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(54) **EXPLOSIVE PRESSURE ACTIVATED SWITCH**

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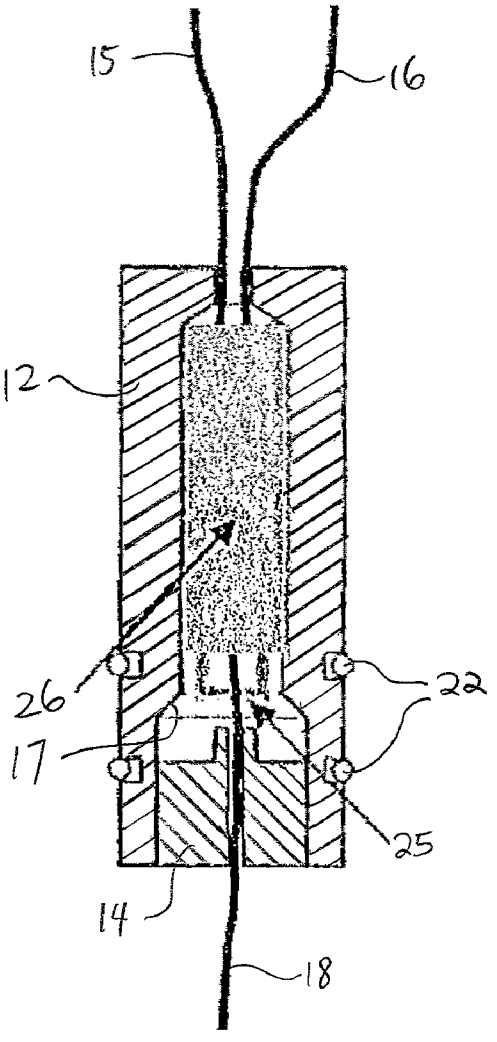
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(57) **ABSTRACT**

A switch connectable to an upper explosive device and a lower explosive device in a perforation gun train is provided. The switch comprises a circuit, a portion of the circuit being openable upon detonation of the lower explosive device, and the switch being changeable from a first position to a second position upon the opening of the portion of the circuit. In the first position, current can flow to the lower explosive device but not to the upper explosive device. In the second position, opposing current can flow to the upper explosive device but not to the lower explosive device.



