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Nielsen

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[45] **Oct. 15, 1974**

[54] **IGNITION SYSTEM**

[75] Inventor: **Tage Nielsen**, Los Angeles, Calif.

[73] Assignee: **Rite Autotronics Corporation**, Los Angeles, Calif.

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[52] **U.S. Cl.** ..... **123/148 E**, 315/209 T

[51] **Int. Cl.** **F02p 3/06**

[58] **Field of Search** ..... 123/148 E; 315/209 T

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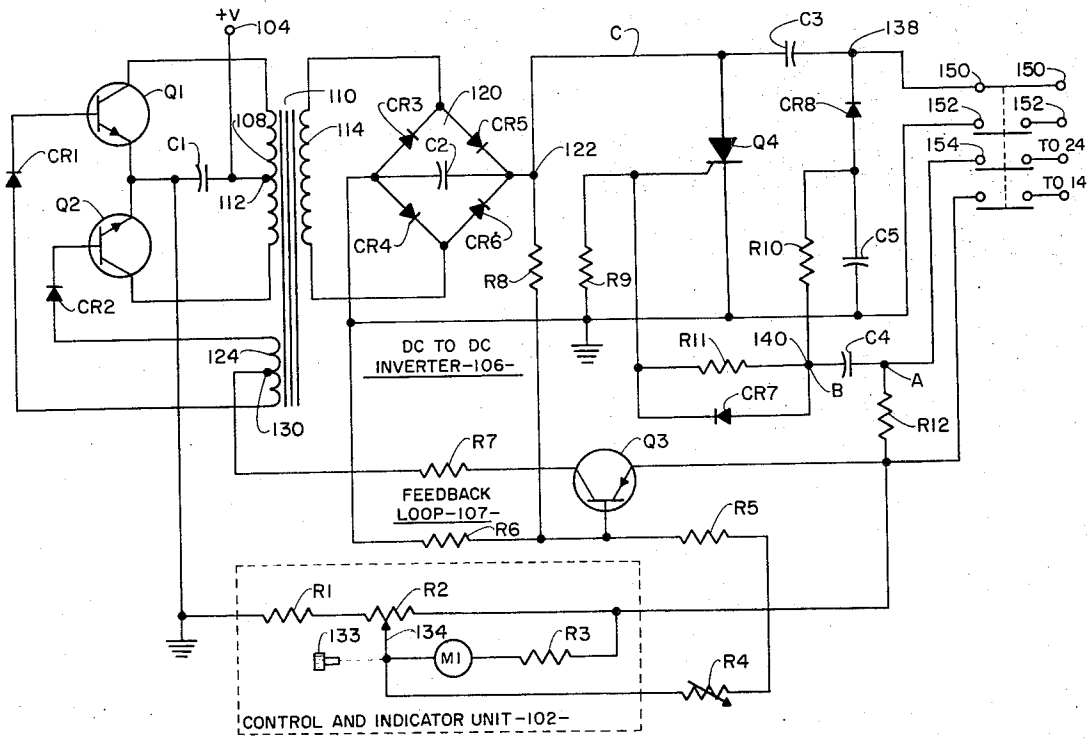
Primary Examiner—Laurence M. Goodridge
Assistant Examiner—Cort R. Flint
Attorney, Agent, or Firm—Robert E. Geauque

[57] **ABSTRACT**

Herein described is an electronic ignition system for an internal combustion engine and the like including a voltage and power controllable DC to DC inverter power supply unit which is controlled by a feedback loop. The system includes an SCR switching circuit which applies the voltage stored in a capacitor across an ignition coil to fire a spark plug. The feedback loop regulates levels of the voltage stored on the capacitor and includes a transistor having the forward conduction thereof regulated to regulate the stored voltage level.

