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DETONATION OF SEISMIC CHARGES

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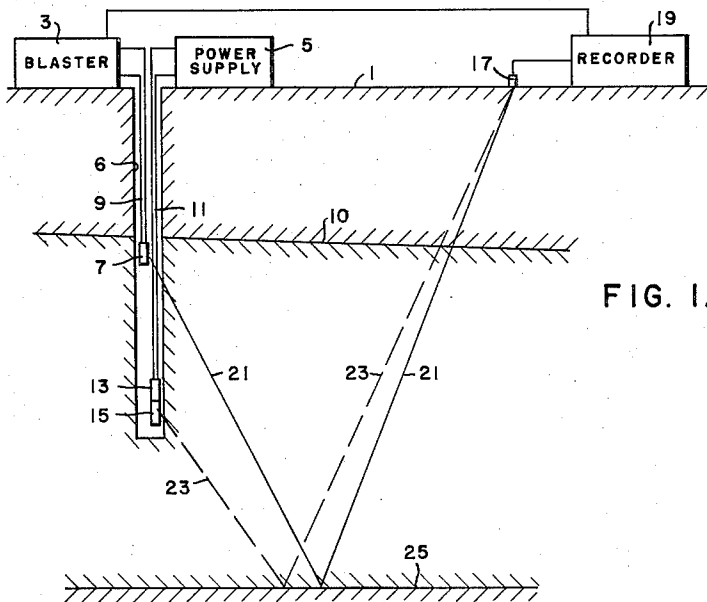


FIG. 1.

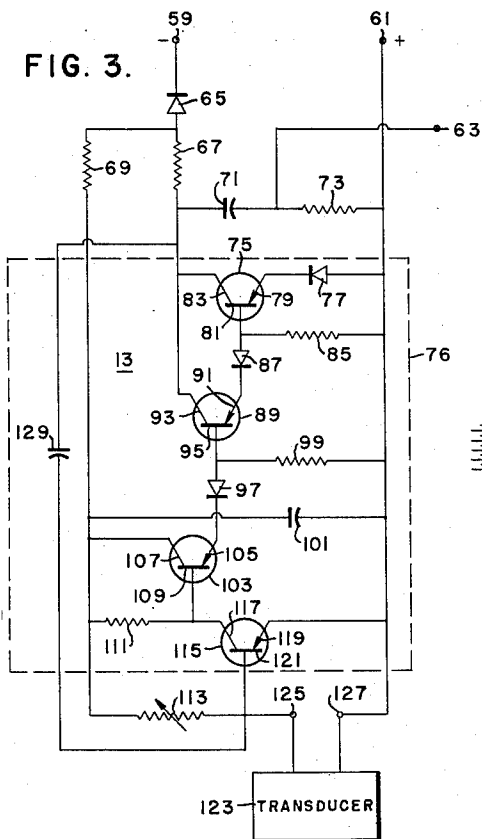


FIG. 3.

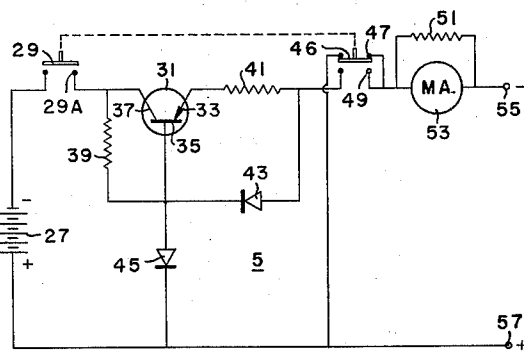


FIG. 2.

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DETONATION OF SEISMIC CHARGES

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This invention relates to the detonation of explosive charges in connection with seismic prospecting, and more particularly to the detonation of a plurality of explosive charges in spaced time sequence.

In connection with the generation of artificial seismic waves in the earth, it has been known to detonate two or more vertically spaced-apart explosive charges in a predetermined time sequence for the purpose of reinforcing downgoing seismic waves produced by the topmost charge, and for the purpose of at least partially canceling multiple reflections. Reference may be had to U.S. Patents No. 2,808,894—Eisler et al. and No. 2,882,988—Dobrin for a description of the technique.

