United States Patent

[11] 3,581,725

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[54] **TRANSISTORIZED IGNITION SYSTEM**
14 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **123/148E,** 315/209
[51] **Int. Cl.** **F02p 3/02**
[50] **Field of Search** ..... 123/148 E; 315/209, 209 M; 250/233

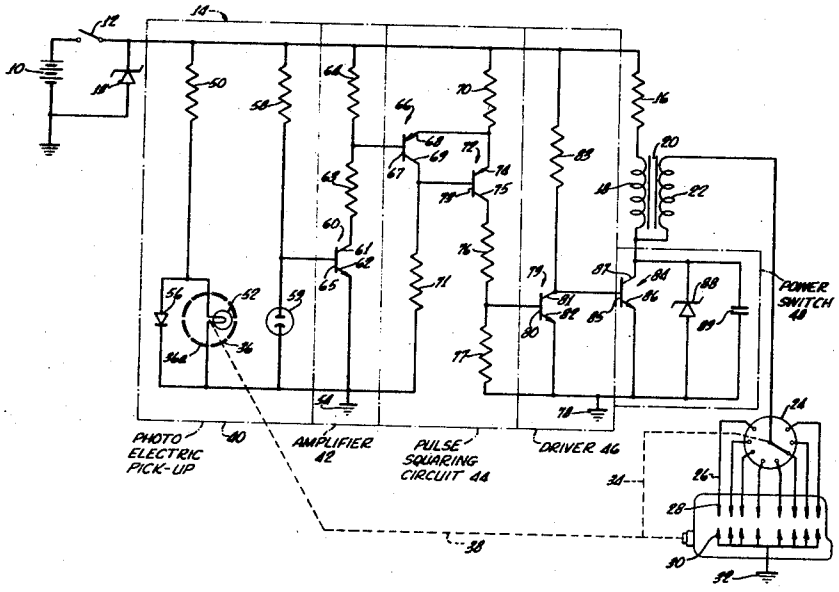
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ABSTRACT: In an ignition system for an internal combustion engine a light beam incident upon a photocell is interrupted at a rate synchronized with the engine speed and angular position of the crankshaft generating timing pulses which are amplified and then shaped into square pulses by a pulse-shaping means and applied to a transistor switch in series with the primary winding of the ignition coil. The square pulses alternately open and close the transistor switch causing the ignition coil to generate ignition pulses in its secondary winding which are applied to the spark plugs of the engine.



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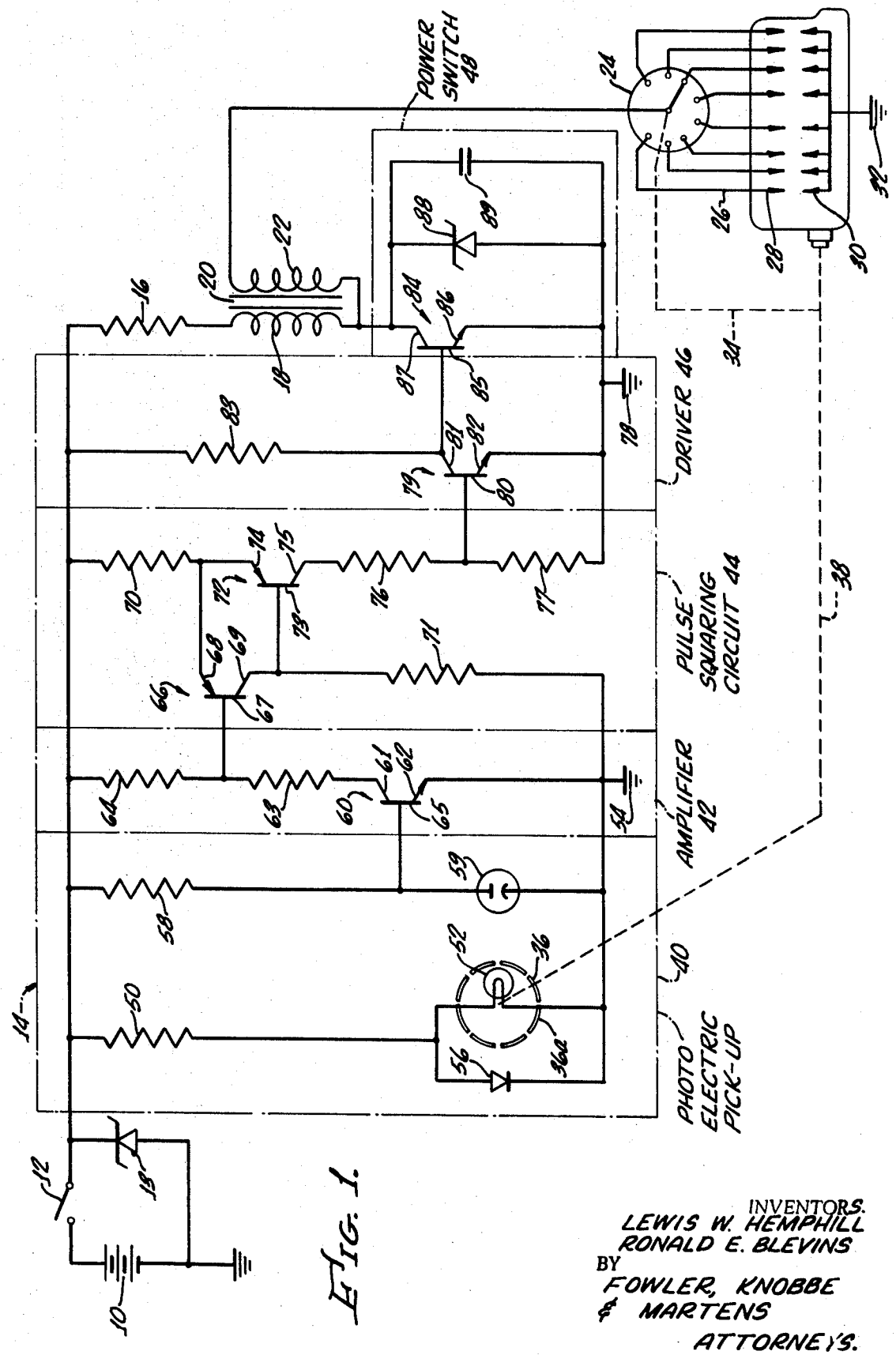


FIG. 1.