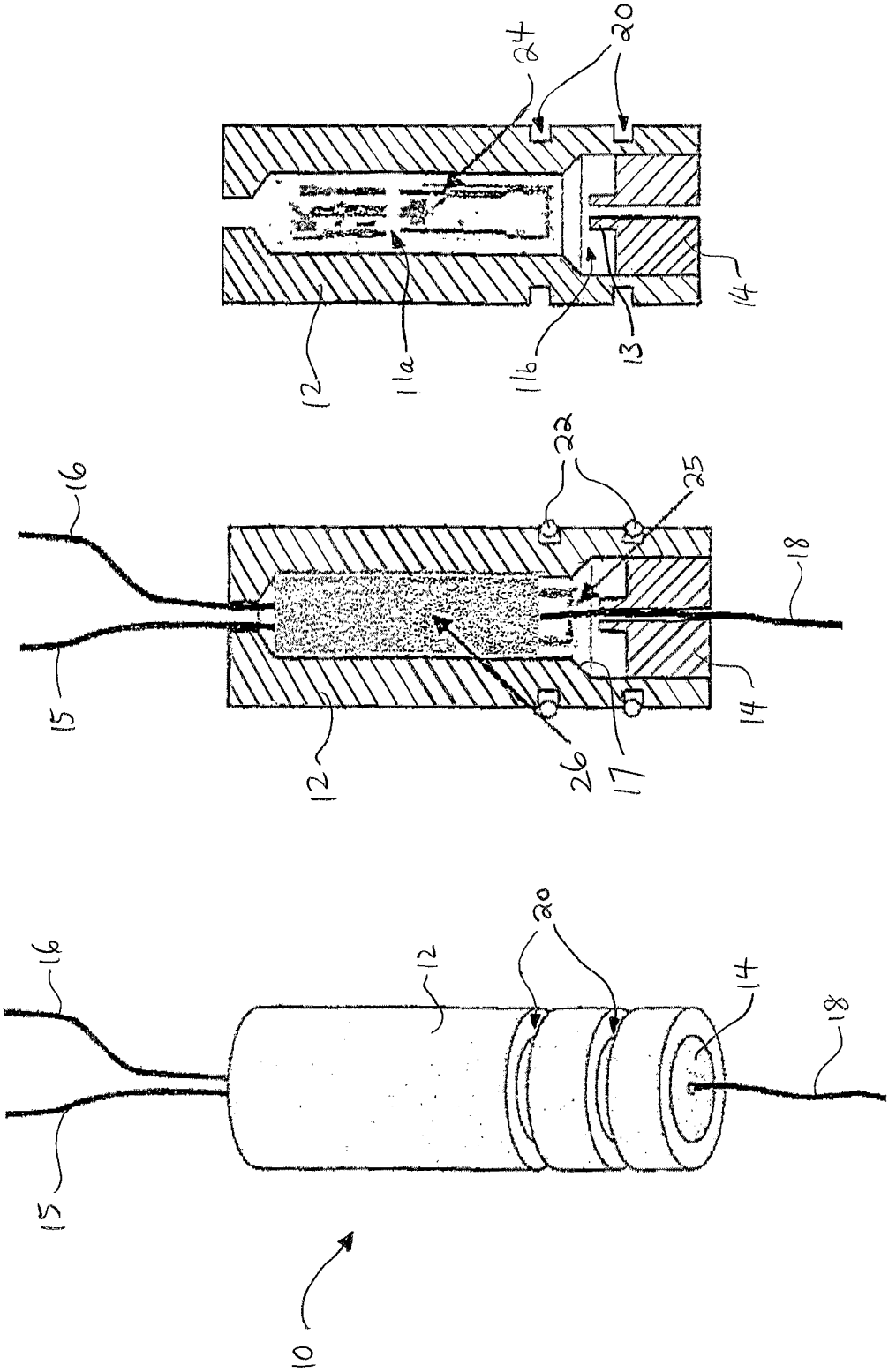


FIG. 1c

FIG. 1b

FIG. 1a

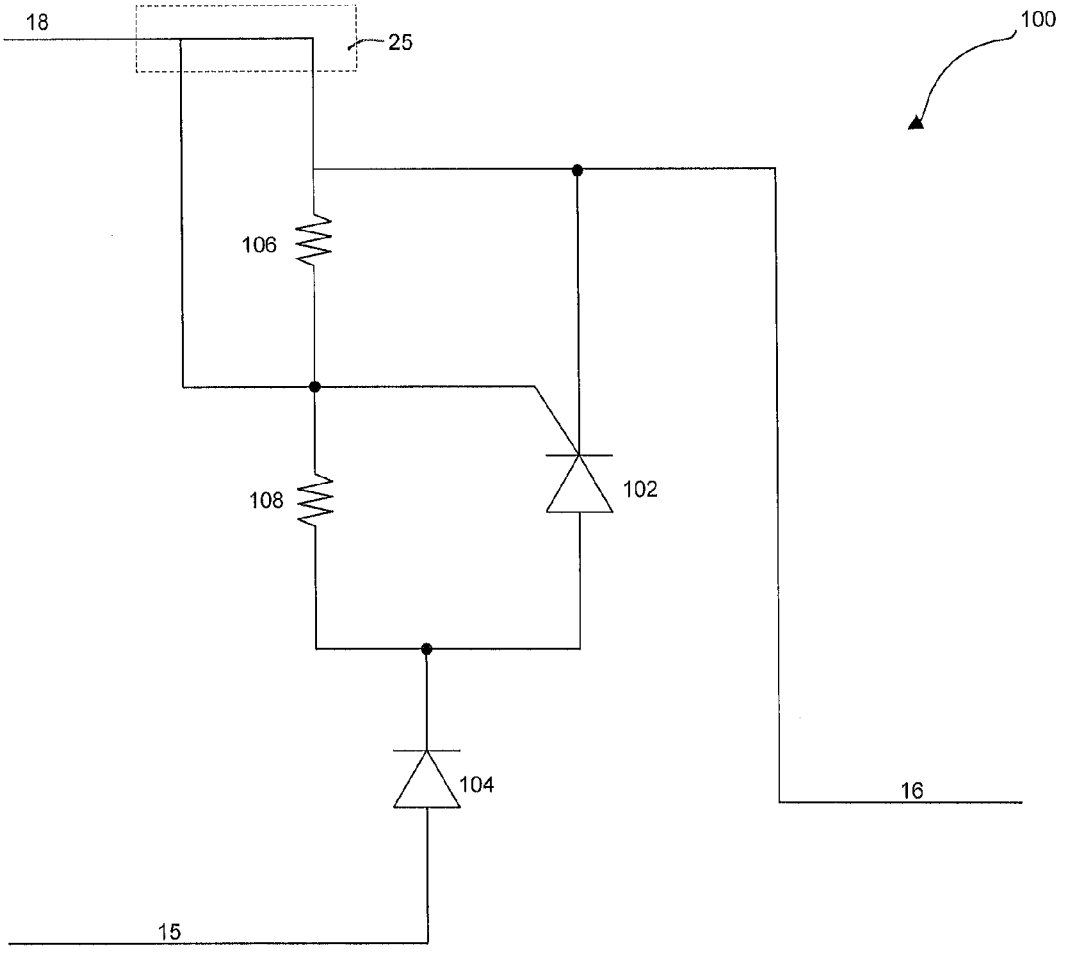


FIG. 2

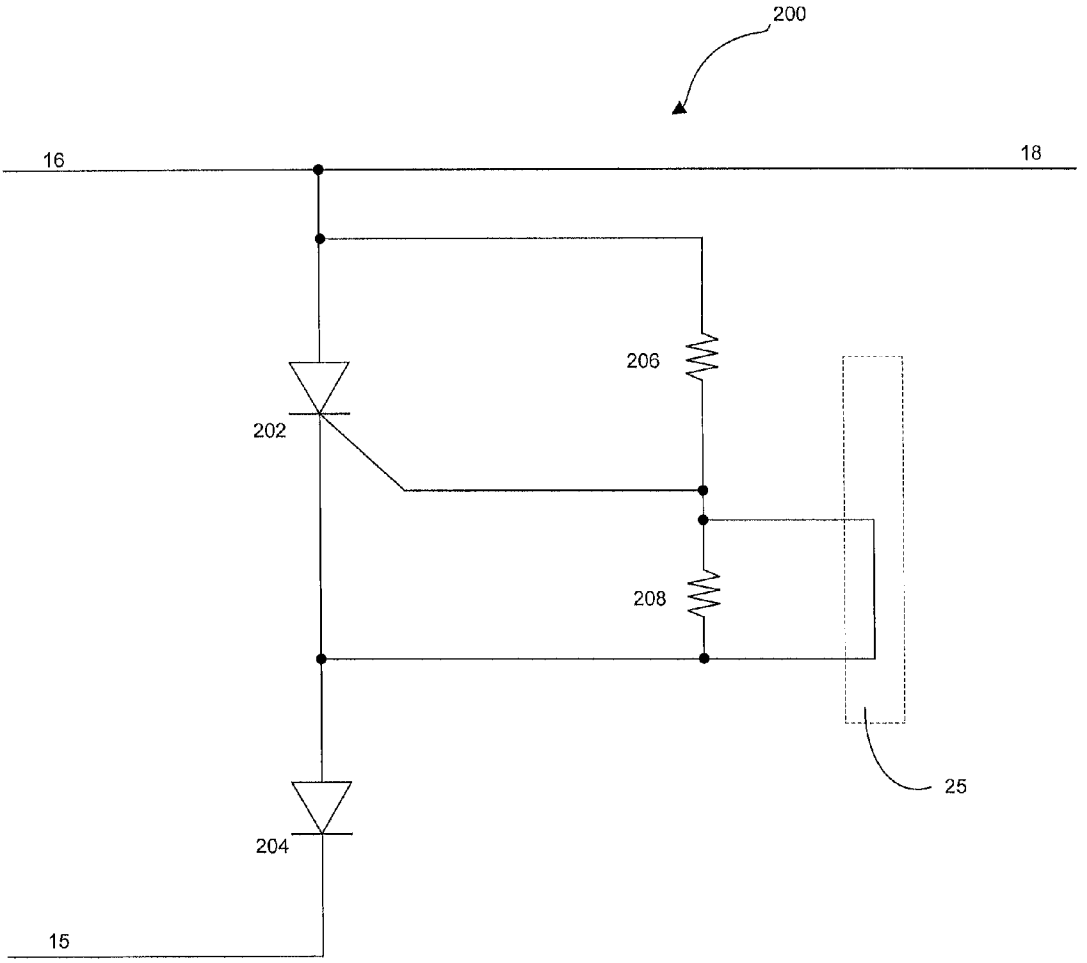


FIG. 3

EXPLOSIVE PRESSURE ACTIVATED SWITCH

FIELD OF THE INVENTION

[0001] The present invention relates to the field of downhole explosive perforation gun technology used in well operations.

BACKGROUND OF THE INVENTION

[0002] A perforation gun train usually consists of several linear segments (sometimes also referred to as "gun segments") which are each loaded with explosives and are separated by perforating gun switches. Existing technology for perforating gun switches typically uses mechanical contacts that close a circuit upon receiving the mechanical impulse from an explosive detonation. These switches are generally not reliable and depend on complicated systems of rigid mechanical tolerances, small parts, and stringent physical material properties to allow the switches to withstand the operating conditions and operate as intended.

SUMMARY OF THE INVENTION

[0003] In accordance with a broad aspect of the present invention, there is provided a switch comprising a circuit, a portion of the circuit being openable upon a detonation and the switch being changeable from a first position to a second position upon the opening of the portion of the circuit.

[0004] In accordance with another broad aspect of the present invention, there is provided a switch comprising an anti-fuse, the anti-fuse being breakable upon reacting to a detonation and the switch being changeable from a first position to a second position upon breakage of the anti-fuse.

[0005] In accordance with another broad aspect of the present invention, there is provided a method of detonating a series of consecutive explosive devices comprising: providing a switch between a first explosive device and a second explosive device, the first and second explosive devices being a pair of adjacent explosive devices in the series, and the switch having a circuit for selectively communicating with either of the first and second explosive devices; sending current to the first explosive device and blocking current to the second explosive device; detonating the first explosive device, thereby providing a detonation force; and opening a part of the circuit using a portion of the detonation force, thereby blocking current to the first explosive device and sending an opposing current to the second explosive device.