In order to detonate the explosive charges in spaced time sequence, it has been the practice to use units of "Elcord," a line explosive somewhat similar to Primacord, to connect two or more explosive charges for sequential detonation. The Elcord is fixed in length and in burning time so that after a velocity survey has been run on a shot hole to determine the vertical travel time of sound in the formations adjacent thereto, the hole can be loaded with the proper amount of explosive charge to provide suitable seismic energy and with proper units of Elcord to provide the desired spacing of shots both in distance and in time.

Unfortunately, the proper surveying of a shot hole is an expensive operation in itself, and therefore most shot holes are loaded under the assumption of uniform acoustic conditions existing in the earth between shot holes in a given area. This assumption may be a source of error which is detrimental to the results achieved. Even if exact acoustic conditions for a shot hole are known, frequently it is impractical to fire the delayed shots with the desired spacing and time sequence because the Elcord units are not completely flexible but are available only in discrete units of burning time and length.

The present invention makes use of apparatus that may be lowered into a shot hole with one or more of the explosive charges. The apparatus detects seismic waves that are produced by detonation of a given explosive charge when they arrive at the location of the explosive charge to be subsequently detonated. For the purpose of providing electrical energy to detonate the explosive charge, the apparatus includes a storage capacitor that may be charged with a small current insufficient to detonate the explosive charge. The charging current passes through the electrically responsive detonating means for the explosive charge. Electric switch means in circuit relationship with the storage capacitor and the charge detonating means is adapted to substantially instantaneously discharge the capacitor through the explosive charge detonating means responsive to an output indication from the seismic wave detonating means. The electrical circuitry is arranged so that inadvertent detonation of the explosive charge is impossible as a result of

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crossed electrical leads between the circuitry and the source of capacitor charging current.

The invention will be described in detail with reference to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic cross-section of the earth showing an embodiment of the invention and certain seismic wave ray paths useful in understanding the operation of the invention;

FIG. 2 is a schematic electrical diagram of the power supply indicated in FIG. 1; and

FIG. 3 is an electrical schematic diagram of explosive charge detonating apparatus responsive to detection of seismic waves in accordance with the teachings of the invention.

With reference now to the drawings, and in particular to FIG. 1 thereof, there is shown a cross-section of the earth with a shot hole 6 extending from the earth's surface 1 to a substantial depth below the bottom 10 of the weathered layer of the earth. For the purpose of generating seismic waves, an explosive charge 7 is positioned in shot hole 6 and connected by insulated firing leads 9 to a blasting device 3 at the earth's surface 1. The blasting device may include the usual power supply and switch for supplying electrical energy to detonate the explosive charge 7. Also disposed at the earth's surface is an electrical signal recording device 19 electrically connected to blasting device 3 in the usual manner, and a geophone 17 connected to the recorder so that geophone output signals are recorded thereby. While only a single geophone 17 is shown, manifestly a line of geophones may be used in accordance with well known seismic prospecting techniques. This technique is well known to the prior art and will not be further described herein.

Also disposed in the shot hole 6 below the depth of explosive charge 7 are a second explosive charge 15 and an explosive charge detonating device 13. The detonating device 13 is adapted to detonate explosive charge 15 responsive to impingement thereon of seismic waves produced by explosive charge 7, and is electrically connected by electrical leads 11 to a power supply 5 at the earth's surface. The power supply 5 and the explosive charge detonating device 13 are respectively shown in schematic form in FIGS. 2 and 3.

Power supply 5 charges certain storage capacitors in detonating device 13 that will be described below. The power supply is adapted to limit the charging current to a predetermined maximum value.

With reference now to FIG. 2, power supply 5 is seen to include a battery 27 or other source of electrical energy, a transistor 31, switch means 29 and 46, diodes 43 and 45, and resistors 41 and 39. A milliammeter 53 with a suitable shunt 51 may be also included in the power supply. The negative terminal of energy source 27 is connected to collector 37 of transistor 31 when the normally open contacts 29A of switch 29 are closed. The emitter 33 of transistor 31 is connected to output terminal 55 through milliammeter 53, contacts 49 of switch 46, and resistor 41. The normally closed contacts 47 of switch 46 connect terminal 55 directly to terminal 57 through milliammeter 53 and resistor 51.

