United States Patent

Hartig

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[54] **PROCESS AND APPARATUS FOR PRODUCING TRIGGER PULSES**

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April 3, 1969 Germany.....P 19 17 389.8

[52] **U.S. Cl.** **328/55,** 328/41, 328/48, 328/63, 328/141, 307/215, 307/247, 307/273

[51] **Int. Cl.**.....**H03k 3/00**

[58] **Field of Search**.....328/55, 63, 72, 73, 74, 140, 328/141; 340/268 T; 307/215, 247, 273

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[57] **ABSTRACT**

Apparatus for producing a trigger pulse at a preselected point which is off-set from a reference point in the movement of a cyclically moving mechanical device which includes a pulse generator adapted to be connected to the device which produces a series of pulses during each cycle of the device. A counter counts the pulses. A gate connects the pulse generator with the counter and control means enables the gate for a time period corresponding to the interval of time between movement of the mechanical device between the preselected and reference points. Trigger means is provided which increments the count in the counter to produce a trigger pulse after a desired count has been reached.

A novel method of producing the trigger is also disclosed.

14 Claims, 9 Drawing Figures

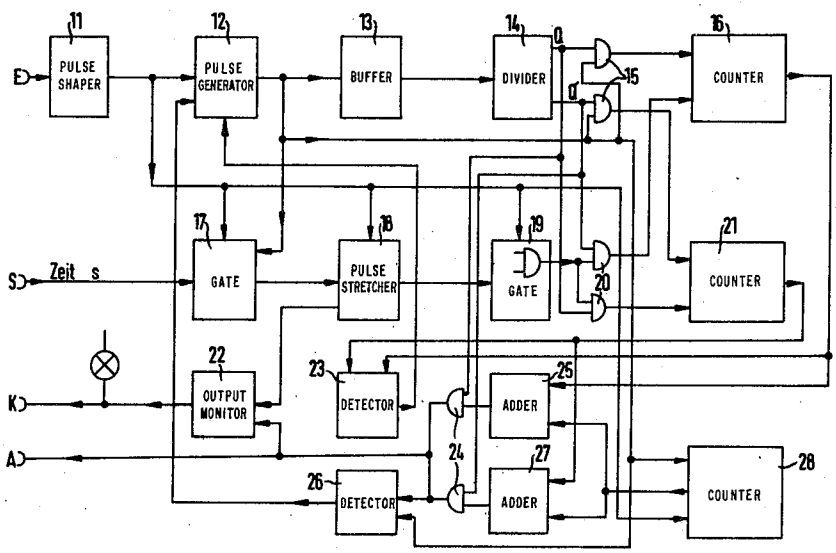
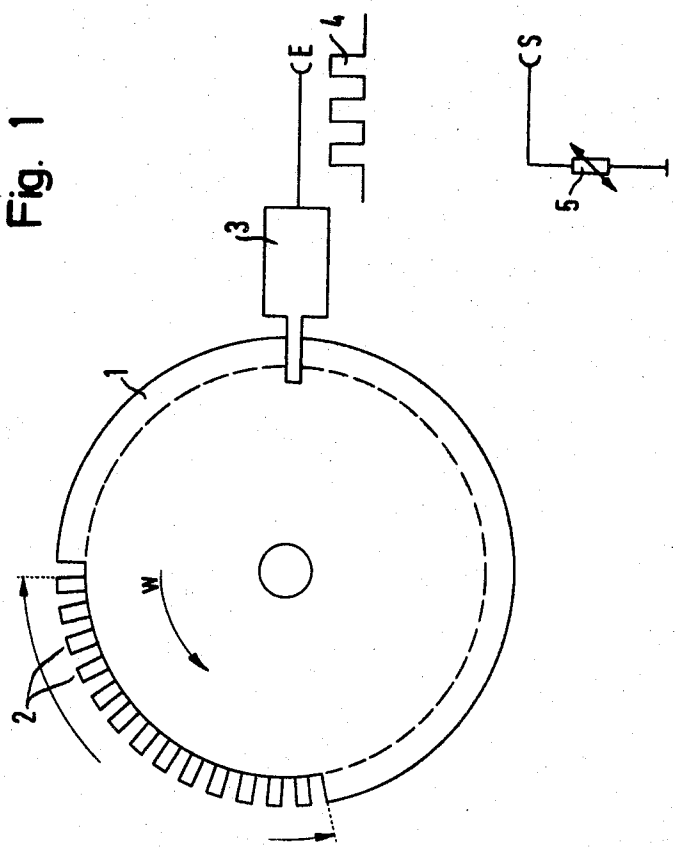