[0006] In accordance with another broad aspect of the present invention, there is provided a switch for use in an explosive firing system for a perforation gun train. The switch is used for detecting an explosion from a gun segment of the perforation gun train and for enabling a subsequent explosive gun segment within the train.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Drawings are included for the purpose of illustrating certain aspects of the invention. Such drawings and the description thereof are intended to facilitate understanding and should not be considered limiting of the invention. Drawings are included, in which:

[0008] FIG. **1***a* is a perspective view of one embodiment of a switch of the present invention;

[0009] FIG. **1***b* is a cross-sectional view of the switch of FIG. **1***a;*

[0010] FIG. **1***c* is a cross-sectional view of the switch of FIG. **1***a*, showing only selected components of the device;

[0011] FIG. **2** is a schematic diagram of a negative switch fuse circuit for use in one embodiment of the switch; and

[0012] FIG. **3** is a schematic diagram of a positive switch fuse circuit for use in another embodiment of the switch.

DETAILED DESCRIPTION

[0013] The following detailed description of embodiments of the invention makes reference to the accompanying drawings in which like references indicate similar elements, showing by way of illustration specific embodiments of practicing the invention. Description of these embodiments is in sufficient detail to enable those skilled in the art to practice the invention. One skilled in the art understands that other embodiments may be utilized and that logical, mechanical, electrical, functional and other changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

[0014] There is provided a switch for use in an explosive firing system for a perforation gun train. The switch is used for detecting an explosion from a gun segment of the perforation gun train and for enabling a subsequent explosive gun segment within the train.

[0015] In one embodiment, each pair of consecutive gun segments in the gun train is separated by the switch. The switch provides activation control of an explosive device in each segment in a step sequence from the lowermost gun segment to the uppermost gun segment. Electrical circuitry in the switch activates and conducts current selectively in response to a detonation shock from an adjacent gun segment. One method of detecting the detonation of the adjacent gun segment is using the forces from the nearby explosion to break an electrical connection in the circuitry. The broken electrical connection causes the circuitry to conduct electricity in an alternative circuit path, which allows current to flow to a detonator of a subsequent gun segment.

[0016] In a preferred embodiment, the explosive devices in the gun segments are shaped charges aimed toward the casing in a wellbore, such that most of the energy from the detonation of the explosives will be directed radially towards the inner surface of the wellbore. However, some energy from the detonation will be directed towards an adjacent gun segment and its associated explosive device, which preferably also comprises shaped charges. In response to this energy, the switch of the present invention reacts by arming the detonation or initiation component associated with and operative to detonate the explosive device in the adjacent gun segment.

[0017] The switch is configured to not respond to forces that are incidental to the insertion and placement of the train of charges in the wellbore, or to handling forces during shipment or assembly. In this way, there will be no false positives or false negatives in the switch's status with respect to a detonation of a downward-adjacent charge. In a further embodiment, the switch operates to disable detonation of an upper explosive device after a detonation command has been sent to an adjacent lower explosive device but before the actual detonation of the lower device. The switch may serve as a safety device to help minimize the possibility of unexpected explosion during wellbore operations.

[0018] Referring to FIGS. **1***a*, **1***b*, and **1***c*, a switch **10** comprises a housing **12**, a piston **14**, and wires **15**, **16** and **18**.

Housing **12** has an inner surface defining an axially extending bore having an upper opening and a lower opening, at an upper end and a lower end of housing **12**, respectively. "Upper" and "up" as used herein denote a position that is closer to the well opening at the surface than "lower" and "below". The bore includes an upper bore area **11***a* and a lower bore area **11***b*. In one embodiment, housing **12** includes a shoulder **17** between upper bore area **11***a* and lower bore area **11***b* for preventing piston **14** from moving beyond a certain point up the bore towards the upper opening. In a further embodiment, shoulder **17** is formed by a radially inwardly extension on the inner surface of the bore. In yet a further embodiment, the outer surface of housing **12** includes grooves **20** for receiving seals **22**, such as for example o-ring seals. Housing **12** is made of durable materials that can withstand wellbore conditions, such as high pressures and high temperatures, and such materials include for example aluminum, steel, titanium, polymers, ceramics, etc. The materials may further include coatings, reinforcements, etc.

[0019] Piston **14** includes a hole which extends therethrough between an upper piston face and a lower piston face. Piston **14** is disposed in lower bore area **11***b*, at or near the lower opening, with the piston's upper piston face facing towards the upper opening of the bore. Piston **14** may substantially cover the lower opening of the bore. Piston **14** is preferably friction-fitted in lower bore area **11***b*. Piston **14** may be made of various resilient materials capable of withstanding high temperatures, including for example polytetrafluoroethylene, polycarbonate, polyphenylene-sulfide, polyamide-imide, polyimide, semicrystalline thermoplastics, ceramics, etc. The upper piston face of piston **14** includes a protrusion **13** that extends axially upwardly away from the upper piston face towards upper bore area **11***a*.

