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Werner et al.

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[54] **ELECTRONIC IGNITION SYSTEM WITH AUTOMATIC IGNITION ADVANCEMENT AND RETARDATION**

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[51] **Int. Cl.** **F02p 5/04**

[58] **Field of Search** .... 123/117 R, 117 A, 148 E, 123/146.5 A, 32 EA, 32 AE

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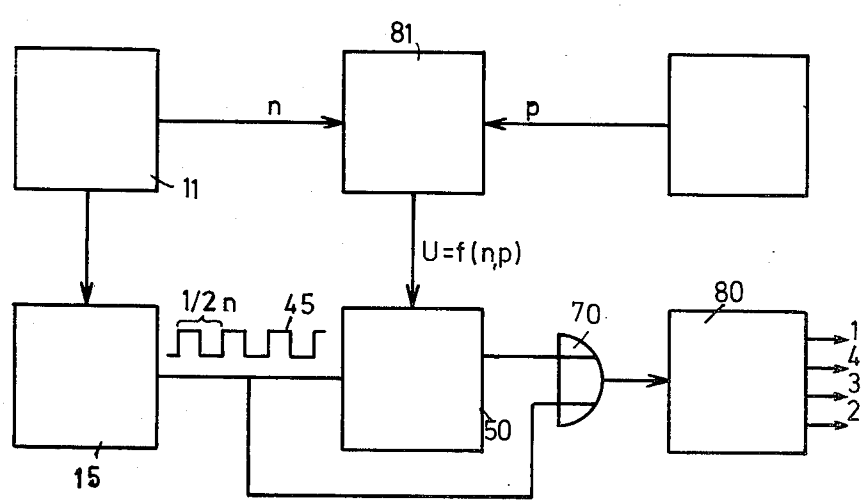
[57] **ABSTRACT**

An igniting arrangement has a control input and is operative for igniting a combustion mixture in an engine cylinder upon receipt of an ignition signal at such control input. A transducer determines the value of at least one engine operating variable. A timing circuit includes an energy-storing timing capacitor, a charging circuit for charging the capacitor during the time the engine crankshaft moves through a predetermined angle, and a discharging circuit operative subsequent to the completion of the capacitor charging for discharging the capacitor, with the charging and/or discharging circuits being connected to the transducer and being operative for effecting charging and/or discharging of the capacitor with a charging and/or discharging current having a magnitude dependent upon the value of the monitored engine operating variable, or variables. An ignition signal generating unit is connected to the energy-storing timing capacitor and is connected to the control input of the igniting means and is operative for applying to the control input of the igniting means an ignition signal upon completion of the capacitor discharging, or equivalently when the capacitor discharging is substantially completed or has proceeded to a predetermined extent.

