United States Patent [19]

Kondo

[11] **3,896,780**

[45] **July 29, 1975**

[54] **BREAKERLESS IGNITION SYSTEM FOR A MULTICYLINDER INTERNAL COMBUSTION ENGINE**

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[22] Filed: **Apr. 3, 1974**

[21] Appl. No.: **457,600**

[30] **Foreign Application Priority Data**

Apr. 5, 1973 Japan .... 48-40536[U]

[52] **U.S. Cl.** .... **123/148 E**

[51] **Int. Cl.²** **F02P 3/02**

[58] **Field of Search** .... 123/148 E, 148 ND

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[57] **ABSTRACT**

A breakerless ignition system for a multicylinder internal combustion engine comprising solid state switching means to allow a primary current to flow and then be cut off through each of the ignition circuits, an improvement wherein a control circuit is provided which is adapted to control the solid state switching means so as to prevent the primary current from flowing through more than two ignition circuits.

4 Claims, 5 Drawing Figures

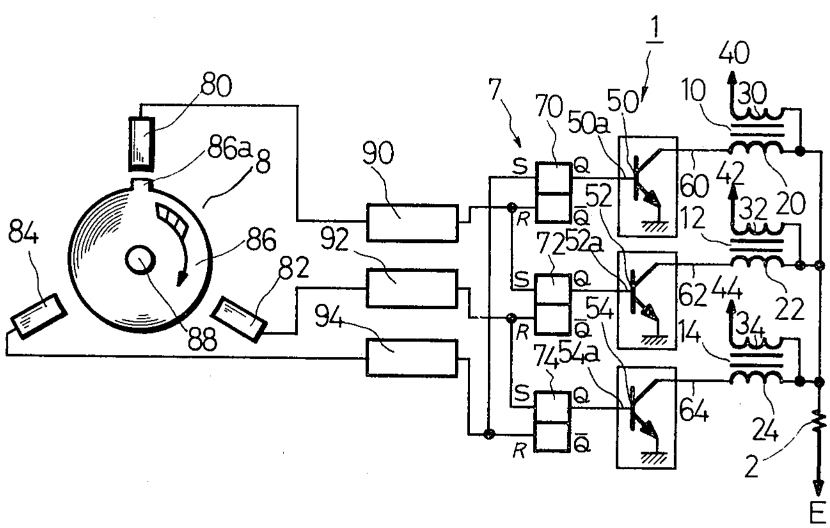


FIG.1

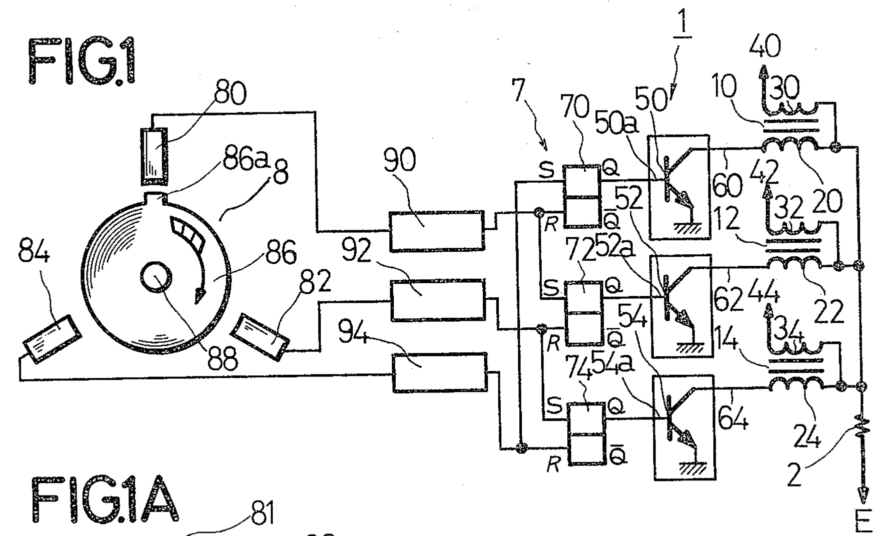


FIG.1A

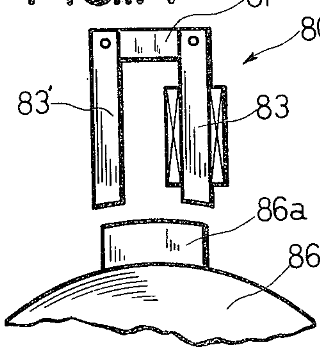


FIG.3

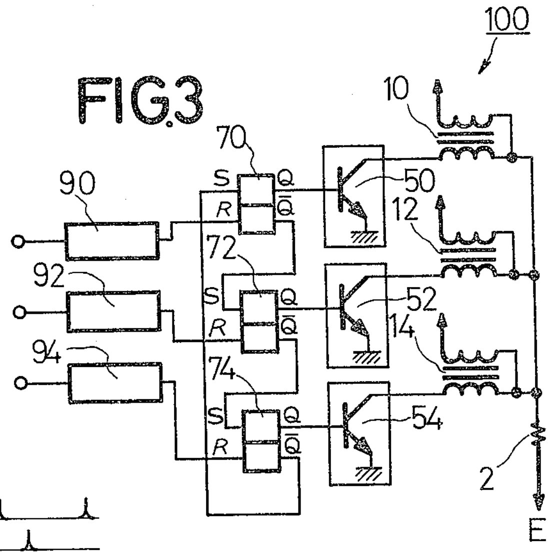


FIG.2

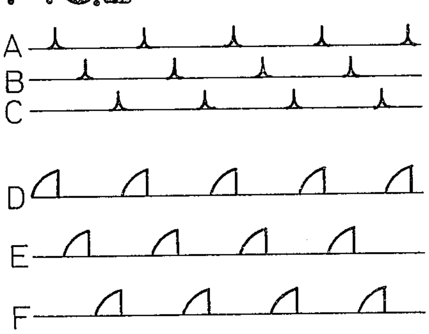