11 Claims, 4 Drawing Figures



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SHEET 1 OF 2

FIG. 1.
PRIOR ART

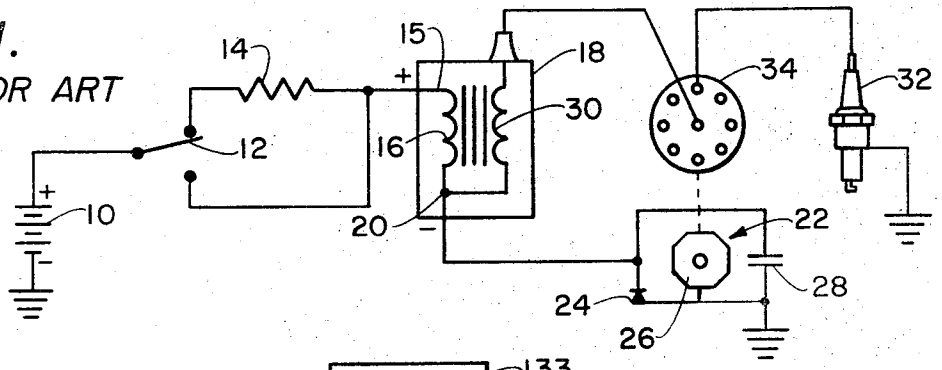


FIG. 2.

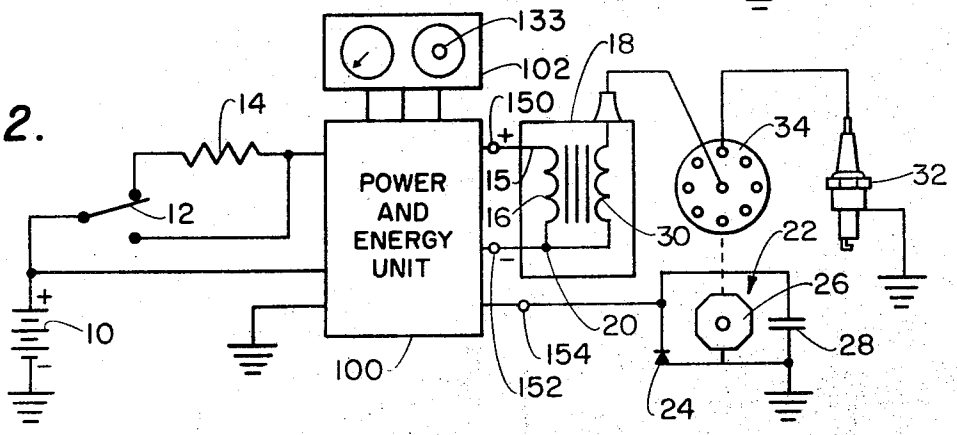
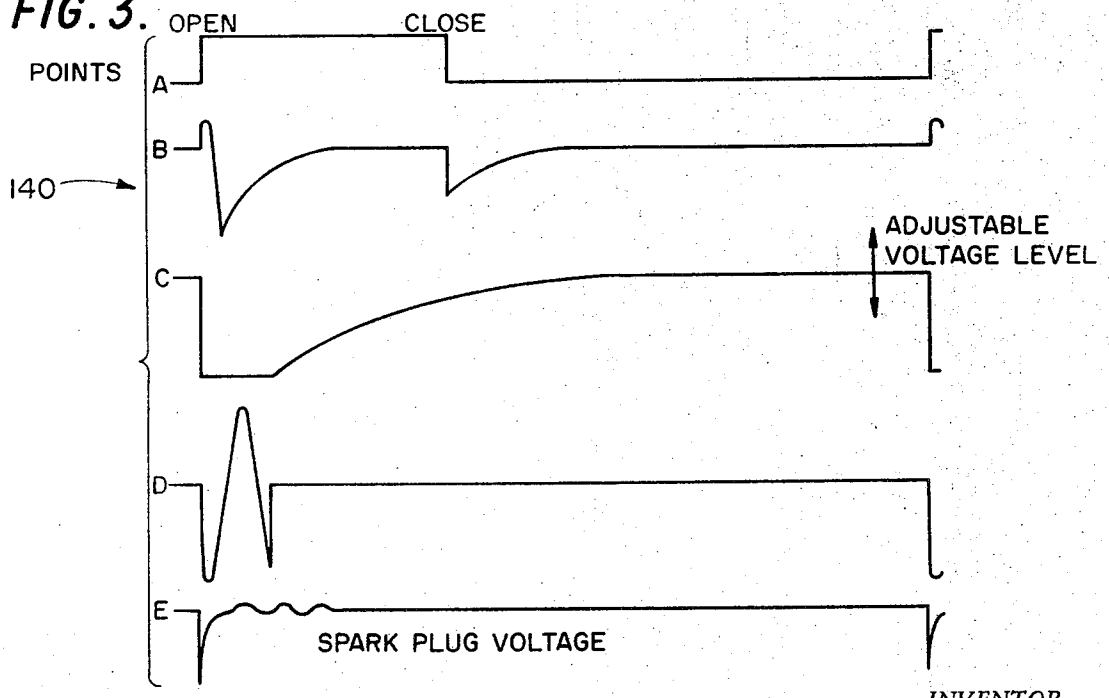