8 Claims, 3 Drawing Figures



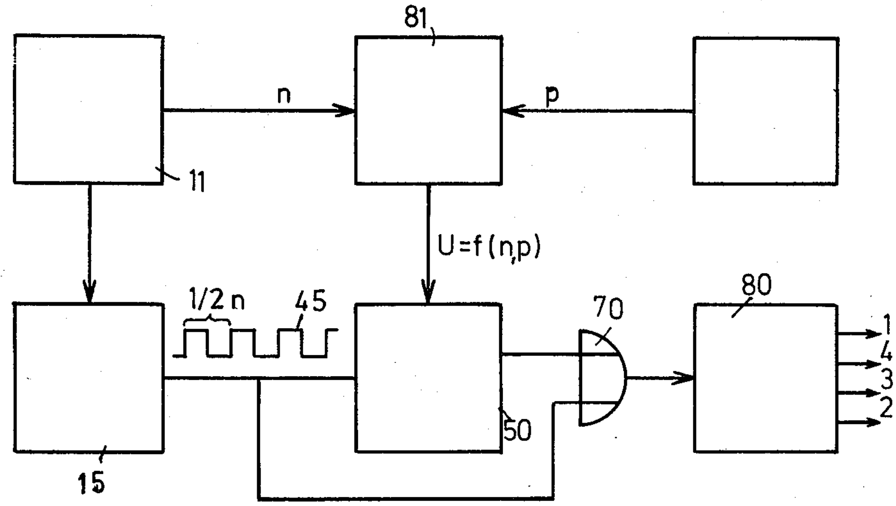

81
n
p
11
U=f(n,p)
1/2 n
45
70
80
1
4
3
2
50
15

Fig.1

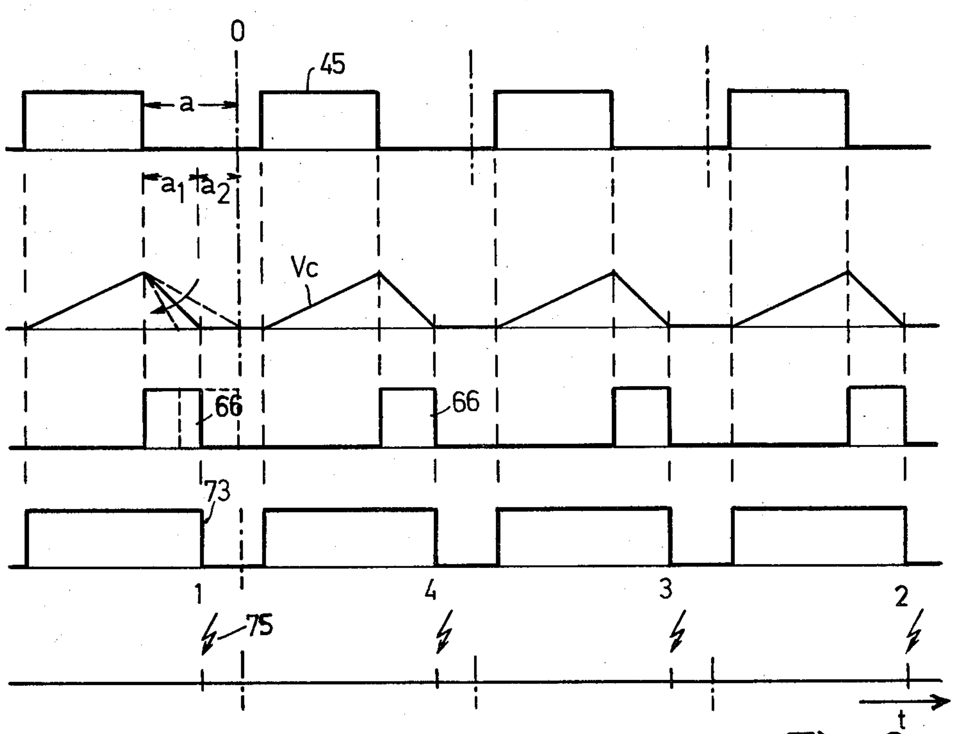

0
45
a
a1
a2
Vc
66
66
73
1
4
3
2
75
t

Fig. 2

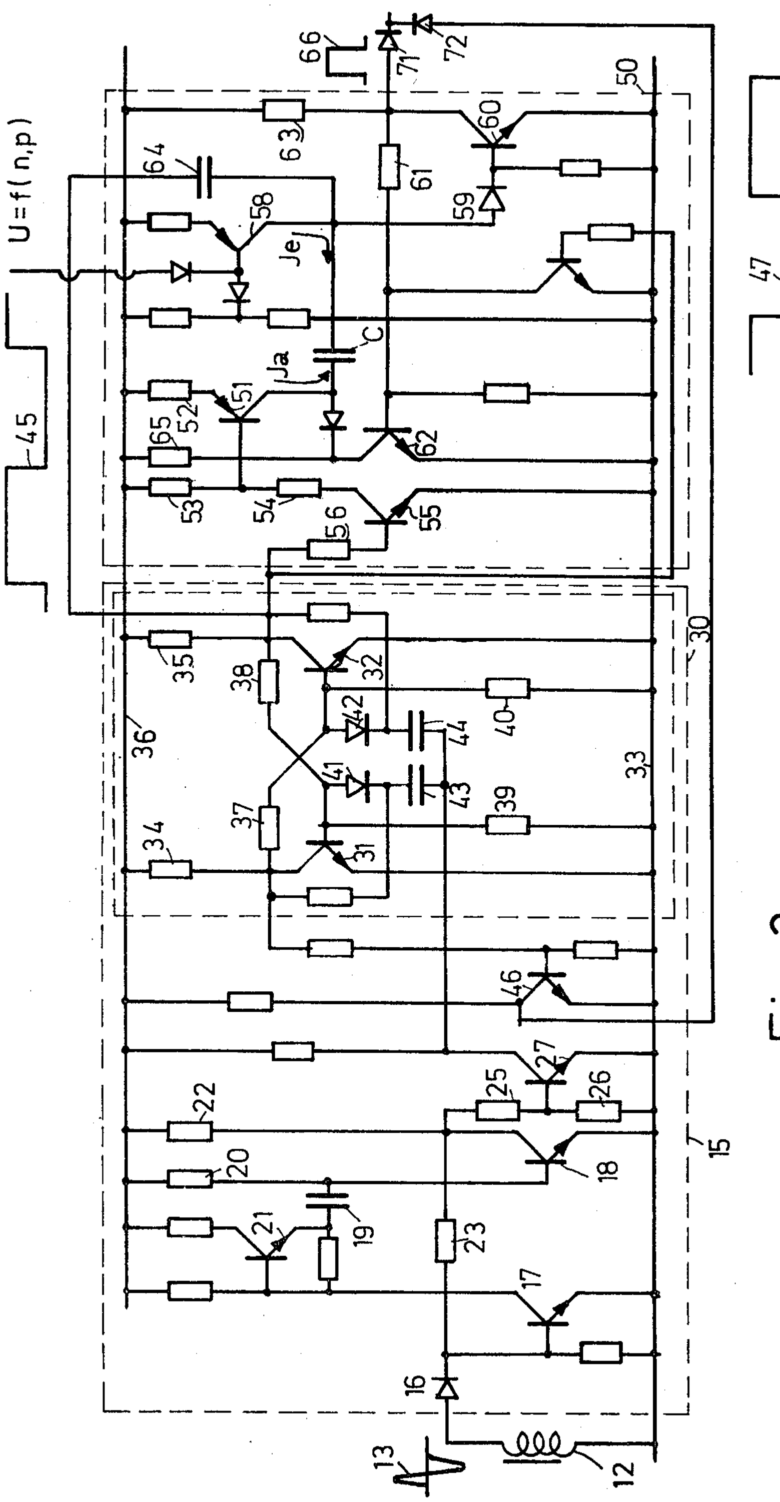


Fig. 3

ELECTRONIC IGNITION SYSTEM WITH AUTOMATIC IGNITION ADVANCEMENT AND RETARDATION

BACKGROUND OF THE INVENTION

The invention relates to electronic ignition systems and especially to such systems as are provided with inductor current interruptors in the form of electronic switches to generate high-voltage ignition voltages, either across the inductor itself or else across the secondary of a transformer with the current flow through the primary winding being interrupted. More particularly the invention relates to electronic ignition systems of the type where an energy-storing element, such as a capacitor, is discharged when the engine crankshaft reaches a predetermined angular orientation, with the discharging occurring at a rate dependent upon at least one engine operating variable, and with the generation of an ignition signal occurring at the end of such capacitor discharging, or the like.

Ignition systems of this type are already known. In one known system a transistor is connected in the current path of the primary winding of an ignition transformer. Current is normally permitted to flow through such primary winding. At the ignition moment, an ignition signal is applied to the transistor to interrupt the current flow in the primary winding, to generate a high-voltage ignition voltage spike across the secondary. The flow of current through the primary winding is controlled by a monostable multivibrator circuit. The monstable multivibrator is triggered at an instant of time corresponding to the maximum amount of ignition advance, relative to top-dead-center, which the system is capable of providing, and the duration of the unstable state of the monostable multivibrator is controlled in dependence upon the speed and power output of the internal combustion engine, with the reversion of the monostable multivibrator to its stable state, after the thusly varied time delay, resulting in generation of an ignition signal and accordingly actual fuel ignition.

With this known arrangement, wherein the duration of the unstable state of the monostable multivibrator is selected in such a manner as to establish the desired ignition advancement, a difficulty exists with respect to the complicated relationship between the absolute duration of such unstable state and the time required for the engine crankshaft to turn through an angle corresponding to the desired ignition advancement, expressed in degrees of crankshaft rotation. If the duration of the unstable state of the multivibrator is maintained constant, then as the engine speed increases, the magnitude of the ignition advancement, expressed in degrees of crankshaft rotation decreases. A very complicated relationship between the duration of the multivibrator unstable state and the actual amount of ignition advancement must be taken into account when designing the means for controlling the duration of the unstable state of the monostable multivibrator.

SUMMARY OF THE INVENTION

It is the general object of the present invention to provide an electronic ignition system for internal combustion engines provided with electronic means for effecting ignition advancement and retardation which is not characterized by the shortcomings of the prior art arrangements.

