United States Patent [19]

Ganoung

[11] **3,882,839**

[45] **May 13, 1975**

[54] **CAPACITIVE DISCHARGE IGNITION SYSTEM UTILIZING A FEEDBACK CONTROLLED OSCILLATOR**

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[22] Filed: **Aug. 27, 1973**

[21] Appl. No.: **391,630**

[52] **U.S. Cl.** ..... **123/148 R;** 123/148 E; 307/106; 315/209

[51] **Int. Cl.** **F02p 1/00**

[58] **Field of Search** ..... 123/148 CD, 148 E; 307/108, 106; 315/209

[56] **References Cited**

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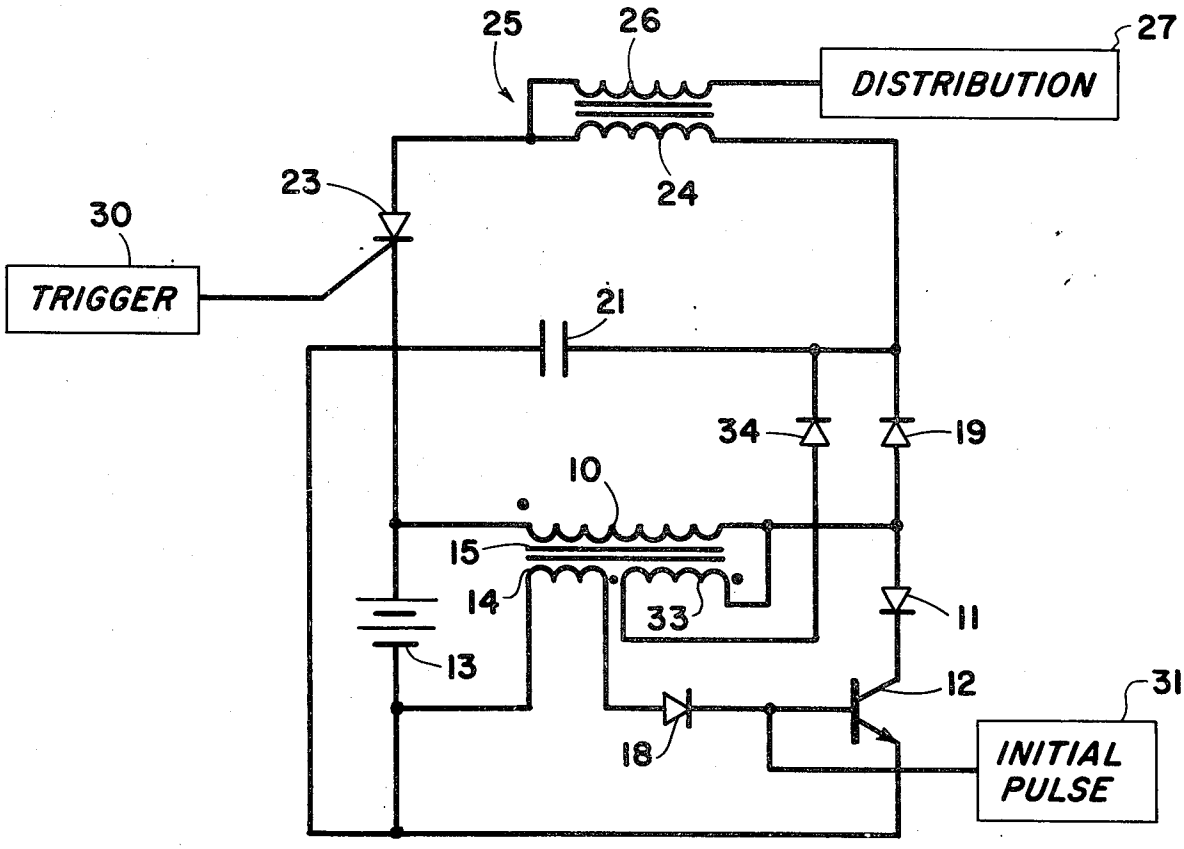
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Primary Examiner—Charles J. Myhre
Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Richard A. Bachand

[57] **ABSTRACT**

An ignition circuit includes a capacitor, an inductor, an oscillator, and a semiconductor switch interconnected in a manner directing the voltage of the inductance of an ignition coil opposing cessation of current therein onto the capacitor. The capacitor charge is then directed onto the inductor, which activates the oscillator by a feedback loop responsive to the current flowing in the inductor. The oscillator conducts to present a current flowpath through the inductor to a battery, until the current reaches a predetermined level, after which the oscillator is turned off. The flyback voltage in the inductor is thereafter applied to recharge the capacitor for the next cycle.