FIG. 3.



INVENTOR.
TAGE NIELSEN

BY

R. E. Beaugue
ATTORNEY

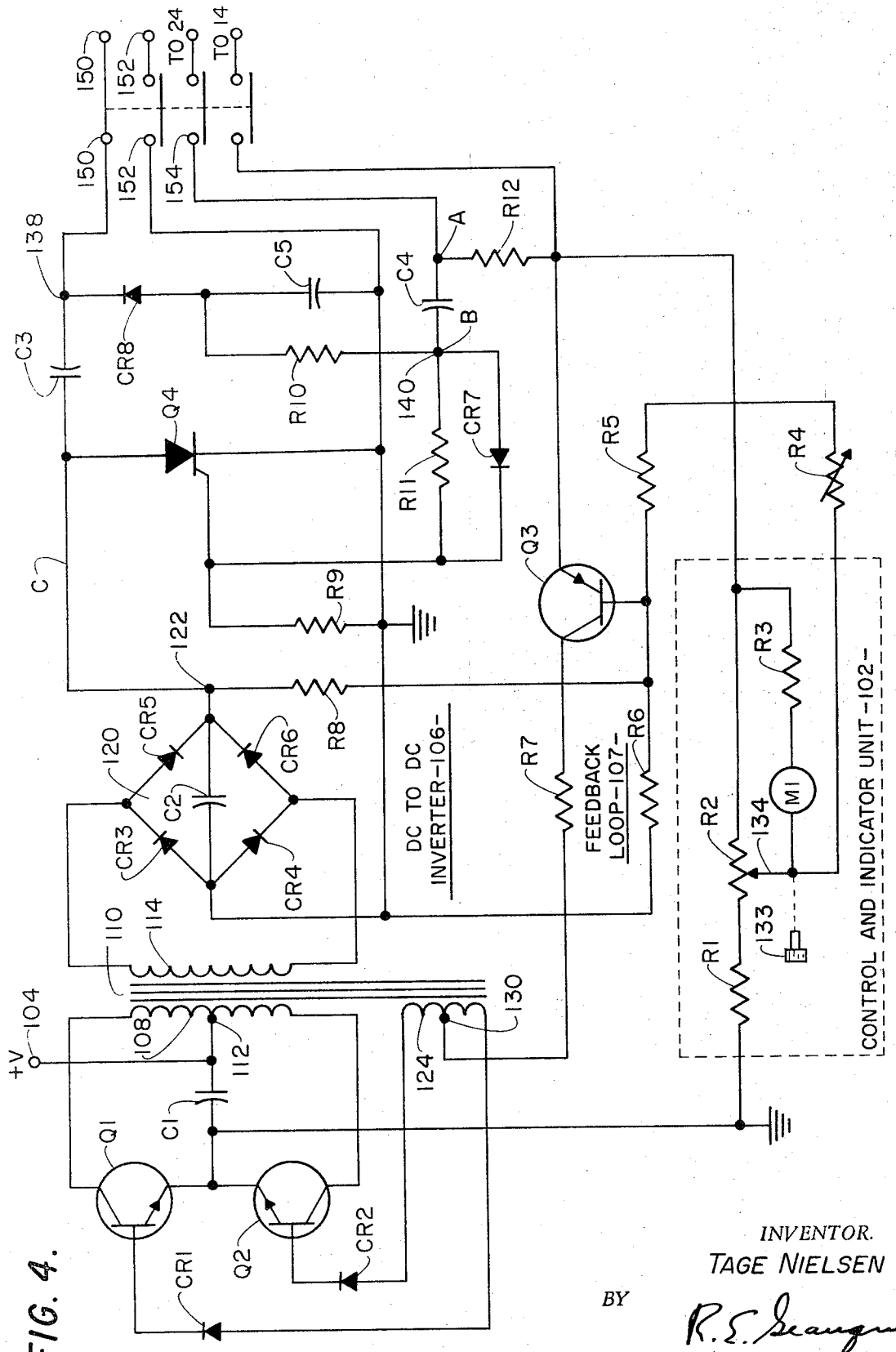


FIG. 4.