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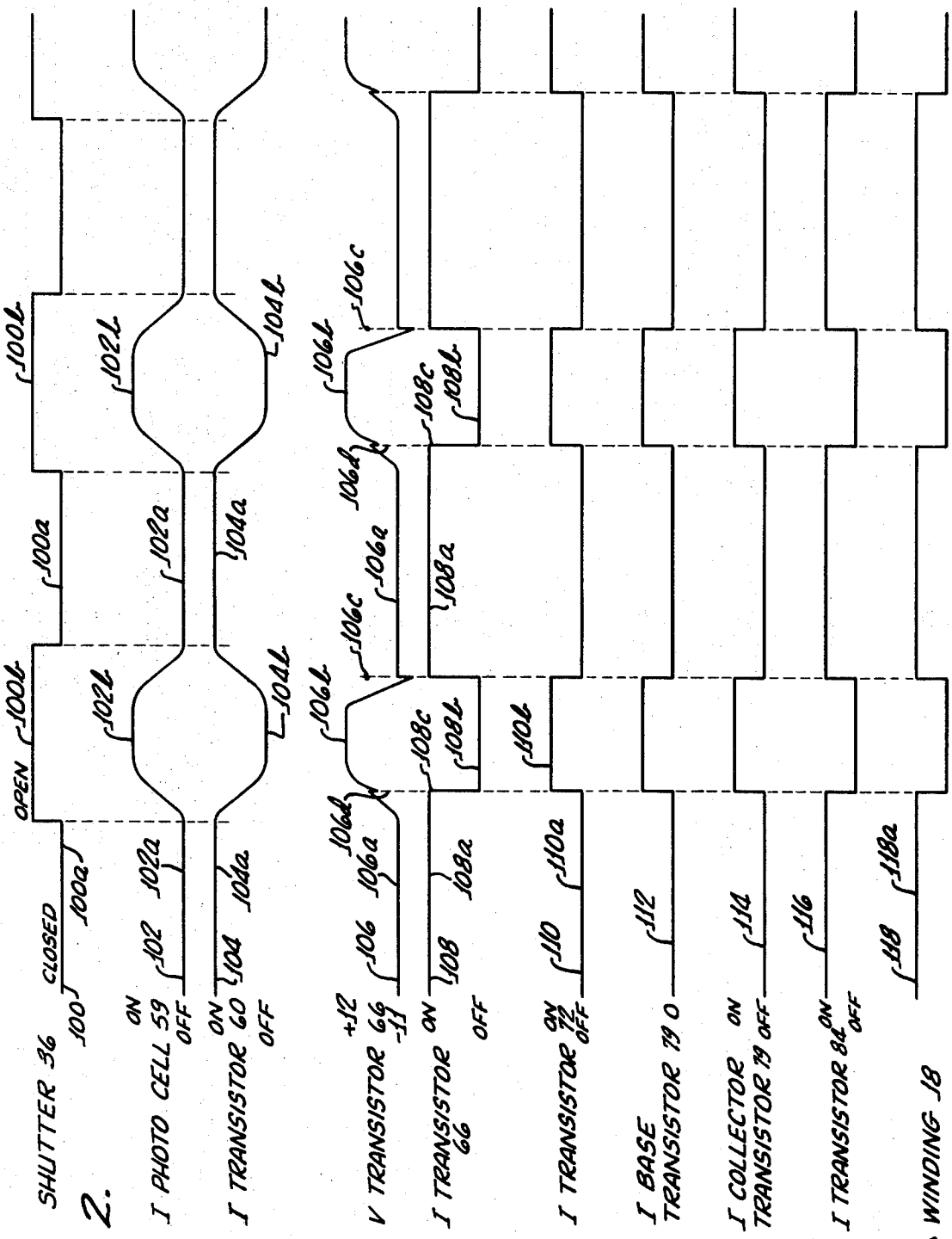
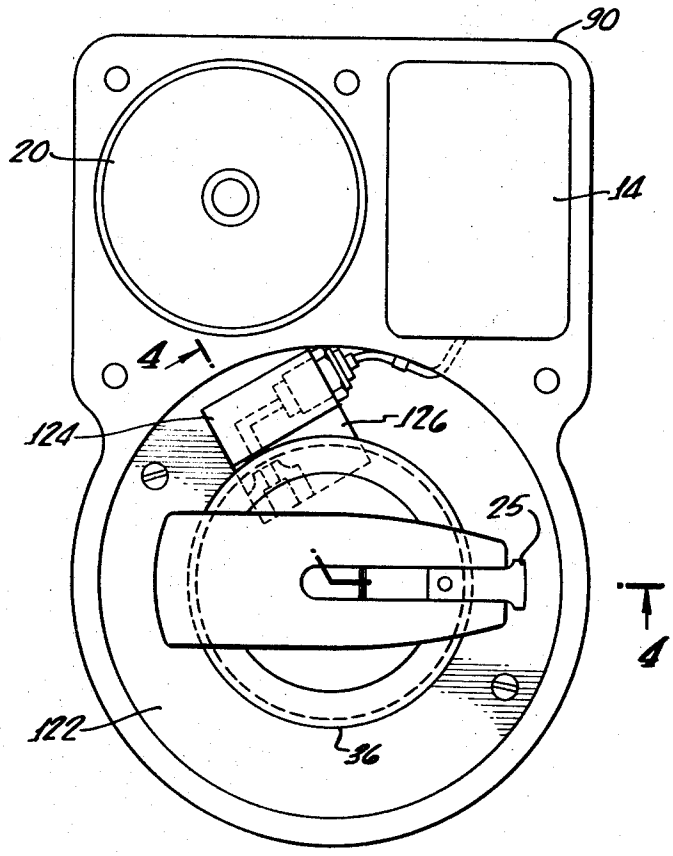


FIG. 2.