It is a more specific object of the invention to provide an electronic circuit capable of effecting ignition advancement and retardation of such design that a signal of a given magnitude, or other characteristic, applied to a control input of such circuit will effect an amount of ignition advancement, expressed in degrees of crankshaft rotation, which is independent of variations in engine speed. This would establish a one-to-one correspondence between the magnitude of the ignition-advancement control signal and the amount of ignition advancement, expressed in crankshaft rotational degrees relative to top-dead-center, actually achieved.

These objects, and others which will become more understandable from the following description can be met, according to one advantageous concept of the invention by providing, in the ignition system of an internal combustion engine, in combination, igniting means having a control input and operative for igniting a combustion mixture in an engine cylinder upon receipt of an ignition signal at such control input. Transducer means is operative for determining the value of at least one engine operating variable, preferably engine speed and/or the pressure prevailing in the engine air-intake passage. A timing circuit is comprised of energy-storing timing means, first means operative for effecting a first change of stored energy of the energy-storing timing means during the time the engine crankshaft moves through a predetermined angle, and second means operative subsequent to the completion of the first change of stored energy for effecting an opposite second change of stored energy of the timing means, with at least one of the first and second means comprising compensating means connected to the transducer means and operative for effecting the respective change of stored energy of the energy-storing timing means at a rate of energy change dependent upon the value of the one or more engine operating variables taken into account. Ignition signal generating means is connected to the energy-storing timing means and is connected to the control input of the igniting means and is operative for applying to such control input an ignition signal upon completion of the second change of stored energy.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 depicts in block diagram form an ignition system employing an exemplary embodiment of the invention;

FIG. 2 depicts in graphical form certain aspects of the operation of the circuit shown in FIG. 3; and

FIG. 3 is a circuit diagram of the exemplary embodiment of the invention and corresponding to a portion of the complete schematically depicted ignition system of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The ignition arrangement of FIG. 1 is comprised of a signal generator 11 including four non-illustrated permanent magnets mounted on a disk which is in turn mounted on the engine crankshaft, the magnets being spaced apart from each other by 90°, and cooperating with a stationary inductive pick-up coil **12** (FIG. **3**) to successively induce voltage pulses in the latter corresponding to the passage by the inductive pick-up coil **12** of the successive permanent magnets. As will be appreciated by those skilled in the art, signal generator **11** can be employed both for use in the determination of the crankshaft position and in the determination of the crankshaft speed. For example, the four permanent magnets just mentioned can be so configurated and/or arranged as to generate pulses having steep leading edges corresponding quite exactly to predetermined crankshaft angles, with the pulses having magnitudes, or having trailing portions having magnitudes indicative of engine rotational speed. Of course, as a further possibility, a separate signal generator could be provided, electromagnetic, mechanical, photoelectric, or of any other suitable type, to generate signals indicative of predetermined crankshaft positions, with a second different signal generator, such as a simple tachometer, being provided to generate a crankshaft speed signal.