INVENTOR.
TAGE NIELSEN

BY

R. E. Seaquist
ATTORNEY

IGNITION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electronic ignition systems useful in connection with internal combustion engines and more particularly to a novel and improved voltage variable controlled power supply unit to supply a voltage to spark plugs of an internal combustion engine or the like.

2. Discussion of the Prior Art

Heretofore, prior art ignition systems generated the high voltage and energy to ignite the spark plug of an internal combustion engine by use of an ignition coil. The primary winding of the coil acts as the energy storage element based on the formulae $E = \frac{1}{2}LI$. The secondary winding of the coil transforms the voltage generated on the primary side to a potential high enough to generate a voltage spark. The release of the energy to the spark plugs is controlled by a set of contact points, which allows current to flow in the primary side of the coil as long as they remained closed. These systems are sometimes known as the Kettering system. Such prior art devices have many disadvantages. For example, the power being used and developed remains the same, regardless of the rate of voltage sparks required at any particular RPM of the engine. Actually in these prior art systems, the power decreases with increased RPM, because the coil at the higher RPM's does not have sufficient time to saturate. This energy loss is reflected in a lower output voltage, which in many cases can be so low that a voltage spark cannot be generated. This, in turn, results in no combustion in that particular cylinder or misfire resulting in a loss of horsepower and an increase in the exhaust of hydrocarbons.

Furthermore, these prior systems actually generated too much energy at lower RPM's, thereby deploying extraneously wear of auxillary parts in the system, such as spark plugs, condenser and points, which in turn requires constant tune-ups and repairs.

It has been found and recognized that an ideal ignition system should be a power and voltage demand type system. That is a system which always generate sufficient voltage to fire a spark plug and use the same peakpower per spark regardless of the rate of firing. It is also known that the voltage amplitude required to generate a voltage spark is a function of several factors. The firing voltage increases if the spark gap is increased, the compression, temperature and air-fuel mixture also have a great effect on the amplitude of the actual firing voltage. That is why an ideal system always must generate sufficient voltage higher than the required firing voltage and maintaining the excess voltage for good efficiency. It also becomes apparent that an ideal system should have a variable output voltage so that it can be adapted universally to any particular engine with difference compression and fuels.

SUMMARY OF THE INVENTION

The present invention overcomes the difficulties encountered in the above-mentioned prior art devices. Briefly described, the present invention provides an ignition system for supplying electrical energy to a spark plug in an internal combustion engine. The system includes a controlled oscillator which is coupled to the battery and supplies oscillating electrical energy in response to the battery. A transformer is coupled to the oscillator and couples the energy into a rectifier where it transforms into DC energy of a higher level. The rectifier is coupled to a capacitor which is charged thereby and stores the electrical energy. A switch is coupled to discharge the capacitor at the time the points of the ignition system are opened. The discharging of the capacitor applies a potential across the ignition coil which fires the associated spark plug. A feedback control means is coupled to a feedback winding of the transformer which in turn controls the voltage level from the oscillator. The feedback control means is responsive to the output from the rectifier to control operation of the feedback winding.

DESCRIPTION OF THE DRAWINGS

These and other features and advantages will become more apparent to those skilled in the art when taken into consideration of the following detailed description wherein like reference numerals indicate like and corresponding parts throughout the several views and wherein:

FIG. 1 is a schematic drawing of the prior art so called Kettering ignition system;

FIG. 2 is a schematic drawing of the system including the embodiment of the present invention;

FIG. 3 is a number of graphs showing signal levels of the circuit set forth in FIG. 4; and

FIG. 4 is an electrical schematic of one embodiment of the present invention.

