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(54) **FIRING ARRANGEMENT**

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Description

FIELD OF THE INVENTION

[0001] This invention relates to a firing arrangement and more particularly, but not exclusively, to a firing arrangement for use with an exploding foil initiator (EFI).

BACKGROUND

[0002] An exploding foil initiator (EFI) is a detonator that may be used to initiate explosives. When a sufficiently large electrical charge is passed through it, a mechanical member termed a flyer or slapper is caused to impact on an explosive charge with sufficient energy to detonate it.

[0003] The firing arrangement used to activate an EFI, or other firing device or detonator, often includes a capacitor in which charge is built up during an arming phase. Safety breaks or switches are usually included to keep the system in a safe state and prevent arming until required on receipt of an arming signal. Following arming, when the EFI is required to be activated, a firing signal is applied to rapidly discharge the capacitor through the EFI.

[0004] An example of a prior art firing arrangement is described in EP 0 616 190 A1.

SUMMARY

[0005] According to a first aspect of the invention, a firing arrangement for an initiator comprises: a capacitor; an arming arrangement for charging the capacitor on receipt of an arming instruction; and a trigger device which, when a trigger condition is achieved indicating sufficient charge on the capacitor, automatically generates a trigger signal to trigger discharge of the capacitor through the initiator to activate the initiator. Thus, by employing a firing arrangement in accordance with the invention, it is not necessary to have a separate externally derived trigger signal as the trigger signal is automatically generated when the trigger condition is achieved. This may allow more consistent operation compared to previous firing arrangements because there is effectively one event from which both the start of the arming phase and the subsequent trigger signal are derived. The operation may be considered as a combined arming/firing phase in contrast to prior firing arrangements in which there is an initial arming phase followed by a separate firing phase which only occurs if and when a firing instruction is given.

[0006] The arming arrangement further includes a sequence validator having a first input, a second input and an output, the sequence validator generating the arming instruction at its output only when a first arming signal is received on the first input followed by a second arming signal being received on the second input. This provides a safety break or condition as it requires two arming sig-

nals to be received in the correct sequence for the arming instruction to be generated.

[0007] In an embodiment in accordance with the invention, one or more safety breaks may thus be used to maintain the firing arrangement in a safe state up until the initiator is required to be activated and during the safe state the capacitor is uncharged. This is particularly advantageous for systems that have a long operational life during which the firing arrangement must be ready to fire at short notice. In one embodiment, it is possible to readily achieve arming and firing within 1ms of the arming instruction being received.

[0008] There are advantages for both safety of the firing arrangement and also reliability of the high voltage circuit in which the capacitor is included as the firing arrangement spends almost all of its operational life in the dormant, unpowered state. Furthermore, the firing arrangement can be immediately returned to the safe state if any safety breaks are removed as no charge is accumulated in the capacitor prior to the arming instruction being received. In contrast, a typical previous arrangement is in an unsafe state from the start of the arming phase until and if activation is required.

[0009] A firing arrangement in accordance with the invention also may have the advantage of an extremely consistent activation time, independent of temperature variation.

[0010] In one embodiment, the trigger condition is a predetermined time from when charging the capacitor begins, this providing predictability of operation.

[0011] In one embodiment, a pulse counter is included to count a series of pulses to determine when the predetermined time is reached. Once a fixed number of pulses have been counted, a trigger signal may be automatically generated to discharge the capacitor into the initiator. Other approaches for determining the predetermined time may be used instead.

[0012] In another embodiment, the trigger condition is when the voltage across the capacitor reaches a threshold value. This gives a direct measure of when sufficient charge has been accumulated to reliably activate the initiator and, in addition, also tends to provide a predictable time of activation as the capacitor charges at a known rate.

[0013] The arrangement may be such, for example by using a latch-based sequence validator, that the first and second arming signals must continue to be present at the first and second outputs in order for the arming instruction to continue. If for any reason one or both of the arming signals is removed, the arming instruction also ceases to appear at the sequence validator output and the arming process is stopped.

