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Young

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[54] **EXHAUST POLLUTION CONTROL APPARATUS**

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[52] **U.S. Cl.** .... **123/119 A,** 123/102, 123/117
[51] **Int. Cl.** **F02m 25/06**
[58] **Field of Search** .... 123/119 A, 102, 117 A

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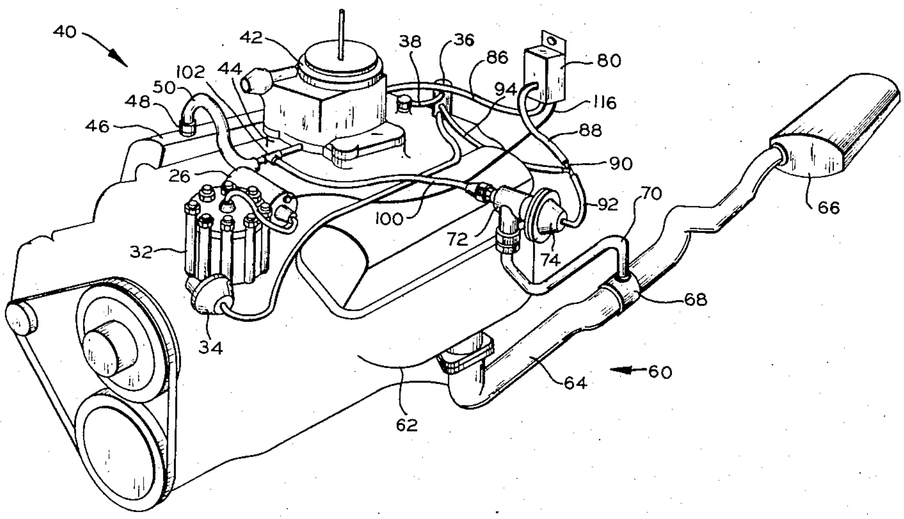
Primary Examiner—Wendell E. Burns

[57] **ABSTRACT**

The invention is disclosed herein in apparatus for minimizing the emission of unburned and partially burned fuel from a vehicle internal combustion engine having a carburetor and intake manifold including means for providing a vacuum source for engine control function, an ignition system including an ignition coil, an electrical energy source connected to the ignition coil, and an exhaust gas manifold. An exhaust gas recirculation valve is utilized for feeding exhaust gases back from an exhaust system to an intake manifold. A solenoid valve is utilized for selectively connecting a vacuum source to operate the exhaust gas recirculation valve. An electronic engine speed sensing means is utilized to control the solenoid valve. Although the electronic engine speed sensing circuit disclosed herein has particular applicability as a control means with the vehicle system described, it should be noted that the novel electronic engine speed sensing circuit has utility elsewhere.