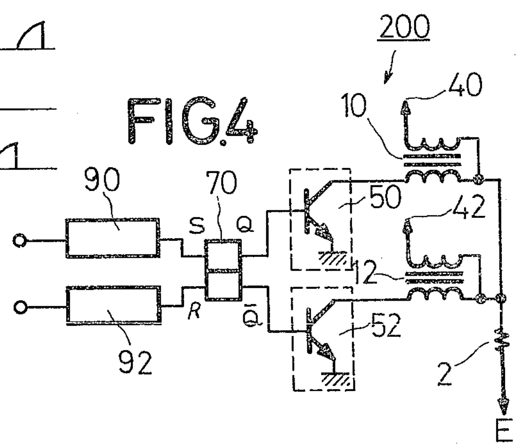


FIG.4



BREAKERLESS IGNITION SYSTEM FOR A MULTICYLINDER INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

A multicylinder internal combustion engine of small size often has a breakerless ignition system employed including a corresponding number of ignition coils to that of the cylinders of the engine without using a distributor in consideration of watertightness of the ignition system. If the ignition system is of a primary current interruption type, it is necessary for the ignition system to have a corresponding number of solid-state switching means to that of the ignition coils for interruption of the primary current through the respective ignition coils, resulting in an increased current consumed when the engine starts to operate or when it operates at low speed. In the case that the engine has two or three cylinders, if the ignition coils corresponding to the respective cylinders each consume 5 to 6 amp. of the primary current therethrough, the engine requires 10 to 18 amp. of the primary current as a whole. Thus, the engine as for a bicycle, which has a battery of relatively lower capacity, unpreferably has great load applied on the battery.