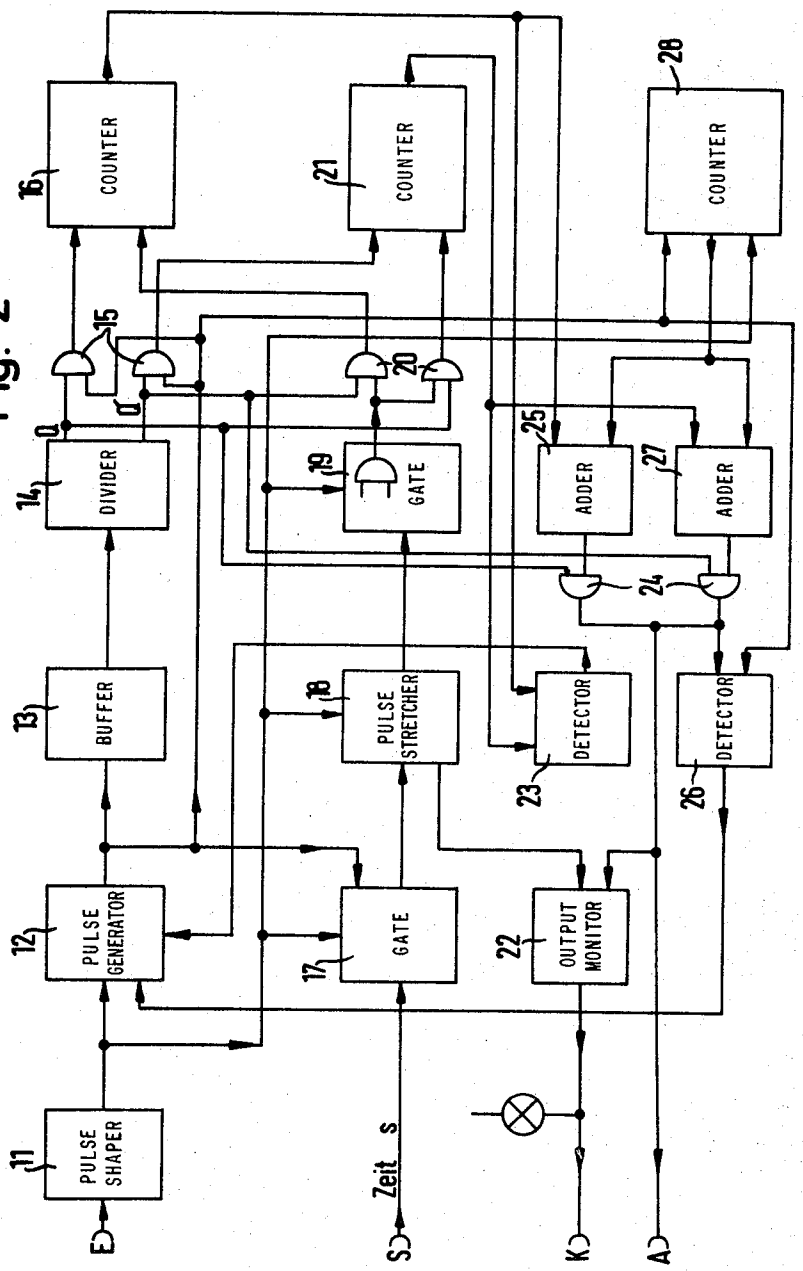
Fig. 1



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Fig. 2



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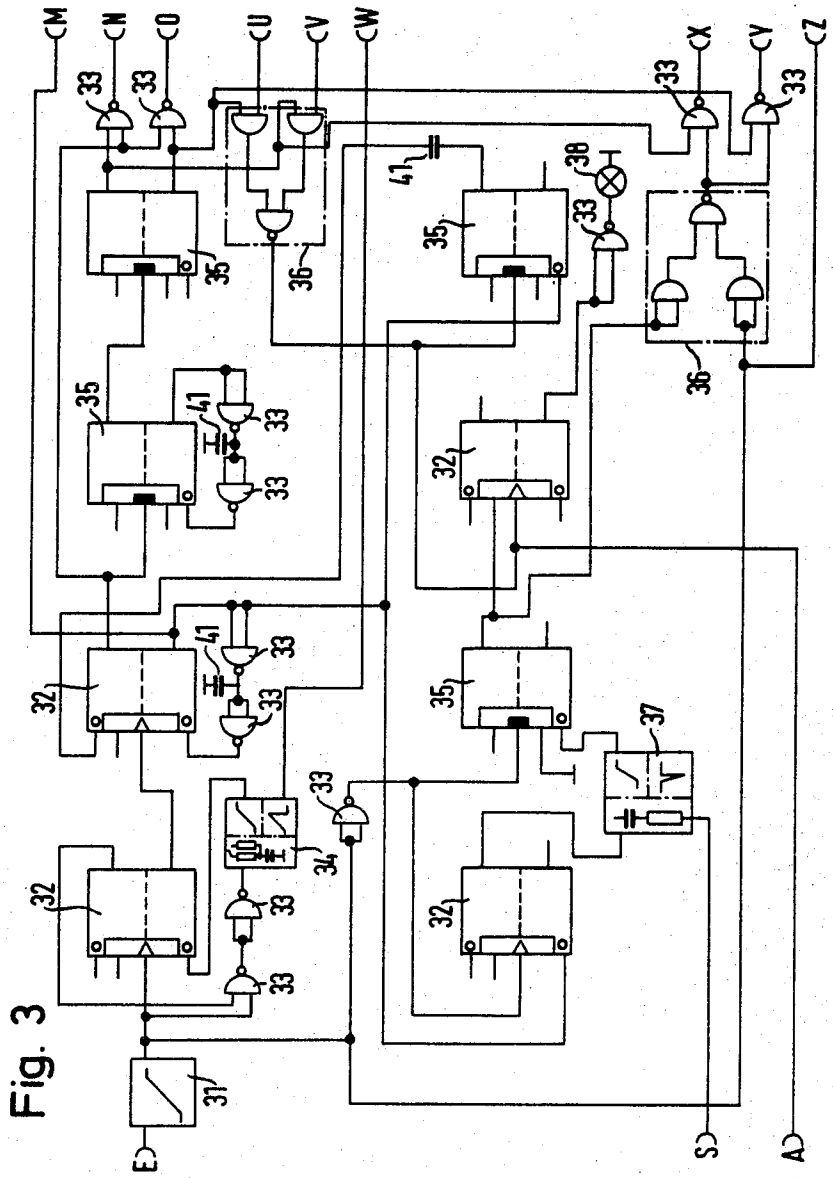


Fig. 3

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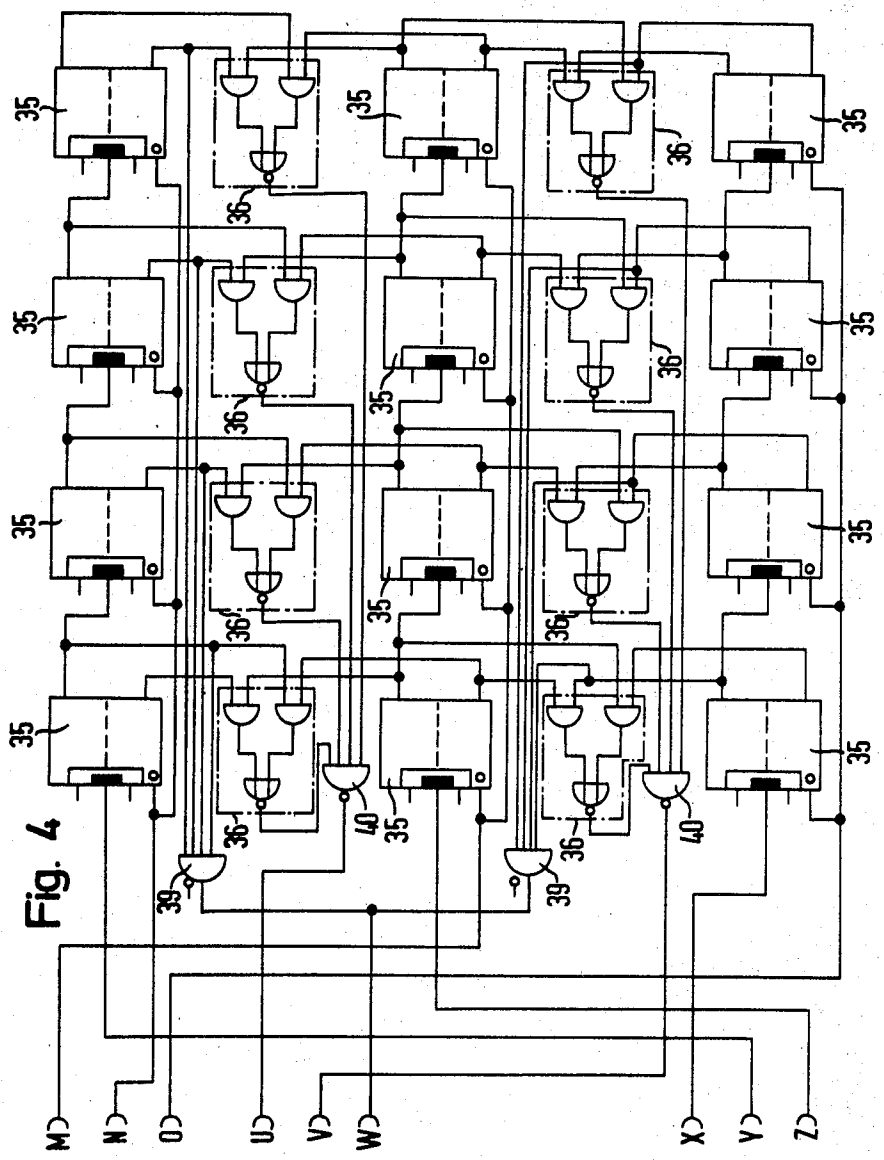


