United States Patent

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[54] **MAXIMUM ENGINE SPEED LIMITER**
15 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **123/118,** 123/102, 123/148, 317/5
[51] **Int. Cl.** **F02p 11/00**
[50] **Field of Search** ..... 123/102, 148 (E), 118; 317/5, 19

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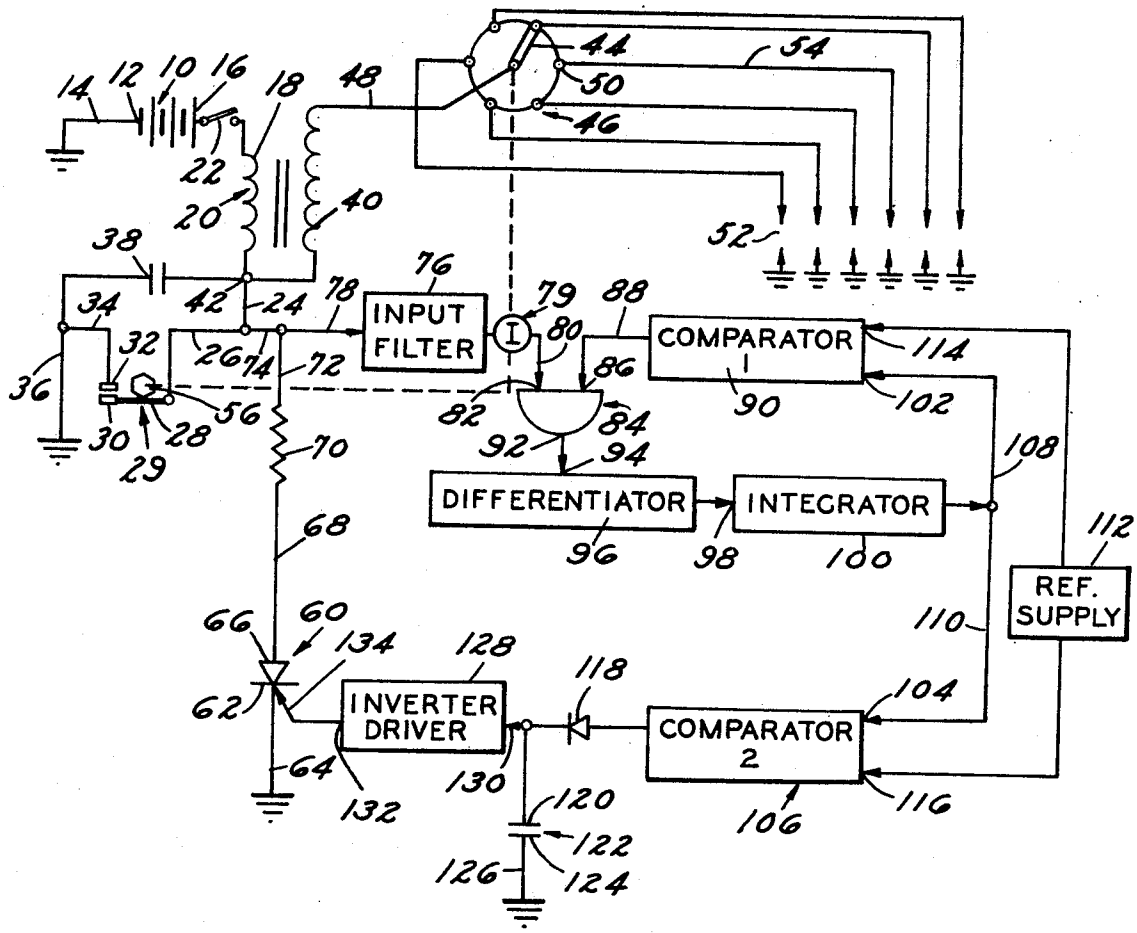
ABSTRACT: A maximum engine speed limiter for an internal combustion engine which is operative to limit the speed of the engine to some predetermined maximum. The engine speed is limited by connecting the primary winding of the ignition coil to ground by means of a limiting resistor and a solid state switching device. Circuit means are connected to the means for interrupting current through the primary winding of the ignition coil and to the solid state switching device to switch it to a conducting state when the predetermined maximum engine speed is reached. When this predetermined speed is reached, the solid state switching device becomes a substantially open circuit and current through the primary winding of the ignition coil is diverted from the circuit interrupting current through the primary winding to the limiting resistor and solid state switching device. The current is diverted to an extent that the output voltage of the secondary winding of the ignition coil is reduced to a level where the spark plugs of the internal combustion engine will not fire. The current through the current interrupting means is adequate, however, to permit adequate voltage to be developed across the means for interrupting current through the primary winding so that a speed signal from the ignition system remains available. As soon as the engine speed falls below the predetermined maximum, the circuit means switches the solid state switching device to a nonconducting state. As a result, current is no longer diverted from the means for interrupting current through the primary winding of the ignition coil and voltages sufficiently high to fire the spark plugs will again be generated in the secondary winding.



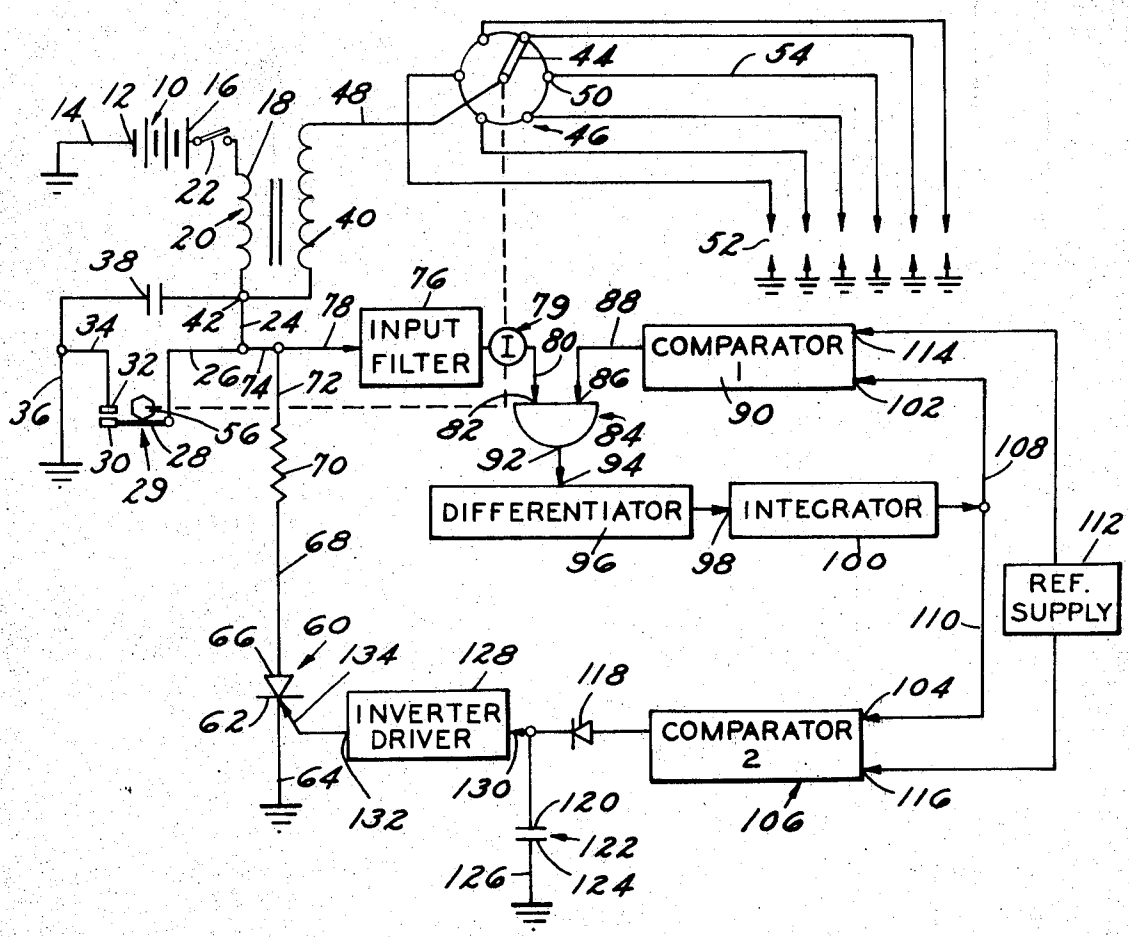


FIG. 1

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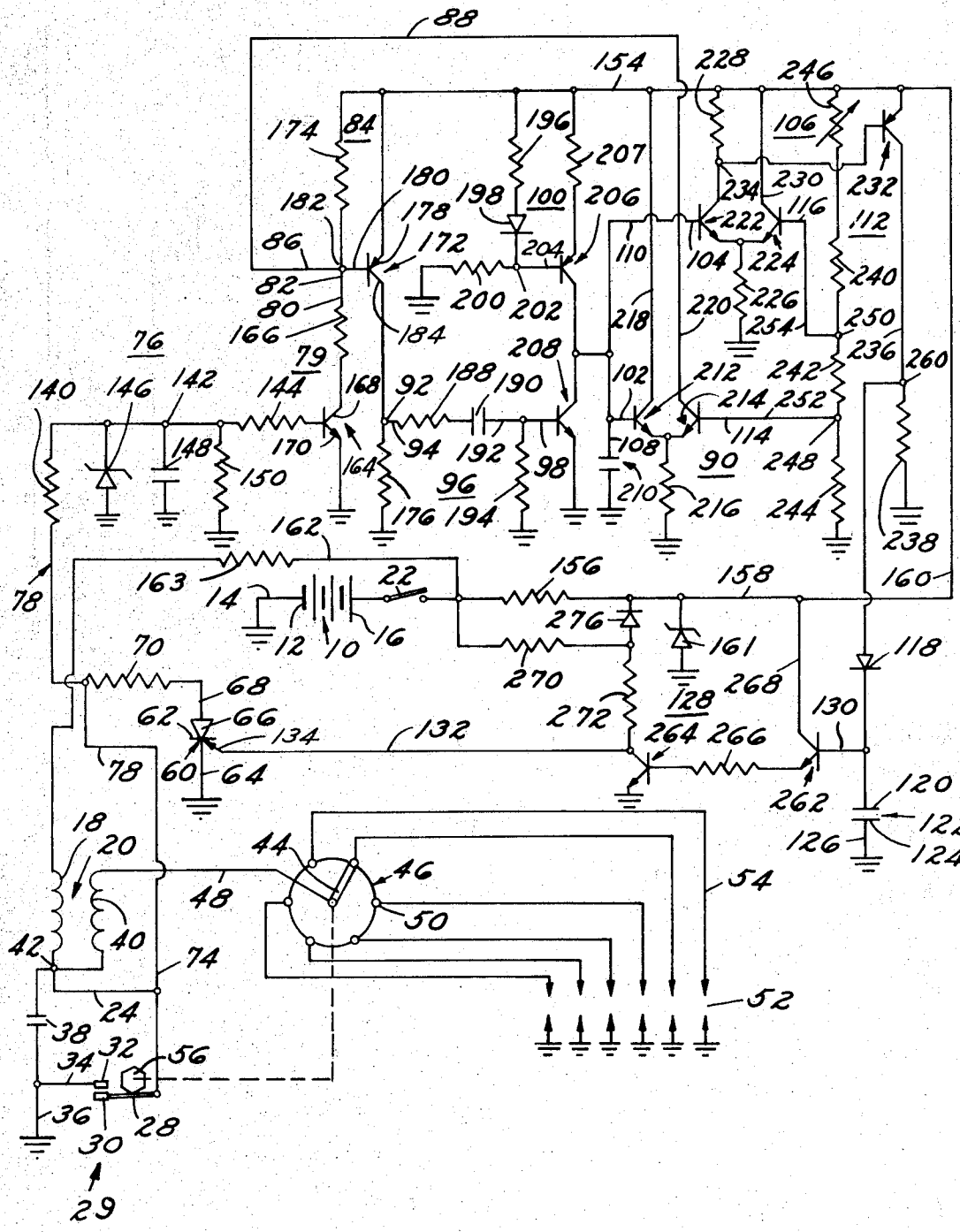
FIG. 2



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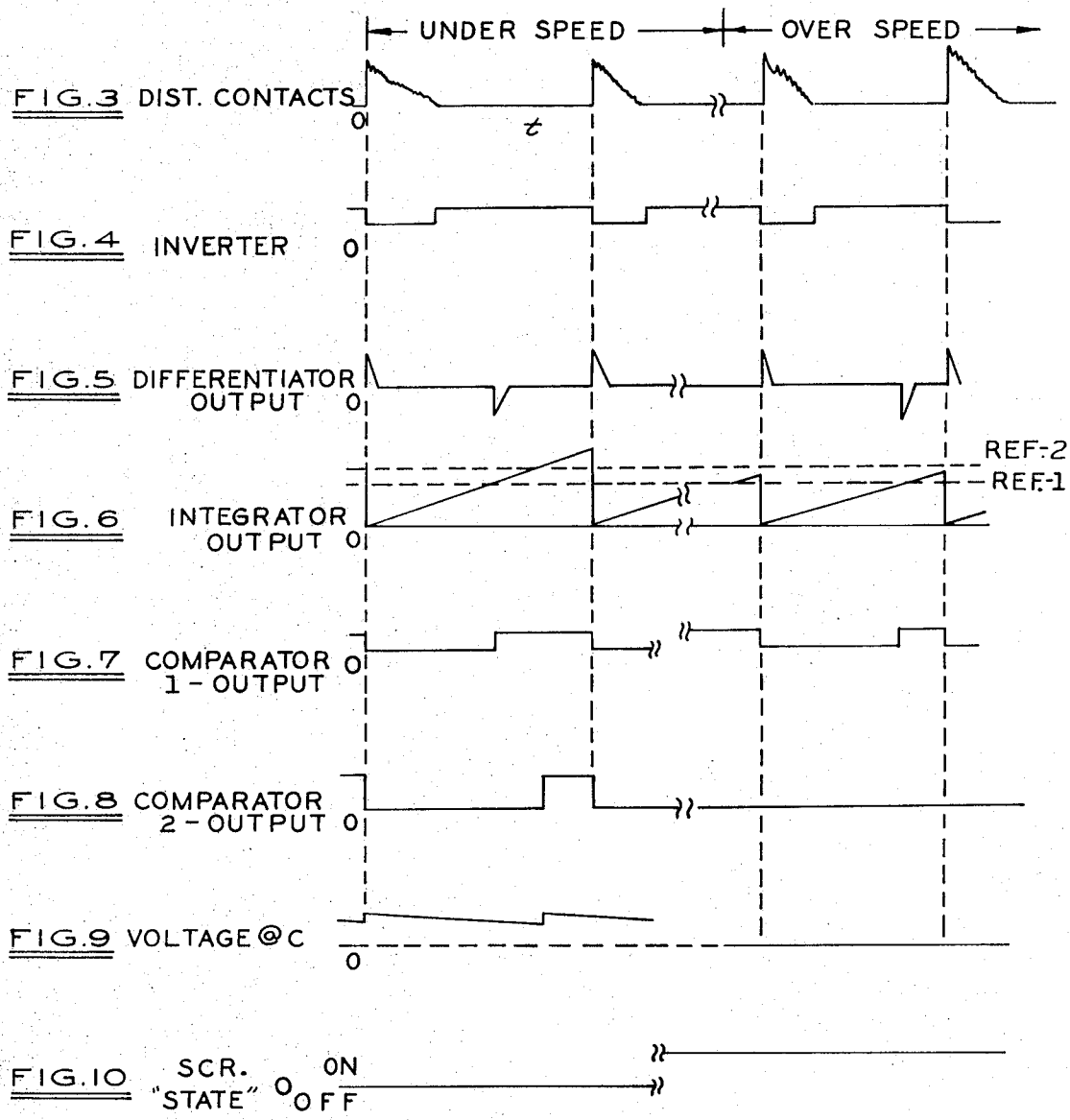

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MAXIMUM ENGINE SPEED LIMITER

BACKGROUND OF THE INVENTION

In internal combustion engines currently being marketed by automobile manufacturers, there is a need to prevent overspeed of the engine since overspeed may tend to damage engine components. A variety of different systems have been proposed to either limit the maximum speed at which an engine can operate or to stop the engine when a predetermined engine speed has been reached.

A number of these systems produce voltage pulses having a predetermined amplitude and width and frequency proportional to the speed of the engine. These pulses are fed to an integrating or averaging capacitor which in turn controls a switch coupled in series with the primary winding of the ignition coil for the vehicle. This capacitor is charged by these pulses to a voltage which is proportional to engine speed. When predetermined speed has been reached, the capacitor is charged to a value sufficient to operate the switch thereby cutting off current flow through the primary winding of the ignition coil and thereby preventing the high voltage pulses necessary to operate the engine from being applied to the spark plugs.

Other devices have been proposed in which a frequency sensitive electronic circuit is coupled to the means for interrupting current through the primary winding of the ignition coil. When the frequency of the interruptions of the current through the primary winding equals a predetermined frequency which is proportional to a predetermined maximum engine speed, a signal will be generated across a capacitor which will open circuit the primary winding of the ignition coil and thus prevent further firing of the spark plugs of the internal combustion engine.

Many of these prior art devices, while operating satisfactorily for a specific purpose, do not have a sufficiently rapid response time to properly control the maximum engine speed of a high performance engine. In addition, those that control this maximum speed (rather than stopping the engine completely) often suffer from large hysteresis, i.e., the speed of the engine will alternately fluctuate between the maximum predetermined speed and a substantially lower speed. This causes a very undesirable engine operating condition, particularly when the engine is used to power an automotive vehicle. In these systems, the speed of the vehicle will alternately vary, within limits, of 10 to 15 per hour as a result of the ignition system alternately energizing and deenergizing the spark plugs of the engine. Furthermore, in many systems, the signal to the engine speed limiter circuit is lost when the engine speed exceeds the maximum predetermined engine speed since the primary winding of the ignition coil is completely open circuited. The signal, therefore, does not reappear until the engine drops below the predetermined speed and the ignition system once more becomes operative. This results in a slow response time and in a large hysteresis.

SUMMARY OF THE INVENTION

The present invention overcomes the disadvantages of the prior art systems described above by providing a maximum engine speed limiter which has a very fast response time and very little hysteresis. The maximum speed of the engine can be controlled with the maximum engine speed limiter of the present invention within very narrow limits. Moreover, a signal proportional to engine speed is always available for sensing the speed of the engine irrespective of whether the circuit is operating in a mode in which the spark plugs of the engine do not receive sufficient electrical energy to fire the fuel-air mixture in the cylinders of the engine.

In the present invention, a solid-state switching means, for example, a controlled rectifier, has its output electrodes connected in circuit with a limiting resistor and the primary winding of an ignition coil for an internal combustion engine. The limiting resistor and solid state switching device are connected across the breaker points or other means that periodically interrupt current through the primary winding of the ignition coil. This action, of interrupting current in the primary winding of the ignition coil, produces in the secondary winding of the ignition coil high voltage pulses which are applied through a conventional distributor to the spark plugs of the internal combustion engine to fire the fuel-air mixture present in the cylinders of the engine.

During normal operation of the internal combustion engine in which the engine is operating below a certain maximum predetermined speed, the solid-state switching device is maintained in a nonconducting state. When the maximum predetermined engine speed is reached, however, the solid-state switching device is switched to a conducting state. As a result, a very substantial portion of the current through the primary winding flows through the limiting resistor and the conducting solid-state switching device. The other portion of the current through the primary winding flows through the current interrupting means or breaker points which operate to interrupt current at a frequency proportional to engine speed. This current, however, is insufficient to produce voltages in the secondary winding of a sufficient magnitude or strength to fire the spark plugs of the engine.

An input filter is coupled to the current interrupting means or breaker points and the voltage pulses generated when the current interrupting means or breaker points interrupt current through the primary winding are applied to this input filter. The input filter limits the magnitude of these pulses and shapes the pulses into a substantially rectangular wave shape. As a result, there appears at the output of this filter, a series of rectangular pulses having very sharp leading edges. The output of this filter is applied through various circuits, described subsequently, to a differentiator which produces a very sharp spike of voltage at the leading edge of each of these pulses. These spikes are applied to a integrator which produces a sawtooth wave form of the positive going type whose slope is determined by the time period between successive pulses from the current interrupting means or breaker points when the internal combustion engine is operating at a speed equal to the maximum predetermined engine speed. The sawtooth wave form produced in the integrator is set to zero whenever a pulse or spike of a given polarity is received from the differentiator.

The output of the integrator is applied to one input terminal of a comparator, and a constant preselected reference voltage is fed to the other input terminal of the comparator. This comparator is operative to produce a positive output pulse whenever the voltage of the sawtooth wave form is equal to or above the value or magnitude of the reference voltage. The output of this comparator is substantially zero whenever the magnitude of the sawtooth wave form is below the value or magnitude of the reference voltage. The comparator output comprises a plurality of rectangular pulses in which the time period between the trailing edge of one pulse and the leading edge of a succeeding pulse is a constant. This constant time period is selected as the time between successive pulses generated by the current interrupting means or breaker points when the speed of the internal combustion engine is equal to the maximum predetermined speed.

The output pulses from the comparator are applied to an energy storage means, for example, a capacitor, and they charge this capacitor to a voltage level of at least a predetermined magnitude. This energy storing device, or capacitor, is connected to the input of an inverter driver whose output is connected to the gate or control electrode of the solid-state switching device. When the voltage on the energy storage device, or capacitor, is above the predetermined level, the inverter driver is operative to connect the gate or control electrode of the solid-state switching device to substantially the same voltage as the cathode of the solid-state switching device. As a result, the solid-state switching device is maintained in a nonconducting state and all of the current through the primary winding flows through the current interrupting means or breaker points. As a result, each time current is interrupted in the primary winding, sufficient electrical energy is

generated in the secondary winding of the ignition coil to fire the spark plugs of the internal combustion engine.

When the speed of the internal combustion engine reaches the maximum predetermined speed, the comparator no longer produces output pulses since the magnitude of the sawtooth wave form generated by the integrator will not have sufficient time to equal or reach the magnitude of the reference voltage applied to the comparator before the sawtooth wave form is reset to zero by an incoming pulse from the differentiator. As a result, the electrical storage means, or capacitor, will no longer receive electrical energy in the form of pulses from the comparator. A discharge path having a very small time constant is provided for the capacitor, for example, between 1 to 10 times the time period between successive operation of the current interrupting means or breaker points when the engine is operating at the maximum predetermined speed. When the capacitor discharges, the inverter driver is operative to connect the gate or control electrode of the solid-state switching device to a positive voltage level with respect to the cathode thereof switching the solid state switching device to a conducting state and diverting a large portion of the current from the primary winding of the ignition coil from the current interrupting means or breaker points. As a result, the secondary winding of the ignition coil will no longer produce sufficiently high voltage to fire the spark plugs of the engine. The current that is not diverted from the current interrupting means or ignition breaker points, however, is sufficient to generate pulses to be applied to the input filter of sufficient magnitude to operate the circuit described above, including the differentiator and the integrator.

With the solid-state switching device in its conducting state and with insufficient energy being generated in the secondary winding of the ignition coil to fire the spark plugs of the engine, the speed of the engine will obviously decrease. This condition will prevail until the speed of the engine decreases to a value below the maximum predetermined speed. At this time, the comparator will again produce output pulses and will charge the electrical energy storage device, or capacitor, very rapidly. As a result, the solid-state switching device will be switched back to its nonconducting state, and the secondary winding of the ignition coil will again produce sufficient output voltage to fire the spark plugs of the engine. The engine will, therefore, again increase in speed.

As a result of the above action, the engine speed is limited to a predetermined maximum, for example, 6,000 or 7,000 r.p.m., and since the response time of the capacitor or energy storage device and the switching time of the solid-state switching device is very small, for example, from 1 to 10 interruptions of the current through the primary winding, the speed of the engine will be maintained very close to this predetermined maximum engine speed.

In addition to the above, a second comparator may be employed which has one input coupled to the output of the integrator or sawtooth wave generator and has a second input terminal coupled to a reference voltage which has a magnitude smaller than the magnitude of the first-mentioned reference voltage which is applied to the second comparator. This comparator is operative to produce a negative going signal whenever the magnitude of the sawtooth wave of the sawtooth wave generator or integrator is below the magnitude of the second mentioned reference voltage.

This output is applied to one terminal of an OR gate. The other input terminal of the OR gate is connected through an inverter to the input filter circuit and the output is applied to the differentiator. The inverter is operative to invert the pulses of positive polarity received from the input filter when the current interrupting means interrupts current through the primary winding of the ignition coil. As stated previously, the differentiator will produce a positive spike or pulse of electrical energy whenever a step function or pulse input is applied to it. The output of the OR gate will always be positive when a negative signal is applied to either of its input terminals from the comparator or the inverter.

The output of the OR gate will always be positive over the given time period that the magnitude of the sawtooth wave from the integrator is below the magnitude of the second mentioned reference voltage. The time period over which this occurs is correlated to the time period between successive operations of the current interrupting means or successive openings of the distributor breaker points. This time period is selected to be sufficient so that any bouncing of the distributor breaker points or any oscillations set up in the primary and secondary windings of the ignition coil will not be operative to produce a positive going signal at the differentiator which could be differentiated into a positive going spike that would reset the sawtooth wave form produced by the integrator to a zero level. Thus, the comparator and the OR gate serve the function of inhibiting the differentiator from producing a signal that would reset the integrator output to zero due to any unwanted or spurious signals being received through the input filter.

An object of the present invention is the provision of a maximum engine speed limiter for an internal combustion engine.

Another object of the invention is the provision of a maximum speed limiter for an internal combustion engine that has a very fast response time.

A further object of the invention is the provision of a maximum engine speed limiter for an internal combustion engine that is operative to control the maximum speed of an engine within very close limits without hunting between widely different engine speeds.

Other objects and attendant advantages of the present invention may be more readily realized when the specification is considered in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of the maximum engine speed limiter of the present invention in block diagram form;

FIG. 2 is a circuit schematic of the maximum engine speed limiter of the present invention showing the electrical components that make up the elements shown in block diagram of FIG. 1;

FIG. 3 shows the voltage wave form produced at the distributor contacts or current interrupting means for the primary winding of the ignition coil;

FIG. 4 shows the output from the inverter shown in FIG. 1;

FIG. 5 shows the output from the differentiator shown in FIG. 1;

FIG. 6 shows the output wave form of the integrator or sawtooth generator shown in FIG. 1;

FIG. 7 shows the output wave form of comparator 1 shown in FIG. 1;

FIG. 8 shows the output wave form of the comparator 2 shown in FIG. 1;

FIG. 9 shows the voltage across the capacitor 122 shown in FIG. 1; and

FIG. 10 shows the state, i.e., conducting or nonconducting, of the solid-state switching device or controlled rectifier shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in which like reference numerals designate like parts throughout the several views thereof, there is shown in FIG. 1 an ignition system for an internal combustion engine comprising a source of electrical energy 10 having one electrode thereof, negative electrode 12, connected to ground through a lead 14. The other electrode, positive electrode 16, of the source of electrical energy 10 is connected to one terminal of the primary winding 18 of ignition coil 20 through an ignition switch 22. The other terminal of the primary winding 18 is connected to ground through lead 24, lead 26, movable arm 28 of ignition breaker points 29, movable contact 30 of these breaker points, stationary contact 32 of these breaker points, lead 34 and lead 36. A capacitor 38 is connected across the contacts 30 and 32

by having one terminal thereof connected to lead 24 and the other terminal thereof connected to lead 36.

The ignition coil 20 also comprises a secondary winding 40 having one terminal thereof connected to one terminal of the primary winding 18 at a junction 42 and having the other terminal thereof connected to a rotatable arm 44 of distributor 46 through a lead 48. The rotatable arm 44 of the distributor is adapted to be rotated in synchronism with the operation of an internal combustion engine and to come into contact successively with contacts 50. These contacts are connected individually to respective ones of the spark plugs 52 through one of the leads 54. The rotatable arm 44 of the distributor 46 is adapted to be rotated in synchronism with a cam 56 which will open contacts 30 and 32 of the ignition breaker points 29 when the rotatable arm 44 comes into contact with one of the stationary contacts 50 of the distributor 46.

The subject matter describe thus far is a conventional ignition system for an internal combustion engine and it operates in conventional manner. Thus, when the contacts 30 and 32 of ignition breaker points 29 are closed, current flows through the primary winding 18 of the ignition coil 20. When the cam 56 moves the contact 30 out of engagement with contact 32, current is interrupted through the primary winding 18 of the ignition coil 20. As a result, a very high voltage is generated across the secondary winding 40 of the ignition coil 20 and is applied to one of the spark plugs 52 through lead 48, rotatable arm 44, stationary contact 50 and one of the leads 54. This energy is sufficient to cause a breakdown in the gap of one of the spark plugs 52 and is sufficient to fire the combustible fuel-air mixture in a cylinder of the internal combustion engine.

A solid-state switching device 60, preferably in the form of a silicon controlled rectifier, has one output electrode, cathode 62, connected to ground through a lead 64 and the other output electrode, anode 66, connected through lead 68 to one terminal of a limiting resistor 70. The other terminal of the limiting resistor 70 is connected through lead 72 to the junction 42 via lead 74 and lead 24.

The lead 74 and hence, junction 42, is connected to an input filter 76 via lead 78 and the output of the input filter is connected to an inverter 79. The output of the inverter is connected through lead 80 to an input terminal 82 of an OR gate 84. The other input terminal 86 of the OR gate 84 is connected through lead 88 to the output terminal of a first comparator 90, comparator 1, and the output terminal 92 of the OR gate 84 is connected to an input terminal 94 of a differentiator 96.

The output terminal of the differentiator is connected to the input terminal 98 of an integrator or sawtooth wave generator 100. The output terminal of the integrator of sawtooth wave generator 100 is connected to a first input terminal 102 of comparator 90 and to a first input terminal 104 of a second comparator 106, comparator 2, via leads 108, and 110, respectively.

A reference supply 112 is provided to supply a reference voltage of a constant magnitude to the second input terminal 114 of comparator 90 and a second reference voltage, having a constant magnitude slightly greater than the magnitude of the voltage supplied to the input terminal 114, to a second input terminal 116 of comparator 106. The output of comparator 106 is fed through a diode or unilateral conducting device 118 to one terminal 120 of a capacitor 122. The other terminal 124 of the capacitor 122 is connected to ground through a lead 126. An inverter driver 128 has an input terminal 130 connected to the terminal or plate 120 of capacitor 122 and an output terminal connected through lead 132 to a gate or control electrode 134 of the solid-state switching device 60.

Referring now to FIG. 2, the input filter 76 comprises a resistor 140 having one terminal connected to the input terminal 78 of the input filter and another terminal connected to a line or lead 142. Another resistor 144 has one terminal connected to the line or lead 142 and the other terminal thereof connected to the output terminal of the input filter 76. A Zener diode 146, a capacitor 148, and a resistor 150 are connected in parallel between the line or lead 142 and ground.

As stated previously, when current through the primary winding 18 of ignition coil 20 is interrupted by the opening of the contacts 30 and 32 of the ignition breaker points 29, a pulse of electrical energy will appear at the junction 42 and across the capacitor 38. This pulse of electrical energy is applied through lead 74 to the input terminal 78 of the input filter 7 and then through resistor 140 to the Zener diode 146 which has a reverse breakdown voltage substantially below the voltage of the input pulses appearing on lead 74. The Zener diode 146, therefore, serves to clip the pulses appearing at the input terminal 78 and limits the magnitude of the output pulses from the input filter to a value equal to the reverse breakdown voltage of the Zener diode 146. The capacitor 148, resistor 150 and resistor 144 serve to shape the wave form into a substantially rectangular pulse.

The pulses appearing at the input terminal 78 of the input filter 76 and that appear across the distributor contacts 30 and 32 are shown in FIG. 3 and these pulses are limited and shaped into rectangular pulses that appear at the output terminal of the input filter 76. It can be appreciated that the frequency of the pulses shown in FIG. 3 is proportional to engine speed since the distributor contacts 30 and 32 are opened at a repetition rate which is proportional to engine speed.

Referring again to FIG. 2, when the ignition switch 22 is closed, a line 154, appearing at the top of FIG. 2, is energized from the positive terminal 16 of the electric storage battery 10 through the ignition switch 22, a limiting resistor 156, a lead 158 and a lead 160. A Zener diode 161 is connected to line 158 and it has a reverse breakdown voltage of slightly less than half the terminal voltage of the source of electrical energy 10. It serves, therefore, to regulate the voltage on line 154 at slightly less than half the terminal voltage of the source 10. As shown, the primary winding 18 of the ignition coil 20 is connected to the source of electrical energy 10 through ignition switch 22, and lead 162 having a ballast resistor 163 positioned therein.

The inverter 79 comprises a transistor 164 and a resistor 166 connected at one terminal to the collector 168 of the transistor 164. The emitter 170 of transistor 164. is connected to ground, as shown, while the base is connected to the resistor 144 of the input filter 76.

The OR gate 84 comprises a transistor 172, a first resistor 174 and a second resistor 176. The emitter 178 of transistor 172 is connected directly to the line 154 while the base 180 thereof is connected to a junction 182 positioned between resistor 174 and the resistor 166 of the inverter 79.

It can be appreciated that the output terminal 80 of the inverter 79 is connected to the input terminal 82 of the OR gate 84 at the junction 182. The output terminal of the OR gate 84 is positioned intermediate the collector 184 of transistor 172 and the resistor 176 and this output terminal is shown at 92. As indicated in FIG. 1, the other input to the OR gate 84 is connected to the output terminal of comparator 90 through lead 88.

It can be appreciated that when a signal is absent at the base of transistor 164 of the inverter 79, transistor 164 will be in a nonconducting state and that the potential appearing at the output terminal 80 of the inverter 79 will be substantially at the potential of line 154. When a positive pulse from the input filter 76 is applied to the base of transistor 164, it will switch this transistor to a conducting state and thereby reduce the potential at the output terminal 80 that is applied to the input terminal 82 and junction 182 of the OR gate 84. This will cause the transistor 172 of the OR gate 84 to switch to a conducting state and raise the potential at the output terminal 92 thereof.

Similarly, a negative going signal applied to the junction 182 of the OR gate 84 via lead 88 from comparator 90 will switch transistor 172 to a conducting state and raise the potential appearing at the output terminal 92 of the OR gate.

The voltage wave form appearing at the output terminal 80 of inverter 79 is shown in FIG. 4 It can be appreciated that the negative going portions of this wave form have a repetition rate or frequency equal to the repetition rate or frequency of the operation of the distributor contacts or other means for interrupting current in the primary winding 18 of the ignition coil 20.

The differentiator 96 comprises a resistor 188 and a capacitor 190 connected in series with the input terminal 94, which in turn is connected to junction 92 of the OR gate 84, and a lead 192, which in turn is connected to the input terminal 98 of the integrator 100. A resistor 194 has one terminal connected to the lead 192 and the other terminal connected to ground. When transistor 172 of the OR gate 84 is switched to its conducting state thereby raising the potential of junction 92 and raising the potential of the input terminal 94 to the differentiator 96, the differentiator will differentiate such an increase in voltage and produce at the output terminal 98 the series of positive pulses or spikes shown in FIG. 5. Similiarly when transistor 172 is switched to a nonconducting state and the potential at the junction 92 and at the input terminal 94 of the differentiator falls, a negative differentiated signal, as shown in FIG. 5, will appear at the output terminal 98 of the differentiator.

The integrator 100 comprises a series connected network of a resistor 196, a diode 198 and a resistor 200 connected between line 154 and ground. The junction 202 between diode 198 and resistor 200 is connected to base 204 of transistor 206. The emitter of transistor 206 is connected to line 154 through resistor 207 and the collector of transistor 206 is connected to the collector of transistor 208 and to one plate of capacitor 210. The emitter of transistor 208 is connected to ground as is the other plate or terminal of capacitor 210. It can be appreciated that transistor 208 is normally in a nonconducting state when no output is received from the differentiator 96 and that it will be switched to a conducting state only when a positive pulse is received on its base from the differentiator 96. On the other hand, transistor 206 is normally in a conducting state since the junction 202 connected to base 204 is at a lower potential than the emitter of transistor 206. Thus, conduction of transistor 206 applies charge to the upper terminal of capacitor 210 and the voltage on this upper plate is the typical sawtooth wave pattern which increases in a substantially linear fashion as shown in FIG. 6. When a positive pulse from the differentiator is received on the base of transistor 208, transistor 208 goes into conduction and capacitor 210 discharges rapidly through the collector-emitter circuit of transistor 208 thereby reducing the voltage on the upper plate of capacitor 210 to substantially zero. The voltage wave form appearing on the upper terminal capacitor 210 is shown in FIG. 6. It can be appreciated that this is a standard sawtooth wave form which is set to zero every time the distributor contacts 30 and 32 open, since a positive pulse of electrical energy, as shown in FIG. 5, is applied to the base of transistor 208 every time the distributor contacts open.

The output terminal of the integrator 100, the upper terminal of capacitor 210, is connected to the input terminal 102 of comparator 90 and to the input terminal 104 of comparator 106 through leads 108, and 110, respectively. The comparator 90 comprises a pair of transistors 212 and 214 having their emitters connected to ground through a common resistor 216. The base of transistor 212 is connected to the input terminal 102 to receive the sawtooth wave form from the capacitor 210 of integrator 100 and the collector of this transistor is connected to line 154 through a lead 218. The base of transistor 214 is connected to the input terminal 114 of comparator 90, and the collector thereof is connected to input terminal 86 and junction 82 of the OR gate 84 via lead 220 and lead 88.

The comparator 106 comprises a first transistor 222 and a second transistor 224 having their emitters connected to ground through a common resistor 226. The collector of transistor 222 is connected to line 154 through a resistor 228, while the collector of transistor 224 is tied directly to line 154 through lead 230. The comparator 106 also includes a third transistor 232 having its base connected to a junction 234 intermediate resistor 228 and the collector of transistor 222. The emitter of transistor 232 is connected directly to line 154 and the collector thereof is connected through lead 236 to one terminal of resistor 238. The other terminal of resistor 238 is connected to ground as shown.

The reference supply 112 comprises three fixed resistors 240, 242 and 244 connected in series with a variable resistor 246. This series circuit has one terminal, the upper terminal of variable resistor 246, connected to line 154 which receives regulated electrical energy from the positive terminal 16 of electrical storage battery 10 through ignition switch 22 and resistor 156 and the other terminal, the lower terminal of resistor 244, connected to ground. As a result, a reference voltage is available at a junction 248 positioned between fixed resistor 242 and 244 of a higher reference voltage is available at junction 250 positioned between fixed resistors 240 and 242. The values of these reference voltages may be changed by adjusting the value of variable resistor 246. The first reference voltage available at junction 248 is applied to the input terminal 114 of comparator 90 via lead 252 and hence is applied to the base of transistor 214. This first reference voltage is shown in FIG. 6 as the first dashed line, denoted REF 1. On the other hand, the second reference voltage aVailable at junction 250 is applied to the input terminal 116 of comparator 106 via lead 254. Hence, this reference voltage is applied to the base of transistor 224 of comparator 106. This reference voltage is shown by the second dashed line shown in FIG. 6, denoted REF 2.

The output of comparator 106, which appears at a junction 260 positioned in lead 236 between resistor 238 and the collector of transistor 232 is fed through diode 118 to the upper terminal 120 of capacitor 122. The inverter driver 128, which couples the plate 120 of capacitor 122 to the gate electrode or control electrode 134 of the solid-state switching device 60, comprises a first transistor 262 and a second transistor 264. The base of the first transistor 262 is connected to the input terminal 130 of the inverter driver 128 and this input terminal 130 is in turn connected to the plate 120 of capacitor 122. The emitter of the transistor 262 is connected to the base of transistor 264 through a resistor 266 while the collector thereof is connected to lead 158 via lead 268. The emitter of transistor 264 is connected to ground while the collector thereof is connected to the ignition switch 22 through resistors 270 and 272. The inverter driver also includes a diode 276 having its anode connected to line 158 and its cathode connected to the junction between resistors 270 and 272.

In operation of the maximum engine speed limiter of the present invention, the pulse train show in FIG. 3 will be produced at the junction 42 by the opening and closing of the contacts 30 and 32 of the ignition breaker points 29. It can be appreciated that the leading edges of the pulses produced and shown in FIG. 3 have a repetition rate and frequency that are proportional to engine speed, since the cam 56 that operates the ignition breaker points 29 is driven in synchronism with the engine.

These pulses are applied through lead 24 and lead 74 to the input terminal 78 of input filter 76 where they are clipped or limited in voltage value and shaped into substantially rectangular pulses. These pulses also have a repetition rate and frequency proportional to engine speed.

The pulses from the input filter 76 are applied to the inverter 79 where they are employed to produce the wave form shown in FIG. 4. The negative going pulses of this wave form are applied to the input terminal 82 of the OR gate 84, and they have a repetition rate and frequency proportional to engine speed. The OR gate 84 will produce a positive going pulse when a negative going signal appears at its input terminal 82 since this switches transistor 172 to a conducting state and raises the potential across resistor 176 at the output terminal 92.

The positive pulses from the OR gate **84** are applied to the input **94** of the differentiator **96** where they are differentiated into the positive going pulses or spikes of electrical energy as shown in FIG. **5**. This wave form is applied to the integrator or sawtooth wave generator **100** where each positive spike or pulse of electrical energy from the differentiator **96** resets the sawtooth wave form to zero by discharging the capacitor **210** through transistor **208** as explained previously. The slope of the sawtooth wave form, in terms of voltage *v.* time, is such that the time between the zero voltage and the time the sawtooth wave form reaches the second reference voltage, designated REF **2**, is equal to the time between successive openings of the ignition breaker contacts **30** and **32** when the engine speed is equal to the maximum predetermined speed. For example, if one wishes to limit an 8-cylinder internal combustion engine to a speed of 6,000 r.p.m., the time required for the sawtooth wave form to go from zero to the REF **2** voltage is made equal to 2.5 milliseconds.

As stated previously, the output of the integrator **100** is applied to the input terminal **104** of comparator **106**, and the other input terminal **116** of the comparator **106** receives the voltage, REF **2**, from the reference supply **112** via junction **250**. When the sawtooth wave form voltage shown in FIG. **6** is applied to the base of transistor **222** of comparator **106** is equal to the reference voltage at junction **250** of reference supply **212** and applied to the base of transistor **224**, the transistor **222** will be switched to a conducting state thereby lowering the potential at junction **234** and permitting transistor **232** to conduct thereby raising the potential at the junction **260** of comparator **106**. This positive pulse of electrical energy is shown in FIG. **8** as the comparator **2** output will be applied to the energy storage device or capacitor **122**.

As long as the engine speed is under the maximum predetermined speed, output pulses, as shown in FIG. **8**, will be applied by the comparator **106** to the capacitor **122** and a voltage will be maintained on this capacitor thereby maintaining transistor **262** of the inverter driver **128** in a conducting state. This provides current into the base of transistor **264** and maintains it in a conducting state. As a result, the gate or control electrode **134** of solid-state switching device **60** will be at substantially ground potential as is the cathode **62**. The solid-state switching device **60**, therefore, will be in a nonconducting state, and all of the electrical energy or current through the primary winding **18** will flow through the ignition breaker points **29**. When this current is interrupted, sufficient electrical energy is applied to the spark plugs **52** to ignite the fuel-air mixture found in the cylinders of the engine and the engine operates in a normal fashion.

Referring now to FIGS. **6** and **7**, the REF **1** reference voltage level, shown in FIG. **6**, is applied from junction **248** of reference supply **112** to the input terminal **114** and the base of transistor **214** of comparator **90**. The sawtooth wave form from the integrator or sawtooth wave generator **100** is applied to the base of transistor **212** of comparator **90**. When the value of the voltage applied to the base of transistor **212**, i.e., the value of the sawtooth wave shown in FIG. **6**, reaches the reference voltage level applied to base of transistor **214**, the negative going pulse of the comparator output, as shown in FIG. **7**, will disappear, but prior to that time, the negative going pulse will be applied to the input terminal **86** of OR gate **84** via the lead **220** and lead **88** thereby holding transistor **172** of the OR gate in a conducting state and maintaining the output of the OR gate at a positive potential.

With the output of the OR gate held at a positive potential as a result of transistor **172** being held in a conductive state, any spurious pulse coming through the input filter **76** and inverter **79** can have no effect on the output of the OR gate **84** and, therefore, no signal can be applied to the differentiator **96** which could reset the sawtooth wave form produced by the integrator **100** to zero. The time period between the zero setting of the sawtooth wave form, as shown in FIG. **6**, and the point where the sawtooth wave form voltage equals the REF **1** voltage that is applied to one of the inputs of the comparator **90** is selected so that all oscillations occurring in the voltage across the secondary winding **40** of the ignition coil **20** are damped out and there is no possibility of spurious contact bounce which could introduce a positive going pulse into the input filter **76**. This time, for example, may be selected at 1.5 milliseconds. Thus, the comparator **90** and the OR gate **84** serve to inhibit the operation of the differentiator and hence, the setting of the sawtooth wave form to zero during the 1.5 millisecond period thereby eliminating any unintentional resetting of the sawtooth wave form produced by the integrator **100** to zero as a result of the generation of any spurious or unwanted signals at the ignition coil **20**.

When the speed of the internal combustion engine reaches the predetermined maximum speed, the pulses, as shown in FIG. **3**, and the positive pulses shown in FIG. **5**, will have a period which is equal to the time necessary for the sawtooth wave form to rise from its zero position to the voltage equal to the REF **2** voltage. At speeds higher than the predetermined maximum speed, the period between these positive pulses is less than the time required for the integrator to reach the REF **2** voltage level before it is reset to zero. If the sawtooth wave form does not reach a voltage value equal to the REF **2** level, it can be appreciated that the comparator **106** will not produce an output pulse and this condition is shown in FIGS. **3—10** as the OVER SPEED condition.

When no positive pulses are produced by comparator **106**, the capacitor **122** discharges rapidly through the base-emitter circuit of transistor **262** and then to ground through the base-emitter circuit of transistor **264** of inverter driver **128**. As a result, the bias on the base of transistor **262** is removed thereby switching transistor **262** to a nonconducting state and switching transistor **264** to a nonconducting state. When this happens, the lead **132** connected to the collector of transistor **264** is no longer connected to ground through transistor **264** and its potential is raised sufficiently to switch the solid-state switching device **60** to a conducting state.

The components of the inverter driver **128** are selected so that the capacitor **122** will discharge sufficiently to accomplish this switching action within 1 to 10 periods between successive connection of the spark plugs **52** to the secondary winding of the ignition coil. As explained previously, this time period is 2.5 milliseconds for a maximum predetermined speed of 6,000 r.p.m, for an 8-cylinder engine.

When the solid-state switching device **60** is switched to its conducting state, a large portion of the current through the primary winding **18** is diverted through the solid-state switching device **60** from the ignition breaker contacts **29**. The limiting resistor **70** is selected so that sufficient current will flow through the ignition breaker contacts **29** to produce pulses having a sufficient magnitude at the junction **42** and applied to the input filter **76** to maintain a signal present there of sufficient magnitude to operate the inverter **79**, the OR gate **84** and the differentiator **96**. The voltage produced in the secondary winding **40** of the ignition coil **20** are insufficient to fire the spark plugs **52** and hence, to ignite the fuel-air mixture present in the cylinders of the internal combustion engine. As a result, the speed of the internal combustion engine will be reduced and will fall below the maximum predetermined engine speed.

As soon as the engine speed falls below the maximum predetermined speed, the comparator **106** will again start producing positive output pulses which are applied to the capacitor **120**. The capacitor **120** will be rapidly charged to the point where it will switch the inverter driver **128** to a conducting state, i.e., transistors **262** and **264** are switched to a conducting state, thereby recoupling the gate or control electrode **134** of the solid-state switching device **60** to ground. This switches the solid-state switching device **60** to a nonconducting state thereby sending all of the current of the primary winding **18** of ignition coil **20** through the contacts **30** and **32** of the ignition breaker points **29**. Consequently, voltages are again generated in the secondary winding **40** of ignition coil **20** of sufficient magnitude to fire the spark plugs **52** and the

combustible mixture in the engine cylinders. The engine will, therefore, again commence to pick up speed. The vehicle operator, at this time, may adjust the speed of the engine if he so desires to a point below the maximum predetermined speed, or if he does not, the above cycle will repeat on a continuous basis and will hold the speed of the engine at this predetermined maximum speed within very small tolerances, i.e., a very narrow speed range centered at the maximum predetermined speed.

The present invention thus provides a very reliable maximum engine speed limiter for an internal combustion engine that has a very rapid response time and that will hold the speed of the engine within a very narrow speed range on either side of a maximum predetermined speed.

I claim:

1. A maximum engine speed limiter for an internal combustion engine comprising an ignition coil having a primary and a secondary winding, a spark plug coupled to said secondary winding, means for periodically interrupting current through said primary winding whereby pulses of electrical energy are produced in said ignition coil having a frequency proportional to engine speed, means coupled to said ignition coil for receiving the pulses of electrical energy pulse producing means coupled to said second mentioned means and responsive to the pulses received by said second-mentioned means for producing a train of pulses at engine speeds below a predetermined maximum speed of the engine and for producing negligible output when the speed of the engine is equal to or above the predetermined maximum speed, and control means coupled to said last-mentioned means and said ignition coil for reducing the output of the secondary winding when negligible output is produced by said pulse producing means and for maintaining pulses of electrical energy at the ignition coil of sufficient amplitude to operate said pulse producing means.

2. The combination of claim 1 in which said pulse producing means includes means for maintaining a substantially constant time period between the trailing edge of one pulse and the leading edge of the next succeeding pulse produced by said pulse producing means.

3. The combination of claim 2 in which said substantially constant time period between the trailing edge of one pulse and the leading edge of the next succeeding pulse is equal to the time period between pulses produced by the periodic interruption of current through the primary winding of the ignition coil when the engine speed is equal to said predetermined maximum engine speed.

4. The combination of claim 3 in which said pulse producing means includes inhibiting means for preventing said pulse producing means from producing an output pulse for a given time period shorter than said substantially constant time period after said current interrupting means interrupts current through said primary winding.

5. The combination of claim 3 in which said pulse producing means comprises means for producing a sawtooth voltage wave form, a means for producing a substantially constant reference voltage, and a comparator having a pair of input terminals and an output terminal, said sawtooth voltage wave form applied to one of said input terminals and said substantially constant reference voltage being applied to the other input terminals, said comparator producing an output pulse at said output terminal when the magnitude of said sawtooth voltage wave form is equal to the magnitude of said substantially constant reference voltage, and means coupled to said second-mentioned means for commencing another cycle of said sawtooth voltage wave form at a reference voltage value substantially below said substantially constant reference voltage value when a pulse is received by said second-mentioned means.

6. The combination of claim 5 in which said means for producing the sawtooth voltage wave form includes means having a time constant such that the magnitude of said sawtooth voltage wave form equals the magnitude of the constant reference voltage in a time period equal to the time period between successive pulses produced in said ignition coil when the speed of the engine is equal the maximum predetermined speed.

7. The combination of claim 6 in which said pulse producing means includes inhibiting means for preventing said pulse producing means from producing an output pulse for a given time period shorter than said substantially constant time period after said current interrupting means interrupts current through said primary winding.

8. The combination of claim 7 in which said inhibiting means comprises a second comparator having a pair of input terminals and an output terminal, said sawtooth wave form applied to one of said input terminals, means for producing a second substantially constant reference voltage having a magnitude lower than the magnitude of the first-mentioned substantially constant reference voltage, said second substantially constant reference voltage being applied to the other input terminal of said comparator, said comparator including means for producing an output signal at said output terminal of given magnitude and polarity when the magnitude of the sawtooth wave form voltage is below the magnitude of said second substantially constant reference voltage, an OR gate having a pair of input terminals and an output terminal, said output signal from said comparator applied to one of the input terminals of said OR gate, means coupled to said means for receiving pulses of electrical energy produced in said ignition coil and to the other input terminal of said OR gate for producing a signal of substantially the same magnitude and of the same polarity as the signal appearing at the output terminal of the second comparator and applied to the first input terminal of said OR gate including means for producing an output signal of given magnitude when said signals appear on either input terminal thereof, a differentiator coupled to the output terminal of said OR gate, the output of said differentiator being applied to said means for producing said sawtooth voltage wave form, the differentiated signal from said differentiator commencing another cycle of said sawtooth voltage wave form when the output signal first appears at the output terminal of said OR gate whereby said means for producing said sawtooth voltage wave form is prevented from commencing another cycle due to any spurious pulses at the first input terminal of the OR gate prior to the time the magnitude of the sawtooth voltage wave form equals the magnitude of the second substantially constant reference voltage.

9. An ignition system for an internal combustion engine comprising an ignition coil having a primary winding and a secondary winding, a source of electrical energy coupled to primary winding, a spark plug connected to said secondary winding, means coupled to said primary winding for periodically interrupting current through said primary winding at a frequency proportional to engine speed whereby a plurality of pulses are produced have a frequency proportional to engine speed, a solid state switching device having a cathode and anode and a control electrode, said anode and cathode coupled in series with said primary winding and in parallel with said means for periodically interrupting current in said primary winding, circuit means responsive to said plurality of pulses and coupled to said first-mentioned means and to said gate electrode, said circuit means including means for producing a plurality of pulses, the time period between the trailing edge of one of said pulses and the leading edge of the next successive pulse being substantially constant and equal to the time period between the pulses produced by the means for interrupting current in the primary winding when the speed of the engine is equal to the maximum predetermined speed, means coupled to said last-mentioned means and said gate electrode for maintaining said solid-state switching device in a nonconducting state when said plurality of pulses are produced and for switching said solid-state switching device to a conducting state when said pulses are not produced, and means coupled to said solid-state switching device for permitting a low level of current through said means for periodically interrupting

current flow through said primary winding when said solid-state switching means is in a conducting state, said level of current being sufficient to produce pulses proportional to engine speed but insufficient to fire said spark plugs.

10. The combination of claim 9 in which said circuit means includes inhibiting means for preventing any spurious pulses from said ignition coil or from said means for interrupting current through said primary winding from being applied to said means for producing said plurality of pulses.

11. In an ignition system for an internal combustion engine having pulse producing means for supplying ignition pulses to the spark plugs of the engine at a rate proportional engine speed, circuit means for limiting the speed of the engine by reducing the level of said pulses to stop ignition when a maximum safe engine speed is reached, said circuit means including in combination a switching circuit means connected in parallel with said pulse producing means, a comparator having an output circuit coupled to said switching circuit means, said comparator having a first input circuit and a second input circuit, means coupled to said first input circuit for supplying said comparator with a substantially constant level voltage, means coupled to said pulse producing means for differentiating said pulses, a sawtooth wave generator coupled to said means for differentiating said pulses and being reset to a reference voltage level each time the means for differentiating said pulses produces a pulse of a given polarity, the output of said sawtooth wave generator being coupled to the second input circuit of said comparator, said comparator including means for producing an output pulse when the output of said sawtooth wave generator equals the voltage level supplied to said first input circuit of said comparator, said output pulses from said comparator being applied to said switching circuit means to maintain said switching circuit means in a nonconducting state as long as the engine speed is lower than the maximum safe engine speed, the period for said sawtooth wave generator to produce a voltage equal to said constant level voltage applied to said first input circuit of said comparator being equal to the time period between successive ignition pulses at the maximum safe engine speed whereby when said maximum engine speed is exceeded said comparator does not produce output pulses, said switching circuit means including means for switching said switching circuit means to a conducting state when said pulses are not received whereby said switching circuit means shunts said pulse producing means, said switching circuit means including means for permitting a predetermined low level of current through the pulse producing means for permitting the pulses to be produced while simultaneously reducing the level of the pulses to prevent ignition.

12. The combination of claim 11 including inhibiting means coupled to said pulse producing means and to said means for differentiating pulses for preventing a pulse from being applied to said means for differentiating said pulses for a given time period shorter than the time period between successive ignition pulses at the maximum safe engine speed.

13. The combination of claim 12 in which said inhibiting means comprises a second comparator having a first input circuit and a second input circuit, means coupled to said first input circuit for supplying said comparator with a substantially constant level voltage having a magnitude lower than the magnitude of said first-mentioned constant level voltage, the output of said sawtooth wave generator being coupled to said second input circuit, said second comparator including means for producing a substantially constant voltage output signal when the magnitude of the voltage of said sawtooth wave generator is less than the magnitude of the voltage of said second mentioned substantially constant level voltage, said second comparator having an output circuit and means coupling the output circuit of said second comparator to the input of said means for differentiating said pulses, whereby said sawtooth wave generator is prevented from being reset to said reference voltage level during the time said substantially constant voltage output signal is present at the output circuit of said comparator.

14. A maximum engine speed limiter for an internal combustion engine having a plurality of spark plugs, each of said spark plugs being adapted to ignite a fuel-air mixture in a cylinder of the internal combustion engine, a source of electrical energy, an ignition coil having a primary winding and a secondary winding, said primary winding being connected to said source of electrical energy, a distributor coupled to each of said spark plugs and to said secondary winding of said ignition coil, the distributor including means operated by the internal combustion engine for sequentially connecting the spark plugs to the secondary winding of the ignition coil, and means operated by the internal combustion engine in synchronism with the means for sequentially connecting said spark plugs to the secondary winding for periodically interrupting current through the primary winding, a solid-state switching means having output electrodes and a control electrode, said output electrodes connected in parallel with said means for periodically interrupting current through said primary winding and in series with said primary winding, and means coupled to said ignition coil and to said control electrode for maintaining said solid-state switching device in a nonconducting state when the speed of engine is below a predetermined level and for switching said solid-state device device to a conducting state when the engine speed is above said predetermined level, and means positioned in circuit with said solid-state switching device for diverting a portion of the current in the primary winding through said means for periodically interrupting current through said primary winding when said solid-state switching device is in a conducting state.

15. The combination of claim 14 in which said means coupled to said ignition coil and said control electrode of said solid-state switching means comprises means responsive to the periodic interruptions of current through said primary winding for producing a plurality of pulses when the speed of the engine is below said predetermined level and for producing no pulses when the speed of the engine is equal to or above said predetermined speed level, energy storage means coupled to said last-mentioned means for storing the electrical energy in said pulses, and circuit means coupled to said energy storage means and said control electrode for maintaining said solid-state switching device in a nonconducting state when the energy storage means is charged to a predetermined level by said pulses and for switching said solid-state switching device to a conducting state a short time period after said energy storage device ceases to receive pulses.