DESCRIPTION OF ONE PREFERRED EMBODIMENT

Turning now to a more detailed description of the conventional prior art ignition system, there is shown in FIG. 1, a battery 10 which may, for example, be a standard automobile battery which provides typically 12 volts into the ignition system. The battery 10 is connected through a switch 12 and a ballast resistor 14 into one end 15 of the primary winding 16 of an ignition coil 18. The other end 20 of the coil 18 is connected to a capacitor 28. The circuit 22 includes a pair of contact points 24 and a cam 26. The cam 26, the points 24 and the distributor 34 hereinafter to be mentioned are well known to those skilled in the art and no attempts will be made herein to give a complete explanation of the operation thereof. When cam 26 causes points 24 to be closed, an electric current flows from the battery 10 through the switch 12, resistor 14 and coil 18. Current can flow as long as the contacts or points 24 remain closed and a power drain equal to the voltage on battery times the current is being consumed.

When the contacts 24 are opened by the rotation of the cam 26, the energy stored in the coil 18 which is equal to $\frac{1}{2}LI^2$ will generate an inductive voltage which by help of the capacitor 28 will have a form and amplitude governed by the principle laws of LC networks. The voltage thus generated across the primary side 16 of the ignition coil 18 will be induced into the secondary side 30 of the coil 18 which is connected to the spark plug 32 through the distributor 34. The voltage generated will have an amplitude of normally 30,000 volts peak to peak for example. However, the prior system described in connection with FIG. 1 has the disadvantage that the amplitude will decrease as the rate with which the contacts 24 open and close increases.

This, in turn, means that when an engine has reached a certain RPM the voltage generated does not have sufficient amplitude to fire or generate a voltage spark across the spark plug **32.**

With reference now to FIG. **2** there is illustrated one embodiment of this invention when it is applied to the conventional prior art system set forth in FIG. **1.** At the outset it should be noticed that no DC current is applied directly to the ignition coil **18,** thus eliminating the coil **18** to function as the energy stored element. The coil **18** in accordance with the principles of this invention now serves as a step-up voltage transformer. All energy required to generate the spark and sustain the same, will be generated and stored in the power and energy storage unit **100.** The advantage here is that the same and equal amount of energy can be stored and released regardless of the firing rate, thus achieving very high power efficiency and uniform ignition voltage sparks. Further it will be noticed that a control unit **102** is coupled directly to the power and energy storage unit, thus providing the system with a variable voltage output, the advantage here being that an exact voltage amplitude can be applied. This virtually makes the system work uniformly with any type of internal combustion engine and/or its associated different types of ignition auxillary items, such as ignition coils, batteries, spark plugs and ignition wires.

Turning now to FIG. **4** there is shown a more detailed description of one embodiment of this invention and particularly to the power and energy unit **100** and the control and indicator unit **102.** The battery **10** is coupled to a terminal **104** which is coupled to a DC to DC inverter **106.** A DC to DC inverter as used in this specification is a converter circuit used to increase the voltage level. Typically this inverter **106** transforms the 12 volt level from the battery to **300** volts for use in this ignition system.

The DC to DC inverter **106** is comprised of a pair of NPN transistors Q1 and Q2 having their emitters coupled together and to a ground reference. The collectors of transistors Q1 and Q2 are each coupled to the opposite ends of the primary winding **108** of a transformer **110.** A terminal **104** is coupled to a center top **112** of the primary winding **108** of a transformer **110** and has a **12** volts applied thereto from the battery **10.** Terminal **104** is also coupled through a capacitor C1 to the ground potential. The secondary winding **114** of transformer **110** is coupled across a diode bridge rectifier circuit **120** which is comprised of diodes CR3, CR4, CR5 and CR6. A feedback winding **124** on transformer **110** has one end coupled through a diode CR2 to the base of transistor Q2 and the other end of feedback winding **124** is coupled through diode CR1 to the base of transistor Q2. In principle the transistors Q1 and Q2 form an oscillator circuit to provide an AC signal to the step up transformer **110,** the diode bridge circuit **120** is a rectifier which converts the amplifier signal to a high voltage level. Thus the oscillator, the transformer **110** and the diode bridge circuit **120** form the DC to DC inverter, which functions in a manner well known to those skilled in the art.