[0014] In one embodiment, a first static switch and a second static switch may be included, each of which, in an open state, interrupts the firing arrangement such that arming is not possible and, in a closed state, completes part of the firing arrangement, the first static switch and the second static switch being connected to close on re-

ceipt of the first and second arming signal respectively. They thus act as safety breaks within the arrangement. An arming signal may thus perform a dual function in both generating the arming instruction and also readying the firing arrangement for arming and firing. It allows a safety break to be used without requiring an additional separate signal for operation of the safety break to be generated or applied.

[0015] One embodiment includes a low voltage capacitor arrangement, a dynamic switch and a transformer, the dynamic switch being operative during arming to discharge the low voltage capacitor arrangement via a transformer to charge the capacitor. The use of a low voltage capacitor arrangement enables extremely high local peak current to be achieved through the transformer with subsequent rapid charging of the capacitor. The dynamic switch may in one embodiment have a frequency of operation of between about 100kHz and 1MHz but it could be operated outside this range.

[0016] One embodiment includes a dynamic pulse generator connected to receive the arming instruction and to output a series of pulses to operate the dynamic switch when the arming instruction is received. If a pulse counter is included, the pulse counter may be connected to receive the series of pulses from the dynamic pulse generator.

[0017] According to a second aspect of the invention, a firing system comprises a firing arrangement in accordance with the first aspect and an initiator. The initiator may be one of an Exploding Foil Initiator (EFI), a Pyrotechnic Ignitor, a Bridge Wire (BW), a Film Bridge (FB), a Conducting Composition (CC), a Semiconductor Bridge (SCB) or Semiconductor Initiator (SCI) or some other device operating on similar principles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Some embodiments of the present invention will now be described by of example only, and with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates a firing arrangement in accordance with the invention;

Figure 2 is a schematic timing diagram relating to the operation of the firing arrangement shown in Figure 1; and

Figure 3 schematically illustrates operation of a prior art firing arrangement and the firing arrangement of Figure 1.

DETAILED DESCRIPTION

[0019] With reference to Figure 1, a firing arrangement for activating an initiator, which in this case is an EFI detonator 1, includes power supply lines 2 and 3 and a low voltage capacitor bank 4 connected across them. To activate the EFI detonator 1, a first arming signal is applied to a first input 5 of a sequence validator 6 and a

second arming signal is applied to a second input 7 of the sequence validator 6. The sequence validator is latched to only generate an arming instruction at 8 when an arming signal is received at both the first and second inputs and in the correct order. If the arming signal on the second input 7 arrives before or simultaneously with that on the first input 5 then no arming instruction signal is generated. Figure 2 shows the first and second arming signals at 2(a) and 2(b) respectively when they arrive in the correct sequence at the validator 6.

[0020] The first arming signal is also applied to a first static FET switch 9 to close it and complete that part of the circuit. Similarly, the second arming signal is also applied to a second FET switch 10 to complete another part of the circuit. In the absence of an arming signal, the relevant static FET switch remains open, providing a safety break in the circuit and preventing the EFI detonator 1 from being activated.

[0021] The arming instruction from the sequence validator 6 is applied to a dynamic pulse generator 11. On receipt of the arming instruction, the dynamic pulse generator 11 starts to produce a series of pulses, shown at Figure 2 (c) and continues to generate pulses providing the arming instruction is present at the sequence validator output 8. The series of pulses is applied to a dynamic FET switch 12 and also to a pulse counter 13. The dynamic FET switch 12 repeatedly opens and closes in response to the received pulses. This causes the low voltage capacitor bank 4 to discharge via the primary winding of a transformer 14 at a frequency set by the pulse frequency with a typical frequency of operation of between 100kHz and 1MHz. The secondary winding of the transformer 14 is connected via a rectifier 15 across a high voltage capacitor 16 such that the charge on the high voltage capacitor 16 builds as shown in Figure 2(d). The use of low voltage storage capacitors of capacitor bank 4 enable extremely high local peak current to be achieved through the transformer 14 and subsequent rapid charging of the high voltage capacitor 16. The low voltage capacitor bank capacitance is in the order of a few thousand micro-Farads (or a few milli-Farads) and the peak current delivered during charging is in the order of a few hundred amps. The dynamic pulse generator 11, dynamic FET switch 12 and transformer 14 can be considered to form a high voltage converter circuit which may operate in a high frequency mode, tuned for efficient conversion through the high voltage transformer 14.