OBJECTS OF THE INVENTION

Accordingly, it is a principal object of the present invention to provide a breakerless ignition system for a multicylinder engine wherein a primary current through the entire ignition system is as small as possible.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a breakerless ignition system for a multicylinder internal combustion engine comprising a plurality of ignition circuits each including an ignition coil and solid state switching means to control said ignition coil so as to allow a primary current to flow through said ignition coil and to be cut off from flowing through said ignition coil and a control circuit to control each of said solid state switching means of said ignition circuits, said control circuit associated with a signal generator rotating in time with said engine for generating signals to operate said control circuit, an improvment wherein said control circuit comprises means to sequentially conduct said solid state switching means for said ignition circuits so that when one of said solid state switching means conducts to allow a primary current to flow through the corresponding ignition coil the remaining solid state switching means are non-conductive, said signal generator including a corresponding number of signal coils to that of said ignition circuits, which control said means to sequentially conduct said solid state switching means.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects and features of the present invention will become apparent from the description of the preferred embodiments of the present invention taken with reference to the accompanying drawing;

FIG. 1 is a schematic diagram showing a breakerless ignition system for a multicylinder engine according to the present invention;

FIG. 1A is illustrative of one of the generating elements of the signal generator shown in FIG. 1 in connection with the rotor thereof;

FIG. 2 shows output signals from a signal circuit and primary currents through ignition coil;

FIG. 3 is a schematic diagram showing another embodiment of the present invention with a signal generator omitted for simplification;

and FIG. 4 is a fragmentary schematic diagram showing further embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the accompanying drawing, there is shown a breakerless ignition system 1 of the present invention for a three cylinder internal combustion engine which comprises three ignition coils **10**, 12 and **14** for respective cylinders of the engine. The ignition coils **10, 12** and **14** have primary coil portions **20, 22** and **24** at one ends commonly connected to one end of a resistance **2** to the other end of which is connected a power source not shown in FIG. **1** and secondary coil portions **30, 32** and **34** connected to respective ignition plugs **40, 42** and **44.** The primary coil portions **20, 22** and **24** have the other ends connected to solid state switching circuit **50, 52** and **54** which are shown to comprise typically NPN type transistors which are in turn grounded. The ignition coil **10** and the solid state switching means **50** constitute an ignition circuit **60** for one of the cylinders, and similarly the ignition coils **12** and **14** and the solid state switching means **52** and **54** constitute ignition circuits **62** and **64** for the remaining cylinder, respectively.

The solid state switching means or transistors **50, 52** and **54** have the respective control electrodes or bases **50***a*, 52*a* and **54***a* connected to a control circuit **7** which may comprise three flip-flop circuits **70, 72** and **74** associated with the respective transistors **50, 52** and **54.** The flip-flop circuits **70, 72** and **74** which are of conventional reset-set type, each include S- and R-input terminals and Q- and $\bar{Q}$-output terminals with the Q-terminals of the flip-flop circuits **70, 72** and **74** connected to the respective bases of the transistors **50, 52** and **54.** As understood by those skilled in the art, each of such flip-flop circuits is adapted to generate a positive voltage at the Q-terminal and a zero voltage at the $\bar{Q}$-terminal when a signal is applied at the S-terminal and to generate a zero voltage at the Q-terminal and a positive voltage at the Q-terminal when a signal is applied at the R-terminal. Thus, when a signal is applied at the S-terminal of the flip-flop circuit **70,** for example, it has the output voltage applied at the base of the transistor **50** so that the primary current flows from the power source E through the ignition coil **10** and then through the transistor **50,** with the result that the energy is accumulated by the primary coil portion **20.** Thereafter, when a signal is applied at the R-terminal of the flip-flop circuit **70,** it has a zero voltage generated at the Q-terminal thereof so that the transistor **50** becomes non-conductibe to thereby interrupt the primary current through the ignition coil **10,** with the result that a high voltage is established across the secondary coil portion **30** of the ignition coil **10** so that the corresponding ignition plug **40** is sparked for ignition of the cylinder in which the plug **40** is contained. The flip-flop circuits **72** and **74** operate the associated ignition circuits **62** and **64** in a similar manner.