In any event, in the exemplary embodiment illustrated, the signal generator **11** is operative for generating four successive triggering pulses per crankshaft rotation. These triggering pulses are applied to a pulse-shaping stage **15**, from the output of which they emerge in a very uniform condition.

In FIG. **1**, signal generator **11** also serves to apply a speed signal n to a schematically depicted circuit **81**. Circuit **81** also receives a further input signal p from a further transducer which is operative for generating an electrical signal indicative of the air pressure prevailing in the air-intake passage of the engine.

The circuit stage **81** is operative for generating an output voltage U which is a function of the input signals n and p, the voltage U having in this embodiment a magnitude which is indicative of the amount of ignition advancement to be introduced into the operation of the ignition system for the particular values of n and p detected.

A pulse-generating stage **50** receives the control voltage U and applies, via an OR-gate **70**, an ignition timing pulse to an ignition distributor **80**, which in turn causes generation of an ignition spark in one of the four engine cylinders, in the proper sequence. Also applied to the input of ignition distributor **80**, via OR-gate **70**, are the input pulses **45** from the output of the pulse shaping stage **15**. It is to be noted that these input pulses **45** are also applied to the pulse-generating stage **50**, serving to control the operation of the latter in a manner which will be described with respect to FIG. **3**. The input pulses **45**, being applied to ignition distributor **80** directly, serve to effect ignition in each cylinder at top-dead-center, or some other predetermined and fixed moment during the combustion cycle, in the event that the ignition advancement signal applied by circuit stage **50** should fail to be generated.

FIG. 3 depicts a circuit diagram of pertinent portions of the system schematically depicted in FIG. **1**. Winding **12** is the inductive pick-up winding mentioned before in which are induced voltage pulses corresponding to the movement past the winding **12** of the four permanent magnets in stage **11**, mentioned before.

The thusly induced triggering pulses, four per crankshaft rotation, are applied, via diode **16**, to the input of a pulse-shaping circuit **15**, which in this embodiment has the form of a monostable multivibrator. The monostable multivibrator **15** has an input transistor **17**, an output transistor **18**, a timing circuit comprised of an energy-storing timing capacitor **19** and a discharge resistor **20**, as well as a charging transistor **21** for the timing capacitor. The input transistor **17** is non-conductive in the stable state of the monostable multivibrator **15**, and is rendered conductive when the monostable multivibrator **15** receives a triggering pulse **13** (FIG. **3**) constituted by the positive half-cycle of the voltage induced across the inductive pick-up winding **12**. The output transistor **18** of the monostable multivibrator **15** is conductive when the monostable multivibrator is in its stable state. When the triggering pulse **13** is applied via diode **16** to the base of input transistor **17**, transistor **17** becomes conductive, and renders output multivibrator transistor **18** non-conductive. This occurs in the conventional manner, due to the accumulated charge on timing capacitor **19** and the consequent voltage drop thereacross, which is of such polarity and magnitude as to maintain the base of transistor **18** at a negative potential or at a potential too low to permit transistor **18** to conduct, until such time as capacitor **19** has substantially completely discharged. The duration of this unstable state of the monostable multivibrator **15** will be on the order of about **1** millisecond. It is to be noted that once the monostable multivibrator **15** enters its unstable state, input transistor **17** is maintained conductive, even after the disappearance of the positive triggering pulse **13**, by means of a feedback resistor **23** connecting the collector of output transistor **18** to the base of input transistor **17**, so as to maintain the base of transistor **17** at a relatively high potential so long as the output transistor **18** remains non-conductive. As soon as the capacitor **19** has become substantially completely discharged, or has discharged to a predetermined extent, the negative or low voltage applied to the base of output transistor **18** is lifted, and transistor **18** becomes conductive. As a result, the collector voltage of transistor **18** drops to a very low value, this drop being communicated to the base of transistor **17** by way of feedback resistor **26**, and transistor **17** is rendered non-conductive. The monostable multivibrator **15** has thus returned to its stable state.

Connected across the output of monostable multivibrator **15**, the output being the collector-emitter path of output transistor **18**, is a voltage divider comprised of resistors **25** aand **26**. The tap of this voltage divider is connected directly to the base of an amplifying transistor **27**. Amplifier transistor **27** serves to control the operation of a frequency-divider stage, which in this embodiment has the form of a bistable multivibrator comprised of a first bistable multivibrator transistor **31** and a second bistable multivibrator transistor **32**.

The two transistors **31** and **32** are both of the npn-conductivity type and have their emitters connected to a common negative voltage supply line **33**, negative voltage supply line **33** being connected to the negative terminal of a non-illustrated battery. The collectors of transistors **31** and **32** are each connected to the positive voltage supply line **36** via a respective one of the two collector resistors **34** and **35**. The bases and collectors of transistors **31**, **32** are cross-coupled, in conventional bistable multivibrator fashion, by means of cross-coupling resistors **37** and **38**, each cross-coupling resistor connecting the collector of one of the two bistable multivibrator transistors to the base of the other. Also, base-emitter resistors 39 and 40 respectively shunt the base-emitter junctions of bistable multivibrator transistors 31 and 32.