22 Claims, 5 Drawing Figures



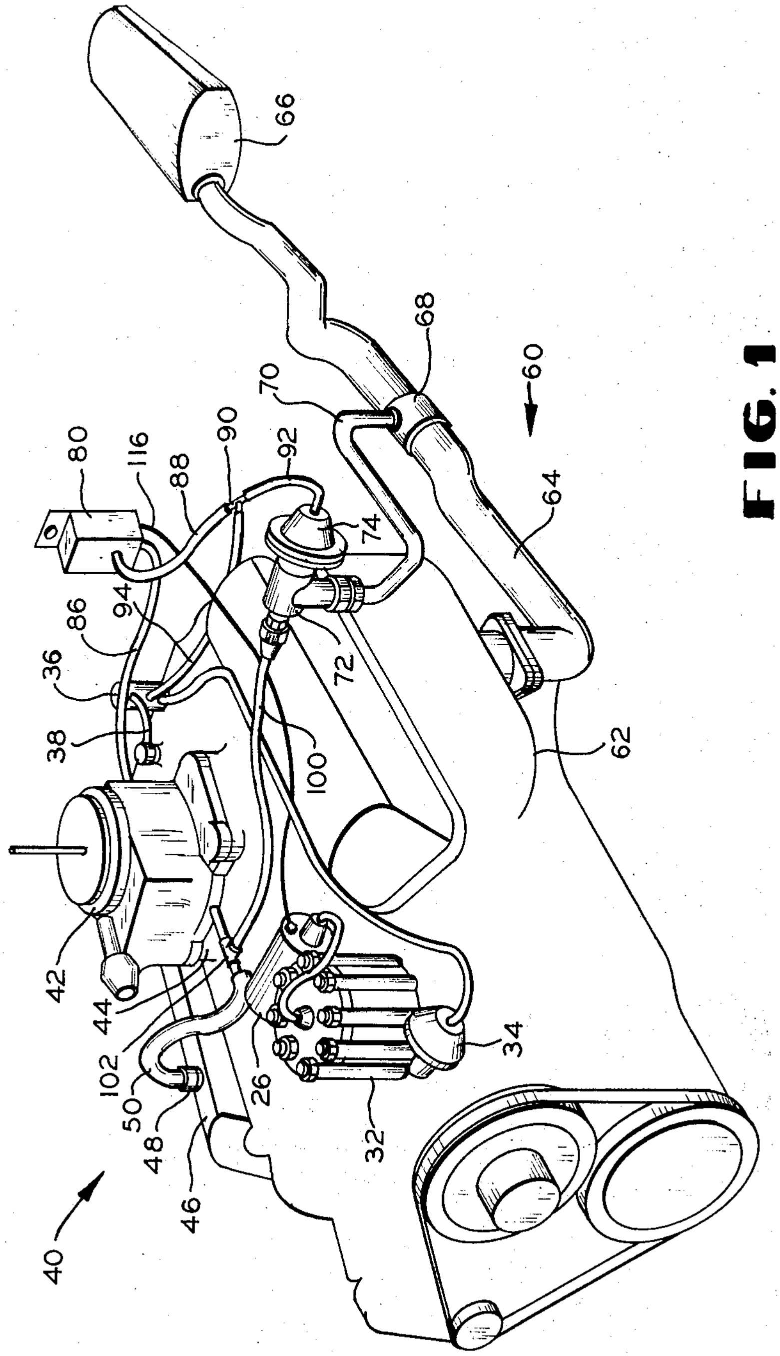

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FIG. 1

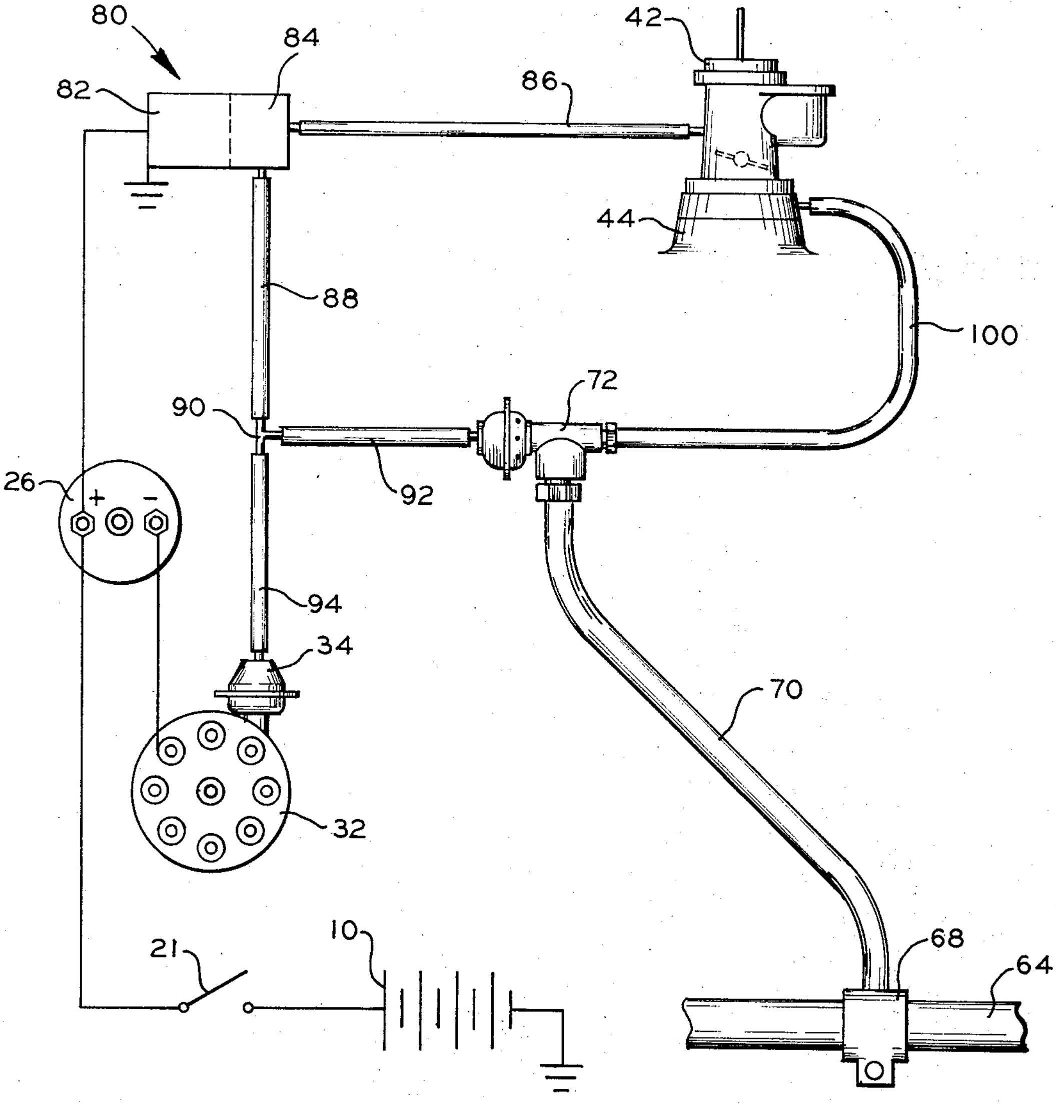

FIG. 2

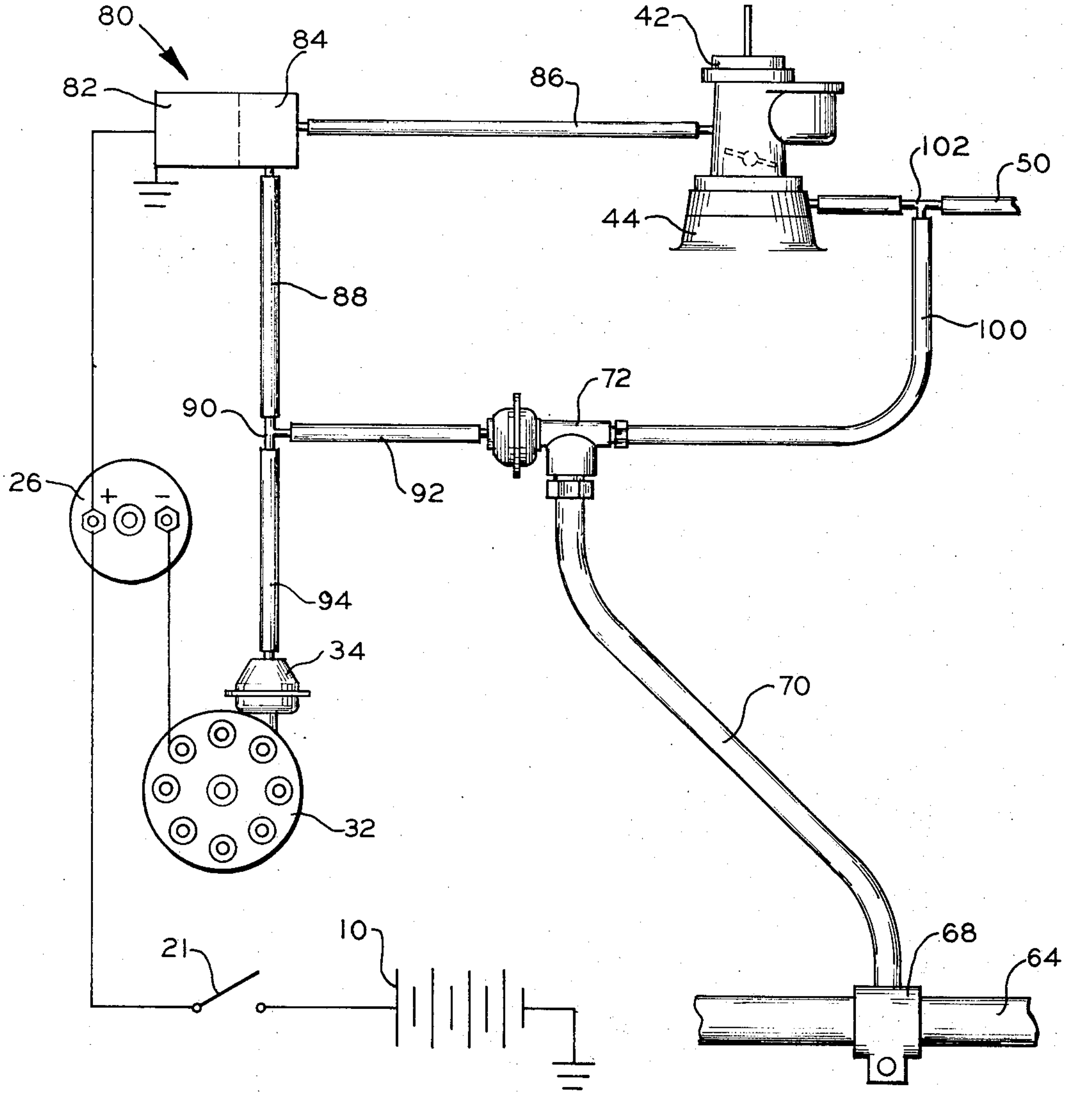

FIG. 3

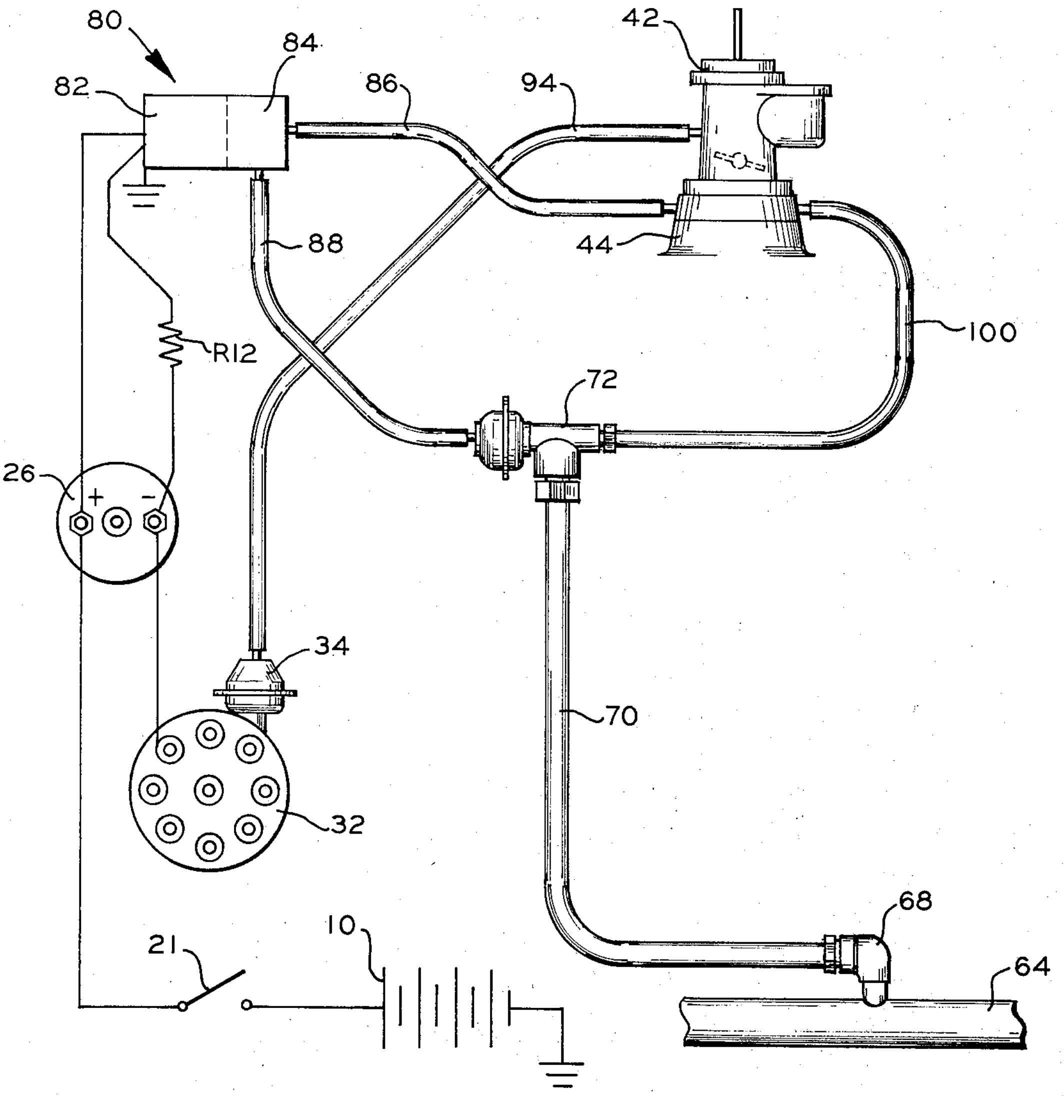

FIG. 4

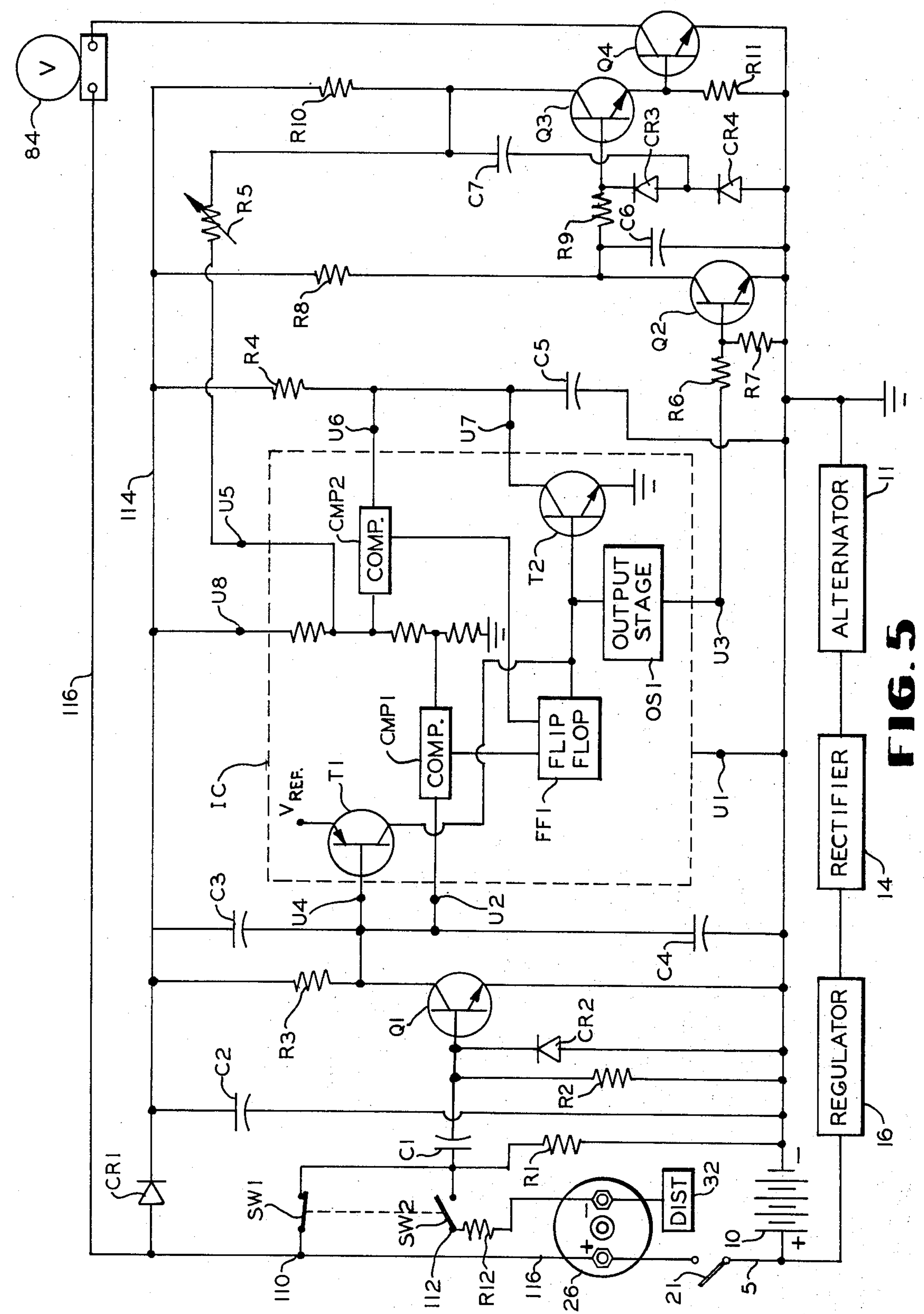
84
V
116
114
R10
Q3
Q4
R11
C7
CR3
CR4
R5
R9
C6
R8
Q2
R4
C5
R7
R6
U6
U7
U5
CMP2
COMP.
T2
U8
OUTPUT STAGE
U3
OS1
FLIP FLOP
FF1
CMP1
COMP.
IC
$V_{REF.}$
T1
U1
C3
U4
U2
C4
R3
Q1
CR2
R2
C2
C1
R1
CR1
SW1
SW2
110
112
R12
116
26
DIST
32
+
−
10
21
5
ALTERNATOR
11
RECTIFIER
14
REGULATOR
16

FIG. 5

EXHAUST POLLUTION CONTROL APPARATUS

BACKGROUND OF THE INVENTION

The problem of air pollution has become of national concern in recent years. To some extent this problem has been related to the exhaust fumes emitted by vehicles powered by internal combustion engines. New cars which are now being produced have installed therein exhaust pollution control devices which are decreasing the amount of exhaust pollution over that found in previously manufactured vehicles. However, there are still a substantial number of vehicles in use which have either no exhaust pollution control devices installed therein or which have less effective pollution control devices.

Accordingly, it is an object of this invention to provide an improved exhaust pollution control apparatus for vehicle internal combustion engines.

It is a further object of this invention to provide an improved exhaust pollution control apparatus which may be easily installed on automobiles or other vehicles which have already been manufactured, and which can also be used as original equipment if desired.

A still further object of this invention is to provide a new and improved engine speed sensing apparatus which may function as the primary control of the exhaust pollution control apparatus disclosed in the embodiments herein, or which may be utilized to provide other functions which are related to engine speed.

SUMMARY OF THE INVENTION

The above objects and features of this invention have been illustrated herein in a preferred embodiment of control apparatus for minimizing the emission of unburned and partially burned fuel from a vehicle internal combustion engine which has a carburetor and intake manifold including means for providing a vacuum source for engine control functions, an ignition system including an ignition coil, an electrical energy source connected to the ignition coil, and an exhaust gas manifold and muffler system. An exhaust gas recirculation valve is utilized to feed exhaust gases back from an exhaust system to an intake manifold. A solenoid valve is utilized for selectively connecting a vacuum source, preferably from the carburetor, to operate the exhaust gas recirculation valve. An electronic engine speed sensing means is utilized to control the solenoid valve.

The engine speed sensing means includes means responsive to voltage variations on the energy source side of the ignition coil, resulting from ignition of fuel in the engine, which converts each of the voltage variations to an input pulse. Means are provided for generating a timing pulse in response to each input pulse and for adjusting the duration of each timing pulse, so that when a predetermined engine speed is reached the timing pulses overlap to provide a steady state output. A pulse detecting network is responsive to the presence of timing pulses for providing an output signal to control the energization of the solenoid valve to prevent vacuum control of the exhaust gas recirculation valve.

The engine speed sensing control means may also be utilized to control the application of a vacuum source to a vacuum responsive spark advance control mechanism. In this instance the solenoid valve opens to connect a vacuum source to the spark advance control mechanism in response to the detection of a predetermined engine speed by the electronic engine speed sensor.

The engine speed sensing means may also include means responsive to the pulse detecting network signal for increasing the duration of each of the timing pulses, after the steady state timing pulse output has been attained, to prevent a hunting condition and require an engine speed lower than the predetermined engine speed setpoint to again obtain a pulse type output from the timing means. In the embodiment herein the pulse detecting network includes inverting amplifier means connected to receive the pulsing output from the timing means and to effectively connect the pulse detecting network to ground in response to the attainment of a steady state output from the timing means in order to inhibit the pulse detecting network output signal.