Diode 43 regulates the base current of transistor 31 to limit the emitter current of transistor 31 to a predetermined maximum value. This is effected by selecting a diode 43 that will begin conducting when the sum of the

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IR drop across resistor 41 and the voltage drop between the base and emitter of the transistor is approximately 0.5 volt. The diode will begin to conduct at this voltage so as to shunt current away from the base of the transistor. The function of Zener diode 45 is to regulate the maximum voltage that may be produced across terminals 55 and 57 after initial current surge. This is done in the usual manner for circuits utilizing Zener diodes.

In FIG. 3 there is shown the electrical circuit for the downhole portion of the explosive charge detonating apparatus 13. The input terminals 59 and 61, respectively, of circuit 13 are connected to output terminals 55 and 57, respectively, of power supply circuit 5. A storage capacitor 71 is connected to terminal 59 through resistor 67 and diode 65, and to terminal 61 through resistor 73. The firing cap of explosive charge 15 is connected to cap terminal 63 and to terminal 61 so as to be in parallel with resistor 73.

Electroacoustic transducer 123 functions to provide an output signal across terminals 125 and 127 responsive to impingement of acoustic waves such as seismic waves, and to provide an actuating signal for discharge of capacitor 71 through the firing cap connected between terminals 61 and 63. Electroacoustic transducer 123 may be any one of several types of transducers that are commercially available, such as a magnetostrictive, variable capacitance, piezoelectric or electrostrictive device. A particularly suitable transducer utilizes a barium titanate crystal.

Monostable multivibrator 76 functions to discharge storage capacitor 71 through the cap connected to terminals 61 and 63 responsive to appearance of an actuating signal across terminals 125 and 127. Multivibrator 76 comprises a normally conducting transistor 115 and normally nonconducting transistors 75, 89, and 103. All of the transistors may be junction p-n-p transistors of types that are commercially available. The output terminals 125 and 127 of transducer 123 are respectively connected to the base 121 and emitter 119 of transistor 115. Terminal 125 also is connected to resistor 69 by variable resistor 113. The function of resistor 113 is to provide correct operating voltage across transducer 123 to bias transistor 115 to conduction when no compressional waves are impinging on the transducer. Emitter-collector potential for transistor 115 is provided by capacitor 101 connected between emitter 119 and collector 117 through resistor 111. Capacitor 101 provides emitter-collector voltage for transistor 103 through resistor 99 and diode 97. Capacitor 101 is charged through resistor 69 connected to terminal 59 through silicon diode 65. Capacitor 101 also is connected to terminal 61.

The collector 117 of transistor 115 is connected to the base 109 of transistor 103. When transistor 115 is conducting to collector current saturation, the voltage between emitter 105 and base 109 will be insufficient to permit transistor 103 to conduct until the internal bias voltage of the silicon diode 97 is overcome.

Transistor 75 is connected between terminal 61 and capacitor 71 by means of silicon diode 77. The collectors 83 and 93 of transistors 75 and 89, respectively, are connected together, and the emitter 91 of transistor 89 is coupled to the base 81 of transistor 75 by means of silicon diode 87. Diode 87 also is connected to terminal 61 by means of resistor 85. Diode 97 also connects base 95 of transistor 89 to the emitter 105 of transistor 103 so that resistor 99 is coupled between emitter and base of transistor 89 through resistor 85 and diode 87. Capacitor 129 is connected between base 121 and collectors 83 and 93 of transistors 75 and 89.

Values of resistance and capacitance for resistors 67, 69, and capacitors 71 and 101 are chosen so that time constant of resistor 69 and capacitor 101 is less than the time constant of resistor 67 and capacitor 71. Capacitor 101 will charge more rapidly than capacitor 71 so that transistor 115 begins conducting before transistors 75 and

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89 have sufficient collector potential to fire the cap connected between terminals 61 and 63. The time constants of the circuit, furthermore, are such that transistors 75 and 89 will not stop conducting after they have been triggered to conduction until capacitor 71 is almost completely discharged.