9 Claims, 3 Drawing Figures



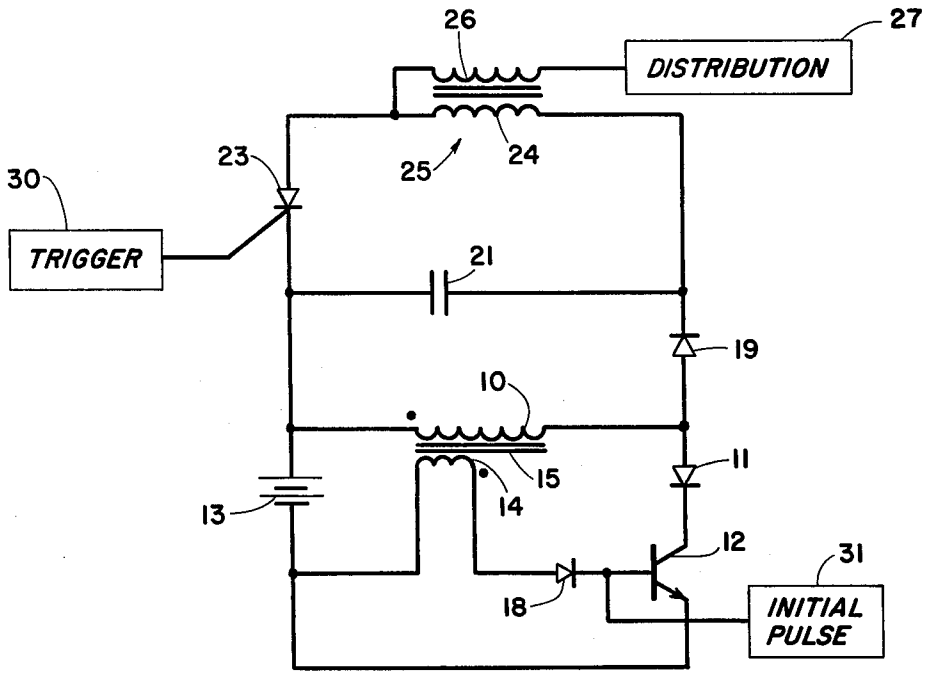

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Fig. 1

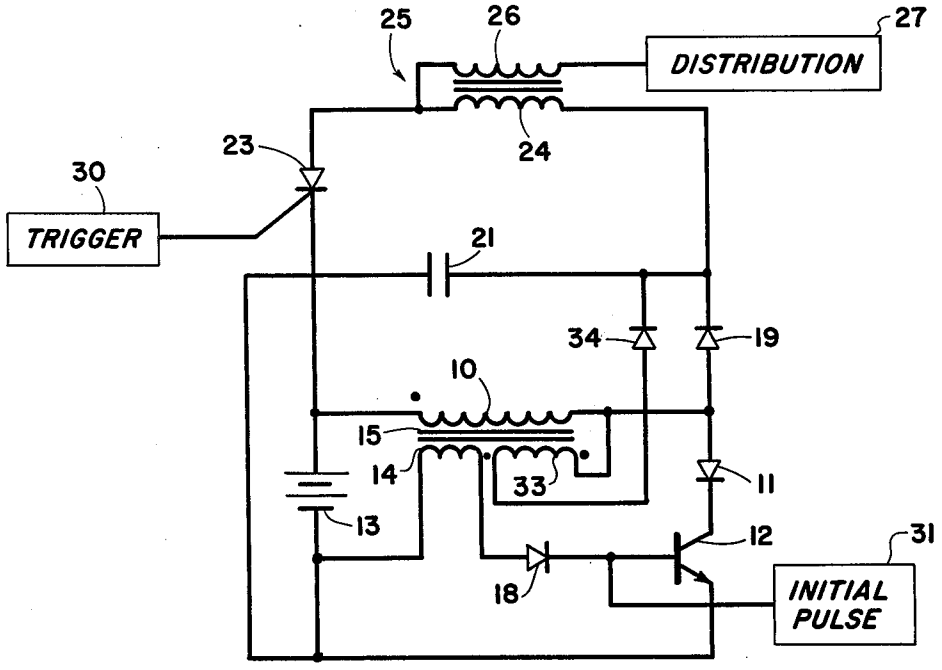

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Fig. 2

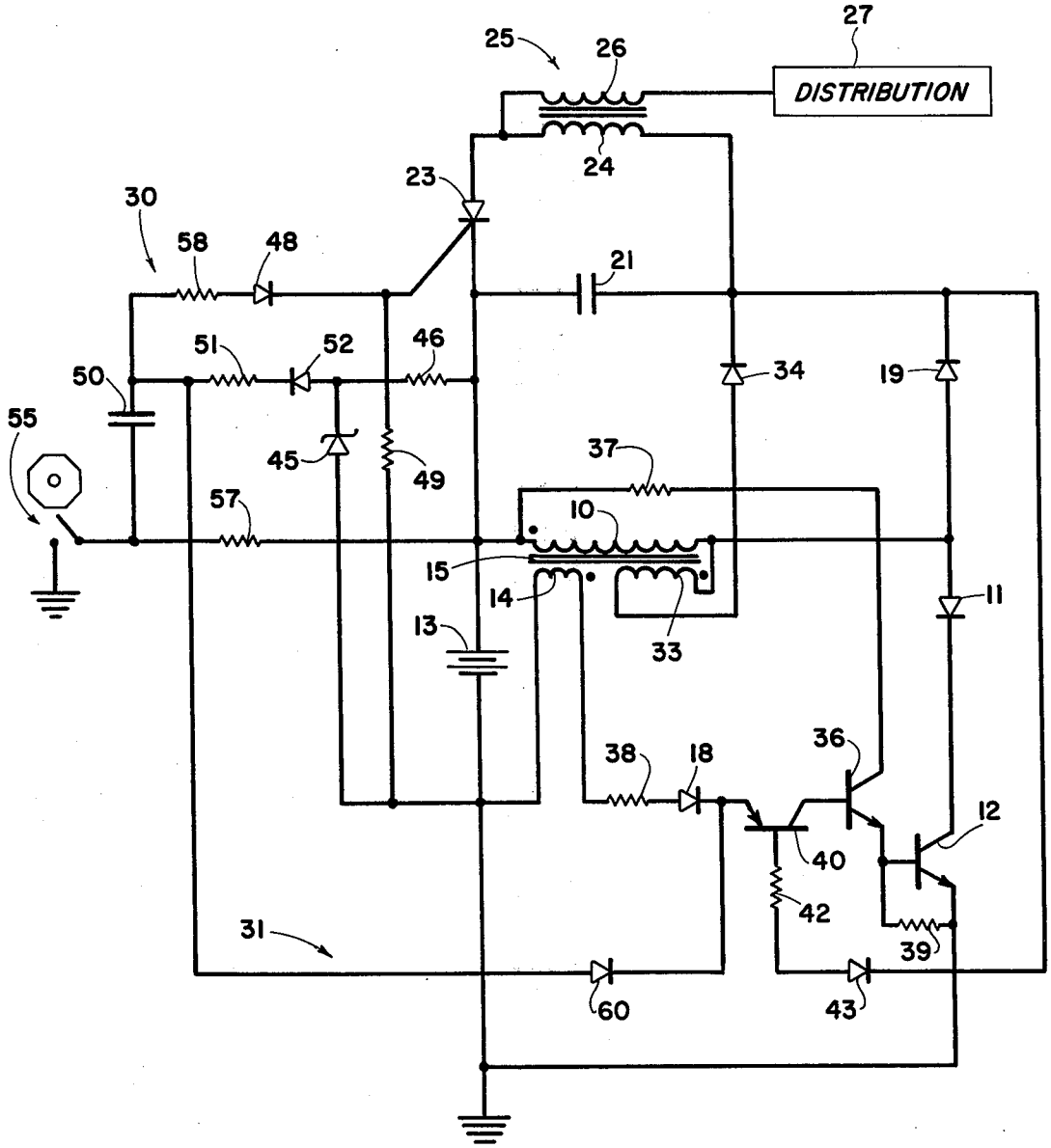

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Fig. 3

CAPACITIVE DISCHARGE IGNITION SYSTEM UTILIZING A FEEDBACK CONTROLLED OSCILLATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to capacitor discharge ignition systems, and more particularly to improvements in capacitor discharge ignition systems including feedback oscillators.

2. Description of the Prior Art

A number of capacitor-discharge electronic ignition circuits are known. Like most other types of electronic ignition circuits, the majority of the capacitor-discharge circuits are intended to reduce maintenance of the ignition system and/or to provide improved ignition system performance, notably under high load and high speed operation of the associated combustion engine. An important recent consideration is the manner in which engine exhaust emission levels are affected by ignition system characteristics. The capacitor-discharge ignition circuits, in particular, have generally been found to be detrimental to pollution levels of newer cars in spite of advantages shared by no other type of electronic ignition.

In actual practice, most capacitor-discharge ignition circuits employ some type of free-running oscillator to charge the capacitor; however, utilization of a single-shot oscillator can provide an advantage if the duration of the oscillation may conveniently be used to time a sub-circuit. Such a sub-circuit can trigger one or more distinct and significantly delayed auxiliary ignition sparks during a single combustion cycle thereby eliminating the increased exhaust emission levels commonly associated with capacitor-discharge ignition circuits.

One class of single-shot oscillator capacitor-discharge ignition circuits is exemplified by the disclosures of Walters (U.S. Pat. No. 3,169,212), Monpetit (U.S. Pat. No. 3,565,048), and Palmer (U.S. Pat. No. 3,623,466). Aside from more serious drawbacks, this class of circuits may not normally be adapted to multi-spark operation because the single oscillation is completely controlled by the ignition breaker points and consequently only one oscillation, with the associated single distinct spark, is available to each combustion cycle.

The circuits advanced by Sasayama (U.S. Pat. No. 3,626,200) employ feedback to drive the main semiconductor switch of the single-shot oscillator, so that the breaker points only initiate the single oscillation. Consequently, these circuits represent another and an improved class of single-shot oscillator circuits wherein the oscillation concludes independently of the condition of the breaker points. Although the objective of these more advanced feedback driven circuits is superior performance and reduced cost, rather than adaptability to multi-spark operation, these circuits are in fact relatively expensive. For example, a conventional free-running oscillator will commonly employ a pair of power transistors, whereas a feedback driven oscillator such as that of Sasayama might employ only one. Nevertheless, the single transistor is usually more expensive than the combined cost of the pair of ordinarily used transistors because the discharge subcircuit usually associated with a free-running oscillator saves the ignition coil flyback energy and thus allows transistors of significantly lower current rating to be used.

SUMMARY OF THE INVENTION

In light of the above, it is, therefore, an object of the invention to present an electronic ignition circuit which provides most of the desirable advantages of known ignition circuits, but at a relatively low cost.

It is also an object of the invention to provide a capacitor-discharge ignition circuit which may conveniently and inexpensively be adapted to multi-spark operation to affect a recently well-known advantage of ultra-long spark duration.

It is still another object of the invention to provide a capacitor-discharge ignition circuit which may conveniently and inexpensively be adapted to multi-ignition coil, multi-trigger source operation.

It is yet a further object of the invention to provide an ignition circuit which inherently possesses desirable features not common to known ignition circuits.

In accordance with the invention in its broad aspect, an ignition circuit for connection to an ignition coil having a primary winding is presented. The ignition circuit includes a capacitor, an inductor, and a rectifier connected in a series loop, and an oscillator which includes the inductor. The oscillation period of the oscillator is initiated by a current flow in the inductor, initiated by the flyback voltage of the ignition coil. During the oscillation period, a current builds up in the inductor to thereafter provide a charging voltage to the capacitor for the next cycle. A semiconductor switch means to control the circuit is provided in series with the inductor, the switch means and inductor being in parallel with the capacitor, to apply the voltage across the capacitor to the primary winding of the ignition coil, which subsequently applies a current maintaining voltage to the capacitor of opposite polarity from that of the charging voltage of the inductor, thereby causing positive feedback to the oscillator to initiate the oscillation period, after which the charging voltage upon the inductor is reapplied to the capacitor to recharge it.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the accompanying drawing wherein,

FIG. 1 is an electrical schematic diagram of an ignition circuit in accordance with the principles of the invention.

FIG. 2 is an electrical schematic diagram of an ignition circuit employing a voltage reducing coil in conjunction with the feedback oscillator, in accordance with the invention.

And FIG. 3 is an electrical schematic diagram of an ignition circuit illustrating trigger circuit and initial pulse charging for use in combination with the circuit of FIG. 2.

In the figures of the drawing, like reference numerals are used to denote like or similar parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention employs feedback to drive one main power transistor in a single-shot oscillator. Since the discharge circuit of the present invention saves the ignition coil flyback energy, a distinct cost advantage results. Perhaps more importantly, this utilization of energy inherently eliminates the problem of its dissipation. If the flyback energy is not dissipated through longer spark duration, the solution becomes quite diffi-

cult, but short duration sparks are especially desirable for multi-spark operation. In actual operation, the present invention is distinguished by the fact that the single oscillation can be, and preferably is, initiated by a transfer of the ignition coil flyback energy rather than by, for example, a condition of the breaker points or other engine-driven trigger source. The oscillator of the present invention also preferably includes a novel use of a transformer that could possibly also be used advantageously in the oscillators of other ignition circuits.

In addition to multi-spark operation, the present invention is ideally suited to multi-ignition coil, multi-trigger source operation. For instance, motorcycle engines commonly employ two or more ignition systems, that, except for synchronization, are entirely separate. The single main capacitor and associated charging oscillator of the present invention may conveniently be extended to operate such synchronized ignition systems simply by duplicating the relatively inexpensive triggering and discharge circuits of the invention. Multi-spark operation provides no significant advantage for this application because motorcycles do not usually have lean carburetor calibration or vacuum ignition timing advance mechanisms.

FIG. 1 shows the circuit forming the basis for the preferred embodiment of an ignition circuit in accordance with the invention. The circuit includes a first inductor **10**, a diode **11** and the collector and emitter of a transistor **12** connected in series across a DC voltage source such as a battery **13**. A second inductor **14** is electromagnetically coupled to the first inductor **10** by a common core **15**, and provides a feedback voltage to the base of the transistor **12** via a diode **18**. The relative inductive polarity of the second inductor **14** with respect to the first inductor **10** is indicated by the dots. The rectifiers **11** and **18** prevent the transistor **12** from being damaged by large reverse voltages. A rectifier **19** and a capacitor **21** are connected to the first inductor **10** to form a current conducting series loop therewith. A third series connection of a silicon controlled rectifier **23** and the primary winding **24** of an ignition coil **25** forms another current conducting loop with the capacitor **21** as shown. The order of the rectifier **19** and the capacitor **21** in the second mentioned series connection may be reversed from that shown in FIG. **1**, but such a reversal is not desirable because it increases the difficulty of triggering the controlled rectifier **23**. Similarly, the order of the third mentioned series connection is preferred as shown in FIG. **1** to facilitate triggering of the controlled rectifier **23**. Also, the rectifier **19** has alternative positions in the circuit of FIG. **1**, but the position shown facilitates the use of a third inductive winding, below described.

A similar circuit may be constructed with a p-n-p polarity transistor replacing the n-p-n transistor **12**, but in either case, the preferred connection requires that the transistor emitter be connected to the source **13** and the collector be connected to the main winding **10**. The n-p-n polarity of the transistor **12** is preferred mainly because of its lesser cost.

Finally, the secondary winding **26** of the ignition coil **25** delivers spark producing voltage to a suitable distribution means **27** or directly to a spark plug. The trigger shown generally as a block **30**, below described in detail, fires the controlled rectifier **23**, and the initial pulse injector, illustrated by box **31**, also described below in detail, momentarily forward biases the transistor **12** to initially charge the capacitor **21**.

In operation, assuming no initial currents in the circuitry, but assuming a charge being retained on the capacitor **21** by the rectifier **19** and the controlled rectifier **23**, a triggering pulse to the gate of the controlled rectifier **23** from the trigger **30** will cause the capacitor **21** to discharge through the primary winding **24** of the ignition coil **25**, thereby producing sparking voltage at the secondary winding **26** for distribution or application to a spark plug (not shown). After the capacitor **21** is discharged, the flyback energy of the primary winding **24** will charge the capacitor **21** in a reverse direction, while simultaneously producing reverse-polarity voltage in the secondary winding **26**. The reverse charge will appear as a substantial negative potential at the previously positively charged plate of the capacitor **21**, and it will be applied to the inductor **10** to establish a forward current therein, and also to establish a forward bias at the base of the transistor **12** via the inductive coupling of the feedback inductor **14**. In addition, the reverse charge will reverse bias the controlled rectifier **23** from cathode to anode, thereby rapidly rendering it unconductive. Such reverse bias will occur, even if the capacitor **21** is not reverse charged beyond the potential of the battery **13**. The forward bias to the base of the transistor **12** still exists when the transfer of flyback energy, via the capacitor **21**, to the inductor **10** is complete. The potential of the battery consequently then continues the increase of the forward current in the inductor **10**. At a predetermined shut-off current level the core **15** saturates thereby causing the forward bias to the base of the transistor **12** to vanish. The current in the inductor **10** continues to flow briefly after the transistor **12** switches off, thus charging the capacitor **21** for a subsequent ignition spark to be delivered upon an appropriate pulse to the gate of the controlled rectifier **23**.

It should be appreciated that unlike present circuits, during the significant time interval during which current is increasing in the inductor **10**, the absence of forward charge on the capacitor **21** provides protection against unwanted trigger pulses to the gate of the controlled rectifier **23** which may arise, for instance, from erratic high-speed operation of the trigger source **30**. Another example of an inherent advantage not common to known ignition circuits is that, at a predetermined frequency of triggering pulses to the controlled rectifier **23**, the finite oscillation time and resulting interference between oscillation cycles will cause erratic, but safe, operation of the ignition circuit, thus preventing the engine from over-speeding.

Since the transfer of the flyback energy of the ignition coil primary **24** to the inductor **10** initiates the cycle of events leading to the forward charging of capacitor **21**, the initial pulse injector **31** is needed only to initiate the cycle establishing the first charge on the capacitor **21**, and it can be conveniently integrated into the trigger circuit **30**. The pulse injector **31** can be used to initiate charging of the inductor **10** for every cycle, but this is not preferred, since such operation increases the oscillation duration.

FIG. 2 shows a circuit enabling the use of components, particularly the transistor **12**, having lesser voltage capabilities for inexpensive fabrication. To provide this lower voltage capability, a booster winding **33** and an associated rectifier **34** are provided. The booster

and rectifier reduce the charging voltage to which the transistor **12** is subjected by a factor of *n* plus 1, where *n* is the ratio of the number of turns in the booster winding **33** to the number of turns in the inductor **10.**

FIG. **2** also shows that the terminal of the capacitor **21** which is referenced to the positive terminal of the battery **13** in FIG. **1** can alternatively be referenced to the negative terminal, without significant difference in the operation of the circuit. Similarly, the cathode of the controlled rectifier **23** may alternatively be connected to the negative terminal of the source **13** (connection not shown) either in combination with, or not in combination with, the alternative referencing of the capacitor **21.**

FIG. **3** shows a working circuit according to a preferred embodiment of the invention. A transistor **36** and associated resistor **37** provides feedback amplification so that a resistor **38** can have a relatively large value to reduce losses through feedback winding **14** during the transfer of flyback energy if the feedback voltage should become excessive. A resistor **39** serves to enhance the operation of the transistor **12.** A transistor **40** and associated resistor **42** and diode **43** operate to prevent any chance of a second oscillation overcharging the capacitor **21,** and to limit the pulse injection biasing of the power transistor **12** only to initial charging cycles i.e., when there is no resting charge on the capacitor **21.** A Zener diode **45,** resistor **46** and rectifier **48** serve to apply a reduced voltage to a triggering capacitor **50** through a resistor **51** and a diode **52.** A resistor **49** serves to enhance the operation of the silicon controlled rectifier **23.** The reduced voltage prevents the capacitor **50** from undesirably triggering the controlled rectifier **23** when the breaker points **55** are closed and the potential of the battery **13** varies, for example, upon dimming the lights or operating an electrical accessory upon the vehicle. The capacitor **50** and the resistor **57** apply the momentary triggering and pulse injection voltages simultaneously when the points open, with the resistor **58** serving to increase the pulse injection voltage applied through the rectifier **60.**

By way of example, typical component values and types which can be employed in the circuit of FIG. **3** are as follows:

Transistors	
12	2N5991
36	MJE200
40	HEP739
Rectifiers	
23	2N6240
34	1N4006 800 piv (2 in series)
19) 18) 43)	1N4005 600 piv
11	MR754 400 piv
48) 52) 60)	1N4001 50 piv
45	1N4736
Inductors	
25	std. ignition coil, 12v
10	4.0 mh, less than 0.4 ohms
33	4.5x (turns of inductor 10), less than 40 ohms
14	1.5x (turns of inductor 10), less than 100 ohms
Resistors	
38	1K ohms
37	27 ohms
39	100 ohms
42	47K ohms
49	120K ohms
57	3.3K ohms
46	1K ohms
58	10K ohms
51	10K ohms
Capacitors	
21	1.5uF, 600v
50	0.027uF

Although the invention has been described and illustrated with a certain degree of particularity, it should be understood that the present disclosure is made by way of example only and that numerous changes in the arrangement and combination of parts may be resorted to without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A capacitor-discharge ignition circuit comprising:
a capacitor,
an inductor,
an ignition coil having a primary winding
a source of direct current potential, and
a unidirectional current passing device,
said primary winding and said source of direct current potential each being switchably connected in parallel across a winding of said inductor, and said capacitor being switchably connected in parallel across said primary winding,
said unidirectional current passing device and said capacitor being connected in series, the series being connected in parallel with said winding of said inductor, and being oriented to receive and store a current maintaining voltage generated in said winding of said inductor.

2. A capacitor-discharge ignition circuit comprising:
an inductor,
a first unidirectional current passing switch means,
a primary winding of an ignition coil connected in series with said first unidirectional switch means, to form a first series circuit,
a second unidirectional current passing switch means,
a direct current voltage source connected in series with said second unidirectional switch means, to form a second series circuit,
a capacitor,
a rectifier connected in series with said capacitor, to form a third series circuit,
trigger means for rendering said first unidirectional current passing switch means conductive,
and means for controlling the conduction of said second unidirectional current passing switch means,
said first and said second series circuits being connected in parallel across a winding of said inductor with said first and second unidirectional current passing switch means being oriented such that the voltages applied across said inductor winding by a flyback voltage of said primary winding and by the voltage of said direct current voltage source are in the same direction to create a charging current in said inductor winding,
said third series circuit being connected in parallel with said inductor winding, said rectifier being oriented to apply a current maintaining voltage generated in said inductor winding to said capacitor, to receive and store said current maintaining voltage, said capacitor also being connected in parallel with said first series circuit, whereby the operation of said first switch means applies the voltage on said

capacitor across said ignition coil primary winding to produce a spark producing voltage.

3. The ignition circuit of claim 2 wherein said inductor further comprises a second winding, one terminal of said second winding being connected between said capacitor and said rectifier, and said second winding being electromagnetically coupled to said first mentioned inductor winding, oriented such that the voltage induced in said second winding from said current maintaining voltage in said first mentioned inductor winding reverse biases said rectifier.

4. The ignition circuit of claim 2 wherein said means for controlling the conduction of said second unidirectional current passing switch means renders said second unidirectional switch means non-conductive when said charging current reaches a predetermined value.

5. The ignition circuit of claim 2 wherein said means for controlling the conduction of said second unidirectional current passing switch means supplies a forward bias to a control terminal of said second unidirectional switch means in response to said voltages across said first mentioned inductor winding to render said second unidirectional switch means conductive.

6. The ignition circuit of claim 1 wherein said trigger means provides forward biasing pulses to a control terminal of said first unidirectional switch means, whereby said pulses are in synchronism with an engine driven element.

7. The ignition circuit of claim 2 wherein said first unidirectional switch means is a silicon controlled rectifier.

8. The ignition circuit of claim 2 wherein said second unidirectional switch means is a transistor.

9. The ignition circuit of claim 8 wherein said second unidirectional switch means further comprises a second rectifier, said second rectifier being connected in series with a collector terminal and an emitter terminal of said transistor.

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