Fig. 4

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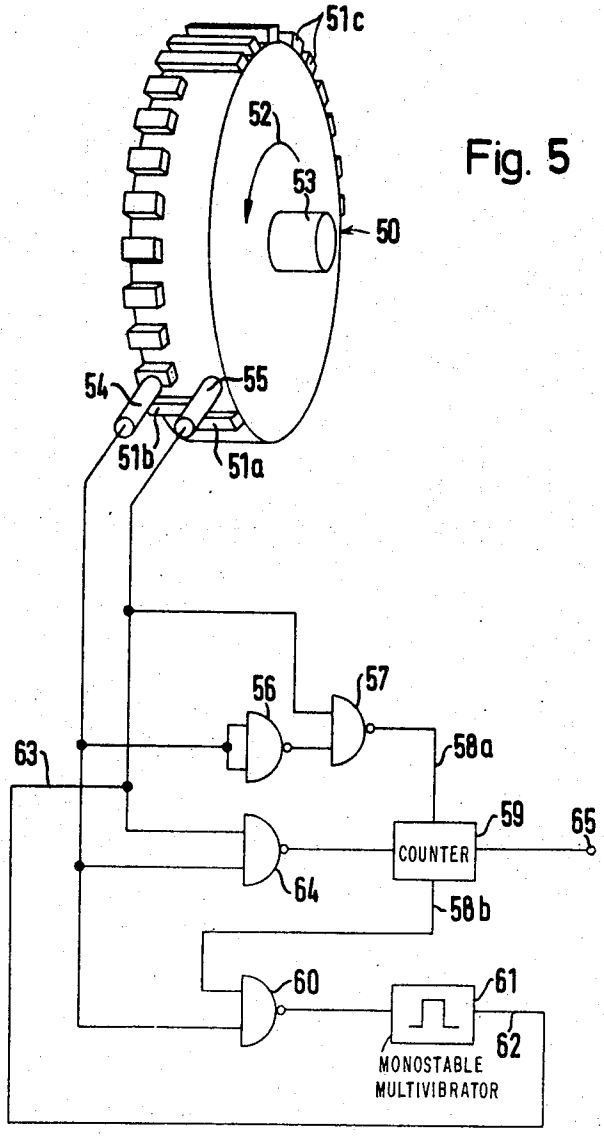


Fig. 5

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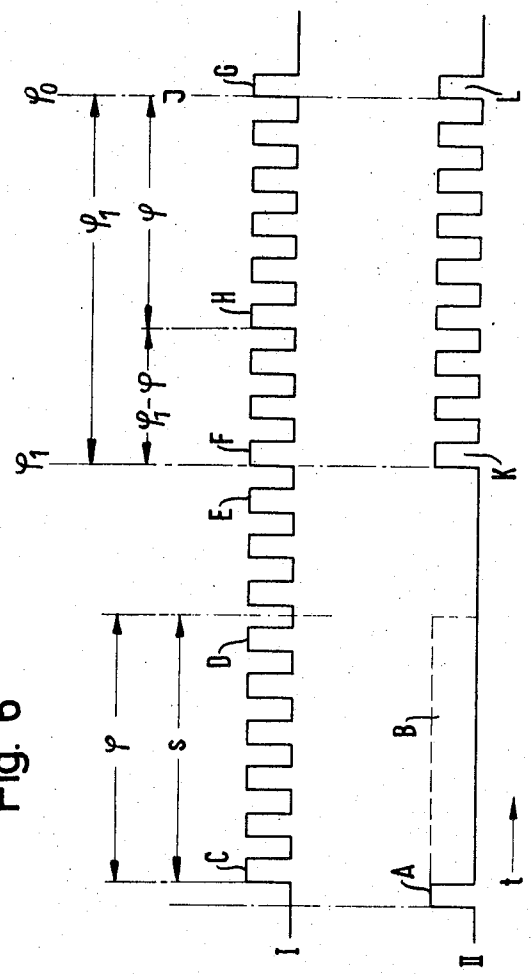
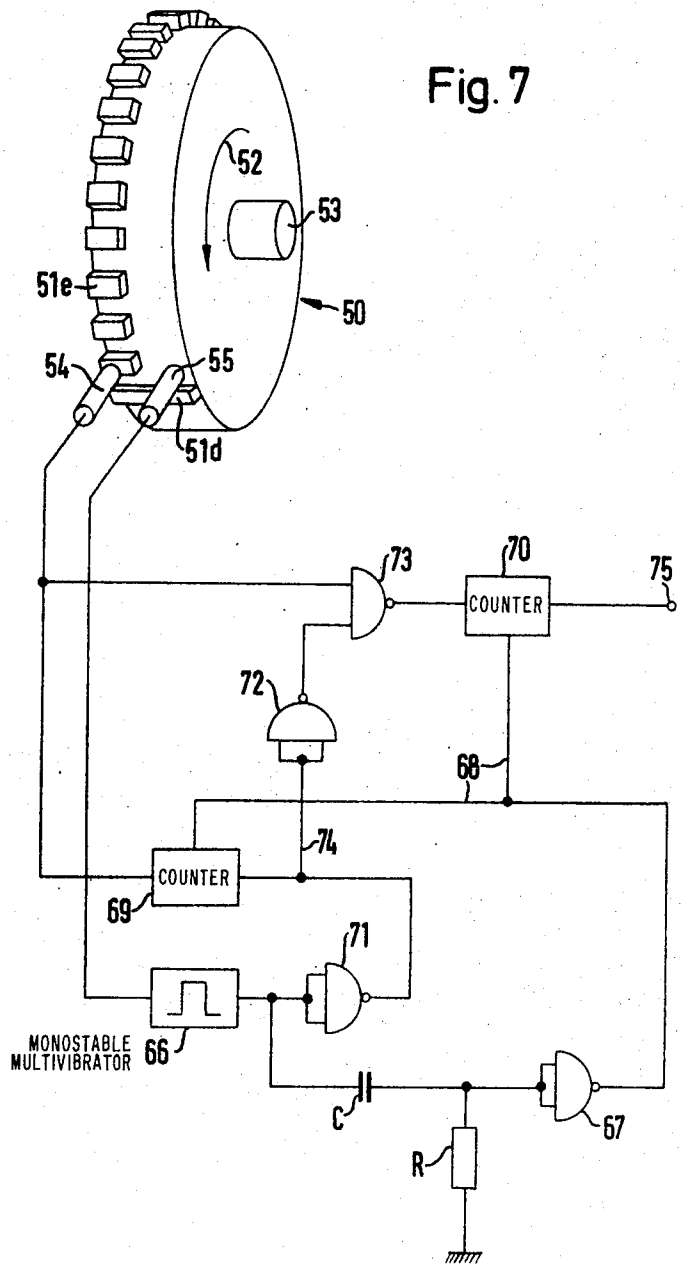