[0020] A circuit board **24** is disposed in upper bore area **11***a*, above piston **14**. Circuit board **24** includes an anti-fuse **25**. In one embodiment, anti-fuse **25** is positioned near protrusion **13** of piston **14**, while other components of circuit board **24** are positioned further away from protrusion **13**. In one embodiment, anti-fuse **25** comprises an electrical conduction pathway. The electrical conduction pathway may be a conductive wire or conductive circuit trace. Circuit board **24** is in communication with a lower wire **18**, which is connectable to a lower gun segment (not shown) in a gun train. In one embodiment, wire **18** extends from the bore through the hole in piston **14** to the outside of housing **12**. Circuit board **24** is also in communication with an upper wire **16**, which is connectable either to an upper gun segment (not shown) in the gun train or to a current supply above the switch. Circuit board **24** is further in communication with a detonator wire **15**, which is connectable to a detonator (not shown). The detonator, which may be an electrical fuse, may be associated with the explosive device in the upper gun segment. Both wires **15** and **16** may extend into the bore from the exterior of housing **12** through the upper opening. In one embodiment, the electronic components of circuit board **24** are solid-state electronics.

[0021] Circuit board **24** may be partially or substantially shielded with a pressure barrier encapsulation material **26**, which includes for example foam, silicone, epoxy based potting materials. Material **26** helps protect circuit board **24** from any vibration and/or changes in pressure as a result of nearby explosions. Material **26** may also function to keep circuit board **24** in place within the bore.

[0022] In operation, switch **10** has two positions: a fuse-intact position (as shown in FIGS. **1***a*, **1***b*, and **1***c*) and a fuse-broken position. In the fuse-intact position, wires **16** and **18** are in communication with the upper gun and lower gun segments, respectively, and wire **15** is in communication with the detonator of the upper gun segment. Also, the anti-fuse is not in contact with protrusion **13** when switch **10** is in the fuse-intact position. In the fuse-intact position, current is allowed to flow between wires **16** and **18** but no current flows through wire **15**. In the fuse-broken position, wire **16** is in communication with the upper gun segment and wires **15** and **16** are in communication with each other. Further, in the fuse-broken position, wire **18** is disconnected from circuit board **24** and the lower gun segment, and protrusion **13** is in contact with anti-fuse **25**, severing the electrical conduction pathway, thereby "breaking" anti-fuse **25**. Once anti-fuse **25** is broken, current can no longer flow between wires **16** and **18** but current is allowed to flow from wire **16** to wire **15** through the remaining intact portions of the circuit ("secondary circuit").

[0023] Switch **10** may operate in various ways and the following describes an example of how device **10** may operate. When the lower gun segment is undetonated, switch **10** is in the fuse-intact position. A current is supplied from wire **16** through circuit board **24** to wire **18**, providing a detonation charge to the lower gun segment via wire **18**. If the detonation charge is sufficient, the lower gun segment detonates and the detonation exerts an explosive force on to the lower end of housing **12** and the lower piston face of piston **14**. In one embodiment, the pressure exerted on the lower piston face from the detonation is approximately 30,000 psi. The explosive force pushes piston **14** upwards in housing **12** towards upper bore area **11***a*, such that protrusion **13** impacts anti-fuse **25** and severs the electrical conduction pathway therein, thereby bringing switch **10** into the fuse-broken position. In one embodiment, the upward movement of piston **14** is restricted by shoulder **17**, such that piston **14** can move upwards until its upper piston face abuts against shoulder **17**. This restriction provided by shoulder **17** helps to ensure that the extent to which protrusion **13** can extend into upper bore area **11***a* is only sufficient to break anti-fuse **25**, but not sufficient to affect other parts of circuit board **24**. The upward movement of piston **14** may also disconnect wire **18** from circuit board **24**. Once anti-fuse **25** is broken, current is allowed to flow from wire **16** via the secondary circuit to wire **15**. In one embodiment, current is supplied through the secondary circuit to wire **15**, which is connected to a detonator of another gun segment, in order to detonate that gun segment in the gun train. In a further embodiment, switch **10** is placed in between each pair of consecutive gun segments in the gun train in order to detonate a series of segments in a particular order.

[0024] The schematics in FIGS. **2** and **3** each illustrate a sample circuit that may be used in circuit board **24** to detect the breakage of anti-fuse **25**. FIG. **2** shows a negative switch fuse circuit **100** and FIG. **3** shows a positive switch fuse circuit **200**. FIGS. **2** and **3** each illustrate one sample configuration and a person skilled in the art will appreciate that other circuit configurations that operate substantially similarly may be used for the present invention. In a preferred embodiment, the electronic components in circuits **200** and **300** are solid-state electronics.