A signal generator **8** is provided which may comprise an inductor type rotor **89** having a pole **86**a integral with the rotor **86** and a stator including three generating elements **80, 82** and **84** angularly spaced by the equal distance adjacent to the periphery of the rotor. One of the generating elements **80** is particularly illustrated in FIG. **1**A, which may comprise an eternal magnet **81** magnetised as shown two core pieces **83** and **83'** mounted on the magnet at both ends thereof with the axes of the core pieces **83** and **83'** normal to the axis of the magnet and a signal coil **85** wound around one of the core pieces **83.** The core pieces are so shaped that when the rotor pole **86**a of the rotor **86** faces them, they are equally spaced from the rotor pole. The rotor is so connected to a crank shaft **88** of the engine that the former rotates in time with the engine (FIG. **1**). Thus, when the rotor of the generator **8** rotates in a direction indicated by an arrow of FIG. **1** one complete revolution, the generating element **80** first generates a signal, then the generating element **82** and last the generating element **84** generate signals, respectively. The signal generator **8** may be alternatively of any other type which can generate signals in synchronism with the revolution of the engine. It will be understood that the signal generator may be disposed in a magneto constituting the power source E so that the magnetic filed of the magneto can be also employed commonly for the signal generator. The signal coils of the generating elements **80, 82** and **84** have the respective outputs connected to inputs of respective amplifying and wave-modifying circuits **90, 92** and **94** which may be of any suitable type. The amplifying and wave-modifying circuit **90** has the output connected both to the R-terminal of the flip-flop circuit **70** and to the S-terminal of the flip-flop circuit **72.** Similarly, the amplifying and wave-modifying circuit **92** has the output connected both to the R-terminal of the flip-flop circuit **72** and to the S-terminal of the flip-flop coicuit **74** and the amplifying and wave-modifying circuit **94** has the output connected both to the R-terminal of the flip-flop circuit **74** and to the S-terminal of the flip-flop circuit **70.**

In operation, upon rotation of the rotor **86** of the signal generator **8** in the direction indicated by the arrow in FIG. **1,** the voltage generated by the signal coil in the generating element **80** is applied to the amplifying and wave-modifying circuit **90** which in turn outputs the voltage having the wave-form as shown in FIG. 3A. Such output voltage from the circuit **90** is applied to the R-terminal of the flip-flop circuit **70** and therefore, the Q-terminal of the flip-flop circuit **70** supplies no voltage to the base of the transistor **50.** Thus, the primary current as shown in FIG. 2D flowing through the ignition coil **10** is then cut off whereby the ignition coil **10** establishes a high voltage across the secondary coil portion **30** so that the plug **40** can be sparked for ignition of the cylinder in which the plug **40** is contained. Meantime, the output voltage from the amplifying and wave-modifying circuit **90** is also applied to the S-terminal of the flip-flop circuit **72** and therefore, the Q-terminal of the flip-flop circuit **72** has the output voltage applied to the base of the transistor **52.** Thus, the transistor **52** becomes so conductive that the primary current starts to flow through the primary coil portion **22** of the ignition coil **12** and through the transistor **52** as shown in FIG. 2E. At that time, since the generating elements **82** and **84** have no signals generated therefrom the remaining transistors **74** and **70** remain still non-conductive to thereby flow no primary current therethrough.