[0022] If either or both of the first and second arming signals are removed, the sequence validator 6 ceases to provide an arming instruction to the dynamic pulse generator 11 which no longer generates pulses and the arming procedure is thus halted.

[0023] The pulse counter 13 counts the number of pulses generated by the dynamic pulse generator 11. When a pre-determined number of pulses has been counted by the pulse counter 13, a trigger condition is reached. The trigger condition thus represents a fixed time period from when the arming instruction is received by the dy-

dynamic pulse generator 11. It also is indicative of the number of times the dynamic FET switch 12 has operated and thus the amount of charge discharged through the primary winding of the transformer 14 and accumulated at the high voltage capacitor 16. When the trigger condition is reached, the pulse counter 13 generates a trigger signal shown at Figure 2(e). The trigger signal is applied to a trigger circuit 17 which in response closes a switch 18, causing the high voltage capacitor 16 to be discharged through the EFI detonator 1 to activate it, as shown at Figure 2(e). The trigger signal is thus generated automatically after a predetermined time from receipt of the arming instruction and requires no separate external input. Due to the relatively short period of time that is taken to accumulate sufficient energy to fire reliably, it is not necessary to start the arming sequence until firing is required.

[0024] Figure 3 provides a comparison in general terms of the operating stages of a prior conventional arrangement, and that of the arrangement shown in Figure 1. In the conventional arrangement shown at Figure 3(a), following application of power, there is a first safety break or switch which must be activated before arming can be initiated. During this period, the system is considered to be safe. When an arming signal is received, a second safety break must be activated to allow arming to begin and charge is built up in the system. During arming, the system is not deemed safe and the system is then held in an armed state without any further safety breaks until and if a separate firing signal is received. The system may thus be held in an unsafe condition for a relatively long time and indeed, the firing signal may never be received. In contrast, the arrangement shown in Figure 1, as shown at Figure 3(b), remains in a safe state until an arming signal is received. The second safety break is activated at the same time as arming is begun and then firing occurs automatically a known time thereafter. Thus it provides a rapid arming and firing circuit that essentially eliminates the armed state but instead transitions rapidly from the safe state to the fired state, maintaining the safe state for almost all of a mission. Firing/arming times of less than 1ms are readily achievable. A firing arrangement in accordance with the invention also has the advantage of an extremely consistent activation time, independent of temperature variation. Furthermore, the system can be immediately returned to the safe state if any safety breaks are removed as no charge is accumulated in the high voltage capacitor prior to the arming instruction.

[0025] In another firing arrangement, the pulse counter 13 is omitted. A voltage monitor is applied across the high voltage capacitor 16, shown as a broken line at 19, and the trigger condition is when the voltage and hence charge exceeds a pre-determined threshold value. In this embodiment, the trigger signal is also automatically generated following receipt of an arming instruction.

[0026] The firing arrangement of Figure 1 is used with an EFI detonator but could be used with, for example, a

pyrotechnic ignitor, bridge wire detonator or any electro-explosive device.

[0027] Previous approaches to arming and firing generally involve a separate arming phase after which the device is held in the armed state until required to fire. Figure 2 shows part of the arming circuit that takes an input to cause arming and a separate input to cause firing. A separate circuit is used to control provide a fire pulse after a fixed number of pulses have been applied to the arming input. This achieves firing after a consistent time period. Due to the relatively short period of time that is taken to accumulate sufficient energy to fire reliably, it is not necessary to start the arming sequence until firing is required. It enables the system to remain in the safe state for the majority of the operational sequence. This is particularly advantageous for systems that have a long operational life during which the system must be ready to fire at short notice. The advantage is both for safety of the system and also reliability of the high voltage circuit as it spends almost all of its operational life in the dormant, unpowered state.

