The darts either engage the clothing worn by the target or engage the target's skin. In most cases, a high impedance air gap exists between one or both of the electrodes and the skin of the target because one or both of the electrodes contact the target's clothing rather than penetrating the target's skin.

A conventional stun gun 100 may be implemented according to the functional block diagram of FIG. 1. In stun gun 100, closing safety switch S1 connects a battery 102 to a microprocessor circuit 124 and places stun gun 100 in the "armed" and ready to fire configuration. Subsequent closure of trigger switch S2 causes microprocessor 124 to activate high voltage power supply 104. High voltage power supply 104 outputs a pulsed voltage of about 2,000 volts that is coupled to charge a capacitor 106 to the 2,000 volt power supply output voltage. When the voltage across spark gap GAP1 exceeds the ionization voltage of air, a relatively high voltage appears across the primary winding of transformer 108. Transformer 108 steps up this voltage to about 50,000 volts across the electrodes E1 and E2, ionizing the air in air gaps GAP_A and GAP_B at the target, modeled as a load having an impedance Z1. A relatively high voltage is thereby applied to load Z1. As the output voltage of capacitor 106 rapidly decreases, current flow through spark gap GAP1 decreases, causing air in the spark gap to deionize and to resume an open circuit impedance. This "reopening" of spark gap GAP1 defines the end of each output pulse applied to electrodes E1 and E2. A



typical stun gun of the type illustrated in FIG. 1 produces from five to twenty pulses per second.

Taser International of Scottsdale, Arizona, has for several years manufactured stun guns of the type illustrated in FIG. 1 and designated as the Taser® Model M18 and Model M26 stun guns. High power stun guns such as these typically incorporate an energy storage capacitor 106 having a capacitance of from about 0.2 to about 0.88 microfarads.

It is desirable to disable targets that may be wearing clothing such as a leather or cloth jacket. Clothing functions to establish a gap of about 0.6 cm (0.25 inch) to about 2.5 cm (1 inch) between the target's skin and an electrode. An output voltage of about 50,000 volts will ionize an air gap of this length and support a current sufficient to induce muscular contractions in the target. With high power stun guns, such as the M18 and M26 stun guns, the magnitude of the current flow across the spaced apart stun gun output electrodes may cause numerous groups of skeletal muscles to rigidly contract. For a human target, the stun gun causes the target to lose its ability to maintain an erect, balanced posture. As a result, the target falls to the ground and is disabled.

At about 50,000 volts, the air in one or both GAP_A and GAP_B between output electrodes E1 and E2 and the target ionizes and current begins flowing through electrodes E1 and E2. When electrodes E1 and E2 are presented with a relatively low impedance load Z1 instead of the high impedance air gap or gaps, the stun gun output voltage will drop to a significantly lower voltage level. For example, with a human target and with about probe to probe separation of about 25 cm (10 inches), the output voltage of a model M26 stun gun might drop from about 55,000 volts to about 5,000 volts. Conventional stun guns exhibit this rapid voltage drop because such stun guns are tuned to operate in only a single mode to consistently create an electrical arc across a very high, near infinite impedance air gap. After a low impedance circuit is formed through the electrodes and air gap or gaps at the target, the effective stun gun load impedance decreases toward the target's impedance, generally about 1,000 ohms or less. A typical human subject may present a load impedance of about 200 ohms.

Conventional stun guns have by necessity been designed to have the capability of causing ionization across one or more very high impedance air gaps at the target. As a result, such stun guns have been designed to produce an output from about 50,000 to about 60,000 volts. After ionization, the gap impedance is reduced to a very low level, yet the stun gun continues to operate in the same mode, delivering current or charge into a now very low

impedance target. Consequently, the conventional high power, high voltage stun gun 100 discussed above operates relatively inefficiently, yielding a relatively low electro-muscular effect with relatively high battery power consumption.

5 The M26 stun gun delivers about 26 watts of output power as measured at the capacitor 106. Due to inefficiencies of the high voltage power supply, the battery provides about 35 watts at a pulse rate of 15 pulses per second. Due to the requirement to generate a high voltage, high power output signal, the M26 stun gun requires a relatively large and relatively heavy eight AA cell battery pack 102. In addition, the M26 stun gun power generating solid state components 104, capacitor 106, step up transformer 108, and related
10 parts on the primary side of transformer 108 must operate with relatively high current and high voltage (2,000 volts) and parts on the secondary side of transformer 108 must operate with repeated exposure to even higher voltage (50,000 volts).

Without devices and methods of the present invention, the cost of manufacturing and operating electronic disabling devices will restrict widespread use of these
15 weapons for law enforcement and personal safety.

SUMMARY OF THE INVENTION

Specific expressions of the invention can be found in claims 1 and 28.

20 An electronic disabling device, according to various preferred aspects of the present invention, for disabling a target includes first and second electrodes to establish first and second spaced apart contact points on the target; and a high voltage power supply for generating an output voltage delivered across the first and second contact points on the target to generate a positive voltage potential at one electrode and a negative voltage potential at the other electrode.

25 A method for disabling a target, according to various preferred aspects of the present invention, includes: providing from a first stored energy device a first signal to the target to ionize an air gap at the target; and providing from a second stored energy device a second signal to the target to continue a current through the gap and through the target.

30 A device for disabling a target, according to various preferred aspects of the present invention, includes a circuit for providing from a first stored energy device a first signal to the target to ionize an air gap at the target; and a circuit for providing from a second stored energy device a second signal to the target to continue a current through the gap and through the target.

A method, according to various preferred aspects of the present invention, for monitoring battery capacity for a device operated by a battery, includes: monitoring an operating mode of a plurality of modes of the device; measuring a time that the device operates in each respective operating mode of the plurality; storing indicia of the original battery capacity and indicia of a rate of battery capacity consumption associated with each operating mode of the plurality; and computing a battery capacity consumed based on data received from the operating mode monitoring means, from the operating time monitoring means and from the memory.

A warranty information system, according to various preferred aspects of the present invention, for a device includes a circuit for storing indicia of a duration of a warranty; a circuit for storing a start time for the warranty; and a circuit for providing power for operating the device. The system may further be provided as an operator replaceable part of the device, a replacement system facilitating an extended warranty.

A method, according to various preferred aspects of the present invention, for providing warranty information to a processor of a device covered by the warranty includes: storing indicia of a duration of a warranty; storing a start time for the warranty; and providing power for operating the device. The method may further include providing as an operator replaceable part of the device a replacement module that performs storing of the indicia, storing of the start time, and providing power, thereby facilitating an extended warranty.

