

March 23, 1971

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3,572,302

INTERNAL COMBUSTION ENGINE SPEED LIMITING APPARATUS

Filed April 16, 1969

4 Sheets-Sheet 1

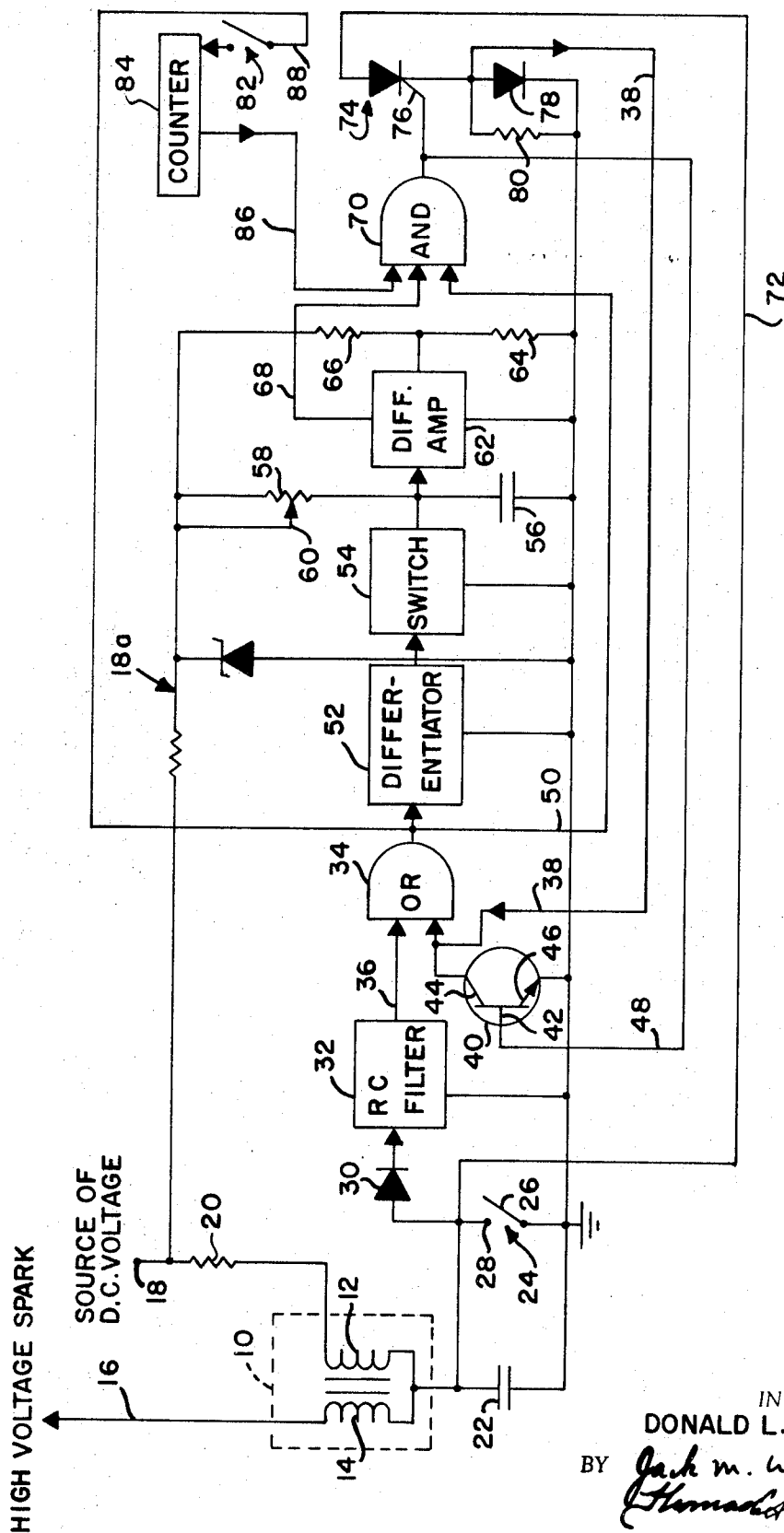


FIG. 1

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4 Sheets-Sheet 2

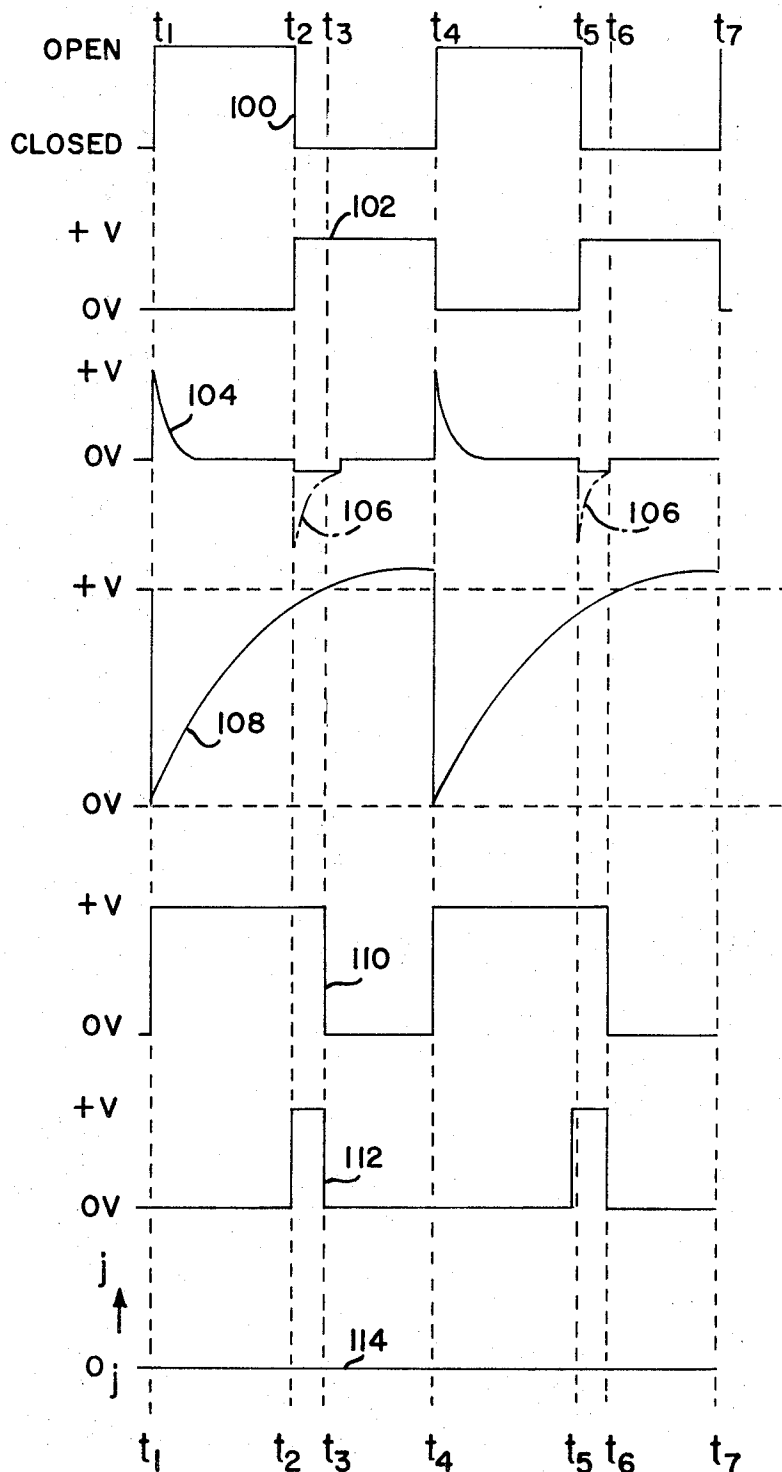


FIG. 2

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Filed April 16, 1969

4 Sheets-Sheet 3

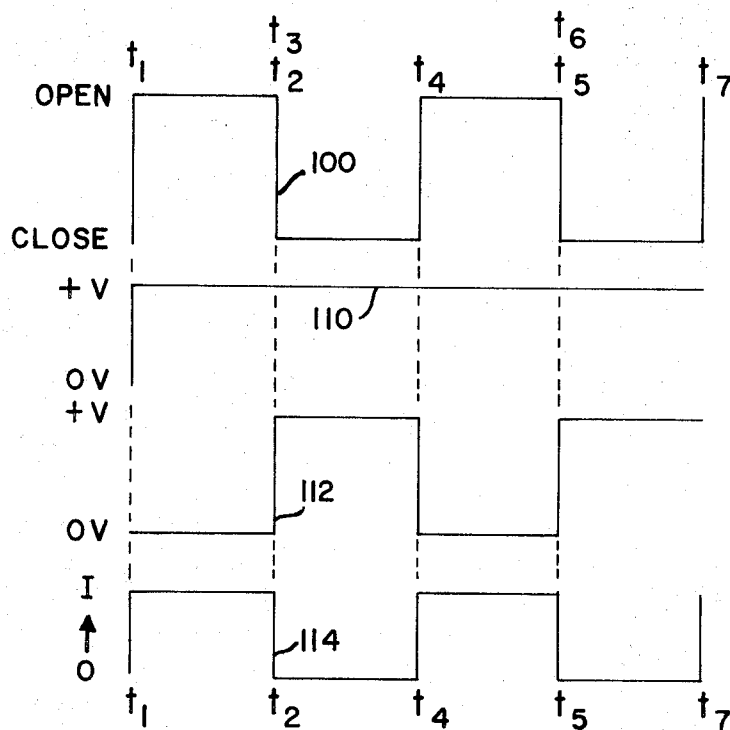


FIG. 3

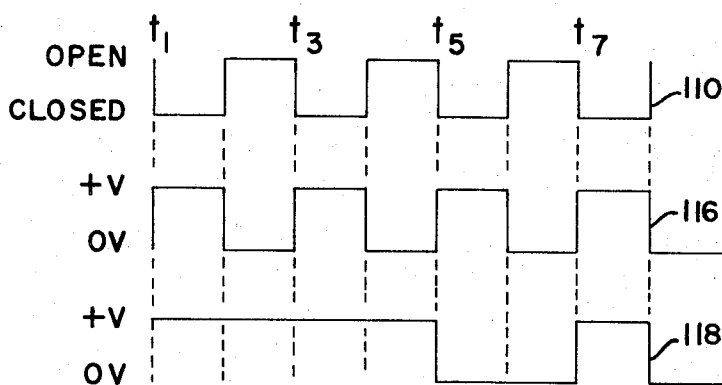


FIG. 4

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4 Sheets-Sheet 4

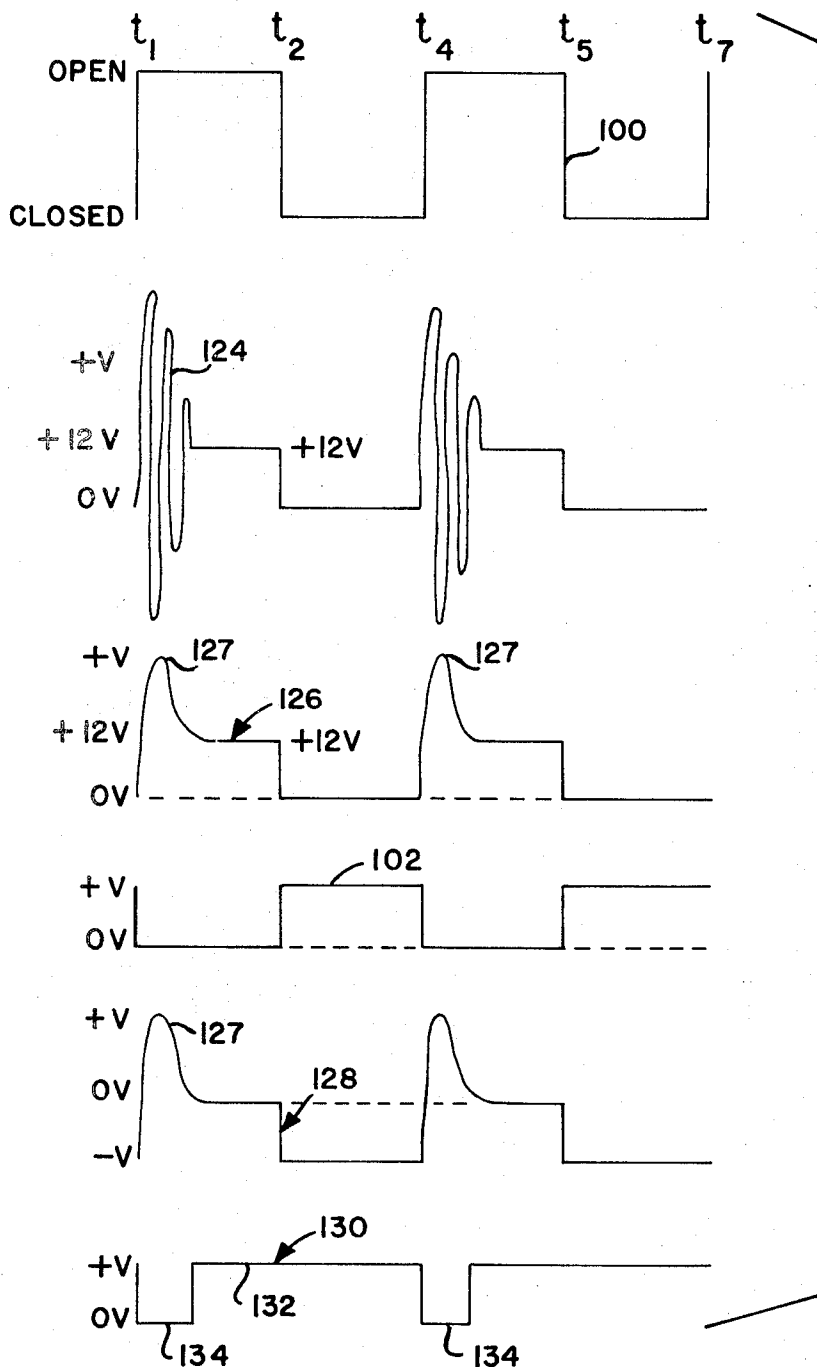


FIG. 6

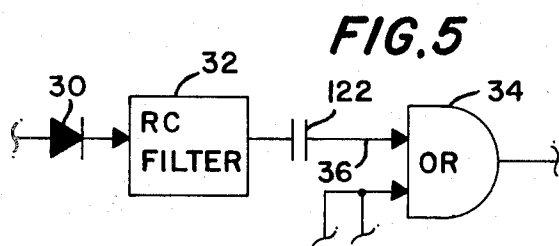


FIG. 5

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INTERNAL COMBUSTION ENGINE SPEED LIMITING APPARATUS

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Filed Apr. 16, 1969, Ser. No. 816,647

Int. Cl. F02p 9/00; H02p 3/00; H02h 3/00

U.S. Cl. 123-118

16 Claims

ABSTRACT OF THE DISCLOSURE

A thyristor in parallel with the ignition timing switch of an internal combustion engine is turned on to prevent ignition sparks at the desired limiting speed. Timing is provided by fixed duration pulses having a time duration equal to the time between ignition sparks at the limiting speed. The effects of ignition timing switch contacts bouncing are prevented by the thyristor shorting out the bouncing contacts and dwell time is increased to near the theoretical maximum by allowing current flow to the ignition coil by way of the thyristor when the ignition timing switch contacts are open and after the ignition spark occurs.

BACKGROUND OF THE INVENTION

This invention relates to internal combustion engine speed limiting apparatus, and more particularly to such apparatus that uses fixed duration pulses to short out the ignition spark producing switch means at the desired engine speed to provide engine speed limiting.

An internal combustion engine speed limiter is a form of governor that prevents engine runaway under conditions that would otherwise allow the engine speed to become excessive. For example, in auto racing when power shifting is taking place, the engine may run faster than is safe while the driver is shifting gears. Engine speed limiting can be accomplished by various means, such as by shorting out the ignition coil; mechanically preventing the breaker points from opening; shorting out the breaker points; and the like. One system heretofore used in the prior art comprises an electrical tachometer coupled to the engine and adapted