The function of resistor 73 is to insure that capacitor 71 has a discharge path in the absence of a cap connected between terminals 61 and 63. The functions of diode 65 are: to prevent a reversal of terminals 55, 57, 59, and 61 so that capacitors 71 and 101 are charged to the correct polarity; to prevent the capacitors 71 and 101 from discharging immediately if the leads 11 should become short circuited by the detonation of explosive charge 7; and to provide a discharge time constant for capacitor 101 and resistor 69 that is longer than the time constant for capacitor 71 such that the circuit will disarm safely in the absence of acoustic signal by keeping transistor 115 conducting until after the potential on capacitor 71 is below that required to fire the cap.

The operation of the apparatus illustrated in FIGS. 1, 2, and 3 is as follows: switches 29 and 46 are actuated to close contacts 29A and 49. At the instant that the contacts are closed, the downhole portion of the circuit connected to terminals 55 and 57 presents a capacitive load to the power supply. Transistor 31 will attempt to pass an emitter current that is limited only by the value of the base current of the transistor multiplied by the D.C. β of the transistor. As soon as the combined voltage drop between base and emitter of the transistor and the IR drop across resistor 41 equals the internal bias of silicon diode 43, diode 43 begins to conduct to shunt current away from the base 35 of transistor 31. The effect is to provide a constant emitter current through the transistor once the bias point has been reached. The current that charges capacitors 101 and 71 thus is limited to a value insufficient to fire the cap connected to terminals 61 and 63. When contacts 29A and 49 are closed, the current indicated by milliammeter 53 will rise abruptly and will then fall off as the capacitors are charged. The voltage to which the capacitors will charge will be slightly less than the Zener voltage of diode 45, and will be independent of the number of explosive charge detonating devices 13 connected to power supply 5. The rise and fall of the current indicated by milliammeter 53, as described above, will indicate that terminal 55 is properly connected to terminal 59 and terminal 57 is connected to terminal 61. Should the terminals be crossed, there will be no momentary charging current indicated by milliammeter 53.

Capacitor 101 will charge more rapidly than capacitor 71 as described above so that transistor 115 is rendered conductive.

Blaster 3 is now actuated to detonate explosive charge 7. Electrical leads 11 will be severed and probably will be short circuited by the conductive tamping fluid. Diode 65 prevents capacitors 71 and 101 from discharging through this path. The compressional waves produced by the explosive charge 7 will impinge upon transducer 123. The transducer is polarized so that a pressure increase causes part of the base current of transistor 115 to be directed to the transducer, thus causing the collector 117 to emitter 119 potential of transistor 115 to increase. When transistor 115 is conductive, the potential at collector 117 is too low to overcome the internal bias of diode 97 and transistor 103, thus no base current flows in transistor 103 and it is rendered nonconductive. The internal bias of this transistor, existing between its base and emitter is quite low, but is aided by the internal bias (approximately $\frac{1}{2}$ volt) of silicon diode 97, which further insures that transistor 103 remains nonconducting under the conditions described above. Transistors 89 and 75 are biased in the same manner, that is, internally, and aided by the internal bias of diodes 87 and 77, respectively. These transistors must therefore also remain

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nonconductive until transistor 103 begins to conduct. Then, the emitter current of transistor 103 flows through resistor 99 until the potential of the base 95 of transistor 89 is raised sufficiently to overcome the aforementioned bias, and base current flows. This results in an emitter current flowing in transistor 89 through diode 87 and resistor 85. The drop across resistor 85 rises until the potential of the base 81 of transistor 75 is sufficiently high to overcome the internal bias of this transistor plus the added bias of silicon diode 77. The capacitor 129 provides a positive feed-back which causes an abrupt change of state such that transistor 115 is almost instantaneously cut off, and transistor 75 is driven to collector current saturation. As mentioned above, the time constants of the circuit are such that when transistor 75 is triggered to conduction, it will continue to conduct until the charge on capacitor 71 is substantially zero. Since all of the current that flow through transistors 75 and 89 must be supplied by capacitor 71, it is apparent that current will flow through the cap as the path of least resistance. The maximum current through the cap will be of the order of 8 amperes within 10 microseconds after arrival of the compressional wave detected by transducer 123. The current from capacitor 71 will drop as capacitor 71 discharges so that it is still greater than 5 amperes after .5 milliseconds. This current is sufficient to cause the cap to fire within 200 to 300 microseconds after arrival of the acoustic signal. While the current through the transistor 75 and 89 may be many times their continuous ratings, the transistors will not be destroyed by current of this magnitude during the short interval that they are required to conduct before they are destroyed by explosive charge 15.