[0025] Referring to FIG. **2**, circuit **100** serves to switch a supply of current from one destination (e.g. the lower gun

segment) to another destination (e.g. the secondary circuit) and the switch is generally initiated by an event (e.g. an explosion and/or detonation). In one embodiment, circuit **100** includes a silicon controlled rectifier (SCR) **102**, resistors **106** and **108**, and a diode **104**. Resistor **106** has a first terminal connected to the cathode of SCR **102**, and a second terminal connected to the gate of SCR **102**. The cathode of SCR **102** is also connected wires **16** and **18**. The first terminal of resistor **106** is also connected to upper wire **16**. Both terminals of resistor **106** are connected to lower wire **18**. Resistor **108** has a first terminal connected to the gate of SCR **102**, and a second terminal connected to the anode of SCR **102**. The first terminal of resistor **108** is also connected to lower wire **18**. The cathode of diode **104** is connected to the second terminal of resistor **108** and the anode of SCR **102**. The anode of diode **104** is connected to detonator wire **15**. In this circuit configuration, anti-fuse **25** is provided in an area of circuit **100** where resistors **106**, **108** and the gate and cathode of SCR **102** connect to lower wire **18**.

[0026] Various types of SCRs, diodes, and resistors may be used in circuit **100**. For example, in one embodiment, SCR **102** in circuit **100** is DR-DPAK-600V-IA5. In a further embodiment, the resistance of resistor **106** ranges between 142.5 K and 157.5 K, but is preferably 150 K. In a still further embodiment, the resistance of resistor **108** ranges between 307.8 K and 340.2 K, but is preferably 324 K. In another embodiment, diode **104** is DR-SOD123-1000-1A.

[0027] In circuit **100**, the cathode and gate of SCR **102** are shorted together, which prevents SCR **102** from conducting current from its anode to its cathode and consequently prevents any current from flowing through the circuit to wire **15**. Current can, however, flow between upper wire **16** and lower wire **18**.

[0028] Before an explosive charge is initiated in the lower gun segment, anti-fuse **25** of circuit **100** is intact such that lower wire **18** and resistors **106**, **108** and SCR **102** are connected as described above. The explosive charge in the lower gun segment may be initiated by a supply of current from the upper gun segment, via upper wire **16**, to the lower gun segment, via lower wire **18**. The current required to initiate an explosive charge (the "firing threshold") depends on the design of the detonator. In one embodiment, the firing threshold is greater than 0.2 amps.

[0029] Once the explosive charge is initiated in the lower gun segment, the lower gun segment is detonated and the detonation breaks anti-fuse **25** as described above and disconnects wire **18**. After anti-fuse **25** breaks, the secondary circuit takes shape, wherein SCR **102** is allowed to conduct current. In the secondary circuit of circuit **100**, SCR **102** is on when a negative current threshold has been reached as determined by the ratio of resistor **108** to resistor **106**. When SCR **102** is on, current can flow through the secondary circuit to wire **15** to provide an energizing signal current to the detonator. The negative switch fuse circuit **100** is configured to only allow negative direct current (DC−) to flow from wire **16** to wire **15** in the secondary circuit.

[0030] Referring to FIG. **3**, circuit **200** serves to switch a supply of current from one destination (e.g. the lower gun segment) to another destination (e.g. the secondary) and the switch is generally initiated by an event (e.g. an explosion and/or detonation). In one embodiment, circuit **200** includes an SCR **202**, resistors **206** and **208**, and a diode **204**. Resistor **206** has a first terminal connected to the anode of SCR **202** and a second terminal connected to the gate of SCR **202** and a first terminal of resistor **208**. The anode of SCR **202** is also connected wires **16** and **18**. The first terminal of resistor **206** is also connected to wires **16** and **18**. Resistor **208** has a first terminal connected to the gate of SCR **202** and also the second terminal of resistor **206**. A second terminal of resistor **208** is connected to the cathode of SCR **202** and the anode of diode **204**. Both terminals of resistor **208** are connected by a wire. The cathode of diode **204** is connected to detonator wire **15**. The anode of diode **204** is connected to the cathode of SCR **202**. In circuit **200**, anti-fuse **25** is the wire connecting the terminals of resistor **208**.

[0031] Various types of SCRs, diodes, and resistors may be used in circuit **200**. For example, in one embodiment, SCR **202** in circuit **100** is DR-DPAK-600V-IA5. In a further embodiment, the resistance of resistor **208** ranges between 142.5 K and 157.5 K, but is preferably 150 K. In a still further embodiment, the resistance of resistor **206** ranges between 307.8 K and 340.2 K, but is preferably 324 K. In another embodiment, diode **204** is DR-SOD123-1000-1A.

[0032] In circuit **200**, the cathode and gate of SCR **202** are shorted together, which prevents SCR **202** from conducting current from its anode to its cathode and consequently prevents any current from flowing through the circuit to detonator wire **15**. Current can, however, flow between upper wire **16** and lower wire **18**.

