United States Patent

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[54] **ELECTRONIC ENGINE R.P.M. LIMITING DEVICE**
22 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **123/118,** 123/102, 123/148
[51] **Int. Cl.** **F02p 9/00,** F02d 11/08
[50] **Field of Search** ..... 123/118, 102, 148 D; 317/19

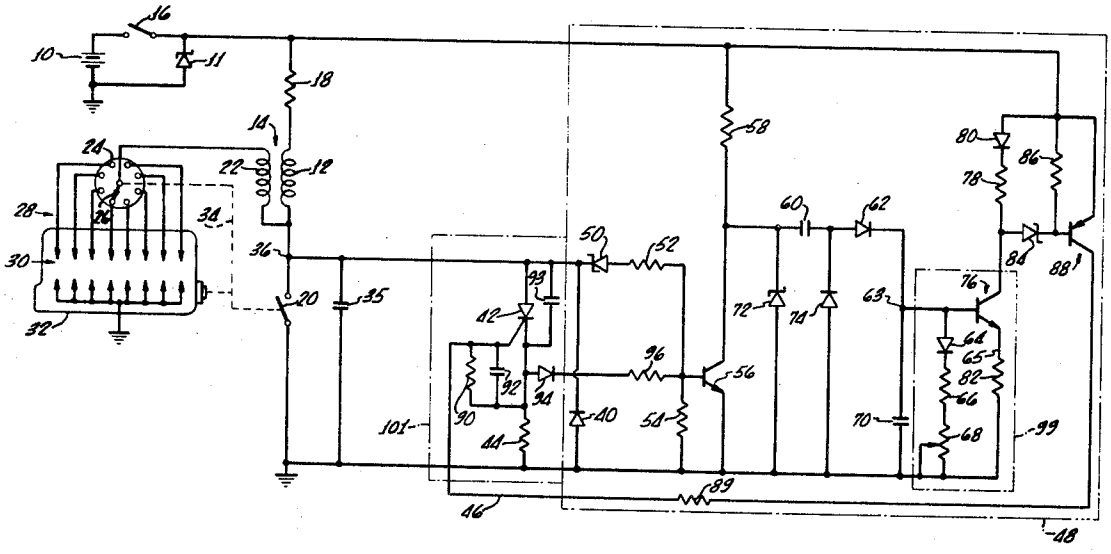
[56] **References Cited**

UNITED STATES PATENTS

2,519,801	8/1950	Tognola	171/97
3,182,648	5/1965	Schneider et al.	123/148
3,235,742	2/1966	Peters	250/233
3,356,082	12/1967	Jukes	123/102
3,363,615	1/1968	Meyerle	123/148
3,410,362	11/1968	Fales	180/110
2,377,591	6/1945	Taylor	123/118
2,726,647	12/1955	Molyneux	123/118
3,153,746	10/1964	Atkinson	123/118
3,220,396	12/1965	Heidner	123/148
3,402,327	9/1968	Blackburn	317/31
3,430,615	3/1969	Chauis	123/102

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ABSTRACT: In the ignition system of an internal combustion engine a switching means is connected in series with the primary winding of an ignition coil. The switching means opens and closes to interrupt current flow through the primary winding generating ignition pulses in the secondary winding of the ignition coil at a frequency determined by the speed of the engine. A sensing means is responsively coupled to the switching means and generates an output signal when the engine reaches a predetermined r.p.m. A silicon-controlled rectifier connected in parallel with the switching means is gated on by the output signal of the sensing means to short out the switching means and thereby disable the ignition system. The silicon-controlled rectifier is turned off by the sensing means when the engine speed returns to an r.p.m. below the predetermined r.p.m. to allow the ignition system to function in a normal manner.



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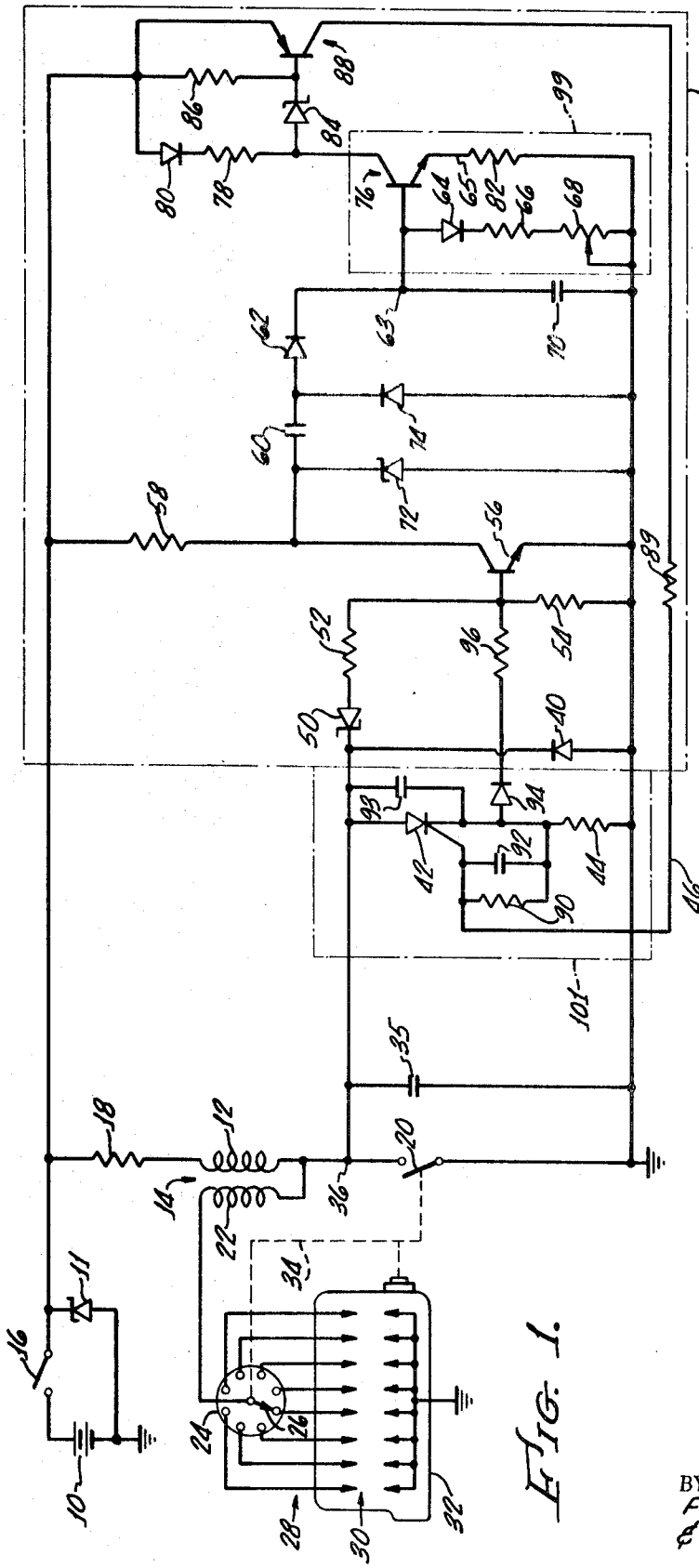