The seismic waves produced by explosive charges 7 and 15 will pass through the earth in the usual manner. Seismic waves following ray paths 21 and 23 are shown as being reflected by reflecting horizon or interface 25, and as being subsequently detected by geophone 17 to produce electrical signals that are recorded by recorder 19 in the usual manner. It is readily apparent that any number of the detonating devices described above with respect to FIG. 3 may be used in any one sequence of shots. The power supply described with reference to FIG. 2 can be used to simultaneously arm several detonators constructed according to the circuit diagram of FIG. 3. It is obvious that the power supply can be modified to provide a plurality of limiting current and voltage values.

In the event that it is decided not to fire explosive charge 7 after capacitors 71 and 101 have been charged, switches 29 and 46 are released. Capacitor 101 will discharge through resistor 113 and transistor 115, and capacitor 71 will discharge through resistors 67, 69, 113, transistor 115, and the cap shunted by resistor 73. However, the resistors 67 and 69 will limit the current through the cap to a value insufficient to fire the cap so that the apparatus is rendered safe.

Note that the time constants of the circuit are such that the charge on capacitors 71 and 101 are kept at a sufficient level to permit the circuit to be actuated by an acoustic wave from explosive charge 7 after electrical leads 11 are severed.

A distinct advantage of the apparatus described above is that the explosive charge 7 may be in a different shot hole from the explosive charge 15. Thus, if it is desired, the explosive charges may be positioned in different boreholes at the same level or on a slant relative to the vertical.

Another distinct advantage of the apparatus is that explosive charge 15 and detonating device 13 can be spaced apart any desired distance for the purpose of advancing or retarding the detonation of explosive charge 15 with respect to the initial arrival of acoustic waves at the explosive charge. This is advantageous in that it permits shaping of the downward traveling wavelet so as to control the dominant frequency of the wavelet.

The following-listed values and types of circuit com-

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ponents have been found to be entirely satisfactory in operation. It is to be understood that the values and types indicated are exemplary only and that other values and types may be substituted.

5	Battery 27	27 volts.
	Transistor 31	2N291.
	Resistor 39	10,000 ohms.
	Resistor 41	20 ohms.
	Diode 43	307A.
10	Diode 45	20 volts Zener type.
	Diode 65	307A.
	Resistor 67	1000 ohms.
	Resistor 69	1000 ohms.
15	Capacitor 71	100 mfd.
	Resistor 73	100 ohms.
	Transistor 75	2N256.
	Diode 77	307A.
	Resistor 85	47,000 ohms.
20	Diode 87	307A.
	Transistor 89	2N256.
	Resistor 99	10,000 ohms.
	Diode 97	307A.
	Capacitor 101	25 mfd.
25	Transistor 103	GT222.
	Resistor 111	10,000 ohms.
	Resistor 113	470,000 to 1 megohm.
	Transistor 115	GT222.
	Capacitor 129	.007 mfd.
30	Transducer 123	Barium titanate cylinder, 1½" x 1½" diameter x ⅛" wall.

While the embodiment disclosed in the preceding specification is preferred, other modifications will be apparent to those skilled in the art which do not depart from the scope of the broadest aspects of the present invention.

What is claimed is:

1. Apparatus for energizing an electrically actuable firing cap positioned at a given depth in a borehole responsive to detection thereby of acoustic waves of predetermined minimum amplitude generated by detonating an explosive charge in the borehole above said given depth, comprising: first and second terminals at substantially said given depth in the borehole to which said firing cap is to be connected, and a third terminal; a storage capacitor in the borehole; means connecting said storage capacitor between said first and third terminals so that said storage capacitor can be electrically charged through the cap by an electrical source at the earth's surface connected to said first and third terminals through electrical leads severable by said explosive charge positioned above said given depth; monostable multivibrator means including a normally conductive input stage and a normally non-conductive output stage adapted to switch conduction states when an actuating signal is applied to said input stage, said output stage being in circuit relationship with said storage capacitor and said first and second terminals so as to effectively connect said storage capacitor directly across said first and second terminals when an actuating signal is applied to said input stage; said monostable multivibrator means including a high impedance discharge path for slowly discharging said capacitor after disconnection of said capacitor from the electrical source; and means, including electroacoustic transducer means at substantially said given depth in the borehole, electrically coupled to said input stage to supply an actuating signal to said input stage responsive to detection of acoustic waves of predetermined minimum amplitude by said electroacoustic transducer means.