When the rotor **86** of the signal generator **8** continues to rotate until it faces the generating element **82,** then the latter generates a signal to apply it to the amplifying and wave-modifying circuit **92** which in turn generates the output voltage as shown in FIG. 2B. The output voltage from the amplifying and wave-modifying circuit **92** is applied to the R-terminal of the flip-flop circuit **72** and therefore, the Q-terminal of the flip-flop circuit **72** applies no voltage to the base of the transistor **52.** Thus, the primary current as shown in FIG. 2E flowing through the ignition coil **12** is then cut off whereby the ignition coil establishes a high voltage across the secondary coil portion **32** so that the plug **42** can be sparked for ignition of the cylinder in which the plug **42** is contained. Meantime, the output voltage from the amplifying and wave-modifying circuit **92** is also applied to the S-terminal of the flip-flop circuit **74** and therefore, the Q-terminal of the flip-flop circuit **74** has the output voltage applied to the base of the transistor **54.** Thus, the transistor **54** becomes so conductive that the primary current starts to flow through the primary coil portion **24** of the ignition coil **14** and through the transistor **54** as shown in FIG. 2F. When the rotor **86** of the signal generator **8** continues to rotate until the pole **86**a faces the generating element **84,** then the signal coil in the generating element **84** generates a signal which is applied to the amplifying and wave-modifying circuit **94** to thereby output the voltage as shown in FIG. 2C therefrom. The output from the circuit **94** causes the flip-flop circuit **74** to operate the transistor **54** to cut off the primary current through the primary coil portion **24** of the ignition coil **14** which establishes a high voltage across the secondary coil portion **34** of the ignition coil **14** for ignition of the cylinder in which the plug **44** is contained, just as described in connection with the operation of the flip-flop circuits **70** and **72.** Also, the output voltage from the circuit **94** causes the flip-flop circuit **70** to operate the transistor **50** to allow the primary current as shown in FIG. 2F to flow through the primary coil portion of the ignition coil **10** for preparation for the next operation thereof. As understood from FIGS. 2D to 2F, the primary currents through the ignition coils **10** to **14** never flow at the same time, with the result that the entire consumed current by the ignition system **1** can be considerably decreased. It will be also understood that the resistance **2** can be commonly employed for all of the ignition coils **10** to **14** because the primary current flows through any one of the ignition coils.

FIG. **3** shows another embodiment of the breakerless ignition system **100** for three cylinder engine in accordance with the present invention, wherein the same numerals designate the same components as those of FIG. **1.** The ignition system **100** of FIG. **2** is substantially similar to that of FIG. **1,** except that the outputs of the amplifying and wave-modifying circuits **90, 92** and **94** are connected only to the R-terminals of the respective flip-flop circuits **70, 72** and **74** with the $\overline{Q}$-terminals connected to the S-terminals of the respective flip-flop circuits **72, 74** and **70.** With this arrangement, when the amplifying and wave-modifying circuit **90** outputs the voltage, the flip-flop circuit **70** operates the transistor **50** to conduct so that the primary current starts to flow the ignition coil **10** and provide the output voltage at the $\overline{Q}$-terminal of the flip-flop circuit to apply it to the

S-terminal of the adjacent flip-flop circuit **72** which in turn controls the transistor **52** to cut off the primary current flowing through the ignition coil whereby a high voltage is established across the secondary coil portion **32** so that the plug **42** is sparked in the corresponding cylinder. It will be understood that the remaining flip-flop circuits **72** and **74** operate in the same manner as described in connection with the flip-flop circuit **70**.

FIG. **4** shows an embodiment of a breakerless ignition system **200** adapted to ignite a two cylinder internal combustion engine and which comprises two ignition circuits **60** and **62** including ignition coils **10** and **12**, NPN type transistors **50** and **52**, a resistance **2** and a power source E (not shown) which are arranged in a substantially similar manner as those of the ignition systems **1** and **100** of FIGS. **1** and **3**. The ignition system **200** also comprises a set-reset type flip-flop circuit **70** with the $\bar{Q}$-terminal connected to the base of the transistor **50** and with the $\bar{Q}$-terminal connected to the base of the transistor **52**. The flip-flop circuit **70** has the S-terminal connected to the output of amplifying and wave-modifying circuit **90** and the R-terminal connected to the output of the amplifying and wave-modifying circuit **92**. When the amplifying and wave-modifying circuit **90** applies an output voltage to the S-terminal of the flip-flop circuit **70** which at the Q-terminal then applies the output voltage to the base of the transistor **50** to conduct it so that the primary current starts to flow through the primary coil portion of the ignition coil **10** and which at the $\bar{Q}$-terminal stops applying the voltage to the base of the transistor **52** to cut off the primary current through the ignition coil **12** so that the ignition coil **12** establishes a high voltage across the secondary coil portion of the ignition coil **12** to thereby spark the plug **42** for ignition of the corresponding cylinder. Next, the amplifying and wave-modifying circuit **92** outputs the voltage which operates the flip-flop circuit **70** to control the transistor **50** to cut off the primary current through the ignition coil **10** and the transistor **52** to allow the primary current to flow through the ignition coil **12**. Thus, the plug **40** is sparked so that the corresponding cylinder is ignited.