However, in accordance with the principles of this invention there is provided a novel method in controlling the voltage and power efficiency of the inverter **106.** As will be discussed hereinafter, the DC to DC inverter **106** is connected into an energy storage element and an energy release switch. This means that the inverter **106** in effect is working into a capacitive load which exhibits a direct short and a no load condition.

A feedback loop **107** is provided which is coupled to a center tap **130** on feedback winding **124** of transformer **110.** A switching feedback PNP transistor Q3 has the collector thereof coupled through a current limiting resistor R7 to the center tap **130** of winding **124.** The base of transistor Q3 is coupled through a forward bias resistor R6 to the ground reference and is also coupled through a voltage sampling resistor R8 to the output circuit of bridge circuit **120.** The base of transistor Q3 is also coupled to a voltage reference source as will hereinafter be described to change the forward biasing of the transistor Q3.

A switching silicon controlled rectifier (SCR) Q4 has the anode thereof coupled to the DC output of diode bridge **120** and the cathode thereof coupled to the ground reference. The gate electrode of SCR Q4 is coupled through resistor R11 with diode CR7 in parallel therewith and through capacitor C4 to the contacts or points **24** of the ignition system set forth in connection with FIG. **2.** Also the anode of SCR Q4 is coupled to one side of an energy storage capacitor C3 and the other side of the energy storage capacitor is coupled to the positive side of the coil **18** as shown in FIG. **2.**

The inverter **106** employs a novel feedback circuit, which comprises the transistor Q3, the voltage output sampling resistor R8, a forward bias resistor R6 and a circuit comprised of the control and indicator units network **102** which provides an adjustable voltage reference for the feedback circuit.

In operation, assuming the output voltage A (FIG. 3) is zero volts, which will be the case at the time initially after the energy storage capacitor C3 has been discharged. The voltage sampling resistor R8 provides forward bias current to the base of the feedback transistor Q3 allowing it to saturate and cause maximum current to flow into the feedback winding **124** on the transformer **110,** the current flow only being limited by the value of the resistor R7. This current will allow the inverter oscillator (transistors Q1 and Q2) to function at its maximum power output and the capacitor C3 will now rapidly be charged to the DC voltage potential output from the diode bridge **120** as set forth in graph C in FIG. **3.** As the voltage builds up on the capacitor C3 the sampling resistor R8 will sense the raising voltage and apply less current to the base of transistor Q3 causing it to come out of saturation. Now a continually decreasing amount of feedback current will flow to feedbackwinding **124** until the transistor Q3 comes out of saturation and finally reach a point where it is completely turned off or not conducting. This then turns off both transistors Q1 and Q2.

The control and indicator unit **102** is comprised of a series coupled voltage sampling resistor R5 and a variable resistor R4 coupled between the wiper arm **134** of a potentiometer R2 and the base of transistor Q3. Further unit **102** is comprised of the potentiometer R2 coupled in series with resistor R1 and between the ground reference and the emitter of transistor Q3. Saturation of transistor Q3 will occur at a voltage output potential depending on the value of the reference voltage set by the variable potentiometer R2.

The output voltage as is normal for DC to DC inverters in principle is a function of the voltage generated across the primary side of the transformer **110** and the turns-ratio between the primary and secondary wind-

ings 108 and 114. However, as the feedback circuit 107 employed in accordance with this invention, controls and regulates the current applied to the two switching transistors Q1 and Q2 coupled across the primary transformer winding 108 and feedback winding 124, then in effect the voltage generated across the primary winding 108 becomes a function of how far the transistors Q1 and Q2 are allowed to turn on. This is in effect a function of the forward bias current generated by the feedback loop 107.

