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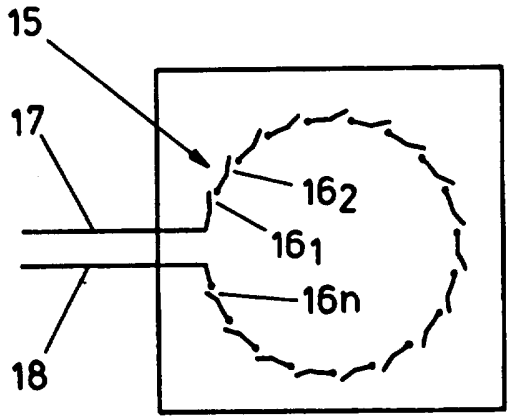
(54) Title: DETONATOR DELAY CIRCUIT

(57) Abstract

The invention relates to a method of, and apparatus for, accurately calibrating an oscillator in an electrical detonator firing circuit by the steps of arranging the oscillator to produce pulses of a predetermined length. In one embodiment disclosed the oscillator comprises a ring oscillator wherein the length of a pulse is determined by a plurality of switches operating in succession and by the method disclosed the number of switches which are to operate successively is adjusted to obtain the desired pulse length for the oscillator.



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DETONATOR DELAY CIRCUIT.

This invention relates to detonating arrangements and, more specifically, to detonating arrangements in which an electrical detonator is activated to detonate, thereby to induce a detonation wave into a bulk explosives, after a predetermined time delay following receipt of a firing signal.

It is common practise in the detonation of bulk explosives to delay the detonation of a detonator for a predetermined time delay period following receipt of a firing signal and this practise is commonly followed when a plurality of explosive materials are to be detonated in a predetermined timed sequence. In most such detonation arrangements the "clock" for determining the different timings for the detonations conveniently comprises an oscillator in each detonator circuit but, unfortunately, the oscillators used to date have inherent inaccuracies and precise desired delays in the detonation of the detonators following a common fire signal have been difficult to obtain.

One method for overcoming this problem, and now well published, is to cause the oscillator to operate and to count the number of pulses made by the oscillator over an accurately measured time interval and to use the number of pulses counted over said interval to calculate the number of pulses to be made by the oscillator to achieve a desired timing for the delay for the detonator.

The present invention seeks to provide an explosive detonator arrangement capable of producing relatively accurate delay periods.

According to the present invention there is provided a method for setting a delay time for an explosive detonator in a detonator circuit comprising the steps of adjusting an

oscillator for the detonator circuit to produce pulses of a predetermined length and subsequently sending a signal to a counter for the oscillator to count a predetermined number of pulses of said predetermined length before activating the detonator associated with the oscillator.

Preferably the method is characterised by the steps of selecting the oscillator to comprise a so-called "ring" oscillator, whereby the length of a pulse of the oscillator is determined by a plurality of switches operating successively, and calibrating the oscillator by selecting the number of switches to be operated successively to achieve the predetermined pulse length for the oscillator.

Preferably the method includes the steps of forming the oscillator, and the "ring" of switches therefore, on an electronic chip.

In a preferred embodiment the method includes the steps of setting the predetermined pulse length for the oscillator whilst its oscillator is in the detonator circuit.

In one embodiment the method is characterised by the steps of selecting the oscillator to produce square wave pulses.

In another embodiment the method is characterised by the steps of selecting the oscillator to produce saw-tooth pulses, with the leading edge of each pulse substantially vertical.

In a further embodiment the method is characterised by the steps of selecting the oscillator to produce saw-tooth pulses, with the trailing edge of each pulse substantially vertical.

The invention also envisages apparatus for setting a delay for firing a detonator after receipt of a firing signal,

said apparatus including a circuit for the detonator, an oscillator in the circuit for the detonator, and means for adjusting the oscillator to produce pulses of a predetermined pulse length.

Preferably the apparatus is characterised in that the oscillator comprises a so-called "ring" oscillator, and where the length of each predetermined oscillator pulse is determined by the successive operation of a plurality of switches.

The invention will now be described further by way of example with reference to the accompanying drawings in which:

Fig 1 shows, diagrammatically, an oscillator with a sinusoidal pulse pattern.

Fig 2 shows, diagrammatically, a switch ring for controlling the pulse length of the oscillator illustrated in Fig 1 and

Fig 3 shows, diagrammatically, a detonator circuit in accordance with the invention.

The oscillator 11 illustrated in Fig 1 is activated by power on line 12.

The oscillator 11 includes a pulse counter 13, the counter 13 is arranged to count the number of pulses made by the oscillator 11 and, on a predetermined number of pulses being counted, the pulse counter 13 transmits a signal on the line 14.

Fig 2 shows a switch ring for the oscillator 11 in accordance with the invention.

The "ring" 15 of switches 16_1 to 16_n illustrated in Fig 2 would normally have all its switches 16_1 and 16_n open and, on receipt of a signal on line 17, the switches 16_1 to 16_n close successively, as each switch 16 closes it extends the signal from line 17 to cause the next switch 16 to close until all the switches 16_1 to 16_n are closed and the signal received on line 17 is transmitted via wire 18.