Claims

1. A firing arrangement for an initiator comprising: a capacitor; an arming arrangement for charging the capacitor on receipt of an arming instruction; and a trigger device which, when a trigger condition is achieved indicating sufficient charge on the capacitor, automatically generates a trigger signal to trigger discharge of the capacitor through the initiator to activate the initiator;
wherein the arming arrangement includes a sequence validator having a first input, a second input and an output, the sequence validator generating the arming instruction at its output only when a first arming signal is received on the first input followed by a second arming signal received on the second input.
2. The firing arrangement as claimed in claim 1 wherein the trigger condition is a predetermined time from when charging the capacitor begins.
3. The firing arrangement as claimed in claim 2 and including a pulse counter to count a series of pulses to determine when the predetermined time is reached.
4. The firing arrangement as claimed in claim 1 wherein the trigger condition is when the voltage across the capacitor reaches a threshold value.
5. The firing arrangement as claimed in claim 1 and including a first static switch and a second static switch each of which, in an open state, interrupts the firing arrangement such that arming is not possible

and, in a closed state, completes part of the firing arrangement, the first static switch and the second static switch being connected to close on receipt of the first and second arming signal respectively.

6. The firing arrangement as claimed in any preceding claim and including a low voltage capacitor arrangement, a dynamic switch and a transformer, the dynamic switch being operative during arming to discharge the low voltage capacitor arrangement via a transformer to charge the capacitor.
7. The firing arrangement as claimed in claim 6 wherein the dynamic switch is operative during arming at a frequency in the range 100kHz to 1MHz.
8. The firing arrangement as claimed in claim 6 or 7 and including a dynamic pulse generator connected to receive the arming instruction and to output a series of pulses to operate the dynamic switch when the arming instruction is received.
9. The firing arrangement as claimed in claim 8 when dependent on claim 2 wherein the pulse counter is connected to receive the series of pulses from the dynamic pulse generator.
10. The firing arrangement as claimed in any preceding claim wherein the time period from receiving the arming instruction to generating the trigger signal is 1ms or less.
11. A firing system comprising a firing arrangement as claimed in any preceding claim and an initiator.
12. The firing system as claimed in claim 11 wherein the initiator is one of: an Exploding Foil Initiator (EFI); a Pyrotechnic Igniter; a Bridge Wire (BW); a Film Bridge (FB); a Conducting Composition (CC); a Semiconductor Bridge (SCB); and a Semiconductor Initiator (SCI).

Patentansprüche

1. Abschussanordnung für einen Zünder, die Folgendes umfasst: einen Kondensator; eine Scharfmachanordnung zum Laden des Kondensators nach Empfang eines Scharfmachbefehls; und eine Triggervorrichtung, die, wenn eine Triggerbedingung erreicht ist, die eine ausreichende Ladung auf dem Kondensator anzeigt, automatisch ein Triggersignal zum Triggern des Entladens des Kondensators durch den Zünder erzeugt, um den Zünder zu aktivieren; wobei die Scharfmachanordnung einen Sequenzvalidator mit einem ersten Eingang, einem zweiten Eingang und einem Ausgang beinhaltet, wobei der Se-

quenzvalidator den Scharfmachbefehl an seinem Ausgang nur dann erzeugt, wenn ein erstes Scharfmachsignal auf dem ersten Eingang empfangen wird, gefolgt von einem am zweiten Eingang empfangenen zweiten Scharfmachsignal.