The pulse detecting network also advantageously includes capacitor means for sensing and storing a pulse output from the timing means to enable a continuous output signal from the pulse detecting network between timing pulses. The capacitor means of the pulse detecting network is further advantageously connected to store an output pulse from the timing means for a length of time sufficient to maintain the continuous output signal from the pulse detecting network in the event that pulses are occasionally missed by or in the control circuit.

The timing pulse generating means includes an RC network including means for charging the capacitor of the RC network through the resistance of the RC network. Means responsive to an input pulse are provided for interrupting a discharge path for the capacitor of the RC network, enabling the capacitor to be charged through the resistor. Means responsive to a predetermined level of charge on the capacitor of the RC network are provided for restoring the discharge path for the capacitor of the RC network. Means responsive to the charging of the capacitor of the RC network provides the timed pulse output while the capacitor is being charged.

The timing pulse generating means advantageously further includes means responsive to the arrival of a second input pulse, during the charging cycle of the capacitor of the RC network of the timing pulse generating means in response to a previously received input pulse, for discharging the capacitor and enabling iniation of a new charging cycle and thus a new timing cycle.

The voltage variation responsive means preferably includes means for differentiating the leading and trailing edges of each variation to obtain positive and negative input pulses, and further includes means for removing one of the positive and negative pulses so that the circuit must only be responsive to a pulse of one polarity.

The power supply for the electronic engine sensing circuit herein is advantageously taken from an alternator energy source side of the ignition coil. The power supply for the sensing circuit advantageously includes rectifier means and capacitor means connected as a peak detecting circuit to provide a stable power supply for the speed sensing means.

The exhaust gas recirculating valve includes valve plunger means biased toward a first position and movable toward a second position via a vacuum responsive servo means. The servo means is then responsive to predetermined vacuum conditions to move the valve plunger to predetermined positions between the fully open and fully closed stops in the valve.

A conduit means is described for connecting the exhaust recirculating valve to an exhaust system which is formed of a material and formed in a configuration to act as a heat exchanger to lower the temperature of the exhaust gas being recirculated.

Other objects, advantages, and features of this invention will become apparent when the following description is taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a view in perspective of a vehicle internal combustion engine with apparatus embodying the teachings of this invention connected thereto;

FIG. 2 is a schematic diagram of a second embodiment of the teachings of this invention;

FIG. 3 is a schematic diagram of a third embodiment of the teachings of this invention;

FIG. 4 is a schematic diagram of a fourth embodiment of the teachings of this invention; and

FIG. 5 is a schematic circuit diagram of an electronic engine speed sensing device which is useful with the embodiments of the invention illustrated in FIGS. 1 through 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is illustrated an internal combustion engine indicated generally at **40** having a carburetor **42** mounted on an intake manifold **44.** A crankcase **46** has a positive crankcase ventilation valve **48** connected thereto and via a conduit **50** to the intake manifold **44.**

An exhaust system indicated generally at **60** includes an exhaust manifold **62,** an exhaust pipe **64,** and a muffler **66.** An exhaust pipe outlet fitting **68** is provided for connecting a stainless steel exhaust gas return tubing **70** between the exhaust system and the exhaust gas recirculation valve **72.**

The exhaust gas recirculation return tube **70** has a dual function. It conducts the exhaust gas from the exhaust pipe **64** to the exhaust gas recirculation valve **72** and acts as a heat exchanger to lower the exhaust gas temperature. It is preferably formed from a thin-walled stainless steel tubing with spiral convolutions enabling hand forming during the installation, but with enough rigidity to eliminate the necessity for supports or tie-downs. Stainless steel was selected for its high degree of corrosion resistance. The attachment fitting **68** is designed so that the pickup end of the return tube **70** is perpendicular to the exhaust stream, eliminating particulate matter from the return system.

The exhaust gas recirculation valve **72** has a diaphragm chamber **74** which includes a servo diaphragm responsive to a vacuum source to position a spring biased valve plunger within the recirculation valve **72.** The valve body is preferably made from cast iron and is steam treated after machining to form a magnetic iron oxide coating to prevent corrosion. The valve plunger is made from stainless steel and the valve servo diaphragm is preferably constructed from a strong, high temperature-resistant material.

Four orifice sizes in the valve cover the full range of engine sizes. It has been experimentally determined that a valve orifice size of 0.125 inches is desirable whenever there are high exhaust back pressures due to the use of air pumps in the system. Engines similar to those now used in a Volkswagen preferably use a valve having an orifice of 0.169 inches. Engines having a displacement of 140 to 375 cubic inches advantageously utilize a 0.196 inch valve orifice, and engines having a displacement of more than 375 cubic inches require a valve orifice size of 0.213 inches. The valve sizes just described have been tested experimentally and obtained optimum nitrous oxide reduction without significantly increasing hydrocarbon and carbon monoxide emissions, increasing fuel consumptions, or causing noticeable driveability problems.

An emissions control device embodying the teachings of this invention is designated at **80** and has an engine speed sensor section **82** which controls a solenoid control valve section **84.** A vacuum source conduit **86** is connected at one end to the solenoid control valve section **84** and at the other end to a vacuum source on the engine. The preferred vacuum source is above the throttle plate of the carburetor (as shown in the embodiments in FIGS. 2 and 3), since the vacuum increases proportionately to the engine speed and power requirements until cruise conditions are reached, and the loss of vacuum at closed throttle position helps cut off the exhaust gas recirculation valve regardless of the engine speed. However, the vacuum source may be located below the throttle plate (as shown in FIG. 4) and provide acceptable operation of the invention.

Referring again to FIG. 1 a vacuum control conduit **88** is connected to the other side of the solenoid control valve and extends to a tee connection **90.** A first branch **92** of the conduit is connected between the tee **90** and the diaphragm control chamber **74** of the exhaust gas recirculation valve **72.** In the embodiment illustrated in FIG. 1, a branch **94** is connected between the tee **90** and the control diaphragm chamber of a vacuum spark advance control mechanism **34** via a thermal bypass valve **36.** If the internal combustion engine does not have a thermal bypass valve, the branch **94** is connected directly to the vacuum advance actuator **34** (as shown in FIGS. 2 and 3). If the engine is of the type in which it is not desired to control the vacuum advance actuator, a conduit **93** is connected between the vacuum source and the vacuum advance actuator. In this last instance (FIG. 4), the conduit **80** extends directly from the control solenoid valve **84** to the exhaust gas recirculation valve **72.**

An exhaust gas recirculation conduit **100** extends between the valve **72** and a tee connection **102** in the conduit **50** between the positive crankcase ventilation valve **48** and the intake manifold **44** to enable the return of the exhaust gas to the intake manifold. This embodiment is shown diagrammatically in FIG. **3.** If there is no positive crankcase ventilation valve on the engine the conduit **100** is connected directly to the intake manifold as shown in FIGS. **2** and **4.**

Referring now to FIG. 5 there is illustrated in detail the control circuit section **82** of the control device **80.** A conventional electrical system for a motor vehicle is illustrated including the power sources of a battery **10** and an alternator **11.** Alternator **11** is connected by way of a rectifier **14** to a regulator **16** with the output of regulator **16** being connected to a power distribution bus **15.** As is well known in the art, power distribution bus **15** may be connected to the positive side of a battery **10,** the negative side of which is connected to ground which usually is the frame of the motor vehicle.

Power distribution bus **15** provides electric power for all of the electrical accessories, instruments, lights and convenience features for the motor vehicle. Another connection is made to bus **15** to supply power for the ignition system. The ignition system has been shown diagrammatically in simplified form for the purposes of clarity and may be traced from bus **15** through the ignition switch **21**, to the primary winding of an ignition coil **26**. The secondary winding of the coil **26** is connected to a distributor **32**. In order to make and break the current through the primary winding of the coil **26**, that winding is connected to a movable arm of a set of breaker points (not shown) which are connected to ground. As is well known in the art the movable arm is actuated by a distributor cam to interrupt the primary current thereby to provide a high voltage in the secondary or ignition circuit.

Ripple voltage pulses are produced by the voltage drop on the battery side of the ignition coil **26** as a result of the closing and opening of the breaker points in the ignition system. This ripple voltage is used as a timing reference. These pulses have a configuration substantially similar to a square wave and are applied to and detected by the control system at terminal **110** connected to the battery or alternator side of ignition coil **26**. Similarly, pulses may be detected at terminal **112** connected to the distributor side of the ignition coil **26**.

Switches SW1 and SW2 are shown ganged together for simultaneous operation to illustrate that when one switch and thus one circuit is open, the other switch and thus the other circuit is closed. If the ignition system is of the type which uses external dropping resistors, (not shown) such as most 12 volt ignition systems for four, six and eight cylinder engines manufactured in the United States and some areas abroad, the switch SW1 is closed and the switch SW2 is opened. The ripple voltage or pulse train generated by the opening and closing of the breaker points is then picked up at the terminal **110** and applied directly to an input capacitor C1. The input capacitor C1 passes only the oscillatory portion of the ripple voltage or input pulse train and prevents application of the direct current level of the input voltage.

If the ignition system does not use external dropping resistors, such as on the four cylinder Volkswagen engine, then the switch SW2 is closed and the switch SW1 is opened. The input pulse train is then received by the control circuit through the terminal **112** and the internal dropping resistor R12 and applied to the input capacitor C1.

An integrated circuit IC having external terminals U1 through U8 and functioning as a timing circuit is designated by the rectangle defined by the dotted lines. An equivalent circuit is diagrammatically shown within the dotted lines. Such integrated circuits are commercially available, e.g. the linear integrated circuit NE/555 manufactured by Signetics, Sunnyvale, California.

The integrated timing circuit IC has been connected for monostable operation so that the timer functions as a one-shot. The external capacitor C5 connected to terminals U6 and U7 is initially held discharged by the transistor section T2 within the circuit IC. Upon application of a negative pulse to input terminal U2, the comparator section CMP1 flips the output of the flip-flop section FF1 within the integrated circuit IC to release a short circuit across the external capacitor C5 and to drive the output from the output section OS1 of the integrated circuit IC to the output terminal U3 to a high level. The capacitor C5 is now charged through resistance R4 and the voltage across the capacitor C5 increases exponentially, depending upon the value of the resistor R4 connected between terminals U6, U7 and a power supply lead **114**.

When the voltage across the capacitor C5 reaches a predetermined threshold value, such as two-thirds of the power supply voltage applied to the terminal U8, the comparator section CMP2 of the integrated circuit resets the flip-flop section FF1. The resetting of the flip-flop section FF1 turns the transistor section T2 "on" again to rapidly discharge the external capacitor C5 and drive the output from the output stage OS1 to its low state.

The integrated circuit IC triggers on a negative-going input signal applied to the input terminal U2 when the level reaches a predetermined threshold value, such as one-third of the power supply voltage. Once triggered, the integrated circuit IC will remain in this state until the set time has elapsed, as determined by the time constant of the R4–C5 circuit, even if triggered again during this interval.

The time that the output from the terminal U3 is in the high state is dependent upon the time constant of the resistor R4-capacitor C5 combination. Since the charge rate and the threshold level of the comparator sections of the integrator circuit IC are both directly proportional to the supply voltage, the timing interval is independent of supply voltage variations.

Applying a negative pulse to the reset terminal U4 during the timing cycle discharges the external capacitor C5 and causes the timing cycle to start over again. The timing cycle will now commence on the positive edge of the reset pulse. During the time that the reset pulse is applied, the output from terminal U3 is driven to its low state. Since the input terminal U2 and the reset terminal U4 are connected together in this embodiment, an input pulse to the terminal U2 also acts as a reset pulse to the terminal U4. Thus, when input pulses are arriving at time intervals shorter than the predetermined cycle, the timing cycles will be reset to start again and no input pulses will be missed.

The pulse train generated by the opening and closing of the breaker points in the ignition system is differentiated by the resistor R2-capacitor C1 network. The resistor R1 will provide a direct current path for the capacitor C1 when the points are opened. The rectifier diodes CR2 limits or substantially removes the negative-going voltage spikes resulting from the differentiation of the trailing edges of the square wave type pulses in the input pulse train. The positive-going pulses resulting from the differentiation by the network R2–C1, switches the collector of the transistor Q1 from a high state to a low state and back again, and the transistor Q1 acts as an inverter amplifier providing negative-going spikes at the junction of the resistor R3 and the emitter of the transistor Q1.

The rectifier diode CR1 connected between terminal **110** and the power supply lead **114** for the control circuit acts as a peak detector and enables the capacitor C2 to charge to the peak value of the output of the alternator and to maintain a stable power supply voltage to the control circuit on lead **114**. The capacitors C3, C4 filter noise from the negative-going output from the inverting amplifier Q1.

The negative-going spike from the inverting amplifier Q1 is then applied to terminals U2, U4 of the integrated circuit IC to initiate an output from the terminal U3 as explained hereinbefore. The "on" time of the timing cycle of the output from the terminal U3 is solely determined by the time constant of the R4–C5 network as also explained hereinbefore. As the engine speed increases, the frequency of the pulse train applied at the terminals **110, 112** also increases, and the length of time between trigger impulses applied to the terminals U2, U4 decreases. This decreases the "off" time of the output from the terminal U3. Therefore, at and above a predetermined engine speed the length of time between the trigger pulses is the same as or less than the length of the timing cycle of the integrated circuit and the "off" time of the output from the terminal U3 is then zero and provides a steady state output level.

The transistor Q2 is connected as an inverting amplifier and drives a pulse detecting output network. Capicator C6 connected to the output of the transistor Q2 acts as a decoupling capacitor to remove noise and filter the output of the transistor Q2.

The pulse detector output network consists of the resistors R9, R10, and R11; the diodes CR3 and CR4; the capacitor C7; and the transistor Q3 in addition to the transistor Q2. A pulsing output from the timing circuit to the inverting amplifier Q2 maintains the pulse detecting transistor Q3 "on." A positive-going pulse from the transistor Q2 turns the transistor Q3 "on" and charges the storage capacitor C7 connected between the collector of Q3 and the junctions of the diodes CR3 and CR4. The pulse sensed and stored as a positive charge on the capacitor C7 then maintains the transistor Q3 "on" through the diode CR3 until the next pulse arrives, since its only discharge path is through the very high resistance between the emitter and base of the transistor Q3. When the transistor Q2 is not supplying a pulse output it is "on" and effectively connects the base of the transistor Q3 to ground or holds at a level below the threshold required to turn the transistor Q3 "on."