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FIG. 3.



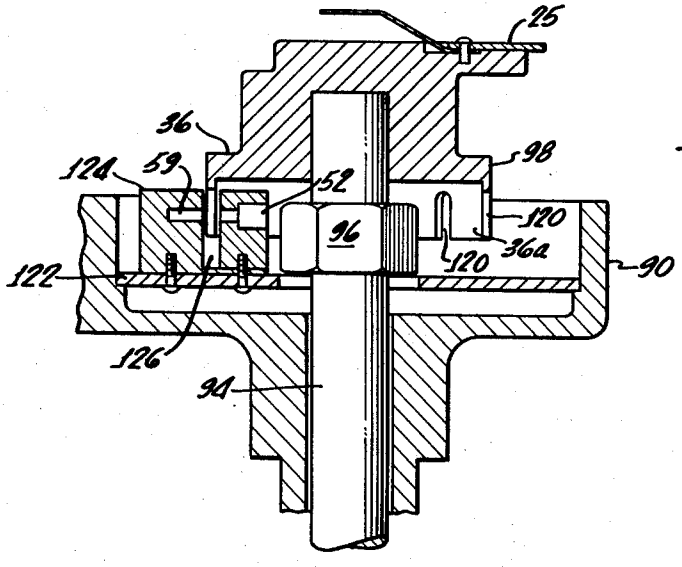


FIG. 4.

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TRANSISTORIZED IGNITION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to an ignition system for an internal combustion engine.

Mechanical timing and switching arrangements for ignition systems for internal combustion engines have been commonly used for several decades. In comparison with contemporary circuit technology, such mechanical systems are quite outdated. In a very real sense, such systems are honored only by time since the replacement of the mechanical points due to wear is one of if not the most common maintenance problems known to automobile owners.

Transistor ignition systems have heretofore been devised incorporating a rotary shutter which is caused to move between a light source and a photoelectric cell in synchronism with the engine speed. Transistor amplifiers connect the output of the photocell to a transistor switch in series with the primary winding of the ignition coil to alternately make and break the current flowing through the coil. Such systems are capable of improved response accuracy and, of course, eliminate the mechanical wear problem by eliminating the mechanical make and break points.

Photoelectric timing arrangements, however, are not without problems of their own in that a finite time is required to increase the conductivity of the photocell to a given level when it is subjected to light energy and another finite time is required to decrease its conductivity to zero when the light energy is removed. This problem is aggravated when there is a finite time interval associated with the rise and fall of the intensity of the light energy as is the case with a mechanical shutter system. Heretofore, this problem has reduced the amplitude of the of the ignition pulse produced by the secondary winding of the ignition coil since the transistor switch is slowly turned on and off as a function of the rise and fall time of the current through the photocell thereby reducing the rate of change of current through the primary winding. In addition, the transistor switch is overloaded during the slow turn on and turn off time and will either fail or, at the very least, provide a degraded performance.

SUMMARY OF THE INVENTION

The present invention provides an improved circuit means for translating the output of a photoelectric timer to a suitable pulse of current for driving the primary winding of an ignition coil. As described in detail below, the circuitry provides a precise control over the transistor switch connected to the primary winding of the ignition coil so as to provide a substantially improved operation. One important aspect of the invention is that the circuitry produces a very rapid rate of change of flux in the primary coil, thereby enabling production of a high energy pulse in the secondary winding thereof which is discharged through spark plugs. Another important feature of the invention is that the switching transistor is turned off very rapidly, thereby preventing any energy in the coil field from being dissipated in the switching transistor which would both tend to reduce the amplitude of the ignition pulse on the secondary winding and would also overstress the transistor and result in its rapid failure.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the transistorized ignition system of the invention;

FIG. 2 is a diagrammatic illustration of the operation of various components in the system including a number of the waveforms produced in the circuit of FIG. 1;

FIG. 3 is a plan view of the distributor assembly with the cap removed; and,

FIG. 4 is a cross section taken along line 4–4 on FIG. 3.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Referring first to FIG. 1, there is shown a direct current source 10 such as the 12-volt storage battery in an automobile, serially connected to a power bus 11 via an ignition switch 12, a timing and control circuit surrounded by dashed lines and generally indicated by the numeral 14, a ballast resistor 16 and the primary winding 18 of an ignition coil 20. The secondary winding 22 of the ignition coil 20 is in turn connected to a distributor 24 having a rotatable wiper arm 25 which distributes ignition pulses through a plurality of ignition wires 26 to one electrode of a corresponding plurality of spark plugs 28 in an internal combustion engine 30, with the other electrodes of each of the spark plugs connected to ground.

The rotatable wiper arm 25 of the distributor 24 is driven by an engine shaft as indicated by the dotted line 34. A shutter wheel 36 forming an integral part of the distributor unit is also driven by the engine shaft 34 and has a plurality of spaced arcuate segments 36*a* corresponding to the number of engine spark plugs 28. Eight as shown in FIG. 1.

Major sections within the timing and control circuit 14 are identified in FIG. 1 as a photoelectric pickup 40, an amplifier 42, a pulse-squaring circuit 44, a driver 46 and a power switch 48.