FIG. 1.

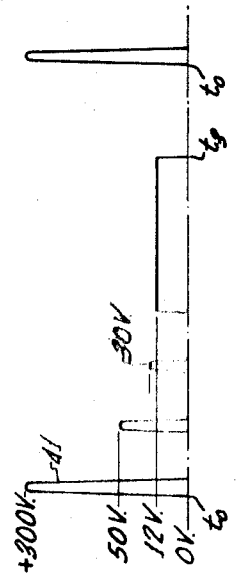


FIG. 4.

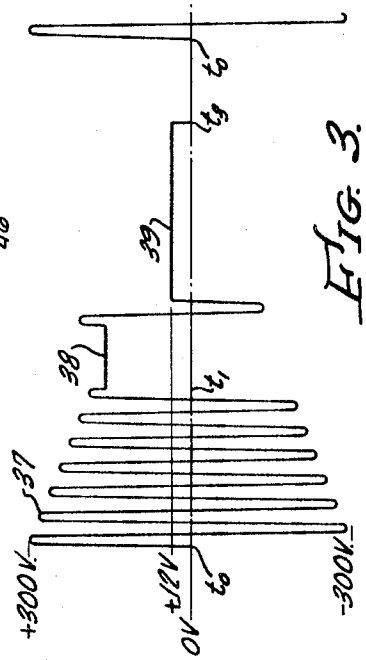


FIG. 3.

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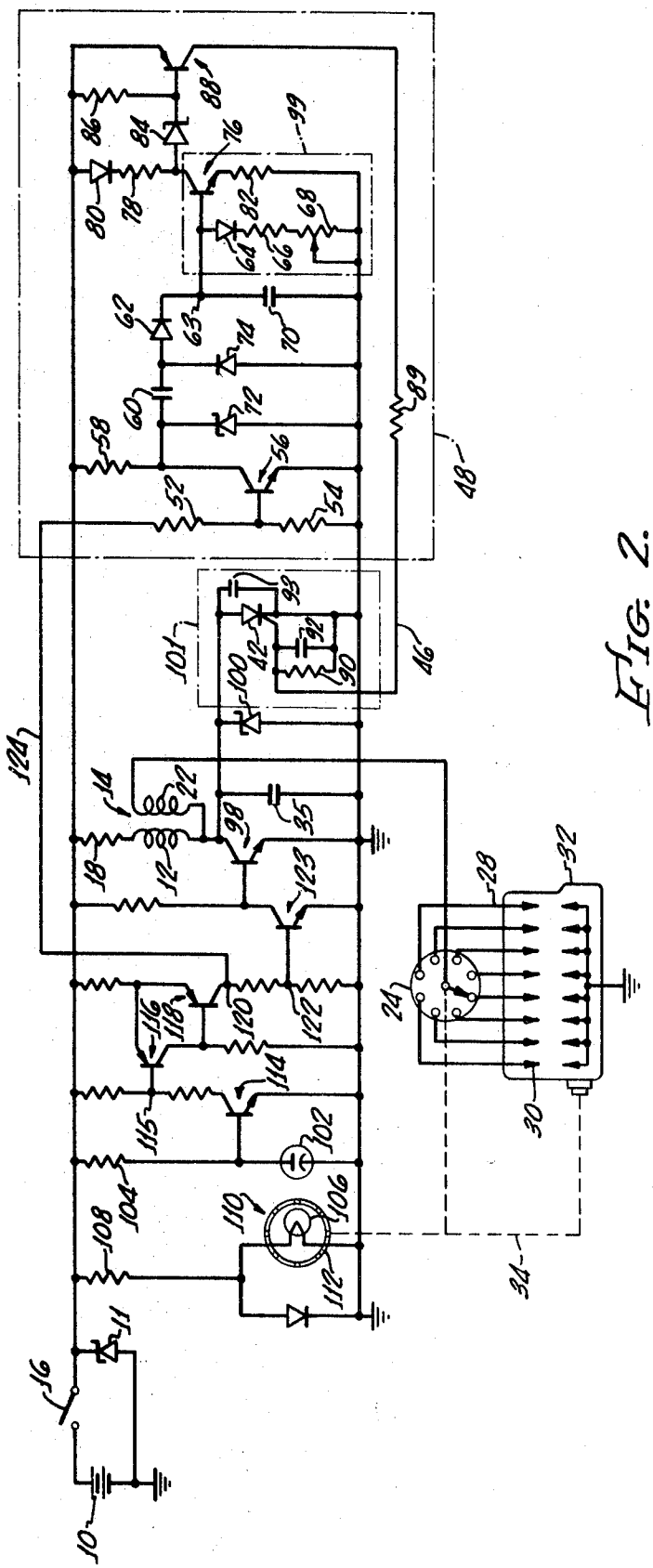


FIG. 2.