2. Abschussanordnung nach Anspruch 1, wobei die Triggerbedingung eine vorbestimmte Zeit ist, ab der das Laden des Kondensators beginnt.
3. Abschussanordnung nach Anspruch 2 mit einem Pulszähler zum Zählen einer Serie von Impulsen, um festzustellen, wenn die vorbestimmte Zeit erreicht ist.
4. Abschussanordnung nach Anspruch 1, wobei die Triggerbedingung die ist, wenn die Spannung über den Kondensator einen Schwellenwert erreicht.
5. Abschussanordnung nach Anspruch 1 mit einem ersten statischen Schalter und einem zweiten statischen Schalter, die jeweils in einem offenen Zustand die Abschussanordnung unterbrechen, so dass Scharfmachen nicht möglich ist, und in einem geschlossenen Zustand einen Teil der Abschussanordnung vollenden, wobei der erste statische Schalter und der zweite statische Schalter so geschaltet sind, dass sie nach Empfang des ersten bzw. zweiten Scharfmachsignals schließen.
6. Abschussanordnung nach einem vorherigen Anspruch mit einer Niederspannungskondensatoranordnung, einem dynamischen Schalter und einem Transformator, wobei der dynamische Schalter beim Scharfmachen die Aufgabe hat, die Niederspannungskondensatoranordnung über einen Transformator zu entladen, um den Kondensator zu laden.
7. Abschussanordnung nach Anspruch 6, wobei der dynamische Schalter beim Scharfmachen mit einer Frequenz im Bereich von 100 kHz bis 1 MHz operativ ist.
8. Abschussanordnung nach Anspruch 6 oder 7 mit einem dynamischen Pulsgenerator, so geschaltet, dass er den Scharfmachbefehl empfängt und eine Serie von Pulsen zum Betätigen des dynamischen Schalters ausgibt, wenn der Scharfmachbefehl empfangen wird.
9. Abschussanordnung nach Anspruch 8 in Abhängigkeit von Anspruch 2, wobei der Pulszähler zum Empfangen der Serie von Pulsen von dem dynamischen Pulsgenerator verbunden ist.
10. Abschussanordnung nach einem vorherigen Anspruch, wobei die Zeitperiode vom Empfang des Scharfmachbefehls bis zum Erzeugen des Trigger-

signals 1 ms oder weniger ist.

11. Abschusssystem, das eine Abschussanordnung nach einem vorherigen Anspruch und einen Zünder umfasst.
12. Abschusssystem nach Anspruch 11, wobei der Zünder einer der Folgenden ist: ein Sprengfolien-Initiator (EFI); ein pyrotechnischer Zünder; ein Überbrückungsdraht (BW); eine Filmbrücke (FB); eine leitende Zusammensetzung (CC); eine Halbleiterbrücke (SCB) und ein Halbleiterinitiator (SCI).

Revendications

1. Agencement de mise à feu pour un initiateur comprenant : un condensateur ; un agencement d'armement pour charger le condensateur à la réception d'une instruction d'armement ; et un dispositif de déclenchement qui, quand une condition de déclenchement indiquant une charge suffisante du condensateur est satisfaite, génère automatiquement un signal de déclenchement pour déclencher la décharge du condensateur à travers l'initiateur pour activer l'initiateur ; dans lequel l'agencement d'armement comporte un validateur de séquence ayant une première entrée, une seconde entrée et une sortie, le validateur de séquence générant l'instruction d'armement à sa sortie uniquement quand un premier signal d'armement est reçu sur la première entrée suivi d'un second signal d'armement reçu sur la seconde entrée.
2. Agencement de mise à feu selon la revendication 1 dans lequel la condition de déclenchement est un laps de temps prédéterminé à compter du début de la charge du condensateur.
3. Agencement de mise à feu selon la revendication 2 et comportant un compteur d'impulsions pour compter une série d'impulsions pour déterminer quand le laps de temps prédéterminé est atteint.
4. Agencement de mise à feu selon la revendication 1 dans lequel la condition de déclenchement est quand la tension aux bornes du condensateur atteint une valeur de seuil.
5. Agencement de mise à feu selon la revendication 1 et comportant un premier commutateur statique et un second commutateur statique qui chacun, dans un état ouvert, interrompent l'agencement de mise à feu de manière à empêcher l'armement et, dans un état fermé, réalisent une partie de l'agencement de mise à feu, le premier commutateur statique et le second commutateur statique étant connectés pour se fermer à la réception des premier et second si-

gnaux d'armement respectivement.