Within the photoelectric pickup section 40, there is provided a resistor 50 and a lamp or light source 52 serially connected between the bus 11 and a ground terminal 54. A photocell 59, in optical communication with the light source 52, is connected in series with a resistor 58 between bus 11 and ground 54. The light source 52 is positioned within the shutter wheel 36 such that the segments 36*a* interrupt the light rays incident upon photocell 59 as the shutter wheel 36 rotates. A voltage-regulating diode 56 is connected in parallel with light source 52 and provides an adequate voltage potential to illuminate light source 52. Diode 56 maintains a nearly constant voltage across light source 52 even when there are large changes in the voltage on the buss 11 such as during starting. This feature results in an operating lifetime for the light source 52 far in excess of the period of time that the ignition system would ever be operated and, accordingly, eliminates the necessity of ever replacing the light source 52 during system operation. The diode 56 also produces small voltage changes across the light source 52 as a function of environmental temperature changes within the distributor housing. These voltage changes vary the light energy emitted by the light source 52 and compensate for the change in the sensitivity of the photocell 59 due to temperature changes. For example, at low temperatures the photocell 59 is less sensitive than it is at high temperatures while under the same conditions. The voltage across the diode 56 is higher than it is at higher temperatures. Thus, due to the voltage across diode 56 more energy is emitted by the light source 52 at a time when the photocell 59 is less sensitive providing temperature compensation for the electrical components of the photoelectric timing means. The slight temporary increase in the operating voltages of the light source 52 does not affect its lifetime appreciably.

The amplifier section 42 includes an NPN transistor 60 having its emitter 62 connected to ground 54 and its collector 61 connected to bus 11 through series connected resistors 63 and 64. The base 65 of the transistor 60 is connected between the resistor 58 and the photocell 59 so that the base 65 and emitter 62 of the transistor 60 form a shunt path across the photocell 59.

The pulse-squaring circuit 44 includes a PNP transistor 66 having its base 67 connected between the resistors 63 and 64 of the amplifier section 42. The emitter 68 and collector 69 of the transistor 66, together with resistors 70 and 71, are serially connected between the bus 11 and ground terminal 54. A second PNP transistor 72 is shown with its base 73 connected between the collector 69 of the transistor 66 and the resistor 71, its collector 75 is serially connected with resistors 76 and

77 to a ground 78, and its emitter 74 is connected to the emitter 68 of transistor 66. The common emitter connection of transistors 66 and 72 is connected to bus 11 through resistor 70.

In the driver section 46, there is provided an NPN transistor 79 having its base 80 connected between the resistors 76 and 77 of the pulse square circuit 44. The collector 81 of transistor 79 is connected to bus 11 via resistor 83 and the emitter 82 is connected to the ground terminal 78.

The power switch section 48 includes an NPN switching transistor 84 having its base 85 connected between the resistor 83 and the collector 81 of transistor 79, and its emitter 86 connected with the ground 78. As a result, the base-emitter circuit of the switching transistor 84 is connected in parallel with the collector-emitter circuit of transistor 79. The collector 87 of transistor 84 is serially connected with the primary winding 18 of the ignition coil 20 and ballast resistor 16 to bus 11. Connected in parallel with the emitter-collector circuit of the transistor 84 is a Zener diode 88. Also connected across the emitter-collector circuit, and in parallel with the Zener diode 88, is a capacitor 89.

OPERATION

The ignition system of FIG. 1 operates as follows: Assume that the ignition switch 12 is closed and that the engine 30 has been started so that the shutter wheel 36 of the distributor is being rotated by the shaft 34 at a speed which is synchronized with the engine speed. The resistor 50 limits the current applied to the lamp 52 and the regulating diode 56 maintains a nearly constant voltage to the light source 52, regardless of voltage changes on bus 11. Advantageously, the magnitude of the voltage maintained across lamp 52 by diode 56 is selected to be high enough to optimize the output of the lamp 52 to provide sufficient light to the photocell 59 and at the same time be low enough to insure an extended lifetime for the light source. Diode 56 also changes the voltage across lamp 52 with changes in temperature of the distributor housing thus maintaining the optimum voltage across lamp 52 for any temperature as previously discusses.

As the shutter wheel 36 rotates, the light from the light source 52 is alternately opened and blocked off by the shutter wheel segments 36*a*. This timing action is represented by the square wave 100 indicated in FIG. 2 with the horizontal dimension representing time. The portion 100*a* of waveform 100 represents the positions of the shutter wheel wherein a segment 36*a* blocks the light emanating from the light source 52 to the photocell 59 while the portion 100*b* represents the intervals when the spaces between shutter wheel segments 36*a* are aligned with the source 52 and the photocell 59 and light is transmitted from the light source 52 to the photocell 59.

As light from the light source 52 strikes the photocell 59, the photocell 59 commences to conduct, thus allowing current flow through the resistor 58 to the ground 54. The current flow through photocell 59 is illustrated by waveform 102 in FIG. 2. Section 102*a* is not conducting and the section 102*b* represents the time interval when the photocell 59 is conducting. As can be seen, the conducting sections 102*b* are vertically aligned with the sections 100*b* of the shutter line 100 indicating that the photocell 59 conducts when the shutter is open.

While utilizing a photocell as the timing means in an ignition system is advantageous from the standpoint that there is little or no wear or maintenance problems, one of the characteristics of a photocell is that the conductivity of the cell gradually increases to given level when it is subjected to light and gradually decreases to zero when the light is removed. This characteristic is shown in waveform 102 of FIG. 2 wherein the current pulses, such as pulse 102*b*, have slow rise and fall times in contrast to a squared waveform. These current pulses, then, do not provide a desirable, high-speed switching pulse. The lack of a distinctive transition by a photocell between the conduction and the nonconductive states is further aggravated at low engine speeds due to the more gradual application and removal of the light energy as the shutter wheel rotates.

The current flow through the photocell 59 is amplified by amplifier 42. As the conductivity of the photocell 59 gradually decreases the voltage potential on the base 65 of transistor 60 gradually increases which in turn causes transistor 60 to gradually become conductive until it is saturated. As the transistor 60 becomes conductive, current will flow through the resistors 64 and 63 through the collector-emitter circuit of the transistor 60 to the ground 54. This current flow is indicated by the waveform 104 in FIG. 2 wherein portion 104*a* represents the current through transistor 60 when it is saturated. Conversely, as the photocell 59 gradually begins to conduct and the voltage applied to the base 65 of the transistor 60 becomes lower, the transistor 60 gradually ceases conduction and turns off. Portion 104*b* of the waveform 104 in FIG. 2 shows that no current flows through transistor 60 when it is not conductive.