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ELECTRONIC ENGINE R.P.M. LIMITING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to ignition systems for internal combustion engines and, more particularly, to an electronic device for limiting the r.p.m. of an internal combustion engine.

2. Description of the Prior Art

A conventional device for limiting the r.p.m. of an internal combustion engine includes a sensing means for measuring the engine speed. The sensing means is generally responsive to the rate at which the mechanical breaker points, which are in series with the ignition coil open and close. When the breaker points are closing at a predetermined rate, the sensing means will actuate a control means which will disable the ignition system to cause the engine to slow down. Mechanical breaker points, however, begin to bounce or chatter as the speed of the engine increases. Thus, the sensing means will inaccurately measure the engine speed due to the point bounce and will prematurely disable the ignition system. This result is highly undesirable.

In the conventional device the control means is usually a mechanical device such as a relay. The relay will have a pair of contacts which are connected in parallel with the mechanical breaker points. When the sensing means actuates the relay, the contacts will close to disable the ignition system by placing a short circuit across the breaker points. If the engine upon which the r.p.m. limiting device is mounted is subjected to strong vibrations, the contacts of the relay are likely to be vibrated between the open and closed positions resulting in spurious ignition pulses. These ignition pulses may cause engine damage.

SUMMARY OF THE INVENTION

The present invention provides a solid-state electronic circuit means for accurately limiting the r.p.m. of an internal combustion engine to prevent engine damage due to excessive engine speed. Further, the circuit means is adaptable for use with conventional engine ignition systems or the relatively new transistorized ignition systems.

In accordance with the preferred embodiment of the present invention a switching means is connected in a series with the primary winding of the ignition coil on an internal combustion engine. The switching means may be either the mechanical breaker points in a conventional ignition system or a switching transistor in a transistorized ignition system. The switching means actuates at a frequency proportional to the engine speed interrupting the current flow through the primary winding of the ignition coil to cause the ignition coil to generate ignition pulses to the spark plugs in the engine. A solid-state sensing means is responsive to the rate at which the current flow through the primary winding is interrupted and generates an output signal to a control means when the engine speed exceeds a predetermined value. The control means will disable the ignition system until the engine speed has been reduced to a speed below this predetermined value at which time it will automatically reenable the ignition system.

In accordance with one aspect of the present invention the sensing means includes a charging capacitor coupled to a direct current source and a discharge means responsively coupled to the switching means. The charging capacitor is charged by a charge current from the direct current source and is discharged each time the switching means interrupts the current through the primary winding. The discharge means is immune to the phenomenon of "point bounce" present in ignition systems using mechanical breaker points and will discharge the charging capacitor only when the ignition coil generates an ignition pulse. The average value of the charge current to the charging capacitor therefore is proportional to the engine speed. A detector means is also included in the sensing means and is responsive to the average value of the charge current. The detector means will generate an output signal to the control means when the average value of the charge current exceeds a value corresponding to the predetermined engine speed.

The present invention provides both an extremely accurate means for sensing engine speed and, due to its solid-state components, a device having a high reliability and immunity from engine vibration. BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the preferred embodiment of the present invention used with an ignition system which employs the conventional mechanical breaker points;

FIG. 2 is a schematic diagram of the preferred embodiment of the present invention modified to be used with a transistorized ignition system;

FIG. 3 is a diagrammatic representation of the voltage waveform which would normally appear across the switching means used to interrupt current flow through the primary winding of an ignition coil; and

FIG. 4 is a diagrammatic representation of the voltage waveform appearing across the switching means as modified by the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the present invention as adapted for use with a conventional ignition system in an internal combustion engine is shown in FIG. 1. The ignition system comprises a direct current source **10**, such as the **12** volt storage battery in an automobile, connected through an ignition switch **16** and a ballast resistor **18** to one side of the primary winding **12** of an ignition coil **14**. The opposite side of the primary winding **12** is connected to ground through a power switching means comprising breaker points **20**. The secondary winding **22** of the ignition coil **14** is connected to a distributor **24** having a rotatable wiper arm **26**. The wiper arm **26** distributes the ignition pulses generated in the secondary winding **22** through a plurality of ignition wires **28** to one electrode of a corresponding plurality of spark plugs **30** in an internal combustion engine **32**. The other electrodes of the spark plugs **30** are connected to ground. An engine output shaft indicated by dotted line **34**, drives the wiper arm **26** and the breaker points **20**. Accordingly, the breaker points **20** will open and close at a frequency determined by the speed of the engine **32**. Each time the breaker points **20** are closed a current from the direct current source **10** will flow through the primary winding **12** to ground. When the breaker points **20** are opened, the current flow through the primary winding **12** will be interrupted resulting in an ignition pulse being generated in the secondary winding **22**. The ignition pulse in the secondary winding **22** is connected to the appropriate spark plug in the engine **32** by the wiper arm **26**. A capacitor **35** is ordinarily connected in parallel with the breaker points **20** to reduce the arcing and the burning of the contacts of the breaker points **20** during system operation.

Referring now to FIG. 3, there is shown a waveform **37** which represents the voltage that would appear at the terminal **36** in FIG. 1 for one cycle of the breaker points **20**. Time t_0, in FIG. 3, corresponds to the instant in time that the breaker points **20** are opened to interrupt the current flow through the primary winding **12**. When the current flow through the primary winding **12** stops, at time t_0, the flux in the core of the ignition coil **14** will begin to collapse and a positive voltage pulse in the order of 300 volts will occur at the terminal **36**. Further, it can be seen that the voltage will oscillate decreasing in amplitude between times $t_0$and t ,as the energy in the core of the coil **14** is exchanged between the coil **14** and the capacitor **35**. Note that although the oscillating voltage in FIG. 3 is decreasing in amplitude, each voltage peak is only slightly less than the preceding voltage peak. At time t_1, the appropriate spark plug in the engine **32** fires resulting in a constant voltage across the primary winding **12** such as segment **38**. When the wiper arm **26** has removed the ignition pulse in the secondary winding **22** from the particular spark plug **30**,

the voltage at terminal **36** will oscillate a few more cycles and will eventually damp out to the voltage potential of the battery **10**, represented by segment **39**. At time t_3, the breaker points **20** will close grounding terminal **36** until time $t_0$of the next cycle when the breaker points **20** will again open to interrupt the current flow through the primary winding **12**.