DESCRIPTION OF THE DRAWINGS

Systems and methods of the present invention will be described with reference to the drawing wherein like numbers denote like elements, and:

FIG. 1 is a functional block diagram of a stun gun of the prior art;

FIG. 2 is a functional block diagram of an electronic disabling device according to various aspects of the present invention;

FIG. 3 is a graph illustrating a generalized output voltage waveform of the circuit portion 201 of FIG. 2;

FIG. 4 is a graph illustrating a generalized output voltage waveform of the circuit portion 203 of FIG. 2;

FIG. 5 illustrates a high impedance air gap which may exist between one of the electronic disabling device output electrodes E1 and a spaced apart location E3 on a target;

FIG. 6 illustrates the air gap of FIG. 5 after ionization;

FIG. 7 is a graph illustrating the impedance of air gap GAP_A of FIG. 5 during time periods of FIGs. 3 and 4;

FIG. 8 is a graph of voltage versus time for the device of FIG. 2;

FIG. 9 is a graph of voltage versus time for the device of FIG. 2;

FIG. 10 is a graph of time for the sequence of two output pulses of FIG. 9;

FIG. 11 is a functional block diagram of another electronic disabling device according to various aspects of the present invention;

FIG. 12 is a functional block diagram of yet another electronic disabling device according to various aspects of the present invention;

FIGs. 13-18 are timing diagrams illustrating the voltages across capacitors C1, C2, and C3 of FIG. 12 during times T0-T3;

FIG. 19 is a table indicating the effective impedance of GAP1 and GAP2 during time intervals of FIGs. 13-18;

FIG. 20 is a functional block diagram of an alternative implementation of circuit portions 201 and 203 of FIG. 2;

FIG. 21 is a schematic diagram of controller 1214 of FIG. 12;

FIG. 22 is a schematic diagram of power supply 1201 of FIG. 12;

FIGs. 23A and 23B form a schematic diagram of another portion of circuitry of the device of FIG. 12;

FIG. 24 is a schematic diagram of an alternative circuit for the circuit of FIG. 23B; and

FIG. 25 is a battery power consumption table.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An electronic disabling device, according to various aspects of the present invention, temporarily disables an animal or person (e.g., the target) and may to some extent immobilize and/or incapacitate the target while an electric current from the device is passing through the target. For example, the electronic disabling device 200 of FIG. 2 includes a power supply 202, first and second energy storage capacitors 204 and 210, and switches S1

and S2 that each operate as SPST switches and serve to selectively connect the two energy storage capacitors to down stream circuit elements. Any number of physical capacitors in parallel or series connection may be used to implement a capacitor as discussed herein. The switches may be implemented in any conventional manner such as spark gaps and/or electronic switches (e.g., transistors). Capacitor 204 is selectively connected by switch S1 to a voltage multiplier 208 that is coupled to first and second electrodes E1 and E2. Electrodes may be fixed or implemented in darts as discussed above. Capacitors 204 and 210 are also coupled through a common conductor (circuit ground) to electrode E2.

Trigger 216 (e.g., a switch similar to a gun trigger) controls switch controller 214 that controls the timing and closure of switches S1 206 and S2 212.

The output voltage V_{OUT} across electrode E1 and E2 provided by operation of device 200 is the superposition of the voltage provided by each of two circuit portions 201 and 203. In operation power supply 202 is activated at time T_0 . Capacitors 204 and 210 charge during the time interval T_0 - T_1 . At time T_1 of FIG. 3, switch controller 214 closes switch S1 to couple capacitor 204 to voltage multiplier 208. FIG. 3 shows V_{OUT} as a relatively high voltage during period T_1 to T_2 .

In the hypothetical situation illustrated in FIG. 5, a high impedance air gap exists between electrode E1 and target contact point E3; and skin contact exists between electrode E2 and target contact point E4. Skin contact provides a low (e.g. near zero) impedance. Contact points E3 and E4 are spaced apart on the target as discussed above. The resistor and Z_{LOAD} symbols represent the internal target resistance, typically less than 1,000 ohms, and may be about 200 ohms for a typical human target.

Application of the V_{HIGH} voltage across the E1 to E3 gap GAP_A ionizes the air in the gap to form an arc. Consequently, the impedance of GAP_A drops from a near infinite amount to a near zero amount as in FIG. 7, producing the circuit configuration as in FIG. 6. After this low impedance ionized path from E1 to E3 has been established by the short duration application of the V_{HIGH} output signal, switch controller 214 opens switch S1 and closes switch S2 to couple capacitor 210 to electrodes E1 and E2 as illustrated during period T_2 to T_3 of FIG. 4. Capacitor 210 continues the ionization and maintains the arc across GAP_A for a significant additional time interval. This continuing, lower voltage discharge of the capacitor 210 during the interval T_2 to T_3 transfers a substantial amount of electrical charge through the target to disable the target. The continuing discharge of capacitor 210 through the target will eventually exhaust the charge stored in capacitor 210 and will

ultimately cause the output voltage to drop to a voltage at which ionization is no longer supported in GAP_A. GAP_A will then revert to the non-ionized, high impedance state causing cessation of current flow through the target. FIGs. 8 and 9 illustrate the voltage across electrodes for times T0 - T3.

5 Switch controller 214 may be programmed to close switch S1 for a predetermined period of time and then to close switch S2 for a predetermined period of time.

During interval T3 to T4, power supply 202 is disabled to maintain a factory preset pulse repetition rate. As illustrated in the timing diagrams of FIGs. 9 and 10, this factory preset pulse repetition rate defines the overall T0 to T4 time interval and its repetitions as in times T4 to T8 corresponding respectively to times T0 to T4. A timing control circuit implemented by a microprocessor maintains switches S1 and S2 in the open condition during the T3 to T4 time interval and disables the power supply until the desired T0 to T4 time interval has been completed. At time T4, the power supply will be reactivated to recharge capacitors 204 and 210 to the power supply output voltage.

15 In an alternate implementation, the duration of the interval T2 to T3 may be extended. For example, electronic disabling device 1100 of FIG. 11 includes components described above and further includes third capacitor 1118 and diode D1. High voltage power supply 1102 charges capacitors 1110 and 1118 in parallel. While the second terminal of capacitor 1102 is connected to ground, the second terminal of capacitor 1118 is returned to ground through diode D1.

20 Another electronic disabling device 1200 of FIG. 12 is an implementation of the functions of device 1100 discussed above with reference to the functional block diagram of FIG. 11. In device 1200, high voltage power supply 1202 provides two outputs of equal output voltage capability. Each output supplies a current: I1 to capacitors 1204 and 1218 (corresponding in function to first and third capacitors discussed above), and current I2 to capacitor 1210 (corresponding in function to the second capacitor discussed above). The first voltage output of high voltage power supply 1202 is also connected to GAP1, a 2,000 volt spark gap; and to the primary winding of output transformer 1208 having a one to twenty-five primary to secondary winding step up ratio. The second terminal of capacitor 1210 is connected to ground while the second terminal of capacitor 1218 is returned to ground through resistor R1. The second voltage output of high voltage power supply 1202 is also connected to GAP2, a 3,000 volt spark gap.

Spark gaps GAP1 and GAP2 are respectively in series with the primary and secondary windings of transformer 1208 having a 1 to 25 step up ratio.

In device 1200, closure of safety switch S1 enables operation of high voltage power supply 1202 and places device 1200 in a standby/ready to operate configuration.