Since the timing signal is only amplified by the transistor 60, the output current waveform of the transistor 60 remains similar in shape to the current waveform through the photocell 59 as may be seen by comparison of waveforms 102 and 104 in FIG. 2. The difference in current magnitude between the waveforms 102 and 104 is not indicated in the drawing nor are the rise and fall times of the timing pulses since this of course varies with engine speed.

Pulse squaring is achieved in circuit 44. When transistor 60 of amplifier 42 is off (coincident with a high conductivity state of photocell 59), there is no current flow through the resistors 63 and 64. Consequently, the voltage applied to the base 67 of the transistor 66 is the voltage potential of bus 11. Since this same voltage is applied through the resistor 70 to the emitter 68 of the transistor 66, the transistor 66 is not forward biased and does not conduct. With the transistor 66 not conducting, there is no current flow through the transistor 66. Accordingly transistor 72 conducts due to the high potential of the emitter 74 with respect to the base 73 which is connected to the ground 54 through resistor 71. When transistor 72 becomes conductive current will flow from bus 11 through resistor 70, transistor 72 and resistors 76 and 77.

As the amplifier transistor 60 begins to conduct (coincident with a low conductivity state of photocell 59), the voltage potential applied to the base 67 of the transistor 66 begins to drop due to the current flow through the resistor 64. The transistor 66 begins to conduct as the voltage potential of the base 67 becomes lower than the voltage potential of the emitter 68. The voltage potential at the emitter 68 of transistor 66 is equal to the voltage of bus 11 minus the voltage drop across resistor 70 due to the current flowing through resistor 70 and transistor 72. As the transistor 66 increases in conductivity, the current through the emitter-collector circuit of the transistor 66 produces an increasing voltage on the base 73 of the transistor 72 by virtue of the increasing voltage drop across resistor 71. The increasing voltage potential on base 73 of transistor 72 causes the transistor 72 to decrease in conductivity, and accordingly, the current flow through the transistor 72 decreases causing the voltage potential of the emitter 74 of transistor 72 and the emitter 68 of the transistor 66 to increase due to a decrease in the voltage drop across resistor 70. This regenerative action, that is, the decreasing voltage on the base 67 of the transistor 66 simultaneous with the increasing voltage on the emitter 68, results in a very rapid conductivity transition by the transistors 66 and 72. It should be noted that the value of the resistor 71 is selected to be greater than the value of resistor 76 to achieve this action. This insures that the voltage drop across the resistor 70 is greater when the transistor 72 is on and the transistor 66 is off than it is when the transistor 72 is off and the transistor 66 is on. Were this not so, the voltage potential of the common emitter connection between the transistors 66 and 72 would begin to decrease as the transistor 66 became conductive causing the transition time for the transistors 66 and 72 to change conduction states to be extended rather that accelerated.

When the transistor **60** becomes nonconductive (coincident with a low conductivity state of photocell **59**), the transistors **66** and **72** change conductivity states in a manner opposite to that described above. That is, as the transistor **60** decreases in conductivity the voltage potential applied to the base **67** of transistor **66** increases which in turn decreases the conductivity of the transistor **66**. As the current through the transistor **66** decreases the voltage drop across the resistor **71** decreases, thereby decreasing the voltage potential on the base **73** of the transistor **72**. The transistor **72** therefore begins to conduct. Because of the increased current flow through the resistor **70**, due to the increased conductivity of the transistor **72**, the voltage potential of the common emitter connecting between the transistors **66** and **72** decreases. The voltage potential of the emitter **68** of the transistor **66** therefore is decreasing at the same time that the voltage potential of the base **67** is increasing. This regenerative action accelerates the transition of the transistor **66** from the conductive to the nonconductive state and consequently the transition of the transistor **72** from a nonconductive to a conductive state.

An illustration of the voltage applied to the base **67** of the transistor **66** is shown by the waveform **106** in FIG. **2** with portion **106***a* representing a lower voltage occurring when the transistor **60** is conductive and portion **106***b* representing a higher voltage occurring when the transistor **60** is nonconductive. At some point, such as point **106***c*, where the voltage on the base **67** of the transistor **66** is less than the voltage applied to the emitter **68**, the transistor **66** sharply transitions to a conductive state. At a point, such as point **106***d*, where the voltage on the base **67** of the transistor **66** becomes greater than the voltage on the emitter **68**, the transistor **66** ceases conduction sharply.

The current through the transistor **66** is indicated by the waveform **108** of FIG. **2** with portion **108***a* representing the current flow when the transistor **66** is conductive and the nonconducting periods being indicated by portion **108***b*. Note that the current fall indicated by **108***c* between sections **108***a* and **108***b* is vertically aligned with and occurs in time coincidence with the point **106***d* on the voltage curve **106** and that the current rise indicated by portion **108***d* between sections **108***b* and **108***a* is vertically aligned with and occurs in time coincidence with point **106***c* on the voltage curve **106**. The rapid change in the conductivity of transistors **66** and **72** as described above produces the desired shaping of the waveform into the square waveform **108**.

Current flow through the transistor **72** is indicated by the waveform **110** with portion **110***a* representing the intervals when the transistor **72** is not conducting and portion **110***b* representing the interval when the transistor **72** conducts.

The resistor **64** is an important element in the pulse-squaring operation of the present invention. For transistors **66** and **72** to change conductivity states rapidly, there must be a step function increase or decrease in the base drive current to transistor **66**. This step change in base current is caused by the step changes in voltages across resistor **64** as shown in waveform **106** at points **106***d* and **106***c* respectively. In other words, for optimum performance of this circuit, it is desirable to have the base current of transistor **66** supplied form a source with the lowest possible impedance. (A zero impedance source, i.e. an ideal voltage source, would be the best). Since the collector circuit of transistor **60** represents a very high impedance, resistor **64** is the only path to provide a low impedance source for the base of transistor **66**. Resistor **64** is chosen to be as small as possible. The minimum value for resistor **64** is determined by the level of current that can be controlled in transistor **60** by photocell **59**.