Connected to the bases of the transistors 31,32 are the anodes of respective diodes 41,42, the cathodes of these diodes being connected to the collector of amplifying transistor 27, via respective differentiating capacitors 43 and 44.

The two transistors 31 and 32, in conventional bistable multivibrator fashion, are alternately conductive, that is, when transistor 31 is conductive transistor 32 is non-conductive, and vice versa. Upon each generation of a positive voltage half-cycle triggering pulse 13, amplifying transistor 27 will be rendered conductive. As a result, whichever one of transistors 31, 32 had hitherto been conductive becomes non-conductive, and the other one of the transistors 31,32 accordingly becomes conductive. In this way, a first triggering pulse 13 renders one of the transistors 31,32 conductive, while the second triggering pulse 13 renders the other of transistors 31,32 conductive, and the third triggering pulse 13 renders the first of transistors 31,32 conductive again, and so forth. As a result, there appears on the collector of transistor 32 a pulse train, shown in FIGS. 1 and 3, and designated by numeral 45.

On the collector of the first bistable multivibrator transistor 31, there appears a pulse train similar to pulse train 45, but of course inverted with respect to pulse train 45. This second pulse train, appearing on the collector of bistable multivibrator transistor 31, is applied via a resistor to the base of a transistor switch element 46. The output waveform of transistor 46, i.e., the voltage waveform appearing on its collector, is inverted with respect to its input waveform, and accordingly, the voltage waveform appearing on the collector of transistor 46 is substantially identical to the pulse train 45. This additional pulse train is shown in FIG. 3 and designated with reference numeral 47.

The first pulse train 5 is used to control the operation of an electronic pulse-generating circuit 50. The pulse-generating circuit 50, in this embodiment, is comprised of an energy-storing timing capacitor C, which is alternately charged and discharged, the timing capacitor C being charged during those time intervals during which the pulse train 45 is at its upper level, i.e., during those time intervals during which second bistable multivibrator transistor 32 is non-conductive. The charging current flowing into capacitor C during this charging interval is indicated in FIG. 3 and designated Ja. It will be appreciated that, owing to the manner in which the pulse train 45 is generated, the time periods during which timing capacitor C is charged by charging current Ja will each correspond to the time required for the engine crankshaft to turn through 90°, from a predetermined first position to a predetermined second position.

As soon as the charging of timing capacitor C by charging current Ja terminates, discharging of capacitor C by a discharging current Je commences. The magnitude of the discharge current Je is controlled and, in this embodiment, is dependent upon the engine speed signal n and upon the signal p indicative of the pressure prevailing in the engine air-intake passage. In this particular embodiment, the magnitude of the charging current Ja is fixed, as will be clear from the following description, whereas the magnitude of the discharging current Je is made a function of the speed signal n and the pressure signal p. According to the invention, it would alternatively be possible to make the magnitude of the charging current Ja dependent upon these variables, with the magnitude of the discharging current being maintained constant. As further possibilities, the magnitude of the charging and discharging currents could both be controlled, either as functions of different engine operating variables or as functions of the same engine operating variables.

In any case, pulse-generating circuit 50 is comprised of a charging current source for the timing capacitor C thereof, in the form of a pnp transistor 51 having an emitter connected via an emitter resistor 52 to the positive voltage line 36. The collector of charging transistor 51 is connected with the left-hand electrode of timing capacitor C, and the base of charging transistor 51 is connected to the junction of two resistors 53,54, these resistors serving jointly as the collector resistor of an npn control transistor 55. The emitter of control transistor 55 is connected directly to the negative voltage line 33, and the base of transistor 55 is connected via a coupling resistor 56 to the collector of second bistable multivibrator transistor 32. During alternate quarter-rotations of the engine crankshaft, second bistable multivibrator transistor 32 will be non-conductive, for the reasons explained above. As a result, its collector voltage will be high, and a high voltage will be applied to the base of control transistor 55, which will accordingly be conductive during such time periods. The flow of collector current of transistor 55 creates a voltage drop across resistor 53, and consequently across the base-emitter junction of charging transistor 51, which likewise becomes conductive during these time periods. Accordingly, charging current Ja flows into the left electrode of timing capacitor C, and out of the right electrode thereof and the voltage drop across the latter increases linearly. The magnitude of the charging current Ja will be approximately equal to the voltage drop across resistor 53, divided by the resistance in ohms of emitter resistor 52, it being assumed that the base-emitter voltage drop of transistor 51 is negligible compared to the voltage drop across resistor 53. Accordingly, the charging current Ja will remain constant during the charging of capacitor C, irrespective of the build-up of the voltage drop across capacitor C.

The discharge current source, which establishes the flow of the discharge current Je of timing capacitor C, is in this embodiment comprised of an npn transistor 58 whose emitter is connected to the positive voltage line 36 via an emitter resistor. The collector of discharging transistor 58 is connected to the right-hand electrode of timing capacitor C, and is furthermore connected to the anode of diode 59. The cathode of diode 59 is directly connected to the base of an output transistor 60. Connected between the collector of output transistor 60 and the base of input transistor 61 of pulse-generating stage 50, is a feedback resistor 61. The two transistors 62 and 60, in conjunction with the other illustrated components of pulse-generating stage 50, form a monostable circuit.