Returning now to the principle functions of the ignition system, in accordance with this invention, so far employs a variable DC regulated voltage which is applied to the energy storage capacitor C3. Capacitor C3 has one end connected to terminal 150 which is coupled to end 15 of winding 16 on coil 18. The switching SCR Q4 coupled across the other end of capacitor C3 end to the ground reference which is also coupled to terminal 152. This terminal 152 is coupled to end 20 of winding 16 on coil 18. Thus, the SCR is connected across this LC network comprised of capacitor C3 and winding 16. The SCR Q4 will be in a non-conducting state when the cam 22 opens points 26 within the Kettering system (FIG. 2). When this happens, the voltage across the capacitor C3 will appear across the primary side 16 of the ignition coil 18 and a closed circuit comprised of the capacitor C3, the SCR Q4 and the primary winding 16 of the coil 18 will be formed and current will start to flow in the closed circuit. This current is induced into the secondary side 30 of the ignition coil 18 and generates a voltage spark at the spark plug 32 and the current will sustain the spark as long as the closed circuit exists and energy is available.

Due to the resonant circuit formed by the capacitor C3 and inductance of the coil 18, the current after sometime will reverse (FIG. 4D) and since the SCR Q4 can only conduct current in one direction, SCR Q4 will then turn off at the point where the current reverses, however, the reverse current will flow through the diode bridge 120 to the ground reference. At the next reversal of the current, an open circuit will exist and the voltage spark will collapse as there is no more current to sustain it. Thus in effect, the circuit has generated a voltage spark and sustained it for a fixed time duration independent of the ignition firing rate.

A network comprised of diode CR8 which has the cathode thereof coupled to a junction 138 between capacitor C3 and winding 16 of coil 18, and the anode thereof coupled through capacitor C5 to ground reference. The network further includes a resistor R10 coupled to a junction 140 between a resistor R11 and capacitor C4. This network serves to supply a negative or reverse current to the gate of SCR Q4 in order to remove the forward gate current, which initially was applied to the SCR Q4 in order to turn it on. This then assures, that only one complete cycle of discharge will take place each time the points or contacts 24 open.

The resistors R11 and capacitor C4 coupled in series and between the gate electrode of SCR Q4 and the points 24 and the resistor R10 form a delay network at the time when the points 24 close (FIG. 3B), thus removing the possibilities of refiring by bouncing points 24.

The variable resistor R4 serves as a calibration resistor to allow the system to be controlled within a fixed voltage output range.

The meter M1 and resistor R3 are connected across the reference voltage and therefore indicating the relative or a direct voltage output.

In summary, when switch 12 is closed, voltage is at the emitter of transistor Q3. Feedback transistor Q3 is saturated in an on position by the current applied to the base of transistor Q3 through the R5 and R8 resistors. The current then is applied through the feedback winding 124 to the base of transistors Q1 and Q2 initially biasing these transistors on. This current allows the inverter oscillator comprised of transistors Q1 and Q2 to function at its maximum power output, charging capacitor C3 to its peak potential. As the voltage builds up, as shown in C of FIG. 3, less feedback current will flow because the bias change applied to the base of transistor Q3. This continues until the transistor Q3 comes out of saturation or turns off. This turn off and saturation time can be controlled by the setting of the potentiometer R2 by the knob 133 thereon.

The output of the secondary winding 114 is dependent upon the amount of conductance through the transistors Q1 and Q2 as dictated by the feedback winding 124 through the feedback loop. Thus the voltage generated across the primary winding is a function of transistor conductance which in effect is a function of the forward bias current generated by the feedback regulator 102. The capacitor C3 and the winding 16 in coil 18 form an LC network. Switch Q4 is closed or turned on at the time the cam 26 activates the point 24. Points 24 then enable the SCR Q4 so that it will conduct discharging capacitor C3 to the ground reference and inducing a current flow through the winding 16 which in turn, of course, induces current into the secondary winding 30 of the ignition coil generating the voltage spark of the spark plug 32.

Because of the fact the LC network is in fact a resonant circuit comprising the capacitor C3 and the inductor 16, the reversing of the current turns transistor Q4 off with the reverse current flowing through the diode bridge 120. The next reversal of current finds an open circuit existing and the voltage spark will collapse as there is no more current to sustain it as shown in graph D of FIG. 3. Thus, this circuit has generated a voltage potential and sustained it for a fixed time duration independent of the ignition firing range.