With the transistor **72** conducting, there is a current flow through the resistors **76** and **77** and the base emitter junction of transistor **79**. This current is shown as waveform **112** in FIG. **2**. This current, when transistor **72** is on, is sufficient to bias the transistor **79** into a saturated conductive state. The current flow through resistor **77**, when transistor **72** is on, is small compared to the current flowing into the base terminal of transistor **79**. When the driver transistor **79** is turned on, current will flow through the resistor **83** to the ground **78**. The voltage drop from the collector **81** to the emitter **82** across the transistor **79** when it is conducting is so low that essentially no current will flow into the base terminal **85** of the switching transistor **84**. Thus, the switching transistor **84** is turned off when the driver transistor **79** is turned on.

The driver transistor **79** is turned off when the transistor **72** becomes nonconductive, and, accordingly, the voltage on the base **85** of transistor **84** increases. Transistor **84** will then become conductive.

The current flow through the transistor **79** is indicated by the waveform **114** in FIG. **2** and the current flow through the transistor **84** is indicated by the waveform **116**. As can be seen, the current flows are complementary.

When the switching transistor **84** is conducting, a flux field is built up in the ignition coil **20** as the current flows from the bus **11**, through the resistor **16**, the primary winding **18**, and the transistor **84** to the ground **78**. When the transistor **84** is turned off, the current flow through the winding **18** stops. This is indicated by the waveform **118** in FIG. **2**. Interrupting current flow through the winding **18** causes the flux field in the coil **20** to rapidly collapse resulting in a high voltage potential being induced in the secondary winding **22** which serves as the desired ignition pulse. This pulse in turn is transmitted to the distributor **24** for distribution to the spark plugs **28**.

From the foregoing, it can be seen that the current through the primary winding **18** of the ignition coil **20** is turned on when a shutter segment **36***a* blocks the light beam from the light source **52** to the photocell **59**. This is indicated respectively by the portions **100***a* and **118***a* of the waveforms in FIG. **2**. Current flow through the primary winding **18** stops when the light beam falls on the photocell **59**. Thus, the photocell **59** and chopper wheel **36** perform the timing function of conventional breaker points and determine both the frequency and the pulse width of the current flow through the winding **18**.

The rapid switching of the transistor **84** from a nonconductive to a conductive state and subsequently from the conductive to the nonconductive state is a significant feature of this invention. One advantage derives from the fact that the magnitude of the ignition pulse output from the secondary winding **22** is dependent upon the rate of change of the flux in the field of the ignition coil **20** which in turn is dependent upon the rate of change of current through the coil **20**. The higher the rate of change of the flux the higher the magnitude of the ignition pulse. Accordingly, since the present invention causes the transistor switch **84** to open and close at the proper times almost instantly, it is an inherent property of this invention to provide a high energy pulse output to the engine spark plugs. Also, this feature of the invention has the correlative advantage of obviating any deleterious stresses upon the switching transistor **84**. This feature may be readily appreciated by considering what happens if transistor **84** were not switched rapidly. Assuming that the transistor **84** were switched slowly off resulting in a slow decrease in the current through the primary winding **18**, a rising voltage potential across the transistor **84** would occur due to the collapsing flux field in the coil **20** at the same time that current was still flowing through the transistor **84**. Thus part of the energy stored in the field of the coil **20** would be dissipated into the transistor **84**. This undesirable power dissipation into transistor **84** will have deleterious effects upon the transistor **84** decreasing its useful lifetime and hence the reliability of the ignition system.

Another safety feature of the invention is Zener diode **88** which is connected across the transistor **84**. The Zener diode **88** has a breakdown voltage which is selected to limit the maximum voltage that can appear across the transistor as a result of the voltage appearing across winding **18** as the flux field in the coil **20** collapses. This value is also high enough to prevent significant degradation of the ignition pulse output of the secondary winding **22**. This diode also protects transistor **84** by virtue of the fact that it limits any reverse voltage (collector negative with respect to emitter) appearing across the transistor **84** to a safe value of approximately 1 volt.

Capacitor **89** in shunt with transistor **84** further reduces the electrical stress on transistor **84** by providing a shunt path to ground for current surges generated by the coil **20** when the transistor **84** turns off thus insuring that the current in transistor **84** has decreased to a negligible value before any appreciable voltage appears across it. Also, the energy stored in the capacitor **89** serves to increase the energy output from the ignition coil **18** by reason of a flow of current in the reverse direction from the capacitor **89** to the winding **18** as the field of the winding **18** is collapsing.

The ballast resistor **16** limits the current flow through the ignition coil **20** and the transistor **84**. Advantageously, the resistor **16** is a temperature sensitive resistor having a lower resistance in a cold environment to facilitate starting during cold weather.

The Zener diode **13** connected across the battery **10** and the switch **12** protects the system from voltage transients and limits the voltage potential on bus **11** to a predetermined maximum value of 16 volts for example.

As another safety feature, the use of spaced grounds **54** and **78** were found advantageous to provide isolation, for the low power components of the system, from the transients which might occur in the high power portion.

As explained above, the voltage drop across resistor **77** causes the driver transistor **79** to turn on. Resistor **77** also assists in rapidly turning off transistor **79** which, of course, causes the transistor **84** to turn on rapidly. The resistor **77** accomplishes this function by providing a rapid discharge path for reverse base current in the transistor **79**, that is, from the collector **81** to the base **80**, which results from the energy stored in the collector-base capacitance of transistor **79**. Consequently, the value of the resistor **77** is selected to be large enough to cause the driver transistor **79** to turn on when the transistor **72** becomes conductive, but small enough such that there is not sufficient voltage built up across it by the reverse base current of the transistor **79** to maintain the transistor **79** conductive. If the resistor **77** were not provided, i.e. if the base **80** of the transistor **79** were free floating, the collector base current of the transistor **79** could provide sufficient base current to maintain transistor **79** on after transistor **72** turns off (which in turn would prevent rapid turn-on of transistor **84**).