The output transistor 60 is conductive when the monostable circuit 50 is in the stable state thereof, and also during the time of charging of the timing capacitor C. So long as transistor 60 remains conductive, its collector voltage is low. This low voltage is communicated via feedback resistor 61 to the base of input transistor

62, keeping the latter non-conductive. When transistor 60 is conductive transistor 62 is non-conductive, and vice versa. The charging of timing capacitor C terminates when the magnitude of waveform 45 reverts to its low level. This abrupt voltage change is differentiated by differentiating capacitor 64, which in turn applies a negative voltage spike to the base of transistor 60, via diode 59. As a result, transistor 60 is immediately rendered non-conductive. The collector voltage of transistor 60 rises, and this voltage rise is communicated via feedback resistor 61 to the base of transistor 62, which accordingly becomes conductive. Diode 59 becomes non-conductive, and the voltage drop across capacitor C is now such as to maintain transistor 60 non-conductive, until capacitor C has discharged substantially completely. This is because the left terminal of capacitor C is markedly more positive than the right terminal thereof, while the capacitor C remains charged. With transistor 62 now conductive, the voltage at the left capacitor terminal is dragged down, likewise dragging down the voltage at the right-hand capacitor terminal. The voltage at the right-hand capacitor terminal will reach a negative value, and maintain transistor 60 non-conductive, as a result.

Capacitor C is discharged linearly, by reason of the flow of discharge current Je and, when capacitor C has discharged sufficiently, transistor 60 reverts to its normal conductive state. During the time that transistor 60 is non-conductive, the voltage on its collector will be at a high level. When transistor 60 reverts to its conductive state, its collector voltage will fall. As a result, a pulse train is generated on the collector of transistor 60, one pulse of this pulse train being shown in FIG. 3 and designated with numeral 66. The duration of the pulse 66 depends upon the prevailing magnitude of the discharge current Je and accordingly on the control voltage U. As mentioned before, the control voltage U is in turn a function of the two variable signals n and p.

FIG. 2 depicts in graphical form certain aspects of the just-described sequence of operations.

The uppermost pulse train in FIG. 2 represents the crankshaft-synchronized pulse train 45. It will be noted that the pulses are of equal duration and the time intervals between successive pulses are likewise of equal duration. This will be true so long as the engine speed remains constant, and when only a few successive pulses are considered, as in FIG. 2, the engine speed can be considered constant. The duration of each pulse in pulse train 45 corresponds to the time required for the engine crankshaft to turn through 90°, from a first predetermined position to a second predetermined position. The pulse train 45 in FIG. 2 is marked with dash-dot vertical lines, one of which is designated O. This indicates the moment at which an engine piston is in the top-dead-center position. It will be noted that the trailing edge of each of the pulses in the pulse train 45 occurs in advance of the time an engine piston reaches top-dead-center, the amount of advance being designated a, in the Figure. Likewise, the leading edge of each pulse in the pulse train 45 occurs some time after an engine piston reaches top-dead-center position, in the illustrated embodiment.

The second pulse train shown in FIG. 2, comprised of triangular pulses, represents the voltage drop across timing capacitor C. For the duration of each of the pulses in train 45, the capacitor C is charged with constant-magnitude charging current Ja, and the voltage across capacitor C therefore rises linearly, in the manner depicted. Upon termination of the pulse in the pulse train 45, discharging of capacitor C commences, and the discharging occurs with a substantially constant discharge current Je, and lasts for a time period a_1. Actually, the magnitude of the discharge current Je may vary slightly during one discharge period in response to corresponding variations in the values of control signals n and p. However, the variations during a single discharge period are usually small enough that the discharge current Je can be said to be approximately constant during such discharge period.

In the second pulse train of FIG. 2, corresponding to the voltage drop across timing capacitor C in pulsegenerating circuit 50, the descending solid line is but exemplary. The two broken descending lines adjoining the solid line but of greater and lesser slope, respectively, correspond to other possible discharge time periods, which would be associated with other values of the control voltage U, and thereby with other values of the signals n and p.

The third pulse train shown in FIG. 2, and composed of pulses 66, will be seen to correspond to the discharge period of the capacitor C. That is, each pulse 66 has a duration equal to and is contemporaneous with the time required for the discharging of timing capacitor C to be substantially completed.

Considering FIG. 2, it will be noted that during the discharge of capacitor C, and accordingly during the existence of the associated output pulse 66, the crankshaft turns through an angle corresponding to the time period a_1, this angle being independent of engine speed so long as the control voltage U remains at a constant value. The lowermost pulse train in FIG. 2, comprised of pulses depicted as lightning bolts, shows the moments of generation of ignition sparks. It will be seen that ignition sparks are generated upon termination of the pulses 66. It will be noted that the crankshaft angle by which the ignition has been advanced relative to the top-dead-center position of an engine piston corresponds to the time interval a_2. This angle of advancement will likewise be independent of engine speed, so long as the control voltage U is constant.