5 Closure of trigger switch S2 causes microprocessor 1224 to assert an activate signal to high voltage power supply 1202. In response, power supply 1202 initiates current flow I1 charging capacitors 1204 and 1218 and current flow I2 charging capacitor 1210. This capacitor charging time interval will now be further described with reference to the voltage versus time graphs of FIGs. 13 through 18.

10 During the interval T0 to T1 capacitors 1204 (C1), 1210 (C2), and 1218 (C3) charge from a zero voltage up to about 2,000 volts in response to outputs from high voltage power supply 1202. Spark gaps GAP1 and GAP2 remain open with near infinite impedance. At time T1 the voltages of capacitors C1 and C3 approach the 2,000 volt breakdown rating of GAP1. At the breakdown voltage of spark gap GAP1, an arc will be formed across GAP1
15 and the impedance of GAP1 will drop to a near zero amount. This drop begins at time T1 in FIGs. 13-16. Beginning at time T1, capacitor C1 will begin discharging through the primary winding of transformer 1208. By operation of transformer 1208, the voltage across electrodes E1 and E2 decreases rapidly to about -50,000 volts as shown in FIG. 16. The voltage across capacitor C1 (FIG. 15) decreases relatively slowly from about 2,000 volts
20 while voltage across spark gap GAP2 increases relatively slowly toward the breakdown voltage of GAP2 (FIG. 16).

Device 1200 exhibits two modes of providing output signal V_{OUT} across output electrodes E1 and E2. In a first operating mode a relatively high voltage is supplied to ionize air in GAP_A with energy supplied by capacitor C1 during time interval T1 to T2. In a
25 second operating mode, a relatively lower voltage is supplied with energy supplied by capacitors C2 and C3 during time interval T2 to T3. At the end of the interval T1 to T2, device 1200 begins operating in the second mode of operation as spark gaps GAP2 and GAP_A conduct at a low (near zero) impedance. The air in spark gaps GAP2 and GAP_A is ionized at time T2 allowing capacitors C2 and C3 to discharge through electrodes E1 and E2 and the
30 relatively low impedance load of the target. As illustrated in FIG. 17, capacitor C1 is discharging to a near zero amount as time approaches T2. Capacitor C1 does not discharge prior to time T2 because spark gap GAP2 is open. During the time interval T2 to T3, the

voltage across capacitors C2 and C3 decreases to zero as these capacitors discharge through the now low impedance (target only) load seen across output terminals E1 and E2.

FIG. 18 presents the voltage across GAP2 and the voltage across electrodes E1 and E2 during time interval T2 to T3. During most of the interval T2 to T3, the voltage across electrodes E1 and E2 has an absolute value less than about 2,000 volts.

In an electronic disabling device according to various aspects of the present invention, capacitor C1 may provide about 0.14 microfarads and discharge during a time interval T1 to T2 of about 1.5 microseconds. Capacitors C2 and C3 may each provide about 0.02 microfarads and discharge during a time interval T2 to T3 of about 50 microseconds.

In other implementations, other durations are used for the duration of interval T1 to T2. This duration may be in the range from about 1.5 to about 0.5 microseconds.

In other implementations, other durations are used for the duration of interval T2 to T3. This duration may be in the range from about 20 to about 200 microseconds.

The duration of interval T0 to T1 depends on the ability of power supply 1201 to supply current sufficient operate device 1200 while charging capacitors C1, C2, and C3. For example, a fresh battery 1201 may shorten the T0 to T1 time interval in comparison to circuit operation with a partially discharged battery. Operation of device 1200 in cold ambient temperature may degrade battery capacity and may also increase the duration of interval T0 to T1.

It is highly desirable to operate electronic disabling devices as discussed above with a predetermined pulse repetition rate as discussed with reference to FIGs. 9 and 10. In one implementation, controller 1214 includes a conventional microprocessor circuit programmed to perform methods according to various aspects of the present invention. According to various aspects of the present invention, controller 1214 provides the activate signal to high voltage power supply 1202 in accordance with a feedback signal to control the duration of digital pulse control intervals (FIG. 10) and consequently cycle durations (TA and TB of FIG. 10). Digital pulse control intervals correspond to interval T3 to T4 discussed above.

For example, controller 1214 of FIG. 12 includes microprocessor 1224 and feedback signal conditioning circuit 1222. Microprocessor 1224 receives a feedback signal from high voltage power supply 1202 via feedback signal conditioning circuit 1222. Feedback signal conditioning circuit provides to microprocessor 1224 a status signal in response to the feedback signal. Microprocessor 1224 detects when time T3 has been

reached as illustrated in FIGs. 4, 7, 8, 9, 10, 17 and 18. Since the commencement time T0 of the operating cycle is known, the microprocessor will maintain the high voltage power supply in a shut down or disabled operating mode from time T3 until a time sufficient to implement the preset pulse repetition rate (e.g., interval T3 to T4). While the duration of interval T3 to T4 may vary to compensate for other intervals, the microprocessor maintains the T0 to T4 time interval to accomplish the preset pulse repetition rate.

The FIG. 19 table entitled "Gap On/Off Timing" represents a simplified summary of the configuration of GAP1 and GAP2 during the four relevant operating time intervals. The configuration "off" represents the high impedance, non-ionized spark gap state while the configuration "on" represents the ionized state where the spark gap breakdown voltage has been reached.

In an alternate device implementation, the voltages within the device are reduced to facilitate the design of a compact electronic disabling device using conventional insulating materials. For example, an implementation may use a voltage multiplier having dual outputs each providing half the output voltage. The voltage across electrodes E1 and E2 may then be the sum of the dual output voltages. For example, voltage multiplier circuit 2000 of FIG. 20 includes transformer 1008 having a single primary winding and a center-tapped or two separate secondary windings. The step up ratio from the primary winding to each secondary winding is 1 to 12.5. Transformer 1208 still accomplishes the objective of achieving a 25 to 1 step-up ratio for generating an output signal of about 50,000 volts from about a 2,000 volt power supply. One advantage of this double secondary transformer configuration is that the maximum voltage applied to each secondary winding is reduced by 50% in comparison to designs using one secondary winding. Such reduced secondary winding operating potentials may be desired to achieve a higher output voltage with a given amount of transformer insulation or for placing less high voltage stress on the elements of the output transformer.

Substantial and impressive benefits may be achieved by using an electronic disabling device according to various aspects of the present invention in comparison to conventional stun guns represented by the Taser M26 stun gun as discussed above. For example, the M26 stun gun utilizes a single energy storage capacitor of about 0.88 microfarads. When charged to 2,000 volts, that capacitor stores and subsequently discharges about 1.76 joules of energy during each output pulse. For a standard pulse repetition rate of 15 pulses per second and 1.76 joules per pulse, the M26 stun gun requires about 35 watts of

input power which, as explained above, must be provided by a large, relatively heavy battery power supply utilizing 8 series-connected AA alkaline battery cells.