Many of the transistor switches heretofore used to switch current through the primary winding of an ignition coil have been biased on and off by a driver transistor having its collector-emitter electrodes connected in series with the base of the switching transistor. Such a configuration requires that additional circuitry be added to insure that the transistor switch is adequately reverse biased. For example, a diode may be added between the emitter of the switching transistor and ground. The present invention eliminates this extra expense by connecting driver transistor **79** across the base **85** and the emitter **86** of the transistor switch **84**. Accordingly, wherein the transistor **79** is conducting, the transistor **84** is positively biased off since the base **85** is clamped to the same potential as the emitter **86**.

Referring now to FIG. **3**, there is shown a plan view of an integrally packaged transistorized ignition system. A housing member **90** is adapted to be installed on the distributor camshaft on an internal combustion engine and has provision for containment of the ignition coil **20**, the electronic elements of the timing and control circuitry **14**, and the photoelectric timing means including the shutter wheel **36**.

A more detailed drawing of the photoelectric timing means is shown in FIG. **4** which is a cross section taken along line **4–4** of FIG. **3**. The housing member **90** is mounted on a distributor camshaft **94** which is mechanically linked to the crankshaft of the engine. The cam shaft **94** rotates in synchronism with the engine's crankshaft and has a cam lobe portion **96** which would normally operate the mechanical breaker points in a conventional ignition system. The cam lobe **96**, however, does not perform any function in the present invention.

The rotatable wiper arm **25** (i.e. the distributor rotor) and the shutter wheel **36** shown in FIG. **1** as two separate elements are advantageously integrated into a one-piece molded unit seen in FIG. **4** which is mounted to the top of the camshaft **94** and rotates in accordance with rotation of the camshaft **94**.

The shutter wheel **36** comprises a hollow cylindrical portion **98** having a plurality of openings **120** around its periphery that divide the periphery into a plurality of arcuate segments **36***a*.

A mounting plate **122** is journaled on the camshaft **94** internal to the housing **90** and provides a means for mounting a block **124** which contains the photocell **59** and the light source **52**. The block **124** has a slotted portion **126** which allows the shutter wheel **36** to pass between the photocell **59** and the light source **52** as it rotates.

I claim:

1. An ignition system for an internal combustion engine having an ignition coil with a primary winding and a secondary winding and a current source comprising:

means driven by said engine for generating timing signals synchronized with the speed of said engine, said timing signals characterized by slow rise and fall times;

pulse-shaping means responsive to said timing means for generating a square pulse train having a frequency and pulse width determined by said timing signals; and

switching means in series with said primary winding, said switching means opening and closing in response to said square pulse train generated by said pulse-shaping means, said switching means allowing current flow from said current source through said primary winding when closed and interrupting said current flow from said current source when open, said pulse-shaping means causing said switching means to operate very rapidly to interrupt the flow of current through said primary winding so that the magnitude of the ignition pulse output from said secondary winding is increased and dissipation of energy stored within said ignition coil into said switching means is prevented.

2. The system of claim **1** wherein said means for generating timing signals comprises:

a light source and a photocell in optical communication; and

a shutter wheel having spaced arcuate segments intermediate said light source and said photocell and adapted to be rotated in synchronism with said engine.

3. The system of claim **1** wherein said pulse-shaping means comprises:

first and second transistors interconnected to have complementary conduction states, said transistors changing from a first to a second conduction state by regenerative action when the magnitude of said timing pulses reach a first value and said transistors returning to said first conduction state when the magnitude of said timing pulses reaches a second value.

4. The system of claim **3** wherein said transistors are PNP transistors having base, emitter and collector electrodes, said first transistor being normally conductive and connected between the emitter and base electrodes of said second transistor to bias said second transistor normally nonconductive, said first transistor having said timing pulses applied to its base electrode causing it to become nonconductive when the magnitude of said timing pulse reaches said first value, as said first transistor transitions from a conductive to a nonconductive state said second transistor transitions from a nonconductive to a conductive state accelerating the transition of said first transistor, when said timing pulse reaches said second value said first transistor becomes conductive causing said second transistor to become nonconductive accelerating the transition of said first transistor to a conductive state.

5. The system of claim **3** wherein said transistors are PNP transistors having base, emitter and collector electrodes, said second transistor having a first resistor connected to its collector electrode, and a third resistor having a value greater than the value of said second resistor connected to its base electrode, said first transistor being normally conductive and having its emitter and collector electrodes connected to the

emitter and base electrodes respectively of said second transistor to bias said second transistor normally nonconductive, said first transistor having said timing pulses applied to its base electrode to bias said first transistor nonconductive when the magnitude of said timing pulses reaches said first value, as said first transistor becomes nonconductive said second transistor becomes conductive reducing the voltage potential at the emitter electrodes of said transistors due to the increased current flow through said first resistor accelerating the transition of said first transistor from a conductive to a nonconductive state and thereby accelerating the transition of said second transistor from nonconductive to a conductive state, said first transistor becoming conductive when said timing pulse reaches said second value causing said second transistor to become nonconductive increasing the voltage potential at the emitter electrodes of said transistors accelerating the nonconductive to conductive transition of said first transistor.

6. The system of claim 5 wherein said switching means includes:

a driver transistor controlled by the output current flow through said second transistor; and,

a switching transistor in series with said primary winding and responsively connected to said driver transistor.