2. Apparatus for energizing an electrically actuable explosive charge firing cap positioned at a given depth in a borehole responsive to detection thereby of acoustic waves of predetermined minimum amplitude generated by detonating an explosive charge in the borehole above said given depth, comprising: first and second terminals

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at substantially said given depth in the borehole to which said firing cap is to be connected; and a third terminal; a storage capacitor in the borehole; means connecting said storage capacitor between said first and third terminal so that said storage capacitor can be electrically charged through the cap by an electrical source at the earth's surface connected to said first and third terminals through electrical leads severable by said explosive charge positioned above said given depth; circuit means including first and second transistor means arranged in a monostable multivibrator circuit with said first transistor means normally conducting and said second transistor means normally nonconducting, said first and second transistor means being adapted to switch conduction states when an actuating signal is applied to said first transistor means, said second transistor means being further connected in circuit relationship with said storage capacitor and said first and second terminals to effectively connect said storage capacitor directly across said first and second terminals when rendered conductive; said circuit means further including a high impedance discharge circuit through said first transistor means to slowly discharge said capacitor after disconnection of the electrical source from said capacitor; and means, including electroacoustic transducer means, at substantially said given depth in the borehole, electrically coupled to said first transistor means and adapted to apply an actuating signal to said first transistor means responsive to impingement of acoustic waves of greater than a predetermined amplitude on said electroacoustic transducer means.

3. Apparatus for energizing an electrically actuable explosive charge firing cap positioned at a given depth in a borehole responsive to detection thereby of acoustic waves of predetermined minimum amplitude generated by detonating an explosive charge in the borehole above said given depth, comprising: first and second terminals at substantially said given depth in the borehole to which said firing cap is to be connected; a storage capacitor in the borehole and an electrical source at the earth's surface, electrically connected in series circuit relationship across said terminals by electrical leads extending through the borehole and severable upon detonation of the explosive charge positioned above said given depth; monostable multivibrator means including a normally conductive input stage and a normally nonconductive output stage adapted to switch conduction states when an actuating signal is applied to said input stage, said output stage being in circuit relationship with said storage capacitor and said terminals so as to effectively connect said storage capacitor directly across said terminals when an actuating signal is applied to said input stage; high impedance circuit means connecting said storage capacitor to said normally conductive input stage to slowly discharge said storage capacitor through said normally conductive input stage when said storage capacitor is disconnected from said electrical source while said normally conductive input stage is conducting; and means, including electroacoustic transducer means positioned at substantially said given depth in the borehole, electrically coupled to said input stage to supply an actuating signal to said input stage responsive to detection of acoustic waves of predetermined minimum amplitude by said electroacoustic transducer means.

4. Apparatus for energizing an electrically actuable explosive charge firing cap positioned at a given depth in a borehole responsive to detection thereby of acoustic waves of predetermined minimum amplitude generated by detonating an explosive charge in the borehole above said given depth, comprising: first and second terminals at substantially said given depth in the borehole to which said firing cap is to be connected; a storage capacitor in the borehole and an electrical source at the earth's surface, electrically connected in series circuit relationship across said terminals by electrical leads extending through the borehole and severable upon detonation of

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the explosive charge positioned above said given depth; means including first and second transistor means arranged in a monostable multivibrator circuit with said first transistor means normally conducting and said second transistor means normally nonconducting, said first and second transistor means being adapted to switch conduction states when an actuating signal is applied to said first transistor means, said second transistor means being further connected in circuit relationship with said storage capacitor and said terminals to effectively connect said storage capacitor directly across said terminals when rendered conductive; high impedance circuit means connecting said storage capacitor to said first transistor means to slowly discharge said storage capacitor through said first transistor means when said storage capacitor is disconnected from said electrical source while said first transistor means is conducting; and means, including electroacoustic transducer means positioned at substantially said given depth in the borehole, electrically coupled to said first transistor means and adapted to apply an actuating signal to said first transistor means responsive to impingement of acoustic waves of greater than a predetermined amplitude on said electroacoustic transducer means.