The capacitor C7 will retain the charge thereon for a sufficient length of time to maintain transistor Q3 "on" even though one or more input pulses are missed by the control circuit or if the timing circuit malfunctions causing one or more timing pulses to be missed.

As the engine speed approaches the setpoint determined by the selection of the values of the resistor R4-capacitor C5 network, the pulsing output from the transistor Q2 is converted to a steady state output and the transistor Q3 is turned "off." The emitter voltage of the transistor Q3 drops, thereby also turning the output transistor Q4 "off." Current flow through the output transistor Q4 and the load device, in this instance the solenoid operated valve **84**, from the power supply lead **116** to ground is stopped. The solenoid of the valve **84** is deenergized and the valve opens.

To prevent a "hunting" condition when the engine speed varies from just above to just below the predetermined setpoint, an adjustable resistor R5 is connected to feed back the increase in collector voltage of transistor Q3 to the terminal U5 of the integrated circuit IC when the transistor Q3 is turned "off."

As shown in the equivalent circuit within the dotted lines, the terminal U5 is connected to an intermediate point of a voltage dividing resistor network connected between the terminal U8 and ground. As noted hereinbefore the voltage and current supplied via the terminal U8 controls the comparator sections CMP1 and CMP2 of the integrated circuit IC. The application of the feedback voltage and current via the resistor R5 and the terminal U5 increases the voltage sensed by the comparator section of the integrated circuit IC to lengthen the "on" time of each pulse provided by the output stage OS1.

This then requires the actual engine speed to drop below the "setpoint" engine speed before the output from the output stage OS1 and the transistor Q2 becomes a pulsating output rather than a steady state output. The value of the resistor R5 may be adjusted to vary the hysteresis effect and determine how far below the original setpoint the engine speed must drop before the steady state output from the terminal U3 changes to a pulsating output.

The system described provides a fail-safe approach in that the solenoid valve is normally opened if not energized. When the ignition switch **21** is closed, current is supplied via the lead **116** to the solenoid of the valve **84** and through the transistor Q4 to energize the solenoid and close the valve **84**. This disconnects the vacuum source from the vacuum advance actuator and enables the engine to idle smoothly. If for any reason the valve malfunctions and does not close under these circumstances, the engine will idle very roughly letting the operator know that the recirculating system is not operating properly.

In summary, there is disclosed herein apparatus which utilizes engine speed to selectively control exhaust gas recirculation and delayed spark advance. Primary control of the system is attained by use of an engine speed switch. The switch controls a normally open solenoid valve which supplies a vacuum to actuate the distributor and the exhaust gas recirculation valve servo motors.

In operation, when the ignition key is turned "on" to start the engine, power is supplied to the coil, engine speed switch, and the vacuum solenoid valve **84**. When the solenoid of valve **84** is energized and the valve closed, the vacuum is removed from the exhaust gas recirculating valve **72** in all four embodiments described herein, and the vacuum is removed from the vacuum advance actuators **34** in the embodiments illustrated in FIGS. **1**, **2**, and **3**. When the engine reaches a pre-set or setpoint speed, for example, 1,300 rpm or about 26 to 28 miles per hour, the speed sensor deenergizes the solenoid and opens the valve **84** to admit vacuum to the exhaust gas recirculation valve servo motors in FIGS. **1** through **4**, and the servo motors of the vacuum advance actuators **34** in FIGS. **1**, **2**, and **3**. The spark is advanced and a metered amount of exhaust gas is returned to the engine via the intake manifold.

When the engine speed drops below a second predetermined point, for example, 1,100 rpm or about 18 to 20 miles per hour, the speed sensing circuit energizes the solenoid and closes the valve **84**. In the embodiments in FIGS. **1**, **2**, and **3** the spark returns to the advanced position, and in the embodiments of FIGS. **1**, **2**, **3**, and **4** the exhaust gas recirculation is shut off. The return spring of the exhaust gas recirculating valve **72** is calibrated so that during wide open throttle accelerations (panic conditions demanding maximum performance under two inches mercury manifold vacuum) above 1,300 engine rpm, no exhaust gas is returned to the engine. When a hard acceleration (2.5 to 4.5 inches mercury manifold vacuum) is made, the valve **72** is starting to open, providing some degree of nitrous oxide reduction under this condition. During a moderate acceleration, an additional metered amount of exhaust gas is returned as the engine can tolerate an increased amount of exhaust gas recirculation since the speed is up and the power requirements are low.

When the vehicle decelerates the vacuum valve is shut off at 1,100 rpm. allowing the engine to return to normal idle. As noted hereinbefore, the preferred vacuum source is above the throttle plate since the vacuum increases proportionally to the engine speed and power requirements until cruise conditions are reached, and the loss of vacuum at the closed throttle position helps cut off the exhaust gas recirculation regardless of the engine speed.

The selective control of the exhaust gas recirculation or delayed spark advance is designed to obtain optimum nitrous oxide reduction with a minimal effect upon vehicle driveability and performances when circumstances demand maximum acceleration.

In most configurations, both the exhaust gas recirculation and the delayed spark advance may be controlled. There may be exceptions, for example with some Volkswagen engines, where it is desirable to utilize only exhaust gas recirculation. Delay of the spark advance for these type of engines may result in undesirable driveability problems. Except for the Volkswagen type engine and other similar engines, most configurations require only one attachment wire as shown in FIGS. **2** and **3**. The single wire furnishes power for the switch and the vacuum solenoid valve and provides a pickup path for the ignition pulses required to measure engine speed. The circuit is completed by grounding the base of the case to the vehicle body on installation. For systems not using external dropping resistors the two-wire connection as illustrated diagrammatically in FIG. **4** and schematically in FIG. **5** is used.

Compensation for ambient temperature changes have been provided for in the circuit design of the engine speed sensing switch. The vacuum solenoid valve **84** may be mounted inside the same case with the engine speed sensing circuit **80** for protection and to simplify and cut down on installation time and errors. If the engine manufacturer provides thermal protection for the spark advance, this feature is retained when the vacuum hoses are connected as illustrated in FIG. **1**.

In conclusion, it is pointed out that while the illustrated examples constitute practical embodiments of my invention, I do not limit myself to the exact details shown, since modification of these details may be made without departing from the spirit and the scope of this invention.