Having thus described but one preferred embodiment of this invention, what is claimed is:

1. In an ignition system for supplying electrical energy to a spark plug in an internal combustion engine when the contacts of the ignition system are open, said system including:

a source of DC energy;

controlled oscillator means coupled to said source for supplying oscillating electrical energy in response to the DC energy, said oscillator means including an output means and a controlled input means;

transformer means including a primary winding coupled to the output means of said oscillator means, a secondary winding, and a feedback control winding being coupled to the control input means of said oscillator means;

rectifier means coupled to the secondary winding of said transformer for converting induced oscillating signals to a DC signal, said rectifier means including an output means;

energy storage means being coupled to the output means of said rectifier means for storing the DC energy from said rectifier means;

gating means being coupled to said energy storage means for discharging the energy stored in said energy storage means, said gating means including a gate input means for gating said gating means on when the contact points of said ignition system are open; and

adjustable feedback control means being coupled to the feedback control winding of said transformer means and to the output means of said rectifier means for varying the amount of energy to the controlled oscillator means and for selecting the energy level from said oscillator means to said transformer means.

2. In the ignition system as defined in claim **1** wherein said energy storage means being a capacitor.

3. In an ignition system as defined in claim **1** wherein said gate being a silicon controlled rectifier having a gate electrode coupled to the points of said ignition system, anode electrode coupled to said energy storage means, and a cathode electrode coupled to a ground reference.

4. In the ignition system as defined in claim **1** wherein; said energy storage means being an capacitor coupled between said rectifier and the ignition coil of said ignition system, and said gating means being a silicon controlled rectifier having the anode electrode thereof coupled to one side of said capacitor, the cathode electrode thereof coupled to a ground reference, and the gate electrode thereof coupled to the points of said ignition system.

5. In the ignition system as defined in claim **1** wherein said feedback control means being a transistor having the emitter electrode being coupled to said DC source, the base electrode being coupled between said DC source and the output means of said rectifier means, and the collector electrodes being coupled to a center tap position of the feedback winding of said transformer means.

6. In an igntion system as defined in claim **1** wherein said rectifier means being a diode bridge coupled across the secondary winding of said transformer.

7. In the ignition system as defined in claim **1** wherein said controlled oscillator including a pair of transistors coupled in a push-pull relationship having the emitter electrodes thereof coupled together and the collector electrodes being coupled on either end of said primary winding, and the base electrodes being coupled to either end of the feedback winding, and wherein feedback control means being coupled to a center tap of said feedback winding.

8. In an ignition system including an ignition coil and timed contact points for supplying electrical energy to the spark plug in an internal combustion engine when the contact points of the ignition system are open, said system including:

a source of DC energy;

a controlled oscillator means comprising a pair of transistors having their emitters coupled together and to a ground reference;

a transformer including; a secondary winding, a primary winding being coupled across the collectors of said transistors, a center tap of the primary winding being coupled to said source, and a center tap feedback winding, one end of said feedback winding being coupled to the base of one of said pair of transistors and the other end of said feedback winding being coupled to the base of the other one of said pair of transistors, said feedback winding having a center tap;

a diode bridge rectifier being coupled across the secondary winding of said transformer and including an output;

a capacitor being coupled in series between the output of said bridge rectifier and the ignition coil of said ignition system;

a silicon controlled rectifier having the anode thereof coupled between said capacitor and the output of said bridge diode and the cathode thereof being coupled to the ground reference and including a gate electrode being coupled to be responsive to said points of the ignition system;

a feedback loop including a transistor having a collector electrode being coupled to the center tap of the feedback winding of said transformer, an emitter electrode being coupled to said source of DC energy and a base electrode being coupled to be responsive to current supplied by the output of said bridge rectifier.

9. The system as defined in claim **8** and further including means coupled to the base of the transistor in said feedback loop to control the amount of feedback current applied thereto.

10. In the ignition system as defined in claim **8** having means for sampling the voltage of said output; means for providing an adjustable voltage reference to be compared with said sampled voltage, and means for applying said sampled voltage and said reference voltage by said base electrode so that any voltage difference changes the feedback until the output assumes the selected value as determined by the adjusted reference voltage.

11. The ignition system as defined in claim **10** having a meter for measuring the adjusted reference voltage to thereby indicate the output voltage.

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