An electronic disabling device according to various aspects of the present invention may use capacitors having capacitance as follows: C1 about 0.07 microfarads and
5 C2 about 0.01 microfarads. The sum of capacitance for C1 and C2 is about 0.08 microfarads. An electronic disabling device 200 using these values for C1 and C2 provides each output pulse from about 0.16 joules of energy stored on these capacitors. With a pulse repetition rate of about 15 pulses per second, these two capacitors consume battery power of about 2.4 watts at the capacitors and roughly 3.5 to 4 watts at the battery. As a result, the battery may
10 be a single AA size battery. This electronic disabling device achieves a 90% reduction in power consumption compared to the M26 stun gun, discussed above.

An electronic disabling device according to various aspects of the present invention generates a time-sequenced, shaped, voltage output waveform as illustrated in FIGs. 3 and 4. The output waveform accommodates two different load configurations
15 presented: a relatively high voltage output operating mode during the high impedance T1 to T2 first operating interval and, a relatively low voltage output operating mode during the low impedance second T2 to T3 operating interval.

As an additional benefit, the circuit elements operate at lower power levels and lower voltage levels resulting in more reliable circuit operation. Further, such electronic
20 disabling devices may be packaged in a much more physically compact design. In a laboratory prototype embodiment of a stun gun according to various aspects of the present invention, the prototype size in comparison to the size of an M26 stun gun is reduced by approximately 50% and the weight is reduced by approximately 60%.

According to other aspects of the present invention, battery capacity is
25 predicted by the controller. Further, a readout of battery capacity may be provided to the user. In most electronic devices the remaining battery capacity can be predicted either by measuring the battery voltage during operation or integrating the battery discharge current over time. Due to the several modes of operation discussed above, prior art battery management methods yield unreliable results. Since ambient temperature strongly affects
30 battery capacity and operation of electronic disabling devices is desired in a wide range of ambient temperatures, non-temperature compensated prior art battery capacity prediction methods produce even less reliable results.

The battery power consumption of an electronic disabling device (e.g., per FIGs. 21-25) according to various aspects of the present invention varies with operating mode as follows. In one implementation, the device includes a real time clock, a laser, and a flashlight in addition to elements discussed above. The real time clock may draw about 3.5 microamps. If the system safety switch S1 is armed, the now-activated the microprocessor and its clock may draw about 4 milliamps. If enabled, and if the safety switch is armed, the laser target designator may draw about 11 milliamps. If enabled, and if the safety switch is armed, the forward facing low intensity twin white LED flashlight may draw about 63 milliamps. If the safety switch is armed and the trigger switch S2 is pulled, the device will draw from about 3 to about 4 amps. Therefore, the minimum to maximum current drain will vary in a ratio of about 1,000,000 to 1.

To further complicate matters, the capacity of lithium batteries packaged in the system battery module may vary greatly over the operating temperature range. At -20°C, the battery module may deliver about 100 5-second discharge cycles. At +30°C, the battery module may deliver about 350 5-second discharge cycles.

From the warmest to the coldest operating temperature range and from the lowest to the highest battery drain functions, battery life varies from about 5,000,000 to 1.

A battery capacity assessment system according to various aspects of the present invention predicts the remaining battery capacity based on laboratory measurements of critical battery parameters under different loads and at different temperature conditions. These measured battery capacity parameters are stored electronically as a table (e.g., columns 1 and 2 of FIG. 25) in an electronic non-volatile memory device included with each battery module. (FIG. 22) As illustrated in FIGs. 21 and 22, appropriate data interface contacts enable the microprocessor to communicate with the table electronically stored in the battery module 2200 to predict remaining capacity of the battery (2202 and 2204). The battery module 2200 with internal electronic non-volatile memory may be referred to as the Digital Power Magazine (DPM) or simply as the system battery module.

The data required to construct the data tables for the battery module were collected by operating the electronic disabling device at selected temperatures while recording the battery performance and longevity at each temperature interval.

The resulting battery capacity measurements were collected and organized into a tabular spreadsheet of the type illustrated in FIG. 25. The battery drain parameters for each system feature were calculated and translated into standardized drain values in

microamp-hours (μAH) based on the sensible operating condition of that feature. For example, the battery drain required to keep the clock alive is represented by a number in μAH that totals the current required to keep the clock alive for about 24 hours. The battery drain to power up the microprocessor, the forward directed flashlight, and the laser target designator for one second are represented by separate table entries with values in μAH . The battery drain required to operate the gun in the firing mode is represented by numbers in μAH of battery drain required to fire a single power output pulse.

To enable operation at all desired temperatures, while keeping track of battery drain and remaining battery capacity, the total available battery capacity at each incremental temperature was measured. The battery capacity in μAH at 25°C (ambient) was programmed into the table to represent a normalized one hundred percent battery capacity value. The battery table drain numbers at other temperatures were adjusted to coordinate with the 25°C total (one hundred percent) battery capacity number. For example, since the total battery capacity at -20°C was measured to approximate 35% of the battery capacity at 25°C , the μAH numbers at -20°C were multiplied by $1/0.35$.

An additional location in the memory for the table discussed above (not shown in FIG. 25) is used by the microprocessor to keep track of used battery capacity. This number (i.e., used battery capacity) is updated about every one second if the safety selector remains in the "armed" position, and about every twenty-four hours if the safety selector remains in the "safe" position. Remaining battery capacity percentage is calculated by dividing this number by the total battery capacity. The device displays this percent of battery capacity remaining on a two digit Central Information Display (CID) for two seconds each time the device is armed.

In the discussion that follows, device 2300 is referred to as the model X26.

Figure 22 illustrates the electronic circuit located inside the X26 battery module. As illustrated in the FIG. 22 schematic diagram, the removable battery module consists of two series-connected, 3-volt CR123 lithium batteries and a nonvolatile memory device. The nonvolatile memory device may take the form of a 24AA128 flash memory which contains 128K bits of data storage. As shown in FIGs. 21 and 22, the electrical and data interface between the X26 system microprocessor and battery module is established by a 6-pin jack JP1 and provides a 2-line I^2C serial bus for data transmission purposes.

While the battery capacity monitoring apparatus and methodology has been described in connection with monitoring the remaining capacity of a battery energized power

supply for a stun gun, this inventive feature could readily be applied to any battery powered electronic device which includes a microprocessor, such as cell phones, video camcorders, laptop computers, digital cameras, and PDA's. Each of these categories of electronic devices frequently shift among various different operating modes where each operating mode
5 consumes a different level of battery power. For example, a cell phone selectively operates in the following different power consumption modes: (1) power off/microprocessor clock on; (2) power on, standby/receive mode; (3) receiving an incoming telephone call and amplifying the received audio input signal; (4) transmit mode generating an RF power output of about 600 milliwatts; (5) ring signal activated in response to an incoming call; and (6) backlight on.

10 To implement the present invention in a cell phone embodiment, a battery module analogous to that illustrated in the FIG. 22 electrical schematic diagram would be provided. That module would include a memory storage device such as the element designated by reference number U1 in the FIG. 22 schematic diagram to receive and store a battery consumption table of the type discussed above with reference to FIG. 25. The cell
15 phone microprocessor can then be programmed to read out and display either at power up or in response to a user-selectable request the battery capacity remaining within the battery module or the percent of used capacity.