Fig. 6

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Fig. 7



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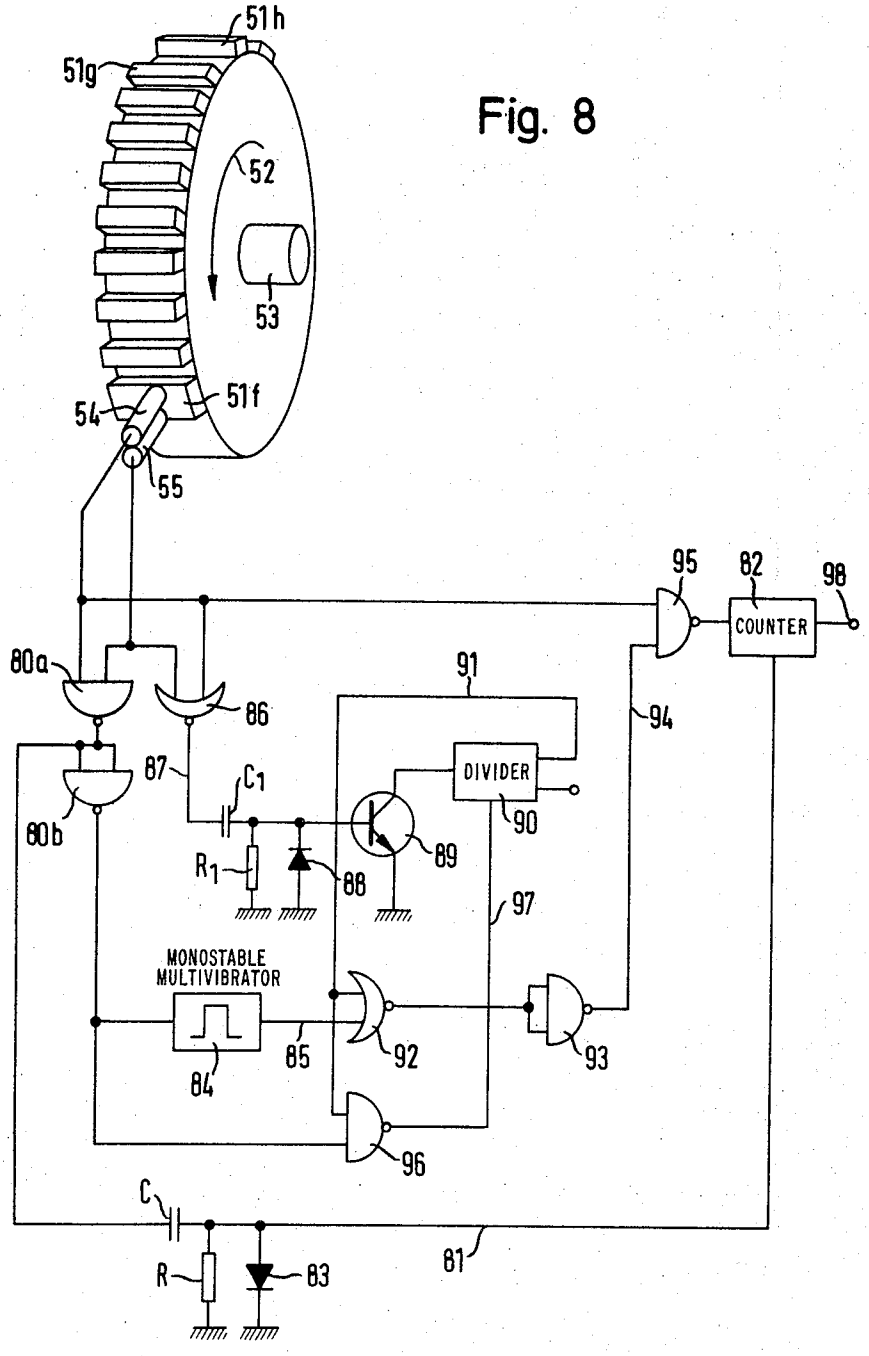
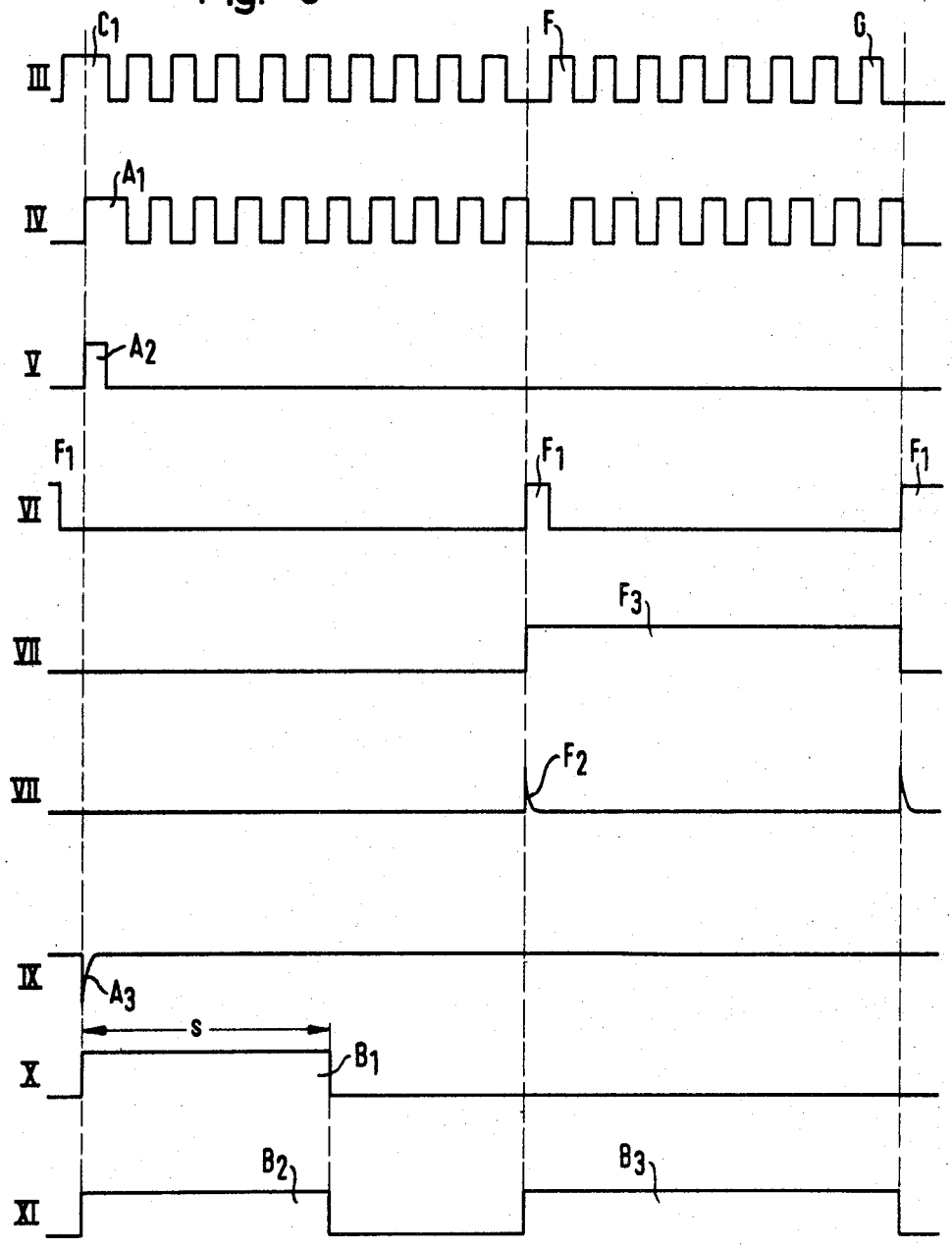


Fig. 8

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Fig. 9



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PROCESS AND APPARATUS FOR PRODUCING TRIGGER PULSES

The invention relates to a method and an apparatus for producing a trigger pulse which is synchronous with an event in a periodical motion of variable period length but displaced therefrom by a predetermined length of time that is independent of the period length.

Such trigger pulses are needed, for example, as ignition pulses in internal combustion engines, in which the length of the cycle of the piston movement continually changes and in which an ignition pulse has to be delivered before the piston reaches the top dead center. Methods and apparatus are already known whereby corresponding ignition pulses can be produced, examples being an apparatus having a centrifugal weight and switch contact, and an apparatus using a vacuum box.

These known apparatus, however, have the disadvantage that, due to their mechanical method of operation and the free play of the parts in relation to one another which this entails, and which is aggravated by mechanical wear, they are relatively inaccurate and become increasingly inaccurate with the passage of time due to fouling. Furthermore, these apparatus are relatively unreliable and are difficult to adapt to various states of operation of the internal combustion engine, such as starting and running, and operation with acceleration of the rotatory speed, or the like.