to provide a voltage output the magnitude of which is proportional to the engine speed. Once this output voltage indicates the speed limit has been reached, a voltage level detector, such as a Schmitt trigger or differential amplifier, produces an output which is used to short out the breaker points thereby preventing interruption of current flow through the ignition coil. This system does not provide uniform performance under various temperature conditions and ignition system noise. Also, the electrical tachometer is relatively expensive and the system does not lend itself to correcting other associated ignition problems, such as point bouncing, dwell time, backfiring and the like.

SUMMARY OF THE INVENTION

A primary purpose of this invention is to provide an all electronic internal combustion engine speed limiting apparatus that also enables the dwell time to be near the theoretical maximum; eliminates the effects of point bouncing; and reduces or eliminates backfiring. Briefly described, this is accomplished for an internal combustion engine ignition system which includes a source of potential coupling to the primary winding of an ignition coil and ignition timing switching means operable in synchronism with the speed of the engine for interrupting current flow through the primary winding to generate an ignition spark. The speed limiting apparatus includes pulse generating means coupled to said ignition switching means for generating pulses having a predetermined duration and

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means, such as a thyristor. The thyristor is connectable to the ignition switching means and the pulse generating means for inhibiting the interruption of current flow through the ignition coil by shorting out the ignition switching means whenever the duration of the pulses is at least substantially equal to the time interval between ignition sparks as determined by the speed of the engine. By causing the thyristor to turn on after an ignition spark has occurred but while the points, or ignition switching means, are open, the dwell time is increased to near its theoretical maximum. Also, point bouncing causes the thyristor to conduct if it occurs during the duration of the pulses to prevent interruption of current flow through the ignition coil by such point bouncing. Further, by suitable means, such as an electronic counter, the inhibiting of ignition sparks at, or above, the limiting speed can be prevented to allow an ignition spark to occur each time a predetermined number of such sparks have been prevented to completely insure that no backfiring occurs or that there is not an abrupt loss of power at the limiting speed.

DESCRIPTION OF THE DRAWINGS

These and other features, objects and advantages of the present invention will be apparent from consideration of the following detailed description taken in conjunction with the annexed drawings, in which like reference characters designate like or corresponding parts throughout the several drawings, and wherein:

FIG. 1 is a schematic illustration of engine speed limiting apparatus in accordance with this invention;

FIGS. 2, 3 and 4 illustrate various waveforms within the apparatus of FIG. 1;

FIG. 5 illustrates a modification of the apparatus of FIG. 1 in accordance with this invention; and

FIG. 6 illustrates various waveforms within the apparatus of FIGS. 1 and 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a portion of a conventional ignition system for an internal combustion engine and includes an ignition coil 10, a primary winding 12 and a secondary winding 14. The secondary winding 14 is electrically coupled to spark discharge devices, such as spark plugs (not shown) in a predetermined sequence by a high voltage distributor (not shown) which is synchronized with the speed of the engine. The primary winding 12 of the ignition coil 10 is coupled to a switch 24 having contacts 26 and 28. Across the contacts 26 and 28 is connected a capacitor 22. Instead of breaker points 26 and 28, the switch 24 may comprise a current switching device, such as a transistor, which is adapted to be turned on and off to function as a current switch.

The other side of the primary winding 12 is coupled to a source 18 of D.C. potential by way of a current limiting resistor 20. This potential source 18 is generally the D.C. battery associated with internal combustion engines. Ideally, the operation of this well-known ignition system is such that, when closed, the switch 24 enables current flow through the primary winding 12. When the switch 24 is opened to interrupt current flow through the primary winding, the high voltage distributor is in a position to efficiently transfer a resulting high voltage, appearing in the secondary windings 14 of the ignition coil due to this interruption of current flow, to one of a plurality of spark plugs. The switch 24 is generally located in the high voltage distributor housing and is generally driven (open and closed) by a cam on the same shaft (not shown) that operates the distributor. The speed of this shaft is synchronized with the speed of the engine.

As shown by FIG. 1, the contact 28 of the switch 24 is coupled to the source 18 of D.C. potential by way of the primary winding 12 and the resistor 20, and the contact 26 is grounded. In accordance with this invention, circuit means for electrically shorting out the ignition timing switch 24 is provided and may comprise a silicon controlled rectifier, or thyristor 74. The anode of the thyristor 74 is coupled to the contact 28 of the switch 24 by way of a lead 72 and the cathode of the thyristor 74 is coupled to ground by way of a parallel diode 78 and a resistor 80. The diode 78 has its cathode grounded and its anode coupled to the cathode of the thyristor 74. As will be apparent to those skilled in the art, current flow through the diode 78 and thyristor 74, which are electrically in parallel with the switch 24, cause a virtual short circuit across the switch 24. The parallel diode 78 and resistor 80 provide a voltage pulse, corresponding to current flow in the thyristor 74, on a lead 38 for reasons discussed hereinbelow. The diode 78 provides good sensitivity at low current levels by providing a high impedance when no current flows or it is non-conducting and a low impedance to current flow or when it is conducting. The resistor 80 provides a path for the thyristor 74 and the diode 78 leakage currents to enable rapid switching of current through the thyristor 74.

The operation of the thyristor 74 is such that once it is turned on by a positive potential appearing on its control element 76, it will remain on. Specifically, current will flow through the thyristor 76, until its anode current is decreased to zero or its anode to cathode voltage is reduced to zero. When the contacts 26 and 28 of the switch 24 close, the anode to cathode voltage of the thyristor 74 becomes zero and if it had been on, it is turned off. If already off, closing of the switch 24 contacts 26 and 28 have no effect on the thyristor 74. Should, however, a positive potential appear on the control element 76 of the thyristor 74 at the time the contacts 26 and 28 of the switch 24 opened for generation of an ignition spark, the thyristor 74 will be turned on. Turning on the thyristor 74 causes the current flow therethrough to be supplied to the primary winding 12 of the ignition coil 10 and also causes the open contacts 26 and 28 to be shorted out. Since current flow through the primary winding 12 of the ignition coil 10 is not interrupted by the switch contacts 26 and 28 opening, an ignition spark is not generated. As soon as the contacts 26 and 28 of the switch 24 close again, the thyristor 74 is turned off as described above and current flow through the switch 24 flows through the primary winding 12.

With the proper signal on the control element 76 of the thyristor 74, the thyristor 74 can control the ignition from one spark to the next, either shorting the ignition switch 24 or not depending upon the potential of the control element 76 of the thyristor 74. In accordance with the present invention pulses having a duration equal to the time interval between ignition sparks at the engine speed at which engine speed limiting is to occur are generated. Below this limiting speed these pulses no longer exist when the contacts 26 and 28 open to generate an ignition spark and such ignition sparks are not prevented by the thyristor 74 turning on. However, at, and above, this limiting engine speed the occurrence of these pulses when the contacts 26 and 28 open cause the thyristor 74 to turn on to prevent the generation of ignition sparks and thereby limit the speed of the associated internal combustion engine.

Referring again to FIG. 1, it is seen that the contact 28 of the switch 24 is coupled to an RC filter 32 by way of a diode 30 which has its anode coupled to the contact 28 and its cathode coupled to the RC filter 32 so that only the positive potential appearing across the switch 24 is applied to the filter 32. The output of the RC filter 32 is applied to one input of an OR gate 34 by way of a lead 36 and the other input to the OR gate appears on a lead 38 and comprises the voltage appearing on the diode 78. The output of the OR gate 34 is applied to a differentiator circuit 52 that drives a capacitor discharge switch 54.

When turned on, the switch 54 provides a virtual short

circuit discharge path for a capacitor 56 to rapidly discharge the capacitor 56. Discharging of the capacitor 56 causes a differential amplifier 62 to produce a positive potential on its output lead 68. This positive potential remains on the lead 68 until the capacitor 56 charges, through the potentiometer 58 which is coupled to the D.C. potential source 18 as shown, through a Zener diode voltage regulator network 18a to a positive level determined by the voltage across a resistor 64. One end of the resistor 64 is grounded and its other end is coupled to the source 18 of D.C. potential by way of a resistor 66. These resistors 64 and 66 comprise a voltage divider network. The junction of these resistors 64 and 66 are coupled to the differential amplifier 62 and provides a reference potential to which the capacitor 56 must charge to reduce the positive potential on lead 68 to zero. The operation of the differential amplifier 62 and associated circuitry is well known in the art and need not be explained in detail. It is clear, however, that the duration of the positive potential, or pulse, appearing on the lead 68 is determined by the time required to charge the discharge capacitor 56 to the reference potential appearing across the resistor 64 and that this charging time is determined by the RC time constant defined by the value of the capacitor 56 and the potentiometer 58. Accordingly, the duration of the positive pulse on the lead 68 can be varied by varying the arm 60 of the potentiometer 58 which varies the resistance in the charging path of the capacitor 56. As will be described below in detail, the capacitor 56 is discharged at the time an ignition spark occurs, or would normally occur, and the setting of the arm 60 is such that the capacitor 56 charges to the reference potential in a time interval that is equal to the time interval between ignition sparks at the engine speed at which speed limiting is to occur. Therefore, ignition sparks are prevented at the preset engine limiting speed by conduction of the thyristor 74 to limit the speed of the engine. Accordingly, the positive pulses on the lead 68 having a leading edge which corresponds to the occurrence of an ignition spark, actual or suppressed, and the positive pulses have a duration equal to the duration between ignition sparks at the desired limited engine speed.

The output of the differential amplifier 62 on the lead 68 is applied as one input to an AND gate 70. Another input of the AND gate 70 is the output of the OR gate 34 appearing on a lead 50. The output of the AND gate 70 comprises the drive to the control element 76 of the thyristor 74. This input to the control element 76 of the thyristor 74 is also applied to the base 42 of a transistor 40. The collector 44 of the transistor 40 is coupled to the input of the OR gate circuit 34 and has its input signal supplied by the conduction of the thyristor 74. The emitter 46 of the transistor 40 is grounded. As is described below in detail, the transistor 40 will conduct and prevent the generation of undesirable ignition sparks whenever the contacts 26 and 28 of the switch 24 bounce at high engine speeds.

The output of the OR gate circuit 34 may be connected to a counter 84, when the switch 82 is closed. The output of the counter 84 is applied to the control element 76 of the thyristor 74 by way of a lead 86. The counter 84 may be used, as described below in detail, to insure that backfiring of the engine is prevented when speed limiting of the engine takes place.

The present invention will now be described in detail with reference to FIGS. 1 and 2. Assume that the associated internal combustion engine is running. The contacts 26 and 28 of the switch 24 will open and close in synchronism with the speed of the engine in a well known manner. When the contacts 26 and 28 are closed, current will flow through the primary winding 12 of the ignition coil 10 and when the contacts 26 and 28 open, an ignition spark will be generated in the secondary winding 14. As shown by graph 100 in FIG. 2, the contacts 26 and 28 are closed during time intervals t_2 to t_4 and t_5 to t_7 . The contacts 26 and 28 are open during time intervals t_1 to t_2 and t_4 to t_5 .

Accordingly, ignition sparks occur at times t_1 , t_4 and t_7 . The diode 30 only enables the positive potential appearing across the ignition switch 24 to be applied to the OR gate 34 by way of the RC filter 32.

When the ignition switch 24 is closed, the potential thereacross is zero and, when opened, a rapidly varying voltage initially appears thereacross due to the collapse of the magnetic field around the primary winding. This rapid fluctuation of voltage at the time of an ignition spark is followed by a constant, D.C. level equal to the value of the D.C. source 18. The A.C. potential rapid fluctuations are filtered by the RC filter 32 in a manner as described herebelow in conjunction with FIGS. 5 and 6, while the constant D.C. level is not affected by the filter 32. The A.C. potential output of the filter 32 is applied to the OR gate 34 which is also an inverter circuit. Accordingly, the output of the OR gate 32, as shown by the waveshape 102 of FIG. 2, is positive when the contacts 26 and 28 are closed (t_2 to t_4 and t_5 to t_7) and zero when the contacts are open (t_1 to t_2 and t_4 to t_5). The output signal 102 is applied to the differentiator 52 which again inverts the signal before it is differentiated. The differentiated signal is shown in FIG. 2 by the waveshape 104. The negative voltage spikes (shown by the reference character 106) produced by the differentiation are clipped by well known means and the positive voltage spikes thus produced are applied to the capacitor discharge switch 54. As shown by FIG. 2, the positive voltage spikes occur at times t_1 and t_4 which correspond to the time occurrence of the ignition sparks. In FIGS. 2-4 and 6, the sources 18 of potential was assumed to be positive. It is realized that the negative source of potential may also be used.

The positive voltage spikes turn the discharge switch 54 on causing the capacitor 56 to rapidly discharge there-through. The voltage across the capacitor is shown in FIG. 2 by the waveshape 108. As shown by FIG. 2, the capacitor 56 begins charging at a rate determined by the arm 60 of the potentiometer 58 as described above, after being discharged to substantially zero volts. Starting the time t_1 , when the capacitor 56 is discharged, the potential on the output lead 68 of the differential amplifier 52 becomes positive as shown by waveshape 110 of FIG. 2. This positive potential remains until the capacitor 56 charges to the reference potential described above. FIG. 2 shows the capacitor 56 being charged to the reference potential by time t_3 at which time the potential of the waveform 110 on the lead 69 (FIG. 2) becomes zero. At time t_4 , when the capacitor is discharged, the potential of the waveform 110 is again positive until time t_6 at which time the capacitor 56 again charges to the reference potential.

The voltage pulses 110 constitute one input of the AND gate 70 which is enabled when both of its inputs are positive. The other input to the AND gate 70 is the output of the OR gate 34 on the lead 50. As shown by FIG. 2, the output signal 102 of the OR gate 34 is positive when the switch 24 contacts 26 and 28 are closed and zero when the contacts 24 and 26 are open. The voltage pulses 110 on the other hand are positive once the contacts 26 and 28 open and remain positive for a predetermined time as described above. It is clear then that the AND gate 70 cannot be enabled during the time periods t_1 to t_2 and t_4 to t_5 , since during this time the contacts 26 and 28 have been opened to generate an ignition spark as shown in FIG. 2. The AND gate 70 can only be enabled when both of its inputs are positive. As shown by FIG. 2, this occurs only after the contacts 26 and 28 close and the positive pulse 110 supplied by the differential amplifier 52 occurs. As shown in FIG. 2, by way of example for a given engine speed, this may occur during time intervals t_2 to t_3 and t_5 to t_6 . When enabled, the AND gate 70 provides a positive potential to the control element 76 of the thyristor 74, as shown by the waveshape 112 of FIG. 2. However, since the contacts 26 and 28 are closed during the time the AND gate 70 is enabled, t_2 to t_3 and t_5 to t_6 , the anode

to cathode potential of the thyristor 74 is zero and the thyristor 74 cannot conduct as shown by the waveshape 114 of FIG. 2, which shows that the thyristor 74 does not conduct for the entire time t_1 to t_7 . The time period illustrated is the time t_1 to t_7 .

FIG. 2 illustrates waveforms for an engine speed where the time duration of the pulses 110 is greater than the time the contacts 26 and 28 are opened. As will now be apparent from the above description and a perusal of FIGS. 1 and 2, for engine speeds slower than that shown in FIG. 2, the time the contacts 16 and 28 are closed can be greater than the duration of the pulses 110. At these low engine speeds, the AND gate 70 will never be enabled. Conversely, as the engine speed increases, the time intervals during which the contacts are open t_1 to t_2 , t_4 to t_5 and closed t_2 to t_4 and t_5 to t_7 become shorter and shorter. As this occurs the time interval between t_3 when the positive potential of the waveform 112 appears on the control element 76 of the thyristor 74, and t_4 when the contacts 26 and 28 again open, becomes less and less. This is so because, as described above, the time duration of the pulses 110 from the differential amplifier 52 is fixed by the position of the arm 60 of potentiometer 58.

By setting the potentiometer 58 to produce a pulse 110 having a duration substantially equal to the time duration between ignition sparks at the engine speed at which engine speed limiting occurs, positive potential of the signal 112 appears on the control element 76 of the thyristor 74 at the engine limiting speed to prevent ignition sparks. This is shown in FIG. 3 where various waveshapes are illustrated for the apparatus of FIG. 2 when the engine speed is being limited. The waveshape 100 illustrates the opening and closing of the contacts 26 and 28. The engine speed is such that the time interval between needed ignition sparks is equal to, or less than, the time duration of the pulses 110 produced by the differential amplifier 62 on the lead 68. For this condition, the capacitor 56 never does have time to charge to the reference potential and the waveshape 110 remains at the positive level as shown by FIG. 3. This results in the AND gate 70 being enabled each time the contacts 26 and 28 close to apply a positive potential of the signal 112 on the control element 76 of the thyristor 74. The next time the contacts 26 and 28 open, the positive potential of the signal 112 on the thyristor control element 76 causes the thyristor 74 to conduct.

The current flow through the conducting thyristor 74 and through the primary winding 12 of the ignition coil 10 by way of the lead 72 shorts out the switch 24 and prevents interruption of current flow through the primary winding 12, thereby preventing the generation of an ignition spark in the secondary winding 14. Since the input to the AND gate 70 appearing on lead 50 (waveshape 102 of FIG. 2) is zero when the contacts 26 and 28 are open, the AND gate 70 is disabled while the contacts 26 and 28 are open and the positive potential signal 110 does not appear on the control element 76 of the thyristor 74 for these intervals t_1 to t_2 , t_4 to t_5 et cetera. However, once turned on, the thyristor 74 remains on until shorted out by the contacts 26 and 28 closing during time intervals t_2 to t_4 and t_5 to t_7 . Current flow through the ignition coil 10 is never interrupted when the speed of the engine is being limited and the engine is alternately supplied by current flow through the closed contacts 26 and 28 and through the thyristor 74 when the switch contacts 26 and 28 open. Waveform 114 of FIG. 3 illustrates current flow through the thyristor 74 during speed limiting.

Referring now to FIG. 1, it will be apparent that the last ignition spark before speed limiting occurs, during which no ignition sparks occur, triggers the output pulse 110 (FIGS. 2 and 3) from the differential amplifier 52. During speed limiting however, the voltage across the switch 24 is always zero. Accordingly, some other means must be used to produce the pulses generated for dis-

charging the capacitor 56. This is accomplished by the voltage drop appearing across the parallel network comprising the diode 78 and the resistor 80 which is in series with the thyristor 74. As shown by FIG. 3, during speed limiting, current flows through the thyristor 74 only when the ignition switch contacts 26 and 28 are open, as described above. This causes the potential appearing across the parallel connected diode 78 and resistor 80 to be positive when the contacts 26 and 28 are open and zero when they are closed. This potential is applied to the OR gate 34 by way of the lead 38 and is of the opposite polarity but has the same timing as the potential of the waveform 102 (FIG. 2). During speed limiting, this signal is applied to the OR gate 34 from the conductor 38 and takes the place of the signal which would come from the RC filter 32 when speed limiting does not occur. Accordingly, the capacitor 56 is discharged each time a spark occurs during engine speeds less than the desired limiting speed through the conductor 36 and is discharged each time a voltage appears across the diode 78 through the conductor 38 at engine speeds equal to or greater than the desired limiting speed.

As will now be apparent, the engine speed at which speed limiting occurs is determined by the duration of the output pulse 110 from the differential amplifier 52 appearing on the lead 68 which in turn is determined by the charging time constant of the capacitor 56 by way of the potentiometer 58. This accurate determination of the limiting speed appears as an instantaneous but gradual loss of acceleration upon reaching the engine speed limit. The engine speed is then held at the limit during the time no ignition sparks can occur until the engine speed falls below the limit at which time full engine power is immediately restored. This is so because the apparatus of FIG. 1 produces little or no hysteresis. Thus, ignition sparks are eliminated when the engine speed exceeds the predetermined limit and ignition sparks return when the engine speed drops below the same predetermined limit. Since the spark plug first fired after the engine speed falls below the speed limit after speed limiting has occurred is entirely random, back-firing of the engine during speed limiting as a result of unfired vapors collecting in unfired cylinders is substantially reduced. Hence, at full power, the engine speed is such that speed limiting is taking place frequently, thereby causing the spark plugs to be randomly but continuously fired as the engine speed falls below the limit each time speed limiting occurs.

Backfiring, as is well known to those in the art, is the result of a cylinder piston being rotated many revolutions without an ignition spark thus enabling the cylinder to load up with fuel causing a rapid and violent burning thereof and is called backfiring. As discussed above, the apparatus of FIG. 1 inhibits backfiring. However, only where slight backfiring can be very damaging, such as when using supercharged engines, or when an abrupt loss of engine torque upon reaching the engine speed limit is undesirable, such as circuit track racing cars in cornering situations, backfiring can be completely eliminated and an abrupt engine torque loss can be prevented by utilizing the counter 84 of FIG. 1 by closing the switch 82. The counter 84, which may comprise a well known frequency divider, receives the voltage pulses appearing on the output of the OR gate 34. These pulses are illustrated by the waveshape 116 of FIG. 4. The operation of the counter 84 is such that through the conductor 86 an additional input is available to the AND gate 70, which produces an output signal appearing on the control element 76 of the thyristor 74, whereby the ignition sparks can occur every third, fifth, seventh, or other non-integral number for an engine having two, four or eight cylinders. Waveform 118 of FIG. 4 illustrates a spark firing on every third pulse. This guarantees that each cylinder is fired periodically thus preventing an abrupt loss of engine torque at the engine speed limit and also prevents backfiring during speed limiting.

Referring now to FIGS. 1 and 4 assuming that the counter provides an output signal 118 from the input signal 116, it is seen that every third ignition pulse is allowed to fire by inhibiting the drive to the thyristor 74 from the AND gate 70 when input signal 118 is at zero volts, at times t_1 and t_7 and ignition spark was prevented by a positive potential pulse 118 from the counter 84. During the time t_3 , the output signal 118 allows an ignition pulse to fire. A counter that provides an output for every two inputs has been described by way of example only it being understood that any counter that enables any non-integral number of ignition sparks to occur would be satisfactory for an engine having two, four and eight cylinders.

The ignition timing switch 24 of FIG. 1 may comprise mechanical "breaker" points. One of the disadvantages of such mechanical breaker points is that they bounce at high engine speeds which causes loss of high spark voltages and causes erratic readings on many ignition operated tachometers. The apparatus of FIG. 1 includes anti-breaker point bounce means which suppresses high speed miss or bouncing. Bouncing occurs when the contacts 26 and 28 open at high engine speeds during a period when they should be closed. FIG. 2 shows when the contacts 26 and 28 are to be closed during the time intervals t_2 to t_4 and t_5 to t_7 et cetera. Also, as discussed above, the fixed time duration output pulses 110 which are applied as one input to the AND gate 70 occur for the entire period of the time intervals t_2 to t_4 and t_5 to t_7 during engine speed limiting and occur for most of the period of these time intervals during high engine speeds below the limit speed during which speed limiting does not take place. Further, as discussed above, the other input to the AND gate 70 is positive when the contacts are normally closed, t_2 to t_4 and t_5 to t_7 .

Assume now that during a time interval t_3 to t_4 or t_5 to t_7 that the contacts 26 and 28 open due to bouncing and that the pulse 110 is positive because engine speed limiting is taking place as the pulse 110 extends into the time interval in which the bounce occurs because of the engine speed will be near a limiting condition. As shown by FIGS. 1, 2 and 3, this condition causes the AND gate 70 to be enabled and a positive potential to appear on the control element 76 of the thyristor 74. Just before the bounce occurs, the contacts 26 and 28 being closed prevent the thyristor 74 from turning on. When the contacts open during the bounce, the positive potential appearing on the control element 76 and the contacts 26 and 28 being open cause the thyristor 74 to turn on thereby providing uninterrupted current flow through the ignition coil 10 to prevent the occurrence of an ignition spark. The thyristor 74 will remain on until the contacts 26 and 28 again close. This occurs before the contacts 26 and 28 are opened at times t_1 , t_4 , t_7 et cetera. More than once bounce may occur during the time intervals the contacts 26 and 28 should be closed. However, for each bounce occurring the thyristor 74 is turned on, as described above, to prevent the generation of an ignition spark. As discussed above, current flow through the thyristor 74 causes a positive potential to be applied to the OR gate 34 by way of the lead 38 that would cause the capacitor 56 to discharge to initiate another fixed duration pulse from the differential amplifier 62. This obviously is undesirable during bouncing and is prevented by the transistor 40 conducting during the time signal 112 is positive.

When the thyristor 74 is turned on during bouncing, the positive potential on the control element 76 is coupled to the base 42 of the NPN transistor 40 by the lead 48. The emitter 46 of the transistor 40 being grounded is less positive than the base 42 of the transistor 40. The collector 44 of the transistor is coupled to the small positive potential being applied to the OR gate 34 by way of the lead 38 which causes the transistor 40 to be conducting. When conducting, the transistor 40 is a virtual short circuit to ground and any positive potential

appearing on lead 38 will be shorted to ground there-through rather than being applied to the OR gate 34. Accordingly, conduction of the thyristor 74 during bouncing does not discharge the capacitor 56. During engine speed limiting, however, when the thyristor 74 is turned on at times t_1 , t_4 , t_7 , et cetera to prevent the occurrence of an ignition spark, the positive potential of the signal 112 (FIG. 3) drops to zero just as the thyristor 74 is turned on. Consequently, no positive potential is applied to the base 42 of the transistor 40 to turn it on at times t_1 , t_4 , t_7 et cetera for grounding out the input signal to the OR gate 34, which input signal appears on lead the 38. Although the apparatus of FIG. 1 does not prevent the contacts 26 and 28 from bouncing, it does prevent the effects of bouncing, that is, interruption of current flow through the ignition coil 10.

As illustrated by the waveshape 100 in FIG. 2, the contacts 26 and 28 are alternatively opened and closed. When open, no current flows through the ignition coil 10 if engine speed limiting is not taking place. When closed, current can build up in the ignition coil 10 before current therethrough is interrupted to produce an ignition spark. At high engine speeds for racing, but at speeds below the engine limiting speed as determined by the arm 60 of the potentiometer 58 (FIG. 1), the time interval during which the contacts 26 and 28 are closed t_2 to t_4 , t_5 to t_7 et cetera is so short that current in the primary winding 12 of the ignition coil 10 does not have time to build up to a desired level. The time constant for current flow through the primary winding 12 is determined by its inductance and its series resistance. At high engine speeds, the current in the primary winding 12 is interrupted long before the energy stored in the primary winding 12 is at a desired level. For example at 8,000 r.p.m. an eight cylinder engine requires an ignition spark at 1.67 millisecond intervals. For a typical ignition coil, this only allows the energy in the primary winding at the time current is interrupted therethrough to produce an ignition spark causes misfiring at such high engine speeds. To overcome this, prior art ignition systems for high speed engines utilized a dual point distributor or dual ignition coils. The present invention greatly increases dwell time (time current flows through the primary winding of the ignition coil before being interrupted) merely by adding a capacitor to the apparatus of FIG. 1 as described below in detail.

Referring now to FIGS. 1 and 2, it is seen that the output signal 102 of the OR gate 34 is zero when the ignition switch 24 is open, thus preventing the AND gate 70 from turning the thyristor 74 on. It can be seen that if, after an ignition spark has been generated, the thyristor 74 is turned on during the time intervals t_1 to t_2 , t_4 to t_5 et cetera during which the ignition switch 24 is open, current can flow through the primary winding 12 of the ignition coil 10 for a much longer period of time before it is interrupted to produce an ignition spark. For example, consider the time period t_1 to t_4 (FIG. 2). Normally, current flows through the primary winding 12 of the ignition coil 10 for the time interval t_2 to t_4 when the ignition switch 24 is closed, but no current flows through the ignition coil 10 for the time period t_1 to t_2 when the ignition switch 24 is open. If current flow through the ignition coil 10 can begin shortly after an ignition spark is generated, that is, shortly after time t_1 , then current would flow through the ignition coil primary winding 12 for most of the time interval t_1 to t_2 and all of the time interval t_2 to t_4 . This would nearly double the time period current flows through the ignition coil primary winding 12 before being interrupted to produce an ignition spark, thereby allowing the energy in the coil 10 to increase to a much greater value to produce higher voltage ignition sparks.

Referring now to FIG. 5, there is illustrated a capacitor 122 coupled in series between the OR gate 34 and the RC filter 32 of the apparatus illustrated in FIG. 1.

This capacitor 122 causes the output from the RC filter 32 to be referenced around zero potential instead of being a one polarity D.C. voltage as is the case when the capacitor 122 is not used. This causes the AND gate 70 to be enabled during the time periods during which the ignition switch 24 is open, thereby turning the thyristor 74 on to produce current flow through the primary winding 12 of the ignition coil 10. When the ignition switch subsequently closes, the thyristor 74 is turned off, as described above, and current flow for the ignition coil 10 now flows through the ignition switch 24. This increasing of dwell time or the time current flows through the ignition coil 10 can best be described with reference to FIGS. 1 and 6 wherein the waveshape 124 of FIG. 6 shows that when the ignition switch 24 is opened to produce an ignition spark at time t_1 , t_4 et cetera, the collapse of the magnetic field produced by the primary winding 12 causes a rapidly fluctuating voltage to appear across the ignition switch 24 open contacts 26 and 28.

The ignition spark coincides with the first, and highest amplitude, positive voltage swing thus produced. After these rapid voltage fluctuations cease, as shown by waveshape 124, and the switch 24 is still open, the potential across the switch 24 is equal to the positive source 18. The waveshape 124 is applied to the RC filter 32 by way of the diode 30. The diode 30 blocks those rapid voltage fluctuations that extend beyond zero potential to a negative potential and the filter 32 smooths out the remaining positive rapid voltage fluctuations in a well known manner. Also, the filter 32 has no effect on the positive D.C. level applied thereto. During the time intervals t_2 to t_4 , t_5 to t_7 et cetera when the ignition switch 24 is closed, the input to and the output from the filter 32 is at zero potential.

The output from the RC filter 32 is shown in FIG. 6 as the waveshape 126 and comprises, during the time intervals t_1 to t_2 and t_4 to t_5 during which time the switch 24 is open, a positive going signal 127 corresponding to the time the ignition spark and the rapid voltage fluctuations occur. This is followed by a positive D.C. level corresponding to the potential source 18. During the time intervals t_2 to t_4 and t_5 to t_7 et cetera when the ignition switch 24 is closed, the potential is at zero.

As discussed above in detail, the input signal 126 to the inverting OR gate 34 generates the waveshape 102 (FIGS. 2 and 6) which only enables the AND gate 70 during time intervals at which the ignition switch is closed and the fixed duration pulse 110 (FIG. 2) occurs. By using the capacitor 122 as shown in FIG. 5, however, the signal 126 applied to the OR gate 34 is changed to that shown by the signal indicated by the reference character 128. The waveform 128 shows that the only positive portion is the positive going signal 127, which corresponds to the occurrence of the ignition spark and the rapid voltage fluctuations. This is followed by a zero potential portion during which time the ignition switch 24 is open. When the switch 24 is closed, time intervals t_2 to t_4 and t_5 to t_7 , the potential is negative as shown. Thus, the capacitor 122 causes the output of the RC filter 32 to fluctuate above and below zero potential rather than being a single polarity. When applied to the inverting OR gate 34, the signal 128 creates an output signal 130 that is at zero potential indicated by the numeral 134 when the ignition spark occurs and a short time thereafter. Most of the time, during all of the time intervals t_2 to t_4 and t_5 to t_7 when the switch 24 is closed and most of the time intervals t_1 to t_2 and t_5 to t_7 when the switch is open, the potential of the signal 132 is positive. The positive potential occurring when the switch 24 is open and the fixed duration pulses 110 combine to enable the AND gate 70 before the switch 24 is closed. This turns on the thyristor 74 to supply current to the primary winding 12 of the ignition coil 10 before the switch 24 is closed, thus increasing the dwell time to produce a "better" ignition spark at high speed r.p.m.

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As will now be apparent, the dwell time, or the time current flows through the primary winding 12 of the ignition coil 10, can be increased by decreasing the width of the positive going portion of the signal 127 of the output signals 126 and 128 from the RC filter 32. Since this portion of the signal 127 corresponds generally to the time occurrence of the ignition spark and related voltage fluctuations, it can be decreased by decreasing the time constants of the resistors and capacitors used in the RC filter 32. The width of the positive going portion of the signal 127 can be reduced to where it ceases to exist just after the ignition spark occurs even though the voltage fluctuations associated with the ignition spark are still taking place. This results in current flow through the ignition coil 10 at all times except when the ignition spark occurs. Any further reduction in the width of the signal 127 would result in conduction of the thyristor 74 quenching the ignition spark. Thus, the capacitor 122 of FIG. 6 allows the dwell time to be increased to substantially its theoretical maximum, since current can begin to be supplied to the ignition coil 10 immediately following an ignition spark.

As will be apparent to those skilled in the art, the apparatus of FIGS. 1 and 5 can readily be fabricated and packaged in a small unit by using printed circuits, transistors and/or integrated circuits. The package, or housing, may serve as a heat sink to the chassis of a racing car or boat and only the battery associated with the engine is required as a power source. As is apparent from the above description, the speed limiting apparatus of this invention does not use any moving parts, such as relatively expensive tachometers, and various other functions such as increased dwell time, elimination of the effects of point bouncing, and reducing or completely eliminating backfiring is readily accomplished.

What is claimed is:

1. For use with an internal combustion engine ignition system which includes a source of electrical potential coupled to the primary winding of an ignition coil and ignition timing switching means operable in synchronism with the speed of said engine for interrupting current flow through said primary winding, engine speed limiting apparatus comprising:

means connectable to said ignition system for generating electrical pulses having a predetermined time duration, and

means connectable to said ignition switching means and coupled to said pulse generating means for inhibiting the interruption of current flow through said primary winding of said ignition coil by said ignition switching means when the duration of said pulses bear a predetermined relationship with respect to the speed of said engine.

2. The engine speed limiting apparatus of claim 1 wherein said electrical pulses occur sequentially, and said means connectable to said ignition switching means and coupled to said pulse generating means inhibits the function of said ignition switching means to prevent interruption of current flow through the primary winding of the ignition coil when the duration of said pulses is at least substantially equal to the time interval between ignition sparks as determined by the speed of said engine.

3. The engine speed limiting apparatus of claim 2 wherein said means connectable to said ignition switching means and said pulse generating means is adapted to enable current flow through said ignition coil after an ignition spark occurs and said ignition switching means is open.

4. The engine speed limiting apparatus of claim 2 wherein said means connectable to said ignition switching means and said pulse generating means is adapted to prevent interruption of current flow through said ignition coil when bouncing of said ignition switching means occurs.

5. The engine speed limiting apparatus of claim 2

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wherein said means connectable to said ignition switching means and said pulse generating means is adapted to allow an ignition spark to occur each time a predetermined number of ignition sparks are prevented.

6. For use with an internal combustion engine ignition system which includes a source of electrical potential coupled to the primary winding of an ignition coil and ignition spark switching means operable in synchronism with the speed of said engine for interrupting current flow through said primary winding to produce ignition sparks, engine speed limiting apparatus comprising:

pulse generating means coupled to said ignition spark switching means and responsive to voltage thereacross for generating electrical pulses of predetermined duration, and

circuit means coupled to said ignition spark switching means and responsive to said electrical pulses for electrically shorting out said ignition switching means when the duration of said electrical pulses bear a predetermined relationship with respect to the speed of said engine to prevent the occurrence of ignition sparks, and

for enabling said pulse generating means to produce said pulses of predetermined duration when said ignition switching means is shorted out by said circuit means.

7. The apparatus of claim 6 wherein said circuit means and said ignition switching means are in series with said primary winding of said ignition coil and in parallel with one another.

8. The apparatus of claim 6 wherein said ignition switching means has a closed condition for which current flows therethrough and through said primary winding of said ignition coil and an open condition for which current does not flow therethrough to said primary winding,

said circuit means has an on condition for which current flows therethrough to said primary winding and an off condition for which current does not flow therethrough, and

said circuit means is off when said ignition switching means is closed and is on when both said ignition switching means is opened and said pulse is occurring.

9. The apparatus of claim 6 further including, counting means coupled to said circuit means to allow an ignition spark to occur in response to said circuit means preventing a predetermined number of ignition sparks from occurring.

10. The apparatus of claim 6 wherein, said pulse generating means and said circuit means enable current flow through said primary winding of said ignition coil when said ignition switching means is open to increase the dwell time of said ignition system.

11. The apparatus of claim 10 further including a series connected filter and capacitor coupled between said ignition switching means and said pulse generating means.

12. The apparatus of claim 6 further including, gating means coupled between said pulse generating means and said circuit means for enabling said circuit means to be on when the ignition switching means is opened and a said pulse occurs.

13. The apparatus of claim 12 wherein, said pulses of predetermined duration have one polarity when they occur,

said pulse generating means is also adapted to produce pulses having the same polarity as said pulses of predetermined duration when said ignition switching means is closed,

said gating means is adapted to receive said pulses of predetermined duration and said pulses denoting said ignition switching means is closed and is enabled when both pulses are applied thereto concurrently.

14. The apparatus of claim 13 wherein said circuit means disable said ignition switching means when said

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gate is enabled and said ignition switching means is opened.

15. The apparatus of claim 6 wherein said pulse generating means produce pulses having the same polarity as said pulses of predetermined duration when said ignition switching means is open after an ignition spark has occurred to enable said gating means to enable said circuit means to allow current flow through said primary winding of said ignition coil when said ignition switch is open to increase the dwell time.

16. The apparatus of claim 15 wherein, said circuit means includes a silicon controlled rectifier in parallel with said ignition switching means and having its control coupled to said gating means.

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U.S. Cl. X.R.

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