Similar analysis and benefits apply to the application of the battery capacity monitor of the present invention to other applications such as a laptop computer which
20 selectively switches between the following different battery power consumption modes: (1) CPU on, but operating in a standby power conservation mode; (2) CPU operating in a normal mode with the hard drive in the "on" configuration; (3) CPU operating in a normal mode with the hard drive in the "off" configuration; (4) CPU "on" and LCD screen also in the "on" fully illuminated mode; (5) CPU operating normally with the LCD screen switched into the "off"
25 power conservation configuration; (6) modem on/modem off modes; (7) optical drives such as DVD or CD ROM drives operating in the playback mode; (8) optical drives such as DVD or CD ROM drives operating in the record or write mode; and (9) laptop audio system generating an audible output as opposed to operating without an audio output signal.

In each of the cases addressed above, the battery capacity table would be
30 calibrated for each different power consumption mode based on the power consumption of each individual operating element. Battery capacity would also be quantified for a specified number of different ambient temperature operating ranges.

Tracking the time remaining on the manufacturer's warranty as well as updating and extending the expiration date may be implemented according to various aspects of the present invention. An X26 system embodiment of the present invention is shipped from the factory with an internal battery module (DPM) having sufficient battery capacity to energize the internal clock for much longer than 10 years. The internal clock is set at the factory to Greenwich Mean Time (GMT). The internal X26 system electronic warranty tracker begins to count down the factory preset warranty period or duration beginning with the first trigger pull occurring about 24 hours or more after the X26 system has been packaged for shipment by the factory.

Whenever the battery module is removed from the X26 system and replaced one or more seconds later, the X26 system will implement an initialization procedure. During that procedure, the 2-digit LED Central Information Display (CID), sequentially reads out a series of 2-digit numbers which represent the following data: (1) The first 3 sets of 2-digit numbers represent the warranty expiration date in the format YY/MM/DD; (2) The current date is displayed: YY/MM/DD; (3) The internal temperature in degrees Centigrade is displayed: XX (negative numbers are represented by blinking the number); and (4) The software revision is displayed: XX.

The system warranty can be extended by communication via the Internet or by purchase of a replacement battery module. The X26 system includes a USB data interface module accessory which is physically compatible with the shape of the X26 system receptacle for battery module 12. The USB data module can be inserted within the X26 system battery module receptacle and includes a set of electrical contacts compatible with jack JP1 located inside the X26 system battery module housing. The USB interface module may be electrically connected to a computer USB port which supplies power via jack JP1 to the X26 system. While the USB interface is normally used to download firing data from the X26 system, it can also be used to extend the warranty period or to download new software into the X26 microprocessor system. To update the warranty, the user removes the X26 battery module, inserts the USB module, connects a USB cable to an Internet enabled computer, goes to the www.Taser.com website, follows the download X26 system warranty extension instructions, and pays for the desired extended warranty period by credit card.

Alternatively, the system warranty can also be extended by purchasing from the factory a specially programmed battery module having the software and data required to reprogram the warranty expiration data stored in the X26 microprocessor. The warranty

extension battery module is inserted into the X26 system battery receptacle. If the X26 system warranty period has not yet expired, the data transferred to the X26 microprocessor will extend the current warranty expiration date by the period pre-programmed into the extended warranty battery module. Once the extended warranty expiration date has been stored within the X26 system, the microprocessor will initiate a battery insertion initialization sequence and will then display the new warranty expiration date. Various different warranty extension modules can be provided to either extend the warranty of only a single X26 system or to provide warranty extensions for multiple system as might be required to extend the warranty for X26 systems used by an entire police department. If the warranty extension module contains only one warranty extension, the X26 microprocessor will reset the warranty update data in the module to zero. The module can function either before or after the warranty extension operation as a standard battery module. An X26 system may be programmed to accept one warranty extension, for example a one year extension, each time that the warranty extension module is inserted into the weapon.

The warranty configuration/warranty extension feature of the present invention could also readily be adapted for use with any microprocessor-based electronic device or system having a removable battery. For example, as applied to a cell phone having a removable battery module, a circuit similar to that illustrated in the FIG. 22 electrical schematic diagram could be provided in the cell phone battery module to interface with the cellular phone microprocessor system. As was the case with the X26 system of the present invention, the cell phone would be originally programmed at the factory to reflect a device warranty of predetermined duration at the initial time that the cell phone was powered up by the ultimate user/customer. By purchasing a specially configured cell phone replacement battery including data suitable for reprogramming the warranty expiration date within the cell phone microprocessor, a customer could readily replace the cell phone battery while simultaneously updating the system warranty.

Alternatively, a purchaser of an electronic device incorporating the warranty extension feature of the present invention could return to a retail outlet, such as Best Buy or Circuit City, purchase a warranty extension and have the on-board system warranty extended by a representative at that retail vendor. This warranty extension could be implemented by temporarily inserting a master battery module incorporating a specified number of warranty extensions purchased by the retail vendor from the OEM manufacturer. Alternatively, the retail vendor could attach a USB interface module to the customer's cell phone and either

provide a warranty extension directly from the vendor's computer system or by means of data supplied by the OEM manufacturer's website.

For electronic devices utilizing rechargeable battery power supplies such as is the case with cell phones and video camcorders, battery depletion occurs less frequently than with the system described above which typically utilizes non-rechargeable battery modules. For such rechargeable battery applications, the end user/customer could purchase a replacement rechargeable battery module including warranty update data and could simultaneously trade in the customer's original rechargeable battery.

For an even broader application of the warranty extension feature of the present invention, that feature could be provided to extend the warranty of other devices such as desktop computer systems, computer monitors or even an automobile. For such applications, either the OEM manufacturer or a retail vendor could supply to the customer's desktop computer, monitor or automobile with appropriate warranty extension data in exchange for an appropriate fee. Such data could be provided to the warranted product via direct interface with the customer's product by means of an infrared data communication port, by a hard-wired USB data link, by an IEEE 1394 data interface port, by a wireless protocol such as Bluetooth or by any other means of exchanging warranty extension data between a product and a source of warranty extension data.

Another benefit of providing an "intelligent" battery module is that the X26 system can be supplied with firmware updates by the battery module. When a battery module with new firmware is inserted into the X26 system, the X26 system microcontroller will read several identification bytes of data from the battery module. After reading the software configuration and hardware compatibility table bytes of the new program stored in the nonvolatile memory within the battery module to evaluate hardware/software compatibility and software version number, a system software update will take place when appropriate. The system firmware update process is implemented by having the microprocessor (see FIG. 21) in the X26 system read the bytes in the battery module memory program section and programming the appropriate software into the X26 system nonvolatile program memory.

The X26 system can also receive program updates through a USB interface module by connecting the USB module to a computer to download the new program to a nonvolatile memory provided within the USB module. The USB module is next inserted into the X26 system battery receptacle. The X26 system will recognize the USB module as

providing a USB reprogramming function and will implement the same sequence as described above in connection with X26 system reprogramming via battery module.