It is the object of the invention to devise a process of the kind first mentioned, and an apparatus for its performance, while avoiding the above-mentioned disadvantages. In particular, great accuracy and repeatability are to be achieved and to be maintained without variation during the life of the apparatus of the invention.

This object is accomplished according to the invention in that, during successive cycles of motion, series of pulses are produced, each of which is associated with one cycle of movement and is synchronized with respect thereto; that the pulses belonging to a first of these pulse series (reference series) and produced during a predetermined time *s* that is shorter than the total duration of the individual pulse series are counted or stored (reference counting or reference storing) beginning with the first pulse of the series; that the pulses of a second series of pulses coming at a later time—preferably the next series of pulses—(trigger series) are counted or stored, beginning with the first impulse of the series, at least until the sum of counted or stored pulses of the first and second series is equal to a certain number N, and is preferably equal to the given number of all pulses of one of the series plus 1 (trigger counting or trigger storing), and that when this counting or storage state is reached, a trigger pulse is produced.

During each period of motion, at least one reference and one trigger series can be produced successively and subjected to a reference and trigger counting or storage for the production of at least one trigger pulse.

The time interval between predetermined successive pulses of the reference series can be a first function (f_1) of the velocity and/or the phase of the motion, while the time interval between predetermined pulses of the trigger series can be a second function (f_2) of the velocity and/or the phase of the motion.

In particular, it is possible that the pulses of the reference series follow one another at uniform time intervals, while the pulses of the trigger series follow one another in pregressively increasing or diminishing time intervals. In a particularly simple embodiment of the process of the invention, which is advantageous in some applications on account of its simplicity, the pulses of each series succeed one another at uniform time intervals whose absolute magnitude depends in each case on the velocity of the motion.

Although the number of pulses in the reference and trigger series will generally be different, it may be especially advantageous for the reference series to consist of the same number of pulses as the trigger series. In this case it is often sufficient for a single pulse series to be produced during each cycle of the motion.

In a preferred embodiment of the process of the invention, it is possible for every ($2n-1$th pulse series to be subjected to a reference count or storage and every ($2n$th pulse series to be subjected to a trigger count or storage, n being a whole number equal to or greater than 1. In many cases it is sufficient to use a single counter or storage and first feed it with the pulses of the ($2n-1$th pulse series for a predetermined time s and then feed it with the ($2n$th pulse series at least until the sum of the counted or stored pulses is equal to N or to an integral multiple of N.

It is especially advantageous for each series of a plurality of successive series of pulses to be subjected both to a reference counting or storage and to a trigger counting or storage, especially in such a manner that each series of pulses is used as a reference series during the one cycle of motion and as a trigger series during the next cycle of motion. In further development of the process of the invention, this can be brought about by registering the pulse series alternately by means of three counters or storages by registering in a first counter or storage only the first pulses of every ($2n-1$th series which appear during the predetermined time period *s*, n being a whole number equal to or greater than 1, and registering in a second counter or storage only the first pulses of every ($2n$th series which appear during the predetermined time period *s*, the first or second counter or storage, as the case may be, being cleared or reset before the commencement of the next count or storage, as the case may be, while all pulses of every series are registered in a third counter or storage and a resetting of the counter or a clearing of the storage being performed prior to the beginning of the next series of pulses, and the first and second storage in the cycle of motion that comes between two counting or storage processes in the particular storage serving as the reference counter or storage, as the case may be, whose reading or content is compared with that of the third counter or storage in order to produce the triggering pulse.

A substantial simplification is achieved if, in addition to the pulses of the reference and trigger series, one or more auxiliary pulses are produced which occur simultaneously with the pulses of the reference and/or trigger series and/or are phase-shifted in relation to the latter, and are used to control the reference and/or trigger count or storage. Of course, pulses of the reference and/or trigger series can also be used for controlling purposes, i.e., they can serve simultaneously as auxiliary pulses.

An especially compact and inexpensive circuitry can be obtained in the performance of the process of the invention if a plurality of auxiliary pulses are produced for each reference and trigger series.

Preferentially, one auxiliary pulse for each reference and trigger series serves to clear (restore to zero) the counter or counters or storages prior to the counting or storing process. Furthermore, one auxiliary pulse per reference and trigger series can serve to trigger a pulse of the length s, which is also used in the controlling of the counting or storing process; in this case the functions of the previously mentioned two auxiliary pulses can be performed by a single auxiliary pulse.

Other auxiliary pulses can serve to control logical circuit elements by which the counting or storing processes are controlled.

It has furthermore been found that the general principle of the invention, in the process for the production of trigger pulses which precede by a certain time interval a certain phase situation (triggering phase) in a movement that takes place in constantly variable periodicity, while during the said time interval series of pulses synchronously associated with successive cycles of motion are produced during the said cycles, consists in the fact that, by means of a first series of pulses (reference series) the phase shift ϕ corresponding to the predetermined time period s is determined and is subtracted by means of a second series of pulses (trigger series) from an arbitrary phase situation ϕ_1 which is advanced by more than ϕ with reference to the triggering phase ϕ_0 so that the trigger pulse is produced after the passage of the phase difference $\phi_1-\phi$ computed from ϕ_1.

Preferentially, with the aid of additional pulses additional adjustment angles can be subtracted from the advanced phase situation ϕ_1 or added thereto.

An apparatus for the performance of the process of the invention, which can also be viewed as a miniature computer, is characterized according to the invention by a pulse generator coupled to the motion that is involved in order to produce series of pulses that are synchronous with reference to the motion; by a logic circuit device coupled to the pulse generator and having at least one gate in the path of conduction of the pulses of the reference series; by a device opening the gate during a predetermined time period s; by at least one counter or storage following the logic circuit device, and by a pulse generator coupled to or combined with the counter or storage for the production of the trigger pulse.

In one possible embodiment, the apparatus according to the invention has a gate which opens alternately, as the pulse series alternate, (a) only for the predetermined time period s after the beginning of a reference series, and then (b) through the entire duration of a series of pulses, and which is disposed in the conduction path both of the reference series and of the trigger series and cooperates preferably with a single counter or storage.

A preferred embodiment of the apparatus of the invention is characterized by a first and second counter or storage, each connected by a switching means to the output of the gate in such a manner that the pulses passing through the gate are alternately registered by the first or second counter or storage as the pulse series alternate, and a third counter or storage constantly coupled to the pulse generator, and an adding device connected to the outputs of all three storages, which has two adding units, one of which processes the values registered by the first and third counter or storage and the other processes the values registered by the second and third counter or storage and, when the predetermined value has been registered, produces a triggering pulse.

If auxiliary pulses, or at least one auxiliary pulse is used, the apparatus for the performance of the process of the invention can be constructed at an especially low investment in circuitry. Such an apparatus is characterized by a main pulse generator in which the pulses of the reference and trigger sequence are produced, and an auxiliary pulse generator in which at least one auxiliary pulse is produced, the main pulse generator being connected through at least a first logical circuit element to the input of the counter or storage which performs the reference or trigger pulse counting or storage (main counter or storage), and the main or auxiliary pulse generator being coupled to the input of a pulse generator for the production of a pulse of the length or duration s, and the outputs of the latter pulse generator and of the main and auxiliary pulse generators being connected through logical circuits alone or through logical circuits in conjunction with additional circuit elements in such a manner that a reference and trigger count or storage is performed in the main counter or storage and the main counter or storage is cleared before or after.