The preferred embodiment of the present invention as seen in FIG. **1** includes a diode **40** connected in parallel with the breaker points **20** having its anode connected to ground and its cathode connected to terminal **36**. The diode **40** modifies the voltage waveform seen in FIG. **3** to a waveform such as waveform **41** seen in FIG. **4**. In FIG. **4**, it can be seen that at time t_0, when the breaker points **20** open, a voltage pulse in the order of 300 volts appears at the terminal **36** as was the case in FIG. **3** (diode **40** has no affect on a positive pulse). Note, however, that the diode **40** will clamp the terminal **36** to ground potential during the negative portions of the voltage oscillation. The diode **40** will not only eliminate the negative portions of the voltage oscillation, but will also reduce the amount of energy exchanged between the capacitor **35** an the coil **14**. This reduced exchange of energy will cause the frequency of the oscillations to be smaller and the amplitude of the positive pulses after the first pulse to be significantly diminished from what they would normally be. The polarity of the diode is such that it can have no effect until after the first positive pulse has occurred. For example, the first pulse occuring after time t_0 in both FIG. **3** and FIG. **4** has an amplitude in the order of 300 volts. The second oscillation of the voltage in FIG. **3** has an amplitude only slightly less than 300 volts, whereas the second positive pulse in FIG. **4** has an amplitude of approximately 50 volts. The diode **40**, then, significantly alters the energy exchange between the capacitor **35** and the coil **14** so that a distinguishing pulse occurs at the terminal **36** when the breaker points **20** open.

It is significant to note that most of the energy for this first positive pulse is stored in the "leakage inductance" of the primary winding **12** of the ignition coil **14**. Accordingly, this pulse occurs due to a characteristic of the coil **14** which is essentially unaffected by conditions existing in the secondary circuit which includes the secondary winding **22**, distributor **24**, wires **28** an spark plugs **30**. Thus, any abnormal condition in the secondary circuit such as a disconnected spark plug wire, open or shorted spark plug, or other abnormality will not affect the first pulse.

A silicon-controlled rectifier (SCR) **42** is connected in series with a resistor **44** across the breaker points **20** from the terminal **36** to ground. The conductive state of the SCR **42** is controlled by a signal appearing on line **46** which is connected to its gate electrode. When an appropriate signal appears on the line **46**, the SCR **42** will become conductive and will short out the breaker points **20** thus disabling the primary circuit of the ignition system. The resistor **44** is a very low value so that the terminal **36** is at approximately ground potential even though it is not connected directly to ground when the SCR **42** becomes conductive.

A sensing means **48** is responsive to the voltage potential appearing on the terminal **36** and will generate an output on the line **46** to cause the SCR **42** to become conductive when the frequency of the voltage pulses appearing on terminal **36** indicates that the engine **32** has reached a predetermined r.p.m.

The sensing means **48** includes an RC charging network comprising a capacitor **60** which is charged by the direct current source **10** through a charge path including a resistor **58** connected between the capacitor **60** and the direct current source **10** and diodes **62** and **64**, connected in series with resistors **66** and **68** between the capacitor **60** and ground.

The sensing means **48** also includes a discharge means comprising a Zener diode **50**, resistors **52** and **54**, and a transistor **56**. The reverse breakdown voltage of Zener diode **50** is selected so that current will be conducted from terminal **36** through resistors **52** and **54** to ground only when the voltage at terminal **36** exceeds a value, 100 volts for example, which is less than the first voltage pulse occurring after the breaker points **20** open, as seen in FIG. **4**, and yet is significantly higher than the second voltage pulse. Referring again to FIG. **4**, it can be seen that the Zener **50** will become conductive only when the first pulse occurs in each ignition cycle. Each time Zener diode **50** conducts, a positive voltage potential will appear on the base electrode of the transistor **56** causing it to become conductive. The transistor **56** will therefore have a conduction rate determined by the conduction rate of the Zener diode **50**.

The breaker points in virtually all mechanical breaker point ignition systems will bounce or chatter as they are closing causing current pulses through the primary winding **12**. These current pulses, however, do not have a significant duration and will not store enough energy in the ignition coil **14** to cause a voltage pulse at the point **36** of sufficient amplitude as the breaker points chatter to cause the Zener diode **50** to conduct. A voltage pulse of the required magnitude will appear at the point **36** only after the points **20** have settled down and been closed for a significant period of time and are then opened. The conduction rate of the transistor **56** therefore is unaffected by this phenomenon of "point bounce."

The transistor **56** has its collector electrode connected between the resistor **58** and the capacitor **60** and its emitter electrode connected to ground. A diode **74** has its anode connected to the emitter electrode of the transistor **56** and its cathode connected between the capacitor **60** and the diode **62**. Accordingly, each time the Zener diode **50** becomes conductive, causing the transistor **56** to turn on, the charge built up on the capacitor **60** is discharged through a path including the transistor **56** and the diode **74**. The diode **62** prevents any reverse current from flowing from ground through the resistors **66** and **68** when the capacitor **60** is discharged. When the voltage potential on terminal **36** decreases to a value such that the Zener diode **50** becomes nonconductive a charge current from the direct current source **10** will charge the capacitor **60** through the resistor **58**.

A Zener diode **72** is connected from one side of the capacitor **60** to ground and will determine the maximum charge which may be placed on the capacitor **60**. Accordingly, since the capacitor **60** is charged to a fixed value, as determined by the Zener diode **72** each time the transistor **56** becomes nonconductive, the average current flowing in the charge path for the capacitor **60** is proportional to the switching frequency of the transistor **56** and hence the frequency at which the breaker points **20** are operating.