The High Voltage Assembly (HVA) schematically illustrated in FIGS. 23 and 24 provides an output of about 50,000 from an input of from about 3 to about 6 volts. To provide maximum safety, to avoid false triggering, and to minimize the risk that the X26 system could activate or stay activated if the microprocessor malfunctions or locks up, the ENABLE signal from the microprocessor (FIG. 22) to the HVA (FIGs. 23A and 23B(or 24)) has been specially encoded.

To enable the HVA, the microprocessor must output a 500 Hz square wave with an amplitude of from about 2.5 to about 6 volts and a duty cycle of about 50%. The D6 series diode within the HVA power supply "rectifies" the ENABLE signal and uses it to charge up capacitor C6. The voltage across capacitor C6 is used to run pulse width modulation (PWM) controller U1 in the HVA.

If the ENABLE signal goes low for more than about one millisecond, several functions operate to turn the PWM controller off. The voltage across capacitor C6 will drop to a level where the PWM can no longer run causing the HVA to turn off. The input to the U1 "RUN" pin must be above a threshold level. The voltage level at that point represents a time average of the ENABLE waveform (due to R1 and C7). If the ENABLE signal goes low, capacitor C7 will discharge and disable the controller after about 1 millisecond.

As the ENABLE signal goes high, resistor R3 charges capacitor C8. If the charge level on C8 goes above about 1.23 volts, the PWM will shut down -- stopping delivery of 50,000 volt output pulses. Every time the ENABLE signal goes low, capacitor C8 is discharged, making sure the PWM can stay "on" as the ENABLE signal goes back high and starts charging C8 again. Any time the ENABLE signal remains high for more than about 1 millisecond, the PWM controller will be shut down.

The encoded ENABLE signal requirements dictate that the ENABLE signal must be pulsed at a frequency of about 500 Hz to activate the HVA. If the ENABLE signal sticks at a high or low level, the PWM controller will shut down, stopping the delivery of the 50,000 volt output pulses.

The configuration of the X26 system high voltage output circuit represents a key distinction between the X26 system and conventional prior art stun guns. Referring now to FIGS. 23A and B, the structure and function of the X26 system high voltage "shaped pulse" assembly will be explained. The switch mode power supply will charge up capacitors

C1, C2, and C3 through diodes D1, D2, and D3. Note that diodes D1 and D2 can be connected to the same or to different windings of 2301 (T1) to modify the output waveform. The ratios of the T1 primary and secondary windings and the spark gap voltages on GAP1, GAP2, and GAP3 are configured so that GAP1 will always breakdown and fire first. When
5 GAP1 fires, 2,000 volts is applied across the primary windings of spark coil transformer 2305 (T2) from pin 6 to pin 5. The secondary voltage on spark coil transformer T2 from pins 1 to 2 and from pins 3 to 4 will approximate 25,000 volts, depending on the air gap spacing between the two output electrodes E1 and E2. The smaller the air gap, the smaller the output voltage before the air gap across output terminals E1 to E2 breaks down, effectively clamping
10 the output voltage level.

The voltage induced in the secondary current path by the discharge of C1 through GAP1 and T2 sets up a voltage across C2, GAP2, E1 to E2, GAP3, C3 and C1. When the cumulative voltage across the air gaps (GAP2, E1 to E2, and GAP3) is high enough to cause them to break down, current will start flowing in the circuit, from C2 through GAP2,
15 through the output electrodes E1 to E2, through GAP3, and through C3 in series with C1 back to ground. As long as C1 is driving the output current through GAP1 and T2, the output current as described will remain negative in polarity. As a result, the charge level stored in both C2 and C3 will increase. Once C1 has become somewhat discharged, T1 will not be able to maintain the output voltage across the output windings (from pin 1 to pin 2, and from
20 pin 3 to pin 4). At that time, the output current will reverse and begin flowing in a positive direction and will begin depleting the charge on C2 and C3. The discharge of C1 is known as the "arc" phase. The discharge of C2 and C3 is known as the muscle "stimulation" phase.

Since the high voltage output coil T2 as illustrated in FIG. 24 consists of two separate secondary windings that create a negative polarity spark voltage on E1 followed by a
25 positive polarity spark voltage on E2, the peak voltage measured from either electrode E1 or E2 to primary weapon ground will not exceed about 25,000 volts yet the peak voltage measured across power supply output terminals E1 and E2 will reach about 50,000 volts. If the output coil T2 had utilized only a single secondary winding as is the case with all prior art stun guns and in other embodiments of the present invention, the maximum voltage from one
30 output electrode (E1 or E2) referenced to primary weapon ground would reach about 50,000 volts. Since a 25,000 volt output can establish an arc across a gap less than half the size of a gap that can establish an arc with a 50,000 volt, reducing the peak output terminal to ground voltage by 50% from about 50,000 volts to about 25,000 volts reduces by more than a 2 to 1

ratio the risk that the user of this version of the X26 system will be shocked by the high voltage output pulses. This represents a significant safety enhancement for a handheld stun gun weapon.

Referring now to the FIG. 23 and 24 schematic diagrams, a feedback signal from the primary side of the HVA (at T1) provides a mechanism for the FIG. 21 microprocessor to indirectly determine the voltage on capacitor C1, and hence where the X26 system power supply is operating within its pulse firing sequence. This feedback signal is used by the microprocessor to control the output pulse repetition rate.

The system pulse rate may be controlled to create either a constant or a time-varying pulse rate by having the microcontroller stop toggling the ENABLE signal for short time periods, thereby holding back the pulse rate to reach a preset, lower value. The preset values may be changed based on the length of the pulse train. For example, in a police model, the system may be preprogrammed such that a single trigger pull will produce a 5-second long power supply activation period. For the first 2 seconds of that 5-second period, the microprocessor may be programmed to control (pull back) the pulse rate to about 19 pulses per second (PPS), while for the last 3 seconds of the 5-second period, the pulse rate could be programmed to be reduced to about 15 PPS. If the operator continues to hold the trigger down, after the 5-second period has lapsed, the X26 system may be programmed to continue discharging at 15 PPS for as long as the trigger is held down. The X26 system could alternatively be programmed to produce various different pulse repetition rate configurations such as, for example:

0-2 seconds	:	17 PPS,
2-5 seconds	:	12 PPS,
5-6 seconds	:	0.1 PPS,
6-12 seconds	:	11 PPS,
12-13 seconds	:	0.1 PPS,
13-18 seconds	:	10 PPS,
18-19 seconds	:	0.1 PPS,
18-23 seconds	:	9 PPS.

Such alternative pulse repetition rate configurations could be applied to a civilian version of the X26 system where longer activation periods are desirable. In addition, lowering the pulse rate will reduce battery power consumption, extend battery life, and potentially enhance the medical safety factor.

To explain the operation of the X26 system illustrated in FIGS. 21-24 in more detail, the operating cycle of the HVA can be divided into the following 4 time periods as illustrated in FIG. 26. In a first period from T0 to T1, capacitors C1, C2 and C3 are charged by one, two, or three power supplies to the breakdown voltage of spark gap GAP1. In a second period from T1 to T2, GAP1 has switched ON, allowing C1 to pass a current through the primary winding of the high voltage spark transformer T2 which causes the secondary voltage (across E1 to E2) to increase rapidly. At a certain point, the high output voltage caused by the discharge of C1 through the primary transformer winding will cause voltage breakdown across GAP2, across E1 to E2, and across GAP3. This voltage breakdown completes the secondary circuit current path, allowing output current to flow. During the T1 to T2 time interval, capacitor C1 is still passing current through the primary winding of the spark transformer T2. As C1 is discharging, it drives a charging current into both C2 and C3. In a third period from T2 to T3, capacitor C1 is now mostly discharged. The load current is being supplied by C2 and C3. The magnitude of the output current during the T2 to T3 time interval will be much lower than the much higher output current produced by the discharge of C1 through spark transformer T2 during the initial T1 to T2 current output time interval. The duration of this significantly reduced magnitude output current during time interval T2 to T3 may readily be tuned by appropriate component parameter adjustments to achieve the desired muscle response from the target subject. During the time period T0 through T3, the microprocessor measured the time required to generate a single shaped waveform output pulse. The desired pulse repetition rate was pre-programmed into the microprocessor. During the T3 to T4 time interval, the microprocessor will temporarily shut down the power supply for a period required to achieve the preset pulse repetition rate. Because the microprocessor is inserting a variable length T3 to T4 shut-off period, the system pulse repetition rate will remain constant independent of battery voltage and circuit component variations (tolerance). The microprocessor-controlled pulse rate methodology allows the pulse rate to be software controlled to meet different customer requirements.

The FIG. 10 timing diagram shows an initial fixed timing cycle TA followed by a subsequent, longer duration timing cycle TB. The shorter timing cycle followed by the longer timing cycle reflects a reduction in the pulse rate. Hence, it is understood that the X26 system can vary the pulse rate digitally during a fixed duration operating cycle. As an example, a pulse rate of about 19 PPS may be achieved for about 2 seconds of initial

operation and then reduced to about 15 PPS for about 3 seconds, further reduced to about 0.1 PPS for about 1 second, and then increased to about 14 PPS for about 5 seconds.

The implementations illustrated in FIGs. 23A and 23B utilizes three spark gaps. Only GAP1 requires a precise breakdown voltage rating, in this case about 2,000 volts.

5 GAP2 and GAP3 only require a breakdown voltage rating significantly higher than the voltage stress induced on them during the time interval before GAP1 breaks down. GAP2 and GAP3 have been provided solely to ensure that if a significant target skin resistance is encountered during the initial current discharge into the target that the muscle activation capacitors C2 and C3 will not discharge before GAP1 breaks down. To perform this
10 optional, enhanced function, only one of these secondary spark gaps (either GAP2 or GAP3) need be provided.

FIG. 24 illustrates a high voltage section with significantly improved efficiency. Instead of rectifying the T1 high voltage transformer outputs through diodes directly to very high voltages, as is the case with the FIG. 23B circuit, transformer T1 has
15 been reconfigured to provide 3 series-connected secondary windings where the design output voltage of each winding has been limited to about 1,000 volts.

In the FIG. 23B circuit, capacitor C1 is charged to about 2,000 volts by transformer winding and diode D1. In the FIG. 24 circuit, C1 is charged by combining the voltages across C5 and C6. Each T1 transformer winding coupled to charge C5 and C6 is
20 designed to charge each capacitor to about 1,000 volts, rather than to 2,000 volts as in the FIG. 23B circuit.

Since the losses due to parasitic circuit capacitances are a function of the transformer AC output voltage squared, the losses due to parasitic circuit capacitances with the FIG. 24 1,000 volt output voltage compared to the FIG. 23B 2,000 volt transformer
25 output voltage are reduced by a factor of 4. Furthermore, in the FIG. 24 embodiment, the current required to charge C2 is derived in part from capacitor C6, the positive side of which is charged to about 2,000 volts. Hence, to charge C2 to about 3,000 volts, the voltage across the transformer winding is reduced to about 1,000 volts in comparison to the 3,000 volts produced across the corresponding transformer T1 winding in the FIG. 23B circuit.

30 Another benefit of the novel FIG. 23B and FIG. 24 circuit designs relates to the interaction of C1 to C3. Just before GAP1 breaks down, the charge on C1 is about 2,000 volts while the charge on C3 is about 3,000 volts. After C1 has discharged and the output current is being supported by C2 and C3, the voltage across C3 remains at about 3,000 volts.

However, since the positive side of C3 is now at ground level, the negative terminal of C3 will be at about -3,000 volts. Hence a differential voltage of about 6,000 volts has been created between the positive terminal of C2 and the negative terminal of C3. During the time interval when C2 and C3 discharge after C1 has been discharged, the T2 output windings
5 merely act as conductors.

The X26 system trigger position is read by the microprocessor which may be programmed to extend the duration of the operating cycle in response to additional trigger pulls. Each time the trigger is pulled, the microprocessor senses that event and activates a fixed time period operating cycle. After the gun has been activated, the Central Information
10 Display (CID) on the back of the X26 handle indicates how much longer the X26 system will remain activated. The X26 system activation period may be preset to yield a fixed operating time, for example, about 5 seconds. Alternatively, the activation period may be programmed to be extended in increments in response to additional, sequential trigger pulls. Each time the trigger is pulled, the CID readout will update the countdown timer to the new, longer timeout.
15 The incrementing trigger feature will allow a civilian who uses the X26 system on an aggressive attacker to initiate multiple trigger pulls to activate the gun for a prolonged period, enabling the user to lay the gun down on the ground and get away.

To protect police officers against allegations of stun gun misuse, the X26 system may provide an internal non-volatile memory set aside for logging the time, duration
20 of discharge, internal temperature and battery level each time the weapon is fired.

The stun gun clock time always remains set to GMT. When downloading system data to a computer using the USB interface module, a translation from GMT to local time may be provided. On the displayed data log, both GMT and local time may be shown. Whenever the system clock is reset or reprogrammed, a separate entry may be made in the
25 system log to record such changes.

It will be apparent to those skilled in the art that the disclosed electronic disabling device may be modified in numerous ways and may assume many embodiments other than the preferred forms specifically set out and described above. Accordingly, it is intended by the appended claims to cover all such modifications of the invention which fall
30 within the true spirit and scope of the invention.

CLAIMS:

1. A device for disabling a target comprising:

means for providing from a first stored energy device a first signal to the target to

5 ionize air in a gap at the target; and

means for providing from a second stored energy device a second signal to the target to continue a current through the gap and through the target.

2. The device of claim 1 further comprising a step-up transformer comprising a primary winding and a secondary winding; wherein:

10 a current through the target comprises the first signal and the second signal, the current producing contractions in skeletal muscles of the target to impede locomotion by the target;

the first stored energy device discharges through the primary winding to provide energy for the current for ionizing air in the gap; and

15 the second stored energy device discharges through the secondary winding to provide energy for the current through the target.