In this apparatus, inverted AND gates and/or inverted OR gates can be used preferentially as logical circuit elements. A monostable multivibrator, for example, is suitable as a pulse generator to produce the pulse of the length or duration s.

The invention will be further explained below with the aid of a number of especially preferred embodiments represented in FIGS. 1 to 9 of the drawing, and additional advantages and features will be discussed, but it is not restricted to these and can be applied successfully under the principles that are set forth, without departing from the scope of the invention and the general idea underlying same.

FIG. 1 shows a pulse generator for the production of periodically recurrent series of pulses.

FIG. 2 shows a block diagram of a first embodiment of the apparatus of the invention.

FIGS. 3 and 4 show a detailed circuit diagram of the apparatus represented in FIG. 2.

FIG. 5 is a circuit diagram of a second embodiment of the invention.

FIG. 6 is a representation of the pulse series that are produced in the transducers of the apparatus of FIG. 5 in the time period t.

FIG. 7 is a circuit diagram of a third embodiment of the apparatus of the invention.

FIG. 8 is a circuit diagram of a fourth embodiment of the apparatus of the invention, and

FIG. 9 is the representation of pulse series which are produced in the apparatus of FIG. 8.

The pulse generator represented in FIG. 1 consists of a disk 1, equipped with teeth 2 over a portion of the periphery, which is coupled to the motion that is involved—to the crankshaft of an internal combustion

engine, for example. In the present example, the teeth **2** are equidistantly arranged, although they can be provided in a different arrangement in which there will be no uniformity between the reference magnitude S and the time between the triggering pulse and the point of reference. When the teeth **2** pass by the pickup **3**, pulses **4** are produced, a series of pulses being generated during each rotation of the disk, and the number of pulses per series depending on the number of teeth **2**. Furthermore, an apparatus **5** is provided, at whose output S a magnitude S resulting from, say, the temperature or some other factor in the operating state of, for example, an internal combustion engine. This magnitude S can be used for the purpose of varying the predetermined time period *s* by which the trigger pulse is to be displaced from the top dead center in the internal combustion engine. By taking S or *s*, as the case may be, as a function of the rotatory speed, any desired control characteristic can be achieved, this characteristic being a curve representing the relationship between the angular velocity W and the time between the trigger point and the point of reference.

The circuit represented in FIG. **2** comprises a pulse former **11** in which non-rectangular pulses of the pulse generator of FIG. **1** are transformed to rectangular shape. If the time interval between two pulse edge is greater than a given time *t*, the canceling pulse generator **12** produces a canceling pulse. This canceling pulse comes at precisely the end of the time interval *t* following the end of the pulse series involved, and lies in the dead period between this preceding pulse series and the following pulse series. The canceling pulses serve the purpose, among other purposes, of clearing at the end of each pulse series the storage **28** which is continuously counting the pulses of each pulse series. At the same time, the canceling pulse forms the start information for the gate circuit **17** which, beginning from the first pulse edge of a series, supplies a pulse of the length *s*. This pulse is lengthened in the pulse lengthener **18** by the length of the pulse of the series still being picked up at the end of *s*, so that the gate **19** admits only full-length pulses from the pulse former **11**. This is important because if the gate **19** is operated on the edge of a pulse additional unwanted pulses might be produced. The pulses of the series which pas through the gate **19**, i.e., the pulses from the first pulse of the series through to the end of the period *s*, are alternately fed through the switches **20** to storages **16** and **21** where they are stored. The alternative switching is brought about by the one-half divider **14** which, in the present embodiment, reverses the counting and canceling inputs of storages **16** and **21**, 2 microseconds after each canceling pulse. The duration of the canceling pulse amounts, for example, to one microsecond, so that the reversal does not take place until the canceling process has completely ended. If, for example, storage **16** has been canceled, or cleared, a portion of the still arriving pulse series is stored through the gate **19**. Before the beginning of the next pulse series the storage **21** is cleared, so that a portion of the latter pulse series then passes into storage **21**. Consequently, storage **16**, for example, is used as the reference storage in each odd-numbered series of pulses and storage **21** as the reference storage in each even-numbered series of pulses, i.e., serves to store the first pulse of these series which occurs during the interval *s*. To each of the outputs of storages **16** and **21** there is connected one adding matrix **25** and **27**, respectively. The addition matrix **25** compares the value recorded by storage **16** with the value recorded by storage **28** and yields a pulse when the sum of the readings of the two storages comes to a predetermined value—15, for example. In like manner, a comparison is made in addition matrix **27** of the readings of storages **21** and **28**, and when the predetermined total of the two storages is reached—a total of 15 stored pulses for example—the addition matrix **27** likewise produces a pulse at the output. The addition matrixes **25** and **27** are alternately reversed by a switching device **24**: whenever pulses are stored in the storage **16** during one switching interval, a comparison of storages **21** and **28** is made, while in the next switching interval a comparison of storages **16** and **28** is performed. The pulse obtained at the output of the switching device **24** is the desired trigger pulse.

In addition to the systems mentioned above, other logic circuits are provided in the embodiment according to FIGS. **2** to **4** in order to meet additional requirements. During the starting period of a movement process—for example during the starting of an internal combustion engine—the period between successive pulses of the series is longer than the above-mentioned time period *t*. The result would be that, within the series of pulses a cancel pulse would follow every individual pulse, so that the required predetermined total—15, for example—which is needed in order to produce the trigger pulse, would never be reached. To prevent this, the time *t* is lengthened 12-fold, for example, to *t'* whenever it is found through matrix **23** that the storage **16** and/or storage **21** have so far stored only one pulse. This is the case in the event of very slow rotations, namely when only the initial pulse of the series falls within the time period *s*.

Another additional logic circuit **26** is advantageous for the following reason. Owing to a disturbance it may come about that the longer time *t'* is operative whereas due to the frequency of the pulse succession the shorter time period *t* would be necessary. In this state of operation, no cancel pulse would be produced, and the storage, in the state corresponding to the occurrence of only an initial pulse, would always continue in this state, since it sets the time *t'* instead of *t*. To prevent this erroneous manner of operation the logic circuit **26** has been provided. This circuit produces an additional cancel pulse if the trigger pulse and the cancel pulse do not occur alternately, which is always the case if the correct state of operation.

Lastly, the additional logic circuit **22** serves to facilitate the correction of the apparatus according to the invention. It permits the apparatus to be supervised in operation and supplies output information from the instant in which the trigger pulse enters time-wise into the *s* interval, which commences precisely in the middle of the control interval.

The length of the time interval *s* can be set externally through the S input and thus the control characteristic can be varied.

In the detailed circuit diagrams represented in FIGS. **3** and **4** for the logic system of FIG. **2**, conventional cirduit symbols are used so as to enable the technical man to understand easily the manner of operation of the cir-

cuits shown in FIGS. 3 and 4 as described above with reference to FIG. 2.

For example, this circuit can be built of the elements listed as follows:

Components 31 and 37	T AA 293
Component 32	½ SN 7474 N
" 33	¼ SN 7400 N
" 34	T AA 293 plus 4 × S X 3708
" 35	½ SN 7473 N
" 36	½ SN 7450 N
" 38	Pilot lamp 6V/40 mA
" 39	½ SN 7460 N
" 40	½ SN 7420 N
" 41	Condensers 100 nF/30V

The designations of these components correspond to the model numbers of Texas Instruments, USA (integrated circuits of series SN 74) and of Valvo of Germany (especially TAA 293) (see also the company's publication "Technische Informationen Valvo," No. 127, October 1968, on the applications of the TAA 293 ("Anwendung des TAA 293")).