7. The system of claim 6 wherein said pulse-shaping means further includes a fourth resistor in series with said series connected second transistor collector electrode and second resistor and wherein the base of said driver transistor in said switching means is connected between said second resistor and said fourth resistor, said fourth resistor having a magnitude sufficiently large so that current flow through said second transistor during said second conduction state develops a voltage potential across said fourth resistor to forward bias said driver transistor to a conductive state, said driver transistor being biased to a nonconductive state during said first conduction state of said second transistor, the magnitude of said fourth resistor being sufficiently small to provide a rapid discharge path for reverse base current in said driver transistor resulting from the collector to base capacitance when said driver transistor is biased to a nonconductive state.

8. The system of claim 1 wherein said switching means includes:

a switching transistor having its collector and emitter electrodes connected to said primary winding and ground respectively, said switching transistor allowing current to flow through said primary winding when conductive and interrupting said current flow when nonconductive;

a driver resistor connected between the base of said switching transistor and a direct current source so that said switching transistor is conductive; and,

a driver transistor having its collector and emitter electrodes connected between the base of said switching transistor and ground respectively and having said square pulses output from said pulse-shaping means applied to its base, said driver transistor becoming conductive while said square pulses are present on its base, said driver transistor shunting the current through said driver resistor to ground when conductive causing said switching transistor to become nonconductive interrupting said current flow through said primary winding.

9. The system of claim 1 further including a parallel connected capacitor and voltage limiting diode said parallel connected capacitor and diode being connected across said switching means, said capacitor increasing the energy output from said ignition coil and also increasing the reliability of said switching means, said voltage-limiting diode protecting said switching means from damage resulting from voltage transients in excess of the breakdown voltage of said switching means.

10. An ignition system for an internal combustion engine having a direct current source connected in series with a primary winding of an ignition coil also having a secondary winding connected through a distributor to spark plugs for the engine comprising:

a shutter wheel rotated by the distributor shaft;

a light source and juxtaposed photocell, said rotating shutter wheel interrupting the light impinging on said photocell at a rate proportional to the engine speed;

a first resistor connecting said direct current power source to said photocell;

an amplifier transistor having its base and emitter electrodes coupled to opposite terminals of said photocell and its collector electrode serially connected with second and third resistors to said current source;

first and second pulse-squaring transistors having their emitter electrodes connected together with said first transistor having its base electrode connected between said second and third resistors, a fourth resistor connected between said current source and the common emitter electrode connection of said pulse-squaring transistors and a fifth resistor connected between the collector electrode of said first pulse-squaring transistor and ground said second pulse shaping transistor having its base electrode connected to the collector electrode of said first pulse shaping transistor and its collector electrode connected to ground through serially connected sixth and seventh resistors;

a driver transistor having its base electrode connected intermediate said sixth and seventh resistors its emitter electrode connected to ground and its collector electrode connected in series with a driver resistor to said direct current power source;

a ballast resistor in series between said current source and said primary winding; and,

a switching transistor having its base electrode connected to the collector electrode of said driver transistor, the emitter and collector electrodes of said switching transistor being connected in series with said primary winding of said ignition coil and said ballast resistor to said direct current power source said emitter electrode being connected to ground.

11. The system of claim 10 wherein said seventh resistor is given a sufficiently high value such that said drive transistor turns on when said second pulse-squaring transistor is turned on and a low enough value such that it will prevent a collector-base current through said driver transistor from causing the driver transistor to remain conductive as the second pulse-squaring transistor is being turned off.

12. The system of claim 11 further including a parallel connected capacitor and voltage limiting diode having its anode electrode connected to ground said parallel connected capacitor and diode being connected in parallel to the collector and emitter electrodes of said switching transistor.

13. An ignition system for an internal combustion engine having an ignition coil with a primary winding and a secondary winding and a current source comprising:

means driven by said engine for generating timing signals synchronized with the speed of said engine, said timing signals characterized by slow rise and fall times, said means for generating timing signals comprising:

a light source and a photocell in optical communication, said light source connected in series with a current-limiting resistor to said current source;

a diode connected in parallel with said light source, said diode providing voltage variation across said light source as a function of environmental temperature to increase the energy emitted by said light source when the environmental temperature reduces the sensitivity of said photocell and to decrease the emitted energy when the environmental temperature increases the sensitivity of the photocell;

a shutter wheel having spaced arcuate segments intermediate said light source and said photocell and adapted to be rotated in synchronism with said engine;

pulse-shaping means responsive to said timing means for generating a square pulse train having a frequency and pulse width determined by said timing signals: and

switching means in series with said primary winding, said switching means opening and closing in response to said square pulse train generated by said pulse-shaping means, said switching means allowing current flow from said current source through said primary winding when closed and interrupting said current flow from said current source when open, said pulse-shaping means causing said switching means to operate very rapidly to interrupt the flow of current through said primary winding so that the magnitude of the ignition pulse output from said secondary winding is increased and dissipation of energy stored within said ignition coil into said switching means is prevented.

14. The system as described in claim 7 wherein said ignition system and said ignition coil are contained in a a housing member adapted to be mounted on an internal combustion engine distributor camshaft and which includes a mounting plate journaled around said camshaft and wherein said means for generating timing signals comprises a shutter wheel coupled to sad camshaft to rotate in accordance therewith, a light source and photocell juxtaposed radially from said camshaft and mounted on said mounting plate said shutter wheel rotating between said light source and photocell to interrupt the light energy emitted by said light source incident upon said photocell at a frequency proportional to said engine speed.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,581,725 Dated June 1, 1971

Inventor(s) Lewis W. Hemphill, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1,	line 57	- after "through" insert --the--
Col. 2,	line 39	- change "buss" to --bus--
Col. 3,	line 41	- Change "discusses" to --discussed--
Col. 3,	line 57	- after "Section 102" insert --of waveform 102 represents the time interval when the photocell 59--
Col. 3,	line 75	- Change "conduction" to --conductive--
Col. 5,	line 59	- Change "form" to --from--
Col. 7,	line 53	- Change "wherein" to --when--
Claim 5,	line 71	- Change "collector" to --emitter--

Signed and sealed this 21st day of December 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents