

- [54] IGNITION SYSTEM UTILIZING A SATURABLE-CORE SQUARE WAVE OSCILLATOR CIRCUIT

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Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 38,279, May 18, 1970, abandoned.

- [52] U.S. Cl..... 123/148 E, 315/209 T
[51] Int. Cl..... F02p 3/02
[58] Field of Search 123/148 E; 315/209 T;
333/113 A

[56] **References Cited**

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[57] **ABSTRACT**

An improved saturable-core transistor oscillator circuit for feeding a negative resistance characteristic load. It includes a Jensen-type oscillator that has an added saturation winding to control starting and time duration of the oscillation. There is a high turns ratio output transformer connected to the load and a saturable-core transformer in the oscillator. And, the electromagnetic characteristics of the output transformer are set to resonate with the output at no load in order to provide high starting voltage, while the electromagnetic characteristics of the saturable-core transformer are set to provide an increase in the oscillator frequency as the load increases in order to reduce the output voltage so as to compensate for the negative resistance effect of the load.

6 Claims, 2 Drawing Figures

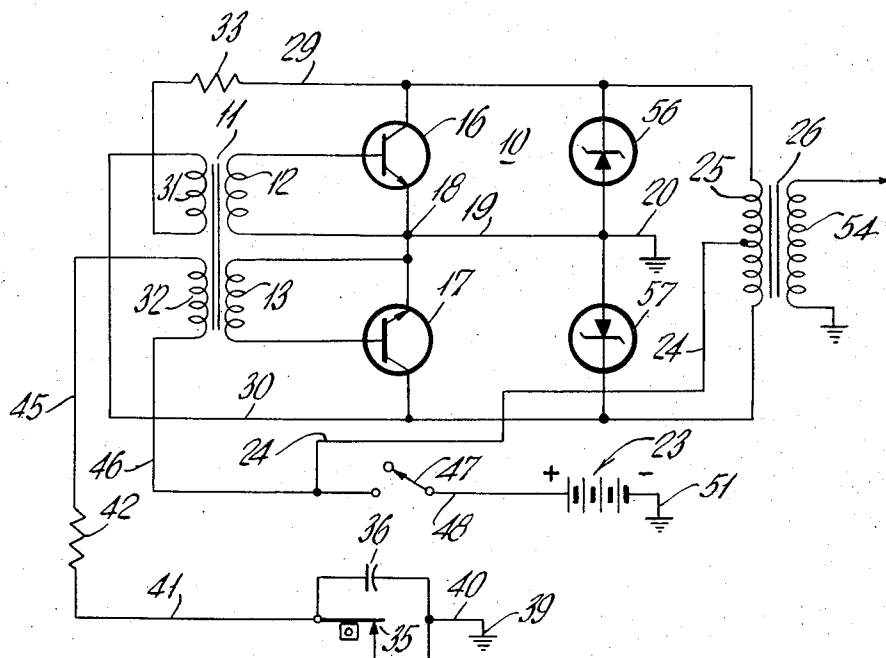


FIG. 1.

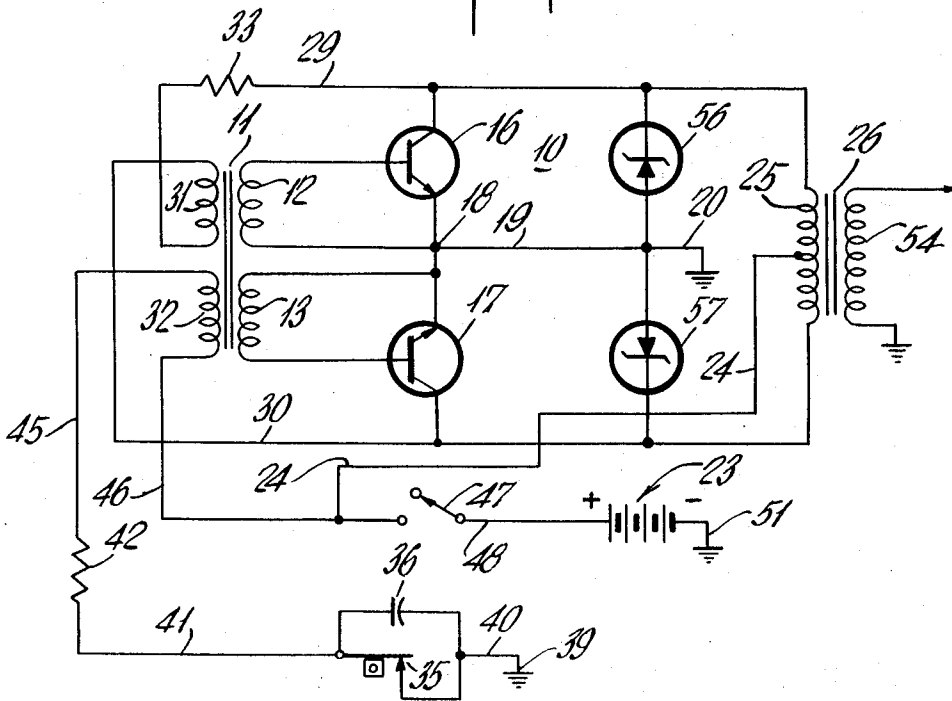
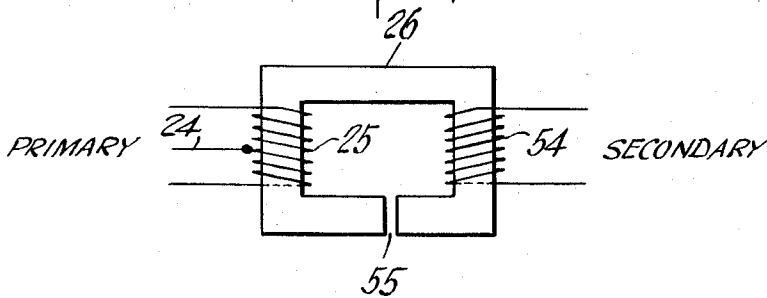


FIG. 2.



IGNITION SYSTEM UTILIZING A SATURABLE-CORE SQUARE WAVE OSCILLATOR CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of my earlier filed co-pending application Ser. No. 38,279 filed May 18, 1970, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to an ignition system utilizing an oscillator circuit. More specifically, it concerns an improvement for an ignition system utilizing a saturable-core square wave transistor oscillator. The invention also is applicable to an ignition system that is particularly for use with an internal combustion engine.

2. Description of the Prior Art

In regard to ignition systems for internal combustion engines, there are many variations which concern a continuous type of energy supply for the spark that is generated. One such system is disclosed in a prior U.S. Pat. No. 3,407,795 dated Oct. 29, 1968, and it employs a saturable-core square wave oscillator for supplying the energy to a sparking circuit. A particular drawback with that system and others that employ a continuous energy supply during the entire spark duration, is that once the spark has been struck the energy being supplied is excessive because of the large reduction in resistance across the spark gap caused by ionization of the gas. This excessive energy causes rapid deterioration of the electrodes in a spark plug and materially shortens the life thereof.

In view of such difficulties, it is an object of this invention to provide for an automatic adjustment, or shift, in energy supply. Such shift comes after voltage output at substantially no load, i.e., before the spark breakdown occurs. Consequently, there will be a reduction in the voltage (as the spark does occur) that is supplied for maintaining a reduced amplitude for the spark discharge after ionization of the gases between the electrodes.

SUMMARY OF THE INVENTION

Briefly, the invention concerns an ignition system for use with an internal combustion engine having breaker points associated therewith for mechanically determining the timing of initiation of an ignition spark for a cylinder of said engine. The said system comprises a saturable-core square wave oscillator that employs a saturable-core transformer to provide electromagnetic feedback coupling and provides a relatively high-frequency electrical energy having continuing duration during oscillation thereof. It also comprises means under control of said breaker points for saturating said feedback coupling with steady-state magnetic flux to stop said oscillator and for cutting off such flux to cause rapid starting of said high-frequency energy. Also, it comprises an output transformer having a high turns ratio for supplying energy to said ignition spark, and a pair of transistors plus circuit means for connecting said transistors to said electromagnetic feedback coupling and to said output transformer. In the foregoing combination, the invention concerns the improvement which comprises means for tuning said output trans-

former to resonate at a harmonic frequency of the fundamental oscillator frequency at no load, and means for determining the magnetic properties of said saturable-core transformer to cause an increase in the frequency of said oscillator as the load on said output transformer increases.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and benefits of the invention will be more fully set forth below in connection with the best mode contemplated by the inventor of carrying out the invention, and in connection with which there are illustrations provided in the drawings, wherein:

FIG. 1 is a schematic circuit diagram illustrating a system that embodies the invention; and

FIG. 2 is a schematic illustration indicating the type of transformer that is used in the output circuit of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

This invention may have general utility in other applications, but it is particularly applicable to an ignition system for internal combustion engines, such as the type described in U.S. Pat. No. 3,407,795, dated Oct. 29, 1968, wherein the applicant was a joint inventor. That patent illustrates one of a general type of ignition supply systems which provides a continuous energy supply during the entire duration of a given spark. The spark duration is determined by the engine cam angle degrees instead of mere time.

Such systems have the drawback when compared to a conventional system, of drawing excessive power from the spark-supply system. This tends to have two detrimental effects: One is the overheating and burning-out of the elements employed in the spark-generating circuit (usually transistors in an oscillator arrangement). The other drawback is in the excessive current flow created at the spark-plug gap once the spark discharge has been initiated. This will cause rapid eroding of the electrodes and thus very materially shorten the spark-plug life.

In overcoming the foregoing problems, this invention provides a system that can produce a high voltage output initially (under no load) so that the spark may be created in a positive manner. At the same time it provides an automatic reduction of the output voltage to a much lower amplitude as the load on the system builds up due to the spark. Both aspects of the system are illustrated by the circuit diagram of FIG. 1 along with the schematic diagram of FIG. 2. These will be brought out as the description with reference to the drawings proceeds.

It is pointed out that, basically, the FIG. 1 system is similar to that illustrated and described in the above-mentioned Aiken et al U.S. Pat. No. 3,407,795. Thus, the system illustrated in FIGS. 1 and 2 is one that employs a saturable-core square wave transistor oscillator 10. Such oscillator includes a saturable-core transformer 11 that has a pair of windings 12 and 13 thereon. These windings supply base drive to each of a pair of transistors 16 and 17, respectively. The transistors have emitters that are connected to a common circuit point 18 that is directly connected via wires 19 and 20 to ground as illustrated.

There is a DC supply 23 for the oscillator 10. This may be any feasible low-voltage power supply, and is preferably a battery or other ignition-system source of DC power, e.g., a 24-volt battery. The negative terminal of battery 23 is connected to ground, as illustrated. The positive terminal is connected when the system is energized, via a wire 24 that leads to the center tap of a primary winding 25 on an output transformer 26.

Part of the oscillator circuit is completed by having the ends of the winding 25 connected directly to the collector terminals of the transistors 16 and 17. The collectors are connected to the ends of a feedback circuit via connections 29 and 30. The feedback power is taken directly from the primary winding 25 across which is also connected a feedback winding 31 that is located on the transformer 11 and has a resistor 33 in series therewith.

As mentioned above with reference to the Aiken et al patent, the oscillator arrangement is basically well-known. It is the type known as a Jensen oscillator. In adapting such Jensen-type oscillator to an ignition-supply system, there is employed a saturation-control winding 32 that is also located on the transformer 11. The saturation control is the determining factor in timing the output spark energy. This is accomplished by having a switch or breaker points 35 connected (along with a shunting capacitor 36) in series with a power source, e.g., the battery 23, to cause current flow through the saturation winding 32. Such circuit may be traced beginning at a ground connection 39 and proceeding via connection 40 to one side of the breaker points 35, and the capacitor 36 connected in parallel. It continues from the other side of the breaker points via a connection 41 to one side of a resistor 42. Resistor 42 is, of course, used to determine the current flow through the circuit. The circuit continues via a connection 45 to one end of the saturation winding 32. The other end of winding 32 is connected via a wire or other connection 46 to one side of an ignition switch 47, and the other side of the switch is connected via a connection 48 to the positive side of the DC supply battery 23. The circuit is completed, of course, by having the negative side of the battery 23 connected to ground (as indicated) by a ground connection 51.

It will be understood, of course, that wherever reference is made to "wire" or "wires" in describing the illustrated circuits, these might take other forms, e.g., printed circuits, etc.

It is to be noted that the output transformer 26 is used to step up the battery voltage of DC supply 23 to a high voltage necessary for firing the spark plugs, i.e., in the range of 20,000 to 30,000 volts. Consequently, this transformer must have a high turns ratio with a large number of secondary turns. This results in large secondary interwinding capacitance.

An output transformer of the type employed is schematically illustrated in FIG. 2. It is purposely constructed to have a high leakage inductance in order that such leakage inductance will limit the current which can be drawn from the transformer, since the leakage inductance is effectively in series with the load. Such high leakage inductance is obtained by winding the primary winding, i.e., winding 25, on one leg of the transformer, while the secondary winding, i.e., winding 54 is wound on another leg of the transformer core, e.g., as illustrated in FIG. 2. Now at some frequency, the reactance of the interwinding capacitance and the leak-

age inductance will be equal. This is the condition for resonance and the transformer is said to be self-resonant at that frequency. At such frequency, the unloaded output voltage will be very much larger than would be indicated from the turns ratio of the transformer. One aspect of this invention makes use of the fact that in order to create resonant condition for a given frequency, the parameters of the physical structure may be predetermined. For example, in the illustrated embodiment of this invention, the parameters relating to the physical shape of the transformer core and the placement of the windings upon it, are adjusted to predetermined values and there is an air gap 55 (FIG. 2) to aid in providing leakage inductance of a preselected value. The number of secondary turns of winding 54 and the manner in which they are wound determines the interwinding capacitance of the transformer 26.

In carrying out this invention, the foregoing parameters including the interwinding capacitance and the leakage inductance are adjusted to resonate at a frequency which is twice the fundamental frequency of the Jensen-type oscillator being employed. Consequently, as the transistors 16 and 17 switch at the fundamental frequency, the secondary winding 54 of the output transformer 26 will oscillate or ring at twice the fundamental frequency. By employing such arrangement, the peak voltage of the transformer secondary can easily be as high as twice or more than the peak voltage of the square-wave output under conditions for a conventional square-wave oscillator in which the fundamental oscillating frequency is far below the resonant frequency of the secondary coil. For example, if the system is one where the battery voltage is 24 volts and the effective turns ratio (number of secondary turns divided by one-half the number of primary turns) is 530, it has been found that the peak voltage may be 30,000 volts, rather than 12,720 volts which would be obtained with a conventional system. Such a peak voltage at the output of transformer 26 is quite adequate to initiate the initial breakdown of the spark plug gap.

Another aspect of this invention concerns the reduction of the amplitude of output voltage from transformer 26 with accompanying reduction in the energy demand on the system. Such reduction occurs as the load on the transformer rises when the spark discharge takes place. This reduction will help avoid rapid erosion of the spark plug electrodes without reducing the voltage below that required to maintain the spark.

An understanding of how this aspect is carried out will be assisted by referring to a paper presented at the 1956 National Conference of Aeronautical Electronics, May 16, 1956 by Donald C. Mogen entitled "Operation of a Saturable-Core Square Wave Oscillator."

It will be understood that the transformer 11 is a saturable transformer, the saturation point of which determines the fundamental operating frequency of the oscillator 10 under no-load and light-load conditions. By determining and/or adjusting parameters in construction of the transformer 11, it is made so that when the load on the output circuit reaches a certain level, the transformer will no longer saturate because of reduced feedback. When that happens the oscillation switchings of the circuit will be precipitated by the saturation of the transistors 16 and 17 alone, and they will therefore

occur at a smaller value of flux which thus increases the frequency of oscillation.

Determination of the structural parameters of the saturable-core transformer 11 may be made by anyone skilled in the art, and particular teaching is provided in published material. For example, see "Application Notes" of Honeywell Semiconductor Products Division of Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota, entitled "Solid-State Square-Wave Oscillator Power Inverters" by Richard C. Swanson. This publication carries a designation "AN5A - Square-Wave Oscillator Power Supply Aug. 1, 1960." Particular discussion of designing a saturable-core (feedback) transformer begins on page 5.

When the oscillation frequency changes it is no longer harmonically related to the resonant frequency of the output transformer 26. Therefore, the amplitude of the output voltage from the winding 54 is reduced to that dependent upon the battery voltage and the effective turns ratio, as indicated above.

It is also to be observed that the higher operating frequency (which is created under the conditions described above, i.e., an increase in the load on the oscillator circuit) will cause an increase in the impedance of the output transformer 26. This is true since the impedance is equal to $2\pi fL$, wherein f =frequency and L = leakage inductance. Consequently, the increase in frequency will also tend to reduce the output voltage from this cause, in addition to the effect of the shift away from the resonant frequency of the output transformer. The combined result will limit the current flow through the spark plugs to a safe value.

A specific example of the structural dimensions of a saturable-core transformer like transformer 11 in the FIG. 2 illustration, is as follows: core (of transformer 11) is a torroid constructed of laminated square-loop magnetic material, e.g., a commercial product known as "Magnetic Metals" type 62 A 8102; primary winding (31) has 130 turns of no. 26-size wire wound over the entire torroid; saturation winding (32) has 600 turns of no. 30-size wire wound over the entire torroid; and base drive windings (12 and 13) have 32 turns each of no. 20-size wire wound in a bifilar manner on the torroid.

In summary, the combined effects of the particular parameter adjustments, as described above, will cause the system to be self-regulating. Thus, following a high peak voltage to strike the spark, the current that flows after ionization at the spark gap will not be excessive.

In order to prevent transient peaks of voltage that accompany oscillator switching from damaging the transistors 16 and 17, there are provided a pair of Zener diodes 56 and 57. These diodes are connected across each of the transistors 16 and 17, respectively, as is clearly illustrated in FIG. 1. By reason of the nature of a Zener diode, the voltage applied across such diode will have a predetermined amplitude above which the diode will conduct. Therefore, the transistor across which the diode is connected is protected from higher voltages by the shunting effect of the diode and, consequently, no damage from higher peaks of voltage can be created. It may be noted that the basic system with-

out the Zener diodes would operate in the manner described above. However, the addition of the diodes provides beneficial avoidance of any damaging effects caused by switching transients that tend to occur across the transistors.

While a particular embodiment of the invention has been described above in considerable detail and in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention but merely as being descriptive thereof.

I claim:

1. In an ignition system for use with an internal combustion engine having breaker points associated therewith for mechanically determining the timing of initiation of an ignition spark for a cylinder of said engine, wherein said system comprises

a saturable-core square wave oscillator having a fundamental oscillator frequency and employing a saturable-core transformer to provide electromagnetic feedback coupling and providing relatively high frequency electrical energy having continuing duration during oscillation thereof,

means under control of said breaker points for saturating said feedback coupling with steady magnetic flux to stop said oscillator and for cutting off such flux to cause rapid starting of said high frequency energy,

an output transformer having a high turns ratio for supplying energy to said ignition spark,

a pair of transistors, and

circuit means for connecting said transistors to said electromagnetic feedback coupling and to said output transformer,

the improvement comprising said output transformer being tuned to resonate at a harmonic frequency of said fundamental oscillator frequency at no load, and

the magnetic properties of said saturable-core transformer being determined so as to cause an increase in the frequency of said oscillator as the load on said output transformer increases.

2. The invention according to claim 1 wherein said magnetic properties comprise construction parameters of said saturable-core transformer.

3. The invention according to claim 2 wherein said construction parameters are determined such that after a predetermined increase in the load on said output transformer said saturable-core transformer no longer reaches saturation during oscillation of said oscillator.

4. The invention according to claim 3, wherein said harmonic frequency is twice said fundamental frequency.

5. The invention according to claim 4, wherein the improvement additionally comprises a pair of Zener diodes connected across said transistors in order to limit transient peaks during cyclic switching of said oscillator.

6. The invention according to claim 5, wherein said oscillator comprises a Jensen-type oscillator.

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