In FIG. 5, 50 represents a wheel that is coupled with the process of movement of an engine piston, e.g., through the crankshaft of a motor vehicle, and that is provided with projections 51*a*–51*c* on its circumference, the said projections being carried past the transducers 54 or 55 as the case may be, when wheel 50 rotates about axis 53 in the direction of the arrow. When such a projection 51*a*, *b* or *c* moves past one of the transducers, a pulse is produced in transducer 54 and/or 55. In transducer 54 there is produced the pulse series I represented in FIG. 6, and in transducer 55 there is produced the pulse series II.

Pulse series II commences ahead of pulse series I with a pulse A which develops when the projection 51a runs past the transducer 55, while at the same time no pulse is produced in transducer 54. The result is that, due to the intereaction of the two inverted AND gates 56 and 57 a restore pulse appears in line 58a and restores the storage 59 to zero. The counter or storage 59 is so constructed that a positive pulse appears in the output line 58b during the period in which the counter or storage 59 is at zero.

After storage 59 has thus been cleared, the movement of projection 51*b* past transducer 54 produces a pulse in the latter which through the inverted AND gate 60 triggers a monostable multivibrator 61 which is so designed that a pulse of the duration *s* is produced at its output, beginning from the moment in which it is triggered. Since the output 62 of the monostable multivibrator 61 is connected by line 63 to transducer 55, a positive pulse is produced at transducer 55 during the period *s* although at first no further projections are passing transducer 55 after projection 51*a* has passed it. This state is represented by the pulse B that is represented in broken lines. During the time period *s* the pulses of the pulse series I produced in the transducer 54 are fed, beginning with pulse C, to the storage 59 through the inverted AND gate 64, and are counted and stored there. In the example shown, these are the six pulses from C to D of the total of 18 pulses of pulse series I. After the time *s*, i.e., after the pulse D has appeared, no further pulses are recorded in storage 59 for a while, because after the end of the period s the inverted AND gate admits no pulses up to and including pulse E. But as soon as pulses occur simultaneously in transducers 54 and 55, i.e., beginning with the appearance of pulses F and K, the inverted AND gate 64 is "open" again, and storage 59 then stores the pulses of series F–G, doing so until a predetermined storage state is reached. When this state is reached, a trigger pulse is given or produced at output 65. In the present example, this storage state is reached after the recording of a total of nine pulses, i.e., at the starting edge of the tenth pulse; in other words, the storage 59 totals the pulses C–D of pulse series C to E (reference series) and the pulses F–H of the pulse series F to G (trigger series). The state of the count when H is counted corresponds to the appearance of the trigger pulse. How many pulses of the reference series and how many of the trigger series are counted or stored depends both on the time period *s* and on the pulse frequency (number of pulses per unit of time). The pulse frequency is, of course, a function of the rotatory speed of wheel 50.

So the series of auxiliary pulses consists of the pulses A and K–L, which occur in the auxiliary pulse transducer 55, while the reference series and the trigger series (C–E and F–G, respectively) appear in the main pulse transducer 54.

It is to be noted that the general principle consists in deducting from the trigger series F–G, at the end of which, at I for example, the top dead center of the internal combustion engine is located, going backwards from I for as many pulses as occur during the time period *s*; practically, this is accomplished by the fact that the number of pulses corresponding to the period *s* which are to be deducted is fed to the counter or storage before the beginning of the trigger series that ends preferably at the top dead center. It is also within the scope of the invention, of course, to enter additional pulses into the storage or deduct them from the pulses stored therein, which can be accomplished, for example, by lengthening or shortening the trigger series that is defined above. These additional pulses can be used to achieve an additional displacement of the trigger pulse from the top dead center or the like.

An embodiment of the invention that differs slightly from FIG. 5 is represented in FIG. 7. In this case the alignment of the two transducers in relation to one another and at the same time in relation to the projections or other pulse-producing elements on wheel 50 does not have to be performed with the same relative precision as in the apparatus of FIG. 5, since only the restore pulse is produced in the second transducer 55.

In detail, the following is the manner of operation:

At the beginning, the projection 51*d* produces a pulse simultaneously in transducers 54 and 55. The first and only pulse in transducer 55 triggers the monostable multivibrator 66. The rising edge of this pulse is differentiated by the differentiating circuit RC. The RC constant can be, for example, between 1 and 100 microseconds. This results in a sharp-tipped pulse which passes through the inverted AND gate 67 and line 68 to the counters or storages 69 and 70 and restores them to zero. During the time period *s* storage 70 counts or stores the pulses from transducer 54, because the pulse produced in the multivibrator 66 acts through the inverted AND gates 71 and 72 on the input of the inverted AND gate 73. Then storage 70 stops storing, but storage 69 stores the rest of the pulses from

transducer **54** until it reaches a predetermined storage state. This storage state corresponds to the total number of pulses in the reference series. When this storage state is reached, a pulse again develops in line **74** and acts through gate **72** on the input of gate **73**, so that storage **70** resumes counting until the predetermined final storage state is reached. Then a trigger pulse is delivered to the output at **75**.

In FIG. **8** there is represented another embodiment of the invention, which will be explained with the aid of FIG. **9** which shows the pulses that occur at certain terminals or in certain leads in the system shown in FIG. **8**.

In this system, main pulses and auxiliary pulses are obtained from a single series of projections rather than two series as in the systems of FIGS. **5** and **7**, so that it is no longer necessary to provide separate projections alongside one another on the circumference of the wheel to produce the main series and auxiliary series of pulses. To this end, the transducers **54** and **55** are arranged in tandem in the direction of movement of the projections, and the projections themselves are so constructed that the main pulse series and auxiliary pulse series are intermeshed with one another, so to speak. This can be brought about by differences in the width of the projections and the intervals between them. In the embodiment, for example, the first projection **51***f* is twice as wide as the rest of the projections, which all have the same width. Furthermore, the interval between the ninth projection **51***g* and the 10th projection **51***h* is twice as large as the rest of the intervals, which are all equal to the normal projection width. In the embodiment according to FIG. **8**, a total of **18** projections are provided.

On the basis of the distribution explained before, the pulse series III (FIG. **9**) is obtained in pulse transducer **54** and pulse series IV is obtained in pulse transducer **55**.

The pulses of the pulse transducers **54** and **55** are delivered to the inverted AND gate **80***a*; at the output of the inverter **80***b* that follows there occurs a pulse A_2 (pulse series V) that is the inverse of pulse A_1 or C_1, as the case may be. The pulse developing between the two last-named gates is differentiated by the C–R circuit (time constant 1 to 10 microseconds, for example), so that a spike pulse A_3 develops in line **81**, which restores the counter or storage **82** to zero. The diode **83** short-circuits the positive spike pulse.

At the same time, pulse A_2 triggers the monostable multivibrator **84** at whose output **85** there appears a pulse B_1 of the length *s*.

Furthermore, a pulse F_1 is obtained in line **87** by means of the inverted OR gate **86** from the pulses occurring in the pulse transducer **54** and **55**, whenever the two transducers fail to deliver a pulse. The pulse F_1 is differentiated by the differentiating circuit C_1–R_1. While the negative spike pulse thereby produced is being short-circuited by the diode **88**, the positive spike F_2 that is additionally developed controls through transistor **89** the binary divider **90**. When the output **91** of this divider becomes positive, as represented by F_3 at VII in FIG. **9**, the counting of the trigger series F–G begins (see III).