6. Agencement de mise à feu selon n'importe quelle revendication précédente et comportant un agencement de condensateur basse tension, un commutateur dynamique et un transformateur, le commutateur dynamique fonctionnant durant l'armement pour décharger l'agencement de condensateur basse tension par l'intermédiaire d'un transformateur pour charger le condensateur.
7. Agencement de mise à feu selon la revendication 6 dans lequel le commutateur dynamique fonctionne durant l'armement à une fréquence dans la plage de 100 kHz à 1 MHz.
8. Agencement de mise à feu selon la revendication 6 ou 7 et comportant un générateur d'impulsions dynamique connecté pour recevoir l'instruction d'armement et produire en sortie une série d'impulsions pour actionner le commutateur dynamique quand l'instruction d'armement est reçue.
9. Agencement de mise à feu selon la revendication 8 quand elle dépend de la revendication 2 dans lequel le compteur d'impulsions est connecté pour recevoir la série d'impulsions en provenance du générateur d'impulsions dynamique.
10. Agencement de mise à feu selon n'importe quelle revendication précédente dans lequel la période de temps à compter de la réception de l'instruction d'armement jusqu'à la génération du signal de déclenchement est de 1 ms ou moins.
11. Système de mise à feu comprenant un agencement de mise à feu selon n'importe quelle revendication précédente et un initiateur.
12. Système de mise à feu selon la revendication 11 dans lequel l'initiateur est un : d'un initiateur à feuille explosive (EH); d'un allumeur pyrotechnique ; d'un fil d'amorce (BW) ; d'une feuille chaude (FB) ; d'une composition conductrice (CC) ; d'un pont à semi-conducteur (SCB) ; et d'un initiateur à semi-conducteur (SCI).