I claim:

1. Control apparatus for minimizing the emission of unburned and partially burned fuel from a vehicle internal combustion engine having a carburetor and intake manifold including means for providing a vacuum source for engine control functions, an ignition system including an ignition coil, an electrical energy source connected to the ignition coil, and an exhaust gas system; comprising

a. an exhaust gas recirculation valve for feeding exhaust gases back from an exhaust system to an intake manifold,

b. a solenoid valve for selectively connecting a vacuum source to operate said exhaust gas recirculation valve, and

c. electronic engine speed sensing means for controlling said solenoid valve,

d. said engine speed sensing means including means responsive to voltage variations at the ignition coil resulting from ignition of fuel in the engine for converting each of said voltage variations to an input pulse,

e. said engine speed sensing means further including means for generating a timing pulse in response to each input pulse and for adjusting the duration of each timing pulse so that when a predetermined engine speed is reached said timing pulses overlap to provide a steady state output,

f. said engine speed sensing means further including a pulse detecting network responsive to the presence of timing pulses for providing an output signal to control the energization of said solenoid valve to prevent vacuum control of said exhaust gas recirculation valve.

2. Control apparatus as defined in claim **1** in which said engine speed sensing means further includes means responsive to said pulse detecting network signal for increasing the duration of each of said timing pulses after said steady state timing pulse output has been attained to prevent a hunting condition and require an engine speed lower than said predetermined engine speed to again obtain a pulse type output from said timing means.

3. Control apparatus as defined in claim **1** in which said pulse detecting network includes inverting amplifier means connected to receive said pulsing output from said timing means and for effectively connecting said pulse detecting network to ground in response to the attainment of a steady state output from said timing means to inhibit said pulse detecting network output signal.

4. Control apparatus as defined in claim **1** in which said pulse detecting network includes capacitor means for sensing and storing a pulse output from said timing means to enable a continuous output signal from said pulse detecting network between timing pulses.

5. Control apparatus as defined in claim **4** in which said capacitor means of said pulse detecting network is connected to store a pulse output from said timing means for a length of time sufficient to maintain said continuous output signal from said pulse detecting network in the event pulses are occasionally missed in the control circuit.

6. Control apparatus as defined in claim **1** in which said timing pulse generating means comprises

a. an RC network including means for charging the capacitor of the RC network through the resistance of the RC network,

b. means responsive to an input pulse for interrupting a discharge path for the capacitor of said RC network enabling said capacitor to be charged through said resistor,

c. means responsive to a predetermined level of charge on said capacitor of said RC network for restoring said discharge path for said capacitor of said RC network, and

d. means responsive to the charging of said capacitor of said RC network for providing an output while said capacitor is being charged.

7. Control apparatus as defined in claim **6** in which said timing pulse generating means further includes means responsive to the arrival of a second input pulse, during the charging cycle of said capacitor of said RC network in response to a previously received input pulse, for discharging said capacitor and enabling initiation of a new charging cycle and thus a new timing cycle.

8. Control apparatus as defined in claim **1** in which said voltage variation responsive means includes means for differentiating the leading and trailing edges of each variation to obtain positive and negative input pulses, and which further includes means for removing one of said positive and negative pulses.

9. Control apparatus as defined in claim **1** in which a power supply for said electronic engine speed sensing means is taken from an alternator energy source side of the ignition coil, said power supply including rectifier means and capacitor means connected as a peak detecting circuit to provide a stable power supply for said speed sensing means.

10. Control apparatus as defined in claim **1** in which said exhaust gas recirculating valve includes valve plunger means biased toward a first position and movable toward a second position by a vacuum responsive servo means.

11. Control apparatus as defined in claim **10** in which said servo means is responsive to predetermined vacuum conditions to move said valve plunger to predetermined positions.

12. Control apparatus as defined in claim **1** which further includes conduit means for connecting said exhaust gas recirculating valve to an exhaust system, said conduit means being formed of a material and in a configuration to act as a heat exchanger to lower the temperature of the exhaust gas being recirculated.

13. Control apparatus as defined in claim **1** which further includes means for connecting said solenoid valve to control the application of a vacuum source to a vacuum responsive spark advance control mechanism, said solenoid valve opening to connect a vacuum source to said spark advance control mechanism in response to the detection of a predetermined engine speed by said electronic engine speed sensor.

14. Electronic engine speed sensing circuit apparatus comprising

a. means responsive to voltage variations at an ignition coil resulting from ignition of fuel in an engine for converting each of said voltage variations to an input pulse,

b. means for generating a timing pulse in response to each input pulse and for adjusting the duration of each timing pulse so that when a predetermined engine speed is reached said timing pulses overlap to provide a steady state output, and

c. pulse detecting network means responsive to the presence of timing pulses for providing an output signal to control the energization of an engine function control device.

15. Apparatus as defined in claim **14** which further includes means responsive to said pulse detecting network signal for increasing the duration of each of said timing pulses after said steady state timing pulse output has been attained to prevent a hunting condition.

16. Apparatus as defined in claim **14** in which said pulse detecting network includes inverting amplifier means connected to receive said pulsing output from said timing means and for effectively connecting said pulse detecting network to ground in response to the attainment of a steady state output from said timing means to inhibit said pulse detecting network output signal.

17. Apparatus as defined in claim **14** in which said pulse detecting network includes capacitor means for sensing and storing a pulse output from said timing means to enable a continuous output signal from said pulse detecting network between timing pulses.

18. Apparatus as defined in claim **17** in which said capacitor means of said pulse detecting network is connected to store a pulse output from said timing means for a length of time sufficient to maintain said continuous output signal from said pulse detecting network in the event pulses are occasionally missed in the control circuit.

19. Apparatus as defined in claim **14** in which said timing pulse generating means comprises

a. an RC network including means for charging the capacitor of the RC network through the resistance of the RC network,

b. means responsive to an input pulse for interrupting a discharge path for the capacitor of said RC network enabling said capacitor to be charged through said resistor,

c. means responsive to a predetermined level of charge on said capacitor of said RC network for restoring said discharge path for said capacitor of said RC network, and

d. means responsive to the charging of said capacitor of said RC network for providing an output while said capacitor is being charged.

20. Control apparatus as defined in claim **19** in which said timing pulse generating means further includes means responsive to the arrival of a second input pulse, during the charging cycle of said capacitor of said RC network in response to a previously received input pulse, for discharging said capacitor and enabling iniation of a new charging cycle and thus a new timing cycle.

21. Control apparatus as defined in claim **14** in which said voltage variation responsive means includes means for differentiating the leading and trailing edges of each variation to obtain positive and negative input pulses, and which further includes means for removing one of said positive and negative pulses.

22. Control apparatus as defined in claim **14** in which a power supply for said electronic engine speed sensing means is taken from an alternator energy source side of an ignition coil, said power supply including rectifier means and capacitor means connected as a peak detecting circuit to provide a stable power supply for said speed sensing apparatus.

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