In one arrangement according to the invention the oscillator 11 may be calibrated by attaching the ring 15 of switches 16_1 to 16_n to a timing arrangement, settable to accurately determine the number of switches 16_1 to 16_n to be closed in order to give a predetermined pulse length L to the oscillator 11 and, when the timing arrangement is actuated, the switches 16 of the ring 15 are allowed to close in succession until, after the predetermined time, the last to close switch 16_x is noted. Thereafter all the switches after the last to close switch 16_x are disconnected from the ring circuit so that the signal from switch 16_x is applied direct to wire 18 and the length L of the pulse of the oscillator 11 is thereby set. Thereafter, the ring 15 of switches 16_1 to 16_x is arranged to operate for each pulse made by the oscillator 11, so that all the pulses generated by the oscillator 11 have the same effective time length. Thus, by using the ring 15 of switches 16, the pulse length oscillator 11 can be accurately calibrated.

In another arrangement, not illustrated, a switch in a line extending from the last to operate switch 16_x, determining a desired pulse length L, is closed and arranged to extend the signal from the last operated switch 16_x to the line 18, thus to by-pass the switches 16 between the last operated switch 16_x and the line 18 in the direction of switch closure.

Other arrangements for terminating the closure of the switches 16 after the number of switches 16x have closed to predetermine the length of the pulse L will be apparent to persons skilled in the art.

In the arrangement illustrated in Fig 3 a control unit C transmits signals via lines 19 and 20 and a plurality of detonator circuits D1, D2 -- DN are connected to the lines 19 20. Each of the detonator circuits D1 D2 -- DN includes an oscillator 11, with its associated pulse counter 13, a condensor 21 and a detonator 22. The condensers 21 are all fully charged by applying power to the lines 19 20 before the oscillators 11 are activated and the arrangement is such that, when the pulse counter 13 of each detonator circuit D1 D2 -- DN has counted the required number of pulses for that circuit, the condensor 21 is discharged to activate the detonator 22.

It would be appreciated that the arrangement shown in Fig 3 is purely diagrammatic and the circuits D1 D2 -- DN may be changed, as desired, and components can be added to said circuits without departing from the scope of the invention.

The oscillators 11 may be fully calibrated before being included in the detonator circuit, or in an alternative arrangement, each detonator circuit will include a ring 15 of switches 161 to 16n and the oscillator may be calibrated whilst in the detonator circuit. Whilst an oscillator can have its pulse length accurately calibrated in one location any number of variants acting on the oscillator, for example the atmospheric temperature, can adversely affect the oscillator and accordingly the setting of the pulse length. Thus, inclusion of the oscillator in the detonator circuit with subsequent calibration of the oscillator pulse length ensures accuracy of the required time delay period.

Whilst in the illustrated embodiment the oscillator is defined as producing a pulse of the form following a point moving with simple harmonic motion it will be appreciated that other forms of pulse may be obtained. Thus, for example, the oscillator may produce saw-tooth pulse forms, with the start to each pulse being substantially vertical or the end of each pulse being substantially vertical and all such pulses must be within the scope of the present invention.

CLAIMS

1. A method for setting a delay time for an explosive detonator in a detonator circuit comprising the steps of adjusting an oscillator for the detonator circuit to produce pulses of a predetermined length and subsequently sending a signal to a counter for the oscillator to count a predetermined number of pulses of said predetermined length before activating the detonator associated with the oscillator.

2. A method according to claim 1 characterised by the steps of selecting the oscillator to comprise a so-called "ring" oscillator, whereby the length of a pulse of the oscillator is determined by a plurality of switches operating successively, and adjusting the oscillator by selecting the number of switches to be operated successively to achieve the predetermined pulse length for the oscillator.

3. A method according to claim 2 including the steps of forming the oscillator, and the "ring" of switches therefore, on an electronic chip.

4. A method according to claims 1, 2 or 3 characterised in that the predetermined pulse length for the oscillator is set for the oscillator whilst the oscillator is in the detonator circuit.

5. A method according to claims 1, 2, 3 or 4 characterised by the steps of selecting the oscillator to produce square wave pulses.

6. A method according to claims 1, 2, 3 or 4 characterised by the steps of selecting the oscillator to produce saw-tooth pulses, with the leading edge of each pulse substantially vertical.

7. A method according to claims 1, 2, 3 or 4 characterised by the steps of selecting the oscillator to produce saw-tooth pulses, with the trailing edge of each pulse substantially vertical.

8. Apparatus for setting a delay for firing a detonator after receipt of a firing signal, said apparatus including a circuit for the detonator, an oscillator in the circuit for the detonator, and means for adjusting the oscillator to produce pulses of a predetermined pulse length.

9. Apparatus according to claim 8 characterised in that the oscillator comprises a so-called "ring" oscillator, and wherein the length of each predetermined oscillator pulse is determined by the successive operation of a plurality of switches.