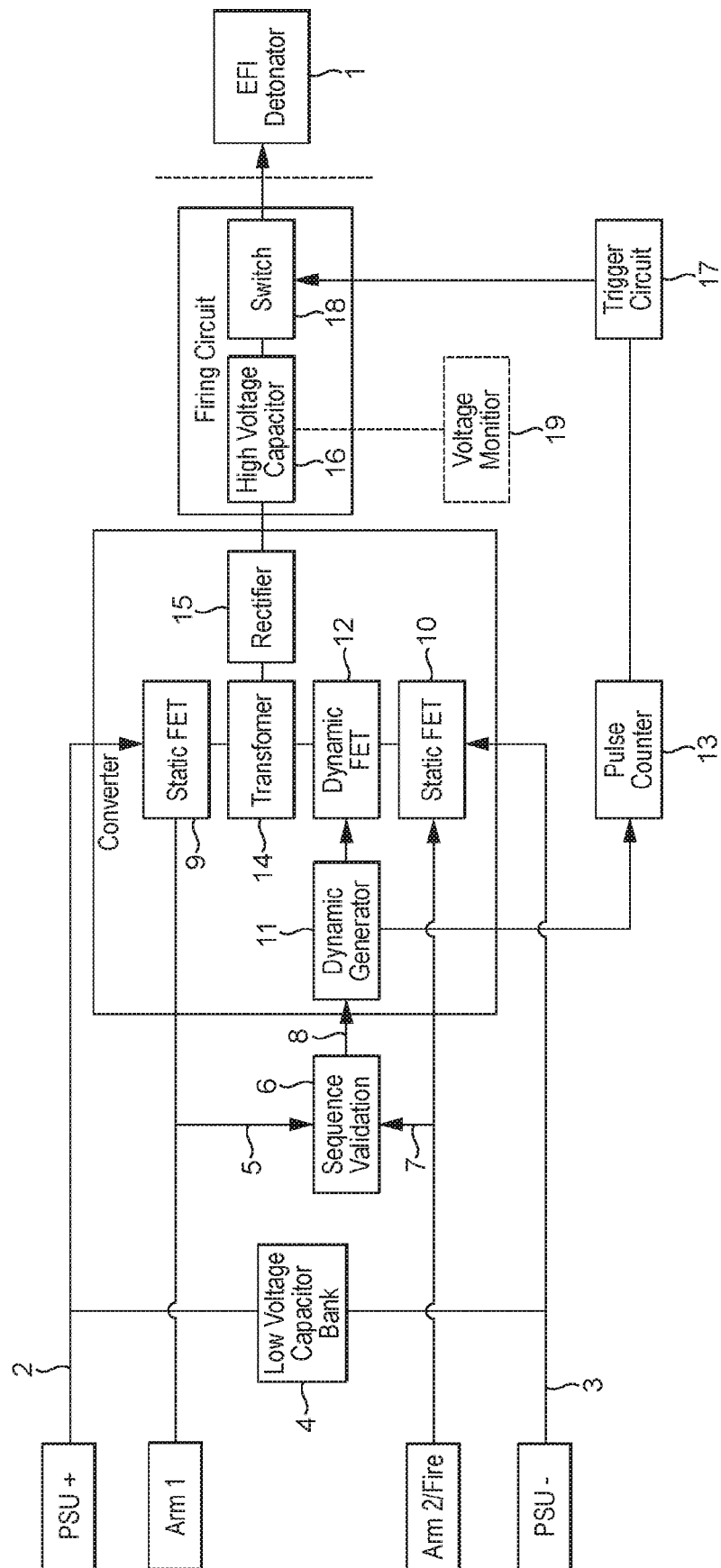


FIG. 1

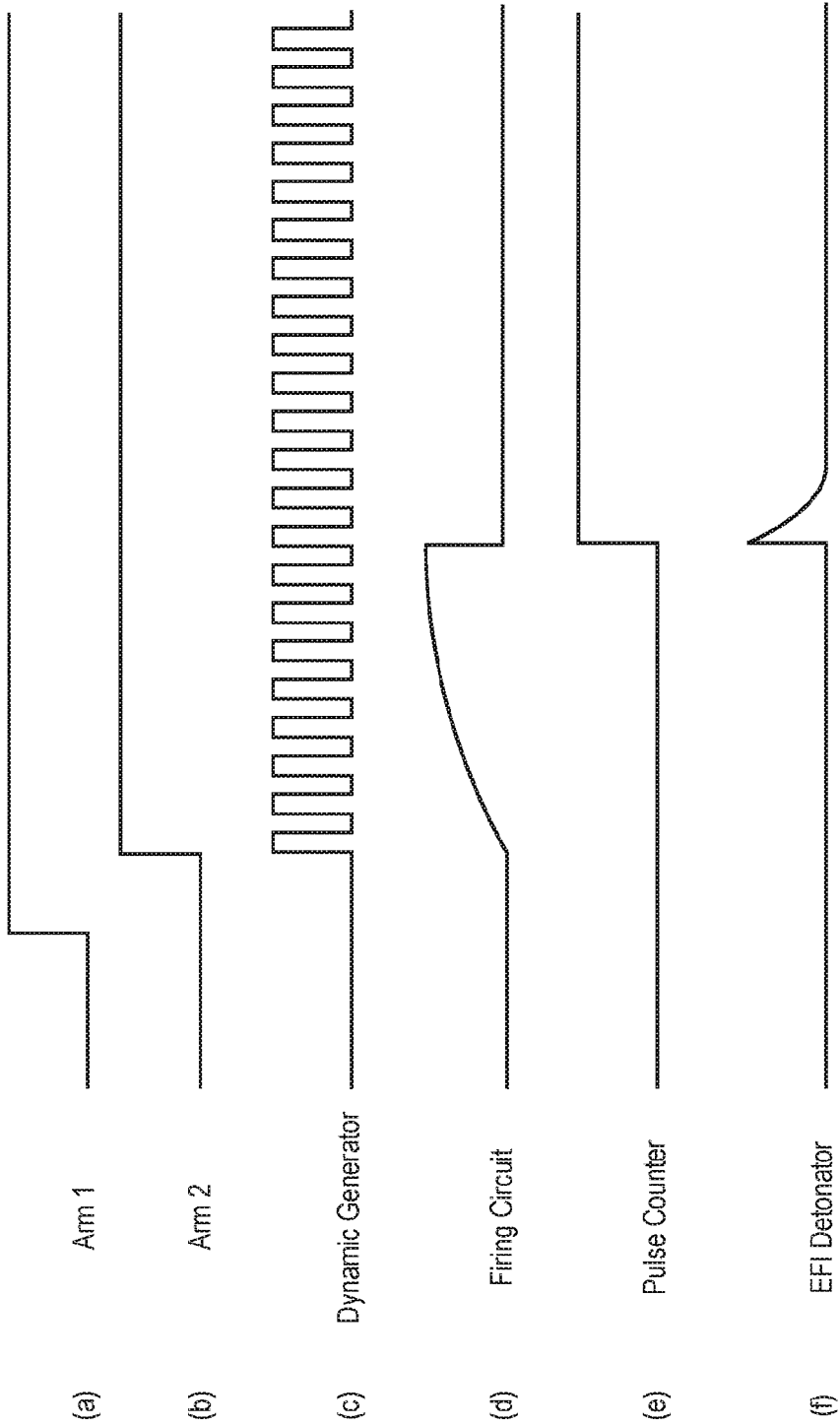


FIG. 2

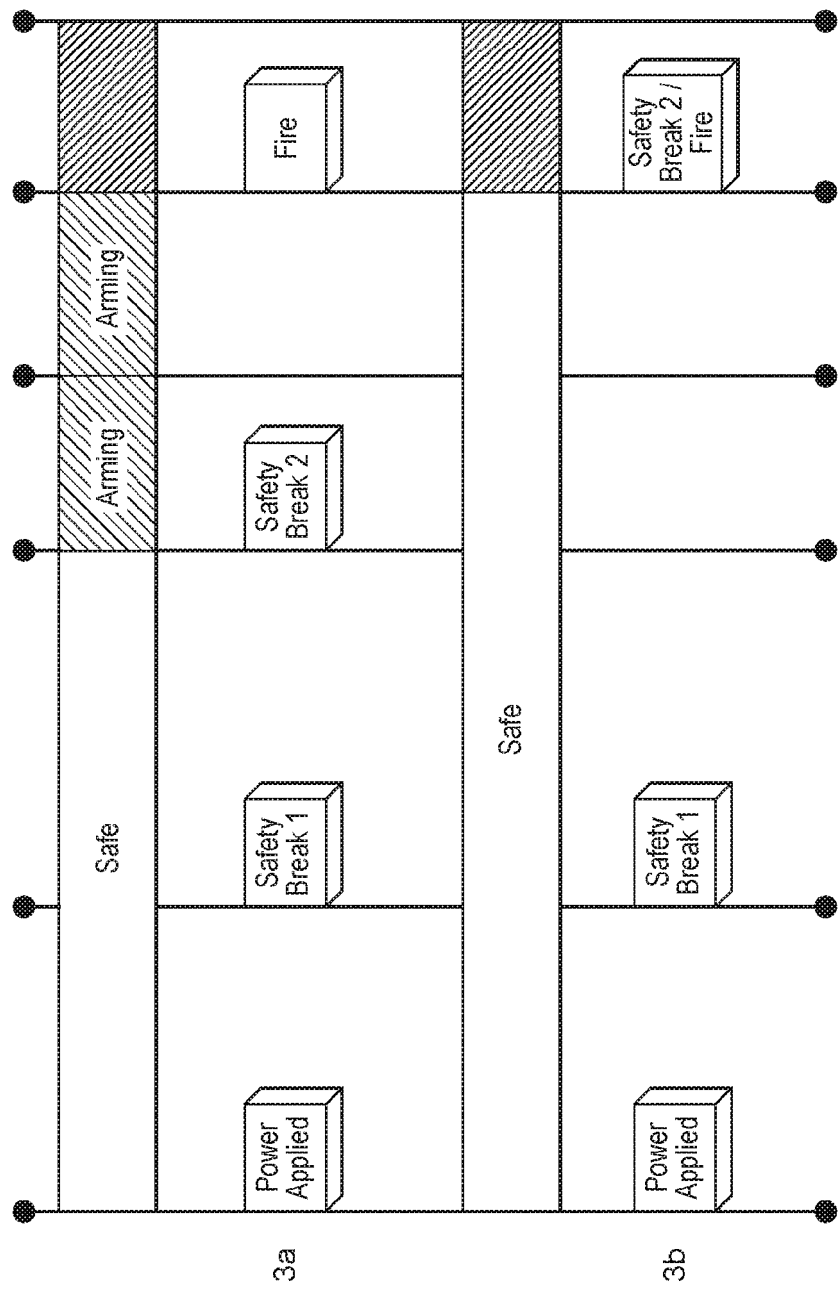


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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