The trailing edges of the pulses 66 can be used to trigger the generation of ignition sparks, the timing of such ignition sparks being indicated in the lowermost pulse train depicted in FIG. 2. The manner in which such control can be effected is as follows:

The output pulse 66 at the collector of transistor 60 is applied via an OR-gate 70 (FIG. 1), comprised of diodes 71,72 (FIG. 3) to the input of a schematically depicted ignition and cylinder selection stage 80. Also applied to the input of stage 80, via OR-gate 70 are the pulses in pulse train 45, corresponding to the uppermost pulse train shown in FIG. 2. The ignition and cylinder selection stage 80 is comprised of a conventional ignition transformer having a primary winding and a secondary winding. Connected in the current path of the primary winding is an electronic switch, such as a transistor or thyristor switch having a control input constituting the illustrated input of stage 80. When the pulse in pulse train 45 is generated, it is applied via OR-gate 70 (see FIG. 1) to the control input of such electronic switch rendering the same conductive, so that current can flow through the primary winding of the ignition transformer. When the pulse in pulse train 45 ends, the pulse 66 commences immediately, and is likewise applied to the control input of the just-mentioned electronic switch, so that current continues to flow in the primary winding of the ignition transformer. However, upon termination of the pulse **66**, and as can be seen in FIG. **2**, there is no longer any positive pulse applied to the input of stage **80** (i.e., to the control input of the electronic switch). As a result, the flow of current in the primary winding of the ignition transformer is interrupted resulting in the generation of a high-magnitude voltage spike across the secondary of the ignition transformer. The successive high-magnitude voltage spikes thusly generated across the secondary of the ignition transformer are applied to successive ones of the spark plugs of the four engine cylinders, in the order **1,4,3,2.** The ignition distribution function can be performed in any suitable manner. As one possibility, a mechanical distributor coupled with the engine crankshaft can be used. Such mechanical distributor, which is of conventional design, would connect the secondary winding of the ignition transformer across successive ones of the spark plugs, by means of rotating electrical contacts, or the like.

In the specific circuit embodiment of FIG. **3**, it will be noted that not the pulses **45**, but rather the pulses **47**, are applied to the control input of circuit stage **80**. This can be seen in FIG. **3** from the fact that the collector of transistor **46** is connected to the anode of OR-gate diode **72**. However, as explained previously, the pulse train **47** is substantially identical to the pulse train **45**.

It will be seen from a consideration of FIG. **2**, that the time period during which current flows through the primary winding of the ignition transformer is equal to the time period required for the crankshaft to turn through an angle of 90°, at the prevailing crankshaft speed, plus the time period a_1. This ensures sufficient time for a build-up of current flow in the ignition transformer primary winding.

The actual determination of the amount of ignition advancement to be effected under each different combination of values of n and p is a very well developed area in this particular art, and the details of the manner of such determination will not be explained herein, except to note that the desired relationship between the signals n and p, and any others taken into account additionally or alternatively, on the one hand, and the amount of ignition advancement, on the other hand, will vary from one engine construction or engine type to the next, and in many cases may best be determined experimentally. When a given functional relationship between the variables n and p has been decided upon, it is a routine matter of design skill to synthesize a two-input one-output network **81** which, for any two particular values of n and p, will produce an output voltage U of such a magnitude as to produce the necessary amount of ignition advancement.

An important advantage of the inventive arrangement is that the ignition advancement angle, being the angle through which the crankshaft turns during time period a_1, will remain constant as long as the control voltage U remains constant, and accordingly the circuit stage **81** has but a simple task to generate a voltage whose magnitude will determine the amount of ignition advancement to be established, in dependence upon the variables n and p, and according to the functional relationship to be realized.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of circuits and constructions differing from the types described above.

While the invention has been illustrated and described as embodied in an electronic ignition system with electronic ignition advancing and retarding circuitry, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended:

1. In the ignition system of an internal combustion engine, in combination, igniting means having a control input and operative for igniting a combustion mixture in an engine cylinder of the engine upon receipt of an ignition signal at said control input; transducer means for determining the value of at least one engine operating variable; a timing circuit comprised of energy-storing timing means, first means operative for effecting a first change of stored energy of said energy-storing timing means during the time the engine crankshaft moves through a predetermined angle, and second means operative subsequent to the completion of said first change of stored energy for effecting an opposite second change of stored energy of said timing means, at least a predetermined one of said first and second means comprising means connected to said transducer means and operative for effecting the respective change of stored energy of said energy-storing timing means at a rate of energy change dependent upon the value of said engine operating variable; and ignition signal generating means connected to said energy-storing timing means and connected to the control input of said igniting means and operative for applying to said control input of said igniting means an ignition signal upon completion of said second change of stored energy, wherein said first and second means together comprise synchronizing means for generating a crankshaft-position-synchronizing signal when the engine crankshaft assumes a predetermined angular orientation, bistable frequency-dividing means having an input connected to said synchronizing means for receipt of crankshaft-position-synchronizing signals therefrom, and having two stable states, and wherein said first means comprises means operative for effecting said first change of stored energy when said bistable means is in a predetermined one of the two stable states thereof, and wherein said second means comprises means operative for effecting said second change of stored energy when said bistable means is in the other of the two stable states thereof.

2. The system defined in claim **1**, wherein said adjusting means comprises means operative for varying the magnitude of the current flowing through said capacitor means from said adjustable constant current source means in dependence upon the value of the engine speed.

3. The system defined in claim 1, wherein said adjusting means comprises means operative for varying the magnitude of the current flowing through said capacitor means from said adjustable constant current source means in dependence upon the value of the pressure prevailing in the air-intake passage of the engine.