For this purpose, pulse B_1 and pulse F_3 are delivered to the input of the inverted OR gate **92**, so that pulses B_2 and B_3 (pulse series XI) are produced, in conjunction with the inverted AND gate **93** (inverter), at the input **94** of the inverted AND gate **95**. While these pulses are occurring at the gate **95**, the pulses of the reference series and trigger series delivered by the pulse transducer **54** are counted and stored in **82**. The trigger pulse appears at the output **98** when the predetermined storage state is reached in storage **82**, even if storage **82** afterward continues to count.

In order to bring the binary divider **90** (e.g., Model SN 7473 of Texas Instruments) into the correct working phase the inverted AND gate **96** is provided. Whenever the pulse F_3 and pulse A_2 occur simultaneously at the output **91** of the binary divider **90** and at the output of the inverter **80***b*, respectively, this AND gate **96** delivers a setting pulse through line **97** to the binary divider **90**, which brings it into the correct working phase.

It should also be noted that an inverted AND gate is also known as a NAND gate and an inverted OR gate is also known as a NOR gate.

The apparatus according to the invention can be manufactured in monolithic integrated circuit form. In particular the transducers can be included in the monolithic circuit. In this case there is the possibility of designing the transducers as phototransistors, certain areas of the monolithic circuit being able to be parts of the phototransistor. For example, the input transistor of gate **60** or **73** can be constructed as the transducer **54**.

Even the production of light to control photosensitive transducers can be performed by means of luminescent semiconductor material which, in contrast to incandescent lamps, cannot burn out (reliability of operation).

Lastly, it is possible for the transducers to be, not phototransistors, but integrated transistors or generally broad-surfaced semiconductors which are controled on the basis of the field effect; that is, the operation of the transducer is performed by an electrostatic field this being done by means, for example, of a segmented disk.

The invention, of course, is not restricted to use in explosion engines, and it can be used wherever similar problems are encountered. An example of such further use would be the production of trigger pulses for lighting in the making of photographic wall pictures in centrifuges of variable rotatory speed.

In FIG. **2**, the notation in **12** is "if time between pulses $> t + t'$, deliver erase pulse;" **13** is a delay; **14** is a divider; the notation in **17** is "start pulse of length $= s$ follows first pulse;" the notation in **18** is "lengthing of the impulse to $s +$ the remainder of the last entered impulse;" the notation in **22** is "signal for trigger pulse in interval *s*;" the notation in **23** is "signal for time base t' when storage **1** and/or storage **3** is on **1'''**; in **25** and **27**, "Imp. für" is "pulse when;" the notation in **26** is "additional erase pulse if trigger and erase pulse do not occur alternately." Other information with respect to FIG. **2** appears supra and on the drawing.

I claim:

1. A method for producing a trigger pulse at a preselected point which is off-set from a reference point in the movement of a cyclically moving mechanical device comprising:

a. producing a series of pulses during each cycle of movement of the device wherein corresponding

pulses in successive series are produced at the same point in the movement of the device,

b. counting a predetermined number of the pulses in at least a first series in which said predetermined number corresponds to the difference in time between said preselected and reference points,

c. incrementing said count by respective succeeding pulses until a desired count is reached,

d. and producing said trigger pulse when the next succeeding pulse after said desired count is produced;

e. said method comprising the further steps of setting to zero prior to initiating a count therein a first, second and third counter; counting said predetermined number of pulses in said first series in a first counter; counting said predetermined number of pulses in a second series in said second counter; counting all of the pulses in a series in said third counter; and alternately incrementing said first and second counters with said third counter to produce said trigger pulse.

2. The method of claim **1**, in which said count is incremented by a number of pulses equal to said predetermined number to reach said desired count.

3. The method of claim **1**, in which said first pulse series is an odd pulse series, and said incrementing comprises counting pulses in a second pulse series wherein said second pulse series is an even pulse series.

4. Apparatus for producing a trigger pulse at a preselected point which is off-set from a reference point in the movement of a cyclically moving mechanical device comprising:

a. a pulse generator adapted to be connected to said device for producing a series of pulses during each cycle related to said movement wherein corresponding pulses in successive series are produced at the same point in the movement of the device,

b. at least a first counter for counting said pulses,

c. gate means connecting said pulse generator with said first counter for passing said pulses to said first counter in response to a control signal,

d. control signal means connected to said gate means for producing a control signal for a predetermined interval of time corresponding to the time for movement of said mechanical device between said preselected and reference points,

e. and trigger means for incrementing the pulses counted by said first counter to produce a trigger pulse after a desired count has been reached,

f. said trigger means including means for applying an additional control signal to said gate means after said predetermined interval of time to permit succeeding pulses to be counted by said counter until said desired count is reached.

5. Apparatus for producing a trigger pulse at a preselected point which is off-set from a reference point in the movement of a cyclically moving mechanical device comprising:

a. a pulse generator adapted to be connected to said device for producing a series of pulses during each cycle related to said movement wherein corresponding pulses in successive series are produced at the same point in the movement of the device,

b. at least a first counter for counting said pulses,

c. gate means connecting said pulse generator with said first counter for passing said pulses to said first counter in response to a control signal,

d. control signal means connected to said gate means for producing a control signal for a predetermined interval of time corresponding to the time for movement of said mechanical device between said preselected and reference points,

e. and trigger means for incrementing the pulses counted by said first counter to produce a trigger pulse after a desired count has been reached,

f. a second counter,

g. said gate means interconnecting said first, and second counters and said pulse generator for applying said series of pulses to said first and second counters alternately whereby said first and second counters count pulses when said control signal is present,

h. a third counter connected to said pulse generator for counting the pulses produced thereby,

i. and adding means connected to said first, second and third counters for alternately adding the contents of said second and first counter with said third counter to produce said trigger pulse after said desired count is reached.

6. Apparatus as in claim **5**, in which said gate means includes switch means responsive to a switch signal for alternately switching the output of said pulse generator from said first counter to said second counter, and a switch signal generator for producing said switch signal when the time interval between pulses exceeds a preselected value.

7. Apparatus as in claim **6**, in which said first, second and third counters are adapted to be set to zero when a signal is applied to an erase terminal, and lead means for connecting said switch signal generator with said erase terminals for setting said counters to zero.

8. Apparatus as in claim **5**, in which said control signal means includes pulse lengthing means for maintaining a control signal for a sufficient interval of time so said gate means passes full width pulses.

9. Apparatus as in claim **6**, in which said control signal means includes means responsive to said switch signal for initiating said control signal in response to said switch signal.

10. Apparatus as in claim **6**, and disabling means connected to said trigger means and said switch signal generator for disabling said switch signal generator when said switch and trigger pulses fail to alternate.

11. Apparatus as in claim **6**, and detection means for detecting the number of pulses in said first or second counter in a predetermined time interval and for delaying the operation of said switch signal generator if the number of pulses in said first and second counters is below a preselected amount.

12. Apparatus as in claim **4**, in which said pulse generator includes a main pulse generator for generating said series of pulses and an auxiliary pulse generator for generating at least an auxiliary pulse for each cycle of operation of said mechanical device, lead means for connecting said auxiliary pulse generator to said control signal means to produce said control signal, said trigger means including means for connecting said main pulse generator to said first counter after said control signal has been removed, whereby said first counter counts additional pulses in said series.

13. Apparatus as in claim 12, in which said first counter has a clear terminal whereby said counter is set to zero when a signal is applied to said clear terminal, and lead means connecting said auxiliary pulse generator with said clear terminal to set said counter to zero.

14. Apparatus as in claim 12, in which said control signal generator comprises a monostable multivibrator.

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