It will be understood that the ignition system **100** of FIG. **3** has the signal generator (not shown) including three signal generating elements connected to the amplifying and wave-modifying circuits **90** to **94**, respectively and similarly the ignition system **200** of FIG. **4** has the signal generator also (not shown) including two signal generating elements connected to the amplifying and wave-modifying circuits **90** and **92**, respectively.

Although some preferred embodiments of the present invention have been described with reference to the accompanying drawings, they are for the purpose of illustration and not intended to define the present invention. It will be understood that various changes and modifications in arrangement and construction might be made without departing from the spirit and scope of the present invention. For example, it will be understood that the present invention can be also applied to a breakerless ignition system for a four or six cylinder internal combustion engine in a similar manner. The present invention should be defined only by the appended claims.

What is claimed is:

1. A breakless ignition system for a multicylinder internal combustion engine comprising a plurality of ignition circuits each including an ignition coil and solid state switching means to control said ignition coil so as to allow a primary current to flow through said ignition coil and to cut off said primary current so that a high voltage is established across said ignition coil and a control circuit to control each of said solid state switching means of said ignition circuits, said control circuit associated with a signal generator rotating in time with a multicylinder internal combustion engine for generating signals to operate said control circuit, the improvement wherein said control circuit comprises a corresponding number of flip-flop circuits to that of said ignition circuits, said flip-flop circuits each having one of the output terminals connected to the control terminal of the corresponding solid state switching means so that it interrupts said solid state switching means with one of the adjacent flip-flop circuits signaling the other flip-flop circuit to cause conduction of the corresponding solid state switching means with said other flip-flop circuit when said one flip-flop circuit interrupts the corresponding solid state switching means, said signal generator including a corresponding number of signal coils to that of said ignition circuits, which control said flip-flop circuits.

2. A breakerless ignition system as set forth in claim **1**, wherein each of said signal coils of said signal generator is connected to the corresponding one of said flip-flop circuits at one of the input terminals and also to the adjacent flip-flop circuit at the other input terminal.

3. A breakerless ignition system as set forth in claim **1**, wherein said flip-flop circuits each has one of the output terminals connected to the control terminal of the corresponding solid state switching means and the other output terminal connected to one of the input terminals of the adjacent flip-flop circuit and wherein each of said signal coils of said signal generator is connected to the corresponding one of said flip-flop circuits at the other input terminal.

4. A breakerless ignition system for a two cylinder internal combustion engine comprising two ignition circuits each including an ignition coil and a solid state switching means to control said corresponding ignition coil so as to allow a primary current to flow through said corresponding ignition coil and to cut off said primary current so that a high voltage is established across said ignition coil and a control circuit to control each of said solid state switching means of said ignition circuits, said control circuit associated with a signal generator rotating in synchronism with a two cylinder internal combustion engine for generating signals to operate said control circuit, the improvement wherein said control circuit comprises a single flip-flop circuit having one of the output terminals connected to the control terminal of one of said solid state switching means and the other output terminal connected to the other solid state switching means so that when said flip-flop circuit interrupts one of said solid state switching means it causes conduction of the other solid state switching means, said signal generator including two signal coils connected to the input terminals of said flip-flop circuit, respectively.

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