4. The system defined in claim 1, wherein said adjusting means comprises means operative for varying the magnitude of the current flowing through said capacitor means from said adjustable constant current source means in dependence upon the value of the engine speed and the value of the pressure prevailing in the air-intake passage of the engine.

5. In the ignition system of an internal combustion engine, in combination, igniting means having a control input and operative for igniting a combustion mixture in an engine cylinder of the engine upon receipt of an ignition signal at said control input; transducer means for determining the value of at least one engine operating variable; a timing circuit comprised of energy-storing timing means, first means operative for effecting a first change of stored energy of said energy-storing timing means during the time the engine crankshaft moves through a predetermined angle, and second means operative subsequent to the completion of said first change of stored energy for effecting an opposite second change of stored energy of said timing means, at least a predetermined one of said first and second means comprising means connected to said transducer means and operative for effecting the respective change of stored energy of said energy-storing timing means at a rate of energy change dependent upon the value of said engine operating variable; and ignition signal generating means connected to said energy-storing timing means and connected to the control input of said igniting means and operative for applying to said control input of said igniting means an ignition signal upon completion of said second change of stored energy, wherein said energy-storing timing means comprises energy-storing timing capacitor means, and wherein said first means comprises first constant current source means connected to said capacitor means and operative for effecting said first change of stored energy by establishing a flow of a first current through said capacitor means in a predetermined first direction, and wherein said second means comprises second constant current source means connected to said capacitor means and operative for effecting said second change of stored energy by establishing a flow of a second current through said capacitor means in opposite second direction, with the constant current source means of at least one predetermined one of said first and second means being an adjustable constant source means and further including adjusting means connected to said adjustable constant current source means and connected to said transducer means and operative for varying the magnitude of the current flowing through said capacitor means from said adjustable constant current source means in dependence upon the value of said engine operating variable, wherein said first and second means together comprise synchronizing means for generating a crankshaft-position-synchronizing signal when the engine crankshaft assumes a predetermined angular orientation, bistable frequency-dividing means having an input connected to said synchronizing means for receipt of crankshaft-position-synchronizing signals therefrom, and having two stable states, and wherein said first constant current source means comprises means operative for establishing said flow of said first current when said bistable means is in a predetermined one of the two stable states thereof, and wherein said second constant current source means comprises means operative for establishing said flow of said second current when said bistable means in the other of the two stable states thereof.

6. The system defined in claim 5, wherein said synchronizing means comprises signal-generating means for generating a pulse when the engine crankshaft assumes a predetermined angular orientation and pulse-shaping means having an input connected to the output of said signal-generating means and having an output connected to said input of said bistable frequency-dividing means and operative for shaping the pulse generated by said signal-generating means to form a shaped pulse constituting said crankshaft-position-synchronizing signal.

7. The system defined in claim 6, wherein said signal-generating means comprises means for generating a pulse when the engine crankshaft assumes any of four predetermined rotational positions equiangularly spaced from each other.

8. In the ignition system of an internal combustion engine, in combination, igniting means having a control input and operative for igniting a combustion mixture in an engine cylinder of the engine upon receipt of an ignition signal at said control input; transducer means for determining the value of at least one engine operating variable; a timing circuit comprised of energy-storing timing means, first means operative for effecting a first change of stored energy of said energy-storing timing means during the time the engine crankshaft moves through a predetermined constant angle, and second means operative subsequent to the completion of said first change of stored energy for effecting an opposite second change of stored energy of said timing means, at least a predetermined one of said first and second means comprising means connected to said transducer means and operative for effecting the respective change of stored energy of said energy-storing timing means at a rate of energy change dependent upon the value of said engine operating variable; and ignition signal generating means connected to said energy-storing timing means and connected to the control input of said igniting means and operative for applying to said control input of said igniting means an ignition signal upon completion of said second change of stored energy, wherein said energy-storing timing means comprises energy-storing timing capacitor means, and wherein said first means comprises first constant current source means connected to said capacitor means and operative for effecting said first change of stored energy by establishing a flow of a first current through said capacitor means in a predetermined first direction, and wherein said second means comprises second constant current source means connected to said capacitor means and operative for effecting said second change of stored energy by establishing a flow of a second current through said capacitor means in opposite second direction, with the constant current source means of at least said predetermined one of said first and second means being an adjustable constant current source means and further including adjusting means con-

nected to said adjustable constant current source means and connected to said transducer means and operative for varying the magnitude of the current flowing through said capacitor means from said adjustable constant current source means in dependence upon the value of said engine operating variable, wherein said igniting means comprises inductive means and additional means having a control input for receipt of a control pulse and operative for maintaining a flow of current through said inductive means so long as a control pulse is applied to said control input, whereby upon termination of such control pulse the current flow through the inductive means is interrupted and an ignition voltage is generated, and wherein said first and second means together comprise synchronizing means for initiating generation of a synchronizing pulse when the crankshaft assumes a first predetermined rotational orientation and for terminating generation of such synchronizing pulse when the crankshaft assumes a second predetermined rotational orientation, and wherein said first means includes means for causing said first change of stored energy to last for the duration of said synchronizing pulse, and further including means for generating a further pulse having a duration coincident with the duration of said second change of stored energy, and means for applying both said synchronizing pulse and said further pulse to said control input of said additional means so that said pulses together form a longer composite pulse serving to maintain said flow of current through said inductive means for the combined duration of said synchronizing pulse and said further pulse.

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