5. Apparatus for detonating explosive charge means at a given depth in a borehole responsive to detection thereby of acoustic waves generated by detonation of an explosive charge in the borehole above said given depth, comprising: explosive charge means; means in the borehole for detonating said explosive charge means including an electrically responsive firing means; a storage capacitor in the borehole; first means at the earth's surface, electrically connected in series circuit relationship with said storage capacitor and said electrically responsive firing means through electrical leads passing through the borehole and severable upon detonation of said explosive charge positioned above said given depth, adapted to charge said storage capacitor through said firing means with a current insufficient to actuate said electrically responsive firing means; monostable multivibrator means in the borehole, including a normally conductive input stage and a normally nonconductive output stage adapted to switch conduction states when an actuating signal is applied to said input stage, said output stage being in series circuit relationship with said storage capacitor and said terminals so as to effectively connect said storage capacitor directly across said terminals when an actuating signal is applied to said input stage; high impedance circuit means connecting said storage capacitor to said normally conductive input stage to slowly discharge said storage capacitor through said normally conductive input stage when said storage capacitor is disconnected from said first means while said normally conductive input stage is conducting; and electroacoustic transducer means at substantially said given depth in the borehole coupled to said input stage adapted to supply an electrical actuating signal to said input stage responsive to impingement thereon of acoustic waves of given amplitude.

6. Apparatus for detonating explosive charge means at a given depth in a borehole responsive to detection thereby of acoustic waves generated by detonation of an explosive charge in the borehole above said given depth, comprising: explosive charge means; a storage capacitor in the borehole; means in the borehole for detonating said explosive charge means including an electrically responsive firing means; power supply means at the earth's surface adapted to supply a limited current less than the current required to actuate said electrically responsive firing means; coupling means, including half-wave rectifier means in the borehole coupling said power supply means to said storage capacitor through said electrically responsive firing means and through electrical leads extending from the earth's surface and severable upon detonation of said explosive charge positioned above said given depth; monostable multivibrator means in the bore-

hole including a normally conductive input stage and a normally nonconductive output stage adapted to switch conduction states when an actuating signal is applied to said input stage, said output stage being in series circuit relationship with said storage capacitor and said terminal so as to effectively connect said storage capacitor directly across said terminals when an actuating signal is applied to said input stage; high impedance circuit means connecting said storage capacitor to said normally conductive input stage to slowly discharge said storage capacitor through said conductive input stage when said storage capacitor is disconnected from said power supply means while said normally conductive input stage is conducting; and electroacoustic transducer means at substantially said given depth in the borehole coupled to said input stage adapted to supply an electrical actuating signal to said input stage responsive to impingement thereon of acoustic waves of predetermined amplitude.

7. Apparatus for detonating explosive charge means at a given depth in a borehole responsive to detection thereby of acoustic waves generated by detonation of an explosive charge in the borehole above said given depth, comprising: explosive charge means; means in the borehole for detonating said explosive charge means including an electrically responsive firing means; a storage capacitor in the borehole; first means at the earth's surface, electrically connected in circuit relationship with said storage capacitor and said electrically responsive firing means through electrical leads extending from the earth's surface and severable upon detonation of said explosive charge positioned above said given depth, adapted to charge said storage capacitor with current insufficient to actuate said electrically responsive firing means; means in the borehole including first and second transistor means arranged in a monostable multivibrator circuit with said first transistor means normally conducting and said second transistor means normally nonconducting, said first and second transistor means being adapted to switch conduction states when an actuating signal is applied to said first transistor means, said second transistor means being further connected in circuit relationship with said storage capacitor and said terminals to effectively connect said storage capacitor directly across said first and second terminals when rendered conductive; high impedance circuit means connecting said storage capacitor to said first transistor means to slowly discharge said storage capacitor through said first transistor means when said storage capacitor is disconnected from said first means while said first transistor means is conducting; and means including electroacoustic transducer means at substantially said given depth in the borehole electrically coupled to said first transistor means and adapted to apply an actuating signal to said first transistor means responsive to impingement of acoustic waves of greater than a predetermined amplitude on said electroacoustic transducer means.