Advantageously, in a system wherein the direct current source **10** has a voltage potential of 12 volts, the Zener diode **72** will allow the capacitor **60** to charge to 9 volts before it becomes conductive. The value of the resistor **58** is chosen to limit the current which will pass through the Zener diode **72**, after the capacitor **60** has been charged, to a value for which the Zener diode **72** has been temperature compensated, 5 milliamps for example.

A current-amplifying means **99** will amplify the current flowing in the capacitor **60** charge path. The diode **64** and the resistors **66** and **68** are connected in series between the base electrode of a transistor **76** and ground. A resistor **82** is connected between emitter electrode of the transistor **76** and ground. The output from the current-amplifying means **99** appears on the collector electrode of the transistor **76**. A terminal **63** intermediate the diodes **62** and **64** is the input terminal for the current-amplifying means **99**.

A capacitor **70** is connected between the terminal **63** and ground. The capacitor **70** has a value large enough, 1,000 microfarads for example, to prevent current spikes, due to the charging current pulses through the capacitor **60**, from flowing into the terminal **63**. The capacitor **70** will filter the current flowing into the current-amplifying means **99** so that it is substantially a direct current with a ripple content of 2 percent or less. This low ripple current enhances the accuracy of the device.

The collector electrode of the transistor **76** is connected to the direct current source **10** through a series-connected resistor **78** and diode **80**. The amount of current flowing in the capacitor **60** charge path, that is, into the terminal **63** and through the diode **64** an resistors **66** and **68**, determines the conductivity of the transistor **76**. Accordingly, the current flowing from the direct current source **10** into the collector electrode of the transistor **76** is proportional to the current flowing into the terminal **63**. This proportionality is the current gain or amplification factor of the current-amplifying means **99** and is determined by the ratio of the sum of the values of the resistors **66** and **68** divided by the value of the resistor **82**. The resistor **68** is a variable resistor and hence may be varied to change the gain of the current-amplifying means **99**. The diode **64** serves to compensate for changes in the base-emitter voltage of the transistor **76** which occur as a result of changes in the ambient temperature. This feature allows the amplification factor of the current-amplifying means **99** to remain constant in spite of ambient temperature changes.

Advantageously, the current amplifier **99** is a temperature compensated, constant gain current amplifier. The constant gain of the current amplifier is achieved by selecting a current gain of the transistor **76** so that it is much higher, ten times as high for example, as the value of the sum of the resistors **66** and **68** divided by the resistor **82**. For example, in an eight-cylinder engine, the amplifier will operate satisfactorily with a gain of 5. Accordingly, the current gain of the transistor **76** should be approximately 50.

As the current flow from the direct current source **10** through the resistor **78** and the transistor **76** increases with an increasing charge current flowing into the terminal **63**, the voltage potential of the collector electrode of the transistor **76** will decrease. A detector means is responsive to the voltage potential on the collector of the transistor **76** and generates an output signal on line **46** to a control means **101** which includes the SCR **42** when the collector potential of transistor **76** corresponds to a predetermined engine r.p.m.

The detector means includes a Zener diode **84**, having its anode connected to the collector of transistor **76** and its cathode connected to the direct current source **10** through a resistor **86**. The base electrode of a transistor **88** is connected intermediate to the cathode of the Zener diode **84** and the resistor **86**. The emitter electrode of a transistor **88** is connected to the direct current source **10** and its collector electrode is connected to the gate electrode of the SCR **42** through a resistor **89**.

When the collector current of the transistor **76** increases to a value such that the voltage drop across the resistor **78** is equal to the breakdown voltage of the Zener diode **84**, the Zener diode **84** will become conductive and conduct current from the direct current source **10** through the base-emitter junction of transistor **88** causing transistor **88** to become conductive. This in turn causes SCR **42** to turn on disabling the ignition system due to a direct current flow from the direct current source **10** through the transistor **88**, resistor **89**, and the gate SCR **42** to ground. The transistor **88** will remain conductive until the current flow into the collector of the transistor **76** decreases sufficiently, due to a decrease in the engine speed, to stop the conduction of the Zener diode **84**. The resistor **89** minimizes the power dissipation in the transistor **88** when it is conductive.

Thus, it can be seen that the SCR **42** will be turned on when the current into the collector of the transistor **76** (i.e. the output signal of the current amplifier **99**) reaches a value equal to the Zener voltage of the Zener diode **84** divided by the value of the resistor **78**. Since a fixed output current from the current amplifier **99** is required to turn on the transistor **88** and hence the SCR **42**, varying the amplification factor of the current amplifier **99** will vary the input current to the terminal **63** required to turn on the transistor **88** and the SCR **42**. The variable resistor **68** thus provides a means for adjusting the input current, and hence the engine r.p.m. required to turn on the SCR **42**. For example, decreasing the value of the resistor **68** reduces the gain of the current amplifier **99**, increasing the required current input, and hence engine r.p.m., to turn on the transistor **88** and the SCR **42**. The resistor **86** serves the dual purpose of reducing the leakage current of transistor **88** at high temperatures and insuring that sufficient current must flow through Zener diode **84** before transistor **88** can be turned on. The first condition insures that SCR **42** will not be accidentally turned on at high temperatures. The second condition assures that the Zener diode **84** is at the Zener breakdown voltage before transistor **88** can be turned on. To maintain the accuracy of the circuit, the current flow through resistor **86**, when transistor **88** is biased on, should be much lower than the current through the resistor **78** under the same condition. For example, the current through the resistor **78** might be 100 times as high as the current through the resistor **86** which includes the base drive current for the transistor **88**.

The diode **80** provides compensation for changes in the base-emitter voltage of the transistor **88** which may occur due to changes in ambient temperature. This assures that the value of the current which is required to flow through the resistor **78** to cause conduction of the Zener diode **84** will be stable. To assure the accuracy of the circuit, resistors **66**, **68**, **78**, **82** and capacitor **60** should be temperature stable types.

A resistor **90** and a capacitor **92** are also included in the control means **101** and are connected in parallel between the gate electrode and the cathode electrode of the SCR **42**. The resistor **90** and the capacitor **92** will act as a filter to prevent spurious voltage pulses on line **46** from inadvertently turning the SCR **42** on. A capacitor **93** is connected in parallel with the SCR **42** and acts as a filter to prevent any high frequency voltage spikes which might appear on the terminal **36** from turning the SCR **42** on. The value of the capacitor **93** is selected to be as large as possible without affecting the resonant relationship between the capacitor **35** and the primary winding **12**. Advantageously, the value of the capacitor **93** is approximately 10 percent to 15 percent of the value of the capacitor **35**.

When the SCR **42** is conductive, current will flow from the direct current source **10** through the primary winding **12** to ground through the SCR **42** and resistor **44**. The resistor **44** has a small value, one ohm for example, resulting in a small voltage drop across the resistor when the SCR **42** is conducting.

Although the SCR **42** shorts out the breaker points **20** when it is conducting, the breaker points **20** continue to operate at a frequency proportional to the speed of the engine **32**. The current which would normally pass through the SCR **42** will be shunted to ground each time the breaker points **20** close due to the lower resistance of the path through the breaker points **20**. Accordingly, when the SCR **42** is conducting a voltage waveform will appear across the resistor **44** and will approximate a square wave having a frequency equal to the actuation frequency of the breaker points **20**.

The voltage waveform appearing across the resistor **44** is coupled to the base electrode of the transistor **56** through a diode **94** and a resistor **96**. Each time the breaker points **20** open, causing the voltage potential across the resistor **44** to increase, the diode **94** will become conductive causing the transistor **56** to turn on. The resistor **96** limits the base current into the transistor **56** to a reasonable value. Therefore, although the breaker points **20** are shorted out when the engine speed reaches the predetermined value and no pulses appear at the terminal **36**, the transistor **56** will continue to function at a frequency proportional to the speed of the engine **32**. Accordingly, the charge current through capacitor **60** will continue to be proportional to the speed of the engine **32** even though the ignition system has been disabled.

It can be seen that the transistor **88** will turn on to cause the SCR **42** to become conductive when the engine speed reaches a predetermined value and will turn off to remove the gate control signal from the SCR **42** when the engine speed falls below this value.

When the transistor **88** is turned off, the SCR **42** will not become nonconductive until the current flowing through it is actually removed. Accordingly, although the signal on line **46** is removed from the gate electrode of the SCR **42**, the SCR **42** will not become nonconductive until the breaker points **20** close. This aspect of the present invention insures that a spurious ignition pulse will not be generated in the secondary winding **22** when the SCR **42** is disabled. That is, the mere removal of the gate signal on line **46** will not cause the current flowing through the primary winding **12** to be interrupted and result in a mistimed ignition pulse.

The diode **94** connected between the cathode electrode of the SCR **42** and the base electrode of the transistor **56** is provided to prevent the current which flows through the Zener diode **50** each ignition cycle to the base electrode of the transistor **56** from being shunted to ground through the low resistance path provided by the resistors **95** and **44**.

Advantageously, the value of the capacitor **60** is selected large enough so that the charging current through the resistors **66** and **68** will result in the transistor **88** being turned on for the lowest engine speed for which the resistor **68** may be adjusted. The value of the capacitor **60** is also selected to be small enough so that it will become fully charged during each cycle of the waveform, seen in FIG. **4**, at the maximum engine speed. These constraints on the size of the capacitor **60** are minimized by the method of discharging the capacitor **60**. The pulse that turns on the transistor **56** lasts for only a small percentage of a total ignition cycle so that the capacitor **60** is discharged in about 1 percent of the time that it is charged. Thus, the allowable time to charge the capacitor **60** is maximized. Since the time required to fully charge the capacitor **60** is determined by its capacitive value and the series charging resistance, which is mostly accounted for by resistor **58** whose value is fixed by the characteristics of Zener diode **72**, maximizing charging time maximizes the allowable value of capacitor **60**. Thus, this approach will allow operation at the lowest possible engine speeds.

The present invention, as seen in FIG. **1**, may be slightly modified for use with an electronic ignition system, such as the ignition system disclosed in my copending U.S. application, Ser. No. 758,209, filed Sept. 9, 1968, entitled "Transistorized Ignition System." The ignition system as described therein is shown in FIG. **2**.

In general, the ignition system seen in FIG. **2** is the same as the ignition system seen in FIG. **1**, with the exception of the power switching means which controls the current flow through the primary winding **12**. It can be seen in FIG. **2** that the mechanical breaker points **20** have been replaced by a transistorized switching means.

In the system shown in FIG. **2**, the direct current source **10** is connected to the primary winding **12** through the ignition switch **16** and ballast resistor **18** as in the system in FIG. **1**. A transistor **98**, however, having its collector connected to the terminal **36** and its emitter connected to ground, performs the current switching function of the breaker points **20** and is turned on and off by the electronic ignition system to generate the ignition pulses in the secondary winding **22**. The capacitor **35** connected in parallel with the transistor **98** performs the same function as it did in the system seen in FIG. **1**. A Zener diode **100** having its anode connected to ground and its cathode to the terminal **36**, protects the transistor **98** from an overvoltage when the transistor **98** is turned off.

The timing function of the electronic ignition system is performed by a photoelectric timing means comprising a photocell **102** coupled to the direct current source **10** through a resistor **104**, and a light source **106** which is coupled to the direct current source **10** through a resistor **108**. A shutter wheel **110** having a plurality of spaced accurate segments **112**, corresponding to the number of spark plugs in the engine **32**, is driven by the engine shaft **34**. Light rays from the light source **106** incident upon the photocell **102**, will cause the photocell **102** to become conductive. As the shutter wheel **110** is rotated, the light rays from the light source **106** will be interrupted causing the photocell **102** to become nonconductive. The voltage potential across the photodiode **102** will alternate between the voltage potential of the base electrode of a transistor **114** when the photodiode **102** is nonconductive and ground when the photocell **102** is conductive.

A signal amplifier comprising transistor **114** is responsive to the voltage potential across the photodiode **102** and will generate an amplified output signal at point **115**.

A pulse shaping means including transistors **116** and **118** will respond to the signal at point **115** and generate a square wave output, appearing at the collector of the transistor **118** and also at points **120** and **122**, having the same frequency as the signal appearing at point **115**.

The square wave appearing at point **122** is applied to the base electrode of a transistor **123** and will turn the transistor **123** on and off at a frequency corresponding to the frequency of the square wave. Accordingly, the voltage potential on the collector electrode of the transistor **123** is also a square wave. The base electrode of the transistor **98** is connected to the collector of the transistor **123**. The transistor **98** will be turned on when the transistor **123** is nonconductive, and will be turned off when the transistor **123** is conductive.

The square wave appearing at point **120** on the output of the pulse-shaping means is an input to the sensing means **48** on a line **124**.

The sensing means **48**, seen in FIG. **2**, functions in the same general manner as was described in conjunction with FIG. **1**. That is, the transistor **56** is turned on and off to discharge the capacitor **60** at a frequency proportional to the speed of the engine **32**. The charging current for the capacitor **60** is amplified by the current-amplifying means **99**. The transistor **88**, included in the detector means, is responsive to the current amplifier **99** output and will become conductive to generate an output signal on the line **46** when the charging current for the capacitor **60** exceeds a predetermined value. The signal on the line **46** will cause the SCR **42** to become conductive to short out the switching transistor **98** and disable the ignition system.

The only significant difference between the engine r.p.m. limiting device seen in FIG. **2** and the one seen in FIG. **1** is the source of the timing signals used to control the transistor **56**. Since the timing signals from the collector electrode of the transistor **118** used in the device of FIG. **2** to control the transistor **56** provides a precise definition of the engine speed, the Zener diode **50** and the diode **40** which are employed in the device of FIG. **1** to insure that the transistor **56** will become conductive but once every ignition cycle may be eliminated. Another advantage derived from using these timing signals is that the diode **94** and the resistors **44** and **96** of the device seen in FIG. **1** may also be eliminated since these signals are present regardless of the conductive state of the SCR **42**.

It should be noted, however, that the source of the timing signals used to control the transistor **56** in FIG. **2** could be the same as the source in FIG. **1** if the Zener diode **50**, diode **94** and the resistors **44** and **96** were retained.

I claim:

1. An electronic device for limiting the speed of an internal combustion engine having an ignition coil including a primary winding and a direct current source series connected to one side of said primary winding, said limiting device comprising:

switching means connected in series with said series connected primary winding and direct current source and responsive to said engine speed for alternate actuation to allow current flow through said primary winding and deactuation to interrupt said current flow at an actuation frequency proportional to said engine speed;

sensing means responsively coupled to said switching means for generating an output signal when said actuating frequency reaches a predetermined value;

a silicon-controlled rectifier connected across said switching means and having a gate electrode, said output signal generated by said sensing means being coupled to

said gate electrode, said silicon-controlled rectifier becoming conductive to allow continuous current flow through said primary winding when said output signal is generated by said sensing means.

2. The device as described in claim 1 wherein said sensing means includes (i) an RC charging network including a charging capacitor coupled to said direct current source, and (ii) discharge means responsively coupled to said switching means for discharging said each time said switching means interrupts said current flow through said primary winding, said direct current source charging said charging capacitor to a predetermined voltage potential by a charging current intermediate said discharges, the average value of said charging current being proportional to said engine speed.

3. The device as described in claim 2 wherein said sensing means further includes a detector means responsive to said charging current for generating said output signal to said gate electrode of said silicon-controlled rectifier when the average value of said charging current reaches a predetermined value.

4. The device as described in claim 3 wherein said switching means comprises mechanical breaker points and wherein said sensing means further includes a diode coupled in parallel with said mechanical breaker points.

5. The device as described in claim 3 wherein said switching means comprise a transistorized circuit including a switching transistor connected in series with said primary winding said switching transistor becoming alternately conductive and nonconductive at a frequency proportional to said engine speed.

6. The device as described in claim 5 wherein said switching means further includes a photoelectric timing means coupled to said engine for generating an output timing signal having a frequency proportional to said engine speed, said timing signal being coupled to the base electrode of said switching transistor.

7. The device as described in claim 1 wherein said silicon-controlled rectifier is series connected with a resistor, said series connected silicon-controlled rectifier and resistor being connected in parallel to said switching means, and wherein said sensing means is responsive to current flowing through said series connected silicon-controlled rectifier and resistor when said silicon-controlled rectifier is conductive.

8. A solid-state device for limiting the speed of an internal combustion engine having a direct current source connected to the primary winding of an ignition coil, said limiting device comprising:

means driven by said engine for generating timing signals synchronized with the speed of said engine;

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

switching means in series with said primary winding and responsive to said pulse shaping means, said switching means allowing current flow through said primary winding when actuated and interrupting said current flow when deactuated, said ignition coil generating an ignition pulse when said current flow is interrupted;

sensing means responsive to said engine speed for generating an output signal when said engine speed exceeds a predetermined value; and

a silicon-controlled rectifier connected in parallel with said switching means and having a gate electrode coupled to said sensing means output signal, said silicon-controlled rectifier becoming conductive when said sensing means generates said output signal to allow continuous current flow through said primary winding.

9. The device as described in claim 8 wherein said sensing means includes (i) an RC charging network having a charging capacitor coupled to said direct current source and (ii) a discharge means coupled to said charging capacitor and responsive to said engine speed for discharging said charging capacitor at a rate proportional to said engine speed, said direct current source charging said charging capacitor by a charging current intermediate said discharges, the average value of said charging current being proportional to said engine speed.

10. The device as described in claim 9 wherein said sensing means further includes a detector means responsive to said charge current for generating said output signal when the average value of said charging current reaches a value corresponding to a predetermined engine speed.