[0033] Before an explosive charge is initiated in the lower gun segment, anti-fuse **25** is intact such that the terminals of resistor **208** are connected by the wire, as described above. The explosive charge in the lower gun segment may be initiated by a supply of current from the upper gun segment, via upper wire **16**, to the lower gun segment, via lower wire **18**.

[0034] Once the explosive charge is initiated in the lower gun segment, the lower gun segment is detonated and the detonation breaks anti-fuse **25** such that the wire connecting the terminals of resistor **208** is severed. The detonation also disconnects wire **18**. After anti-fuse **25** breaks, the secondary circuit takes shape, wherein SCR **202** is allowed to conduct current. In the secondary circuit of circuit **200**, SCR **202** is on when a positive current threshold has been reached as determined by the ratio of resistor **206** to resistor **208**. When SCR **202** is on, current can flow through the secondary circuit to wire **15** to provide an energizing signal current to the detonator. The positive switch fuse circuit **200** is configured to only allow positive direct current (DC+) to flow from wire **16** to wire **15** in the secondary circuit.

[0035] The switch of the present invention uses solid-state electronics and a mechanically breakable "anti-fuse," which aims to reduce the number of mechanical parts required, to reduce the complexity and tolerance requirements of the mechanical parts, and to allow the use of simpler manufacturing methods to automate production to help minimize the cost of manufacturing.

[0036] In one embodiment, the circuit used in consecutive switches in the gun train alternates between a negative switch fuse circuit and a positive switch fuse circuit. In other words, if a first gun segment has a positive switch (i.e. a switch that has a positive switch fuse circuit) above it, a second gun segment immediately above the positive switch connected to the first gun segment will have a negative switch (i.e. a switch that has a negative switch fuse circuit) above it, and a third gun segment immediately above the negative switch connected to the second gun segment will have a positive switch above it, and so on. By alternating between negative switches and positive switches along the gun train, adjacent switches

will have different circuits that allow current flow in opposite directions. This alternating switch configuration functions as a safety measure, which is to help prevent all the gun segments from detonating at the same time.

[0037] For example, if a lowermost gun segment with a first detonator is connected to a positive switch above it, then only a negative current is allowed to flow through the switch to the first detonator. When the power to the first detonator reaches a predetermined threshold, the lowermost gun segment detonates, thereby breaking anti-fuse **25** of the positive switch above and enabling the secondary circuit to communicate with wire **15**. Wire **15** is in communication with a second detonator of a second lowermost gun segment, which is adjacent to the lowermost gun segment. Because of the configuration of the secondary circuit of the positive switch, negative current cannot flow through wire **15** to the second detonator, regardless of the magnitude of the current. The second lowermost gun segment has a negative switch above it. When the current supply is switched from negative to positive direct current, which may be done manually, then the secondary circuit of the positive switch will allow the positive current to flow through wire **15** to the second detonator to detonate the second lowermost gun segment, thereby breaking the anti-fuse of the negative switch above. The breaking of the anti-fuse of the negative switch enables the secondary circuit of the negative switch, which has a wire **15** in communication with a third detonator of a third lowermost gun segment above the second lowermost gun segment. However, the secondary circuit of the negative switch prevents positive direct current, regardless of its magnitude, from flowing through wire **15** to the third detonator. When the current is switched back to negative direct current, the secondary circuit of the negative switch allows the negative current to flow through wire **15** to the third detonator to detonate the third lowermost gun segment. The above-described alternating-switch configuration and detonation process may be carried out through the entire gun train. As such, alternating between positive and negative switches in a series of gun segments allows the sequential detonation of the gun segments in a controlled manner.

[0038] In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

1. A switch comprising a circuit, a portion of the circuit being openable upon a detonation and the switch being changeable from a first position to a second position upon the opening of the portion of the circuit.

2. The switch of claim **1**, the circuit being connectable to a first explosive device, a second device, and a selectively startable current supply.

3. The switch of claim **2**, wherein the circuit permits transmission of current between the first explosive device and the current supply when the switch is in the first position.

4. The switch of claim **3**, wherein the circuit permits transmission of an opposing current from the current supply to the second device when the switch is in the second position.

5. The switch of claim **2**, further comprising a housing, and the circuit is placed inside the housing.

6. The switch of claim **5**, further comprising a piston disposed near a first end of the housing, the piston being movable from a lower position to an upper position by a force from the detonation.

7. The switch of claim **6** wherein, in the upper position, the piston opens the portion of the circuit.

8. The switch of claim **1**, wherein components of the circuit are solid-state electronics.

9. The switch of claim **1**, wherein the circuit is a negative switch fuse circuit or a positive switch fuse circuit.

10. The switch of claim **2**, wherein the current supply is from the second device or from a source above the switch.

11. The switch of claim **2**, wherein one or both of the first explosive device and second device is a gun segment of a perforation gun train.

12. The switch of claim **4**, wherein the second device is an explosive device and the supply of current to the second device initiates detonation of the second device.