8. Apparatus for firing an electrically detonated explosive charge positioned at a given depth in a borehole responsive to detection of acoustic waves produced by detonating an explosive charge positioned above said given depth, comprising: a first storage capacitor in the borehole; first transistor means in the borehole in circuit relationship with said first storage capacitor and the explosive charge adapted, when rendered conductive, to discharge said first storage capacitor through said explosive charge to detonate said explosive charge; a first resistor means; power supply means at the earth's surface, electrically connected in series circuit relationship with said first storage capacitor, said resistor means and the explosive charge through electrical leads extending from the earth's surface and severable upon detonation of said explosive charge positioned above said given depth, adapted to charge said first storage capacitor through said first resistor means and the explosive charge while limiting the charging current to a value insufficient to detonate said explosive charge; second transistor means

in the borehole having base, emitter, and collector electrodes; a second storage capacitor in circuit relationship with said second transistor means adapted to supply emitter-collector potential thereto; second resistor means in the borehole, electrically connected in series circuit relationship with said power supply means and said second capacitor so as to charge said second storage capacitor; circuit means interconnecting said second transistor means and said first transistor means in a multivibrator circuit; the time constant of said first resistor means and said first capacitor being greater than the time constant of said second resistor means and said second storage capacitor so that said second transistor means is rendered conductive and said first transistor means is rendered nonconductive when said power supply means is activated; circuit means including said second resistor means for connecting said first storage capacitor to said second transistor means to slowly discharge said first storage capacitor through said second transistor means when said first storage capacitor is disconnected from said power supply means while said second transistor means is conducting; and electroacoustic transducer means positioned at substantially said given depth in the borehole, coupled in circuit relationship to the base and emitter electrodes of said second transistor means adapted to trigger said second transistor means to nonconduction responsive to impingement of acoustic waves of predetermined amplitude thereon, whereby said first transistor means will be rendered conductive to detonate the explosive charge.

9. Apparatus for firing an electrically detonated explosive charge positioned at a given depth in a borehole responsive to detection of acoustic waves produced by detonating an explosive charge positioned above said given depth, comprising: a first storage capacitor in the borehole; first transistor means in the borehole in circuit relationship with said storage capacitor and the explosive charge adapted, when rendered conductive, to discharge said first storage capacitor through the explosive charge to detonate said explosive charge; a first resistor means; power supply means at the earth's surface, electrically connected in series circuit relationship with said storage capacitor, said resistor means and the explosive charge adapted to charge through electrical leads extending from the earth's surface and severable upon detonation of said explosive charge positioned above said given depth, said capacitor through said resistor means and said explosive charge while limiting the charging current to a value insufficient to detonate said explosive charge, said power supply comprising a source of electrical energy, means including junction transistor means having emitter, collector, and base electrodes, coupling said source to said storage capacitor through the emitter to collector current conduction path of said junction transistor means, and control means in circuit relationship with junction transistor means for limiting the voltage between the emitter and base electrodes of said junction transistor means; second transistor means in the borehole having base, emitter, and collector electrodes; second storage capacitor means in circuit relationship with said second transistor means adapted to supply emitter-collector potential thereto; second resistor means in series circuit relationship with said power supply means and said second capacitor so as to charge said second capacitor; circuit means interconnecting said second transistor means and said first transistor means in a multivibrator circuit; the time constant of said first resistor means and said first capacitor being greater than the time constant of said second resistor means and said second capacitor means so that said second transistor means is rendered conductive and said first transistor means is rendered nonconductive when said power supply means is activated; circuit means including said second resistor means for connecting said first storage capacitor to said second transistor

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means to slowly discharge said first storage capacitor through said second transistor means when said first storage capacitor is disconnected from said power supply means while said second transistor means is conducting; and electroacoustic transducer means positioned at substantially said given depth in the borehole, coupled in circuit relationship to the base and emitter electrodes of said second transistor means adapted to trigger said second transistor means to nonconduction responsive to impingement of acoustic waves of predetermined amplitude thereon, whereby said first transistor means will be rendered conductive to detonate the explosive charge.

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