3. The device of claim 2 wherein the first stored energy device comprises a first capacitance and the second stored energy device comprises a second capacitance.

4. The device of claim 3 further comprising a switch, in series between the second capacitance and the secondary winding, that operates to discharge the second capacitance.

5. The device of claim 4 wherein the switch operates in response to discharging of the first capacitance through the primary winding.

6. The device of claim 4 wherein the switch operates in response to a voltage of the secondary winding.

25 7. The device of claim 3 further comprising a first spark gap in series between the second capacitance and the secondary winding that conducts to discharge the second capacitance.

8. The device of claim 3 further comprising a voltage activated switch, in series between the second capacitance and the secondary winding, that operates to discharge the second capacitance, wherein the activation voltage is greater than a voltage across the second
30 capacitance.

9. The device of claim 1 wherein:

the first stored energy device comprises a first capacitance and the second stored energy device comprises a second capacitance;

5 a current through the target comprises the first signal and the second signal, the current producing contractions in skeletal muscles of the target to impede locomotion by the target;

the device further comprises a first switch that operates to discharge the first capacitance to provide energy for the current; and

10 the device further comprises a second switch that operates to discharge the second capacitance to provide energy for the current; wherein the second capacitance is not substantially discharged without operation of the second switch.

10. The device of claim 9 wherein the second switch operates in response to discharging of the first capacitance.

11. The device of claim 9 wherein the second switch operates in response to a multiplied voltage
15 of the of the first capacitance.

12. The device of claim 9 further comprising a first spark gap that conducts to discharge the second capacitance.

13. The device of claim 9 wherein the second switch further comprises a voltage activated switch, wherein the activation voltage is greater than a voltage across the second capacitance.

20 14. The device of claim 3 or 9 wherein:

the first capacitance discharges for a first period; and

the second capacitance discharges for a second period greater than the first period.

15. The device of claim 10 wherein the first period is about 1.5 microseconds.

16. The device of claim 10 wherein the second period is about 50 microseconds.

25 17. The device of claim 10 wherein a ratio of the second period to the first period is about 33.

18. The device of claim 3 or 9 wherein the first capacitance comprises less than or about 0.14 microfarads.

19. The device of claim 3 or 9 wherein the second capacitance comprises less than or about 0.02 microfarads.

30 20. The device of claim 3 or 9 further comprising:

a first spark gap, having a first breakdown voltage, that operates to discharge the first capacitance; and

a second spark gap, having a second breakdown voltage, that operates to discharge the second capacitance; wherein

5 the second breakdown voltage is greater than the first breakdown voltage.

21. The device of claim 20 wherein the first breakdown voltage is about 2000 volts.

22. The device of claim 20 wherein the second breakdown voltage is about 3000 volts.

23. The device of claim 3 or 9 wherein:

 the first capacitance discharges a first quantity of energy to establish the arc; and

10 the second capacitance discharges a second quantity of energy to impede locomotion by the target, the second quantity being less than the first quantity.

24. The device of claim 23 wherein the first quantity is less than or about 0.28 joules.

25. The device of claim 23 wherein the second quantity is less than or about 0.04 joules.

26. The device of claim 23 wherein a ratio of the first quantity to the second quantity is about 7.

15 27. The device of claim 1 further comprising means for propelling an electrode toward the target, the electrode for conducting the current through the target.

28. A method for disabling a target comprising:

 sourcing at a first voltage a signal to ionize an air gap at the target; and

20 sourcing at a second voltage less in magnitude than the first voltage the signal to continue current flow through the target.

29. The method of claim 24 wherein:

 sourcing at the first voltage comprises discharging a first capacitance to provide energy for ionizing air between an electrode of the weapon and the target; and

25 sourcing at the second voltage comprises, after beginning discharging of the first capacitance, operating a switch for discharging a second capacitance to provide energy for the current through the target, the second capacitance not substantially discharged without operating the switch, the current passing through the target for impeding locomotion by the target.

30 30. The method of claim 29 wherein discharging the first capacitance comprises discharging the first capacitance through a voltage multiplier to provide, at a multiplied voltage, the energy for ionizing air.

31. The method of claim 30 wherein discharging the second capacitance is performed not through the voltage multiplier.
32. The method of claim 30 wherein the voltage multiplier comprises a step-up transformer comprising a primary winding and a secondary winding.
- 5 33. The method of claim 32 wherein discharging the second capacitance comprises discharging the second capacitance through the secondary winding.
34. The method of claim 32 wherein the switch operates in response to a voltage of the secondary winding.
35. The method of claim 32 further comprising conducting the current through a second
10 electrode coupled to a second secondary winding of the transformer.
36. The method of claim 32 wherein:
discharging the first capacitance comprises discharging through a first spark gap in series between the first capacitance and a primary winding of the transformer;
discharging the second capacitance comprises discharging through a second spark gap
15 in series between the second capacitance and a secondary winding of the transformer, the switch comprising the second spark gap; and
the first spark gap has a first breakdown voltage, the second spark gap has a second breakdown voltage greater than the first breakdown voltage.
37. The method of claim 36 wherein the first breakdown voltage is about 2000 volts.
- 20 38. The method of claim 36 wherein the second breakdown voltage is about 3000 volts.
39. The method of claim 32 wherein:
discharging the first capacitance comprises discharging a first quantity of energy through the primary winding;
discharging the second capacitance comprises discharging a second quantity of
25 energy through the secondary winding; and
the second quantity is less than the first quantity.
40. The method of claim 39 wherein the first quantity is less than or about 0.28 joules.
41. The method of claim 39 wherein the second quantity is less than or about 0.04 joules.
42. The method of claim 39 wherein a ratio of the first quantity to the second quantity is about 7.
- 30 43. The method of claim 29 wherein:

the method further comprises charging the second capacitance to provide a voltage across the second capacitance;

discharging the second capacitance comprises discharging through a voltage activated switch; and

5 an activation voltage of the switch is greater than the voltage across the second capacitance.

44. The method of claim 29 further comprising propelling the electrode toward the target.

45. The method of claim 29 further comprising:

charging the first capacitance to provide a third voltage across the first capacitance;

10 and

charging the second capacitance to provide a fourth voltage across the second capacitance different from the third voltage.

46. The method of claim 29 wherein:

discharging the first capacitance comprises discharging for a first period; and

15 discharging the second capacitance comprises discharging for a second period greater than the first period.

47. The method of claim 46 wherein the first period is about 1.5 microseconds.

48. The method of claim 46 wherein the second period is about 50 microseconds.

49. The method of claim 46 wherein a ratio of the second period to the first period is about 33.

20 50. The method of claim 29 wherein discharging the second capacitance comprises discharging through the switch.

51. The method of claim 29 wherein the switch operates in response to discharging the first capacitance.

25 52. The method of claim 29 wherein discharging the second capacitance comprises discharging through a spark gap, the switch comprising the spark gap.

53. The method of claim 29 wherein the first capacitance comprises less than or about 0.14 microfarads.

54. The method of claim 29 wherein the second capacitance comprises less than or about 0.02 microfarads.