13. The switch of claim **11**, wherein the switch is one of a series of switches in the perforation gun train, and wherein the circuit of consecutive switches alternates between a negative switch fuse circuit and a positive switch fuse circuit.

14. The switch of claim **6**, wherein the housing further comprises a shoulder to limit the upper position of the piston.

15. The switch of claim **1**, wherein the circuit is at least partially shielded by protective material.

16. The switch of claim **5**, wherein an outer surface of the housing further comprises a groove for receiving a sealing element.

17. The switch of claim **5**, wherein the housing provides a pressure barrier between the first explosive device and the second device.

18. A switch comprising an anti-fuse, the anti-fuse being breakable upon reacting to a detonation and the switch being changeable from a first position to a second position upon breakage of the anti-fuse.

19. The switch of claim **18**, further comprising a circuit connected to the anti-fuse, the circuit being connectable to a first explosive device, a second device, and a selectively startable current supply.

20. The switch of claim **19**, wherein the circuit permits transmission of current between the first explosive device and the current supply when the switch is in the first position.

21. The switch of claim **20**, wherein the circuit permits transmission of an opposite current from the current supply to the second device when the switch is in the second position.

22. The switch of claim **19**, wherein the anti-fuse comprises an electrical pathway of the circuit.

23. The switch of claim **19**, wherein components of the circuit are solid-state electronics.

24. The switch of claim **19**, further comprising a housing, and the circuit and the anti-fuse are placed inside the housing.

25. The switch of claim **24**, further comprising a piston disposed near a first end of the housing, the piston being movable from a lower position to an upper position by a force from the detonation.

26. The switch of claim **25** wherein, in the upper position, the piston breaks the anti-fuse.

27. The switch of claim **19**, wherein the circuit is a negative switch fuse circuit or a positive switch fuse circuit.

28. The switch of claim **19**, wherein the current supply is from the second device or from a source above the switch.

29. The switch of claim **19**, wherein one or both of the first explosive device and second device is a gun segment of a perforation gun train.

30. The switch of claim **29**, wherein the switch is one of a series of switches in the perforation gun train, and wherein the circuit of consecutive switches alternate between a negative switch fuse circuit and a positive switch fuse circuit.

31. The switch of claim **21**, wherein the second device is an explosive device and the supply of current to the second device initiates detonation of the second device.

32. The switch of claim **25**, wherein the housing further comprises a shoulder to limit the upper position of the piston.

33. The switch of claim **24**, wherein the housing provides a pressure barrier between the first explosive device and the second device.

34. The switch of claim **19**, wherein at least a portion of the circuit is shielded by protective material.

35. The switch of claim **24**, wherein an outer surface of the housing further comprises a groove for receiving a sealing element.

36. A method of detonating a series of consecutive explosive devices comprising:

providing a switch between a first explosive device and a second explosive device, the first and second explosive devices being a pair of adjacent explosive devices in the series, and the switch having a circuit;

sending current to the first explosive device and blocking current to the second explosive device;

detonating the first explosive device, thereby providing a detonation force; and

opening a part of the circuit using a portion of the detonation force, thereby blocking current to the first explosive device and sending an opposing current to the second explosive device.

37. The method of claim **36**, further comprising detonating the second explosive device.

38. The method of claim **37**, further comprising providing a second switch between the second explosive device and a third explosive device, the second and third explosive devices being a pair of adjacent explosive devices in the series, and the second switch having a circuit.

39. The method of claim **38**, further comprising blocking the opposing current to the third explosive device.

40. The method of claim **39**, further comprising opening a part of the circuit of the second switch using a portion of a detonation force from the detonation of the second explosive device, thereby blocking opposing current to the second explosive device and sending current to the third explosive device.

41. The method of claim **40**, further comprising detonating the third explosive device.

42. The method of claim **36** wherein the switch comprises a housing, and the circuit is placed inside the housing.

43. The method of claim **42**, wherein the switch further comprises a piston disposed near a first end of the housing, the piston being movable from a lower position to an upper position by the portion of the detonation force from the detonation of the first explosive device.

44. The method of claim **43**, wherein the opening of the part of the circuit is achieved by the movement of the piston into the upper position.

45. The method of claim **36**, wherein components of the circuit are solid-state electronics.

46. The method of claim **36**, wherein the circuit is a negative switch fuse circuit or a positive switch fuse circuit.

47. The method of claim **36**, wherein the consecutive explosive devices are gun segments of a perforation gun train.

48. The method of claim **38**, wherein the switch is a positive switch and the second switch is a negative switch, or vice versa.

49. The method of claim **43**, wherein the housing further comprises a shoulder to limit the upper position of the piston.

50. The method of claim **36**, wherein the circuit is at least partially shielded by protective material.

51. The method of claim **42**, wherein an outer surface of the housing further comprises a groove for receiving a sealing element.

52. The switch of claim **42**, wherein the housing provides a pressure barrier between the first explosive device and the second explosive device.

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