11. In an internal combustion engine having an ignition system including an ignition coil having a primary and a secondary winding, and a direct current source coupled to one side of said primary winding an engine r.p.m. limiting device comprising:

switching means having a first terminal connected to ground and a second terminal coupled to the other side of said primary winding and responsive to the speed of said engine for actuating to allow current flow from

said direct current source through said primary winding and deactuating to interrupt said current flow at an actuation frequency proportional to said engine speed, said ignition coil generating an ignition pulse when said current flow is interrupted;

a diode having an anode and a cathode connected to said first and second terminals respectively of said switching means;

a silicon-controlled rectifier having (i) an anode electrode coupled to said second terminal of said switching means, (ii) a cathode electrode coupled to said first terminal of said switching means, and (iii) a gate electrode, said silicon-controlled rectifier becoming conductive to disable said ignition system when an appropriate signal is applied to said gate electrode;

a resistor connected intermediate said cathode electrode of said silicon-controlled rectifier and said first terminal of said switching means, and

a sensing means coupled to said second terminal of said switching means and responsive to said ignition pulses generated by said ignition coil for generating an output signal to said gate electrode of said silicon-controlled rectifier to disable said ignition system when said ignition pulses occur at a frequency corresponding to a predetermined engine speed, said control means being further responsive to current flow through said series connected silicon-controlled rectifier and resistor to maintain said output signal to said gate electrode when said ignition system is disabled until said engine speed slows to a value below said predetermined value.

12. The device as described in claim 11 wherein said sensing means includes an RC charging network including a charging capacitor coupled to said direct current source and discharge means responsive to said ignition pulses generated by said ignition coil and coupled to said charging capacitor for discharging said charging capacitor at a frequency determined by the frequency of said ignition pulses, said direct current source charging said charging capacitor with a changing current intermediate said discharges, the average value of said charge current being proportional to said engine speed.

13. The device as described in claim 12 wherein said sensing means further includes a detector means responsive to said charge current for generating said output signal when the average value of said charging current reaches a value corresponding to a predetermined engine speed.

14. The device as described in claim 13 wherein said switching means comprises mechanical breaker points.

15. The device as described in claim 13 wherein said switching means comprises a photoelectric timing means responsive to said engine speed for generating a timing signal proportional to said engine speed, and a switching transistor connected in series with said primary winding said switching transistor having a base electrode responsively coupled to said timing signal.

16. The device defined in claim 1 wherein said current flow through said silicon-controlled rectifier is limited when said silicon-controlled rectifier is conductive, to inhibit ignition

pulses while allowing sufficient current changes in said primary circuit to allow actuation of said sensing means, thereby allowing operation of said device while the ignition system is disabled.

17. The device defined in claim 1 additionally comprising:
a diode, parallel connected to said switching means, said diode eliminating spurious signals from said switching means and thereby allowing said sensing means to produce said output signal at a frequency no lower than said predetermined frequency.

18. A solid-state device for limiting the speed of an internal combustion engine having a direct current source connected to the primary winding of an ignition coil, said limiting device comprising:
means driven by said engine for generating timing signals synchronized with the speed of said engine;
pulse shaping means responsive to said timing means for generating a square wave having a frequency determined by said timing signals;
switching means in series with said primary winding and responsive to said pulse shaping means, said switching means allowing current flow through said primary winding when actuated and interrupting said current flow when deactuated, said ignition coil generating an ignition pulse when said current flow is interrupted;
a capacitor;
means responsive to said engine speed for charging said capacitor;
sensing means responsive to said capacitor charging means for generating an output signal when said engine speed exceeds a predetermined value; and
a silicon-controlled rectifier connected in parallel with said switching means and having a gate electrode coupled to said sensing means output signal, said silicon-controlled rectifier becoming conductive when said sensing means generates said output signal to allow continuous current through said primary winding.

19. The device as described in claim 18 wherein said capacitor charging means charges said capacitor with a charging current the average value of which is proportional to said engine speed.

20. An electronic device for limiting the speed of an internal combustion engine having an ignition coil including a primary winding and a direct current source series connected to one side of said primary winding, said limiting device comprising:
switching means connected in series with said series connected primary winding and direct current source and responsive to said engine speed for alternately actuating to allow current flow to be said primary winding and deactuating to interrupt said current flow at an actuation frequency proportional to said engine speed;
a diode parallel connected with said switching means, to control the waveform produced by said switching means; and
control means responsive to said switching means for inhibiting the operation of said ignition coil when said actuation frequency reaches a predetermined level.

21. An electronic device for limiting the speed of an internal combustion engine having an ignition coil including a primary winding and a direct current source series connected to one side of said primary winding, said limiting device comprising:
switching means connected in series with said series connected primary winding and direct current source and responsive to said engine speed for alternate actuation to allow current flow through said primary winding and deactuation to interrupt said current flow at an actuation frequency proportional to said engine speed;
sensing means responsively coupled to said switching means for generating an output signal determined by said actuation frequency; and
a solid-state switch connected across said switching means and having a gate electrode, said output signal generated by said sensing means being coupled to said gate electrode, said solid-state switch becoming conductive to allow continuous current flow through said primary winding when said actuation frequency reaches a predetermined value.

22. An electronic device as defined in claim 21 additionally comprising:
a resistor, series connected with said solid-state switch, said series resistor and solid-state switch being connected in parallel with said switching means, said solid-state switch, when conductive, allowing current flow through said coil primary and said resistor when said switching means is deactuated, said resistor having a value which is sufficiently low that changes in the current flow through said primary winding caused by actuation and deactuation of said switching means when said solid-state switch is conductive will not produce ignition pulses; and
sensing means is responsive to changes in the current flow in said primary winding caused by actuation and deactuation of said switching means regardless of actuation or deactuation of said solid-state switch.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,581,720 Dated June 1, 1971

Inventor(s) Lewis W. Hemphill et al.

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

Column 3, line 21, "an" should read -- and --; line 42, "an" should read -- and --. Column 5, line 5, "an" should read -- and --. Column 7, line 17, "95" should read -- 96 --. Column 9, line 9, after "said", first occurrence, insert -- charging capacitor --; line 26, "comprise" should read -- comprises --. Column 10, line 16, should not have started new paragraph after "from"; line 35, after "means" the comma should be a semicolon.

Signed and sealed this 4th day of January 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents

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