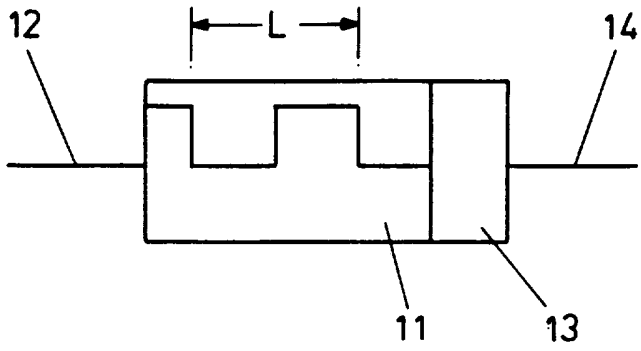

FIG. 1

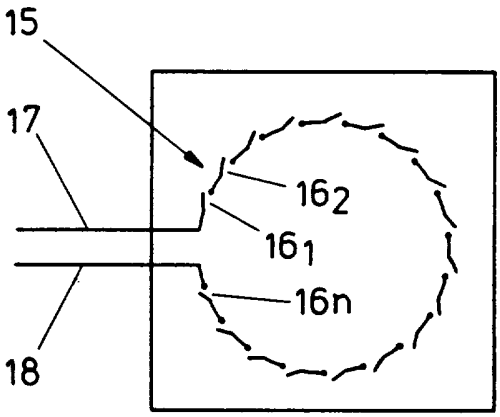

FIG. 2

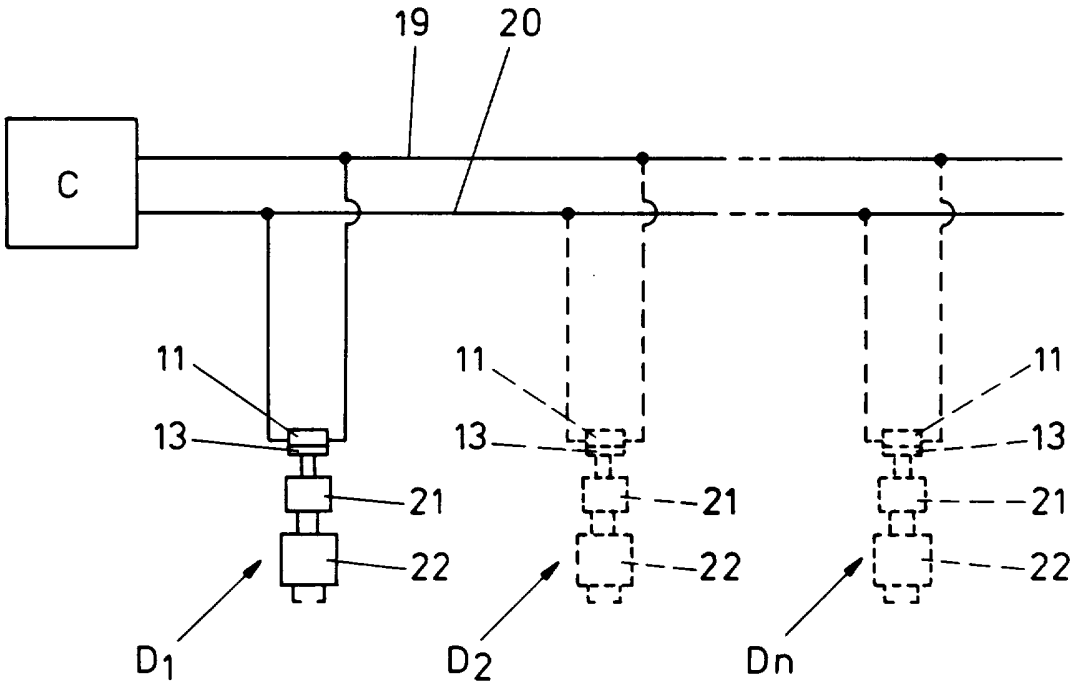

FIG. 3

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F42D1/055

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F42D F42C H03L H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 443 221 (ATLAS POWDER COMPANY) 28 August 1991 see column 2, line 45 - column 3, line 27; figures	1
Y		2-9

Y	US,A,4 517 532 (NEIDORFF) 14 May 1985 see column 1, line 58 - column 3, line 36; figures	2-9

X	EP,A,0 616 190 (ASAHI KASEI KOGYO KABUSHIKI KAISHA) 21 September 1994 see column 3, line 1 - column 4, line 3; figures	1
Y		2-9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 February 1996	14. 03. 96

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP,A,0 440 389 (SEAGATE TECHNOLOGY INTERNATIONAL) 7 August 1991 see column 1, line 40 - column 2, line 31; figures	2-9
A	US,A,4 714 977 (HOELZER ET AL.) 22 December 1987 see column 1, line 38 - line 58; figures	1-9

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Information on patent family members

In. :tional Application No
PCT/GB 95/02665

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EP-A-443221	28-08-91	NONE		
US-A-4517532	14-05-85	NONE		
EP-A-616190	21-09-94	AU-B-	664423	16-11-95
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		JP-A-	7046120	14-02-95
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US-A-4714977	22-12-87	NONE		