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[54] PRECISION FUEL METERING SYSTEM HAVING OPERATIONAL MODE CHANGE DURING TRANSIENT INTERVALS

16 Claims, 2 Drawing Figs.

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[51] **Int. Cl.** **F02d 5/00**
[50] **Field of Search** 123/32, 32SPA, 32E, 32E1, 119, 139.17

[56] **References Cited**

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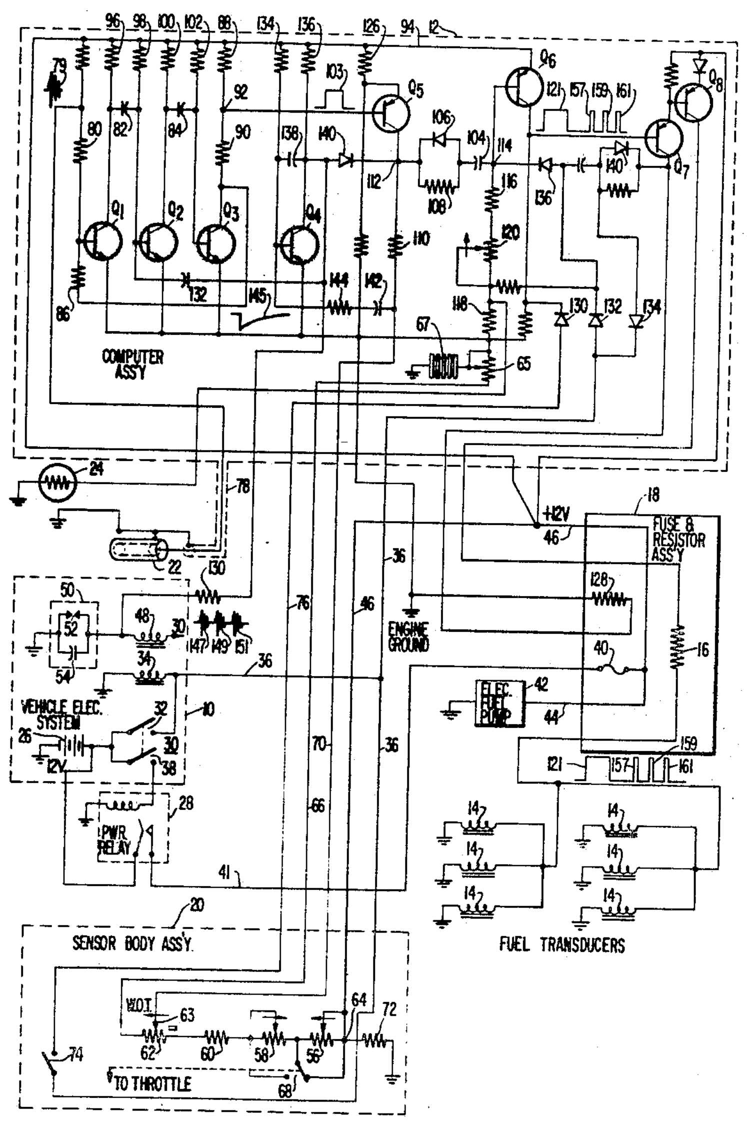
ABSTRACT: An electronic precision fuel metering system which computes the necessary amount of fuel to be delivered simultaneously to each of the cylinders at least once per engine cycle, that is once every other revolution of the engine crankshaft of a four-stroke cycle engine or once every revolution of a two stroke cycle engine, in response to the engine operating requirements under a steady state condition of operation. During a period of transient inlet manifold pressure increase, such as, but not limited to the occurrence of acceleration in which a transient interval exists from one steady state of operation to another, the system however undergoes a mode change wherein fuel is simultaneously delivered to all of the cylinders at a rate equal to the firing rate of all cylinders that is each time a cylinder fires, over a predetermined portion of one or more engine cycles. This system provides for proper computation of the fuel required by the engine under transient conditions, and is sensitive to both magnitude, duration, and rate of manifold pressure changes, such as may occur during throttle actuation. The system reverts to the steady state operational mode, of at least once per engine cycle, when the fuel requirements have been updated and provided, for transient interval during the predetermined portion of the engine cycle where the computer was operating at a rate equal to the firing rate of all cylinders. The duration of the mode change interval may also be terminated through circuit action when manifold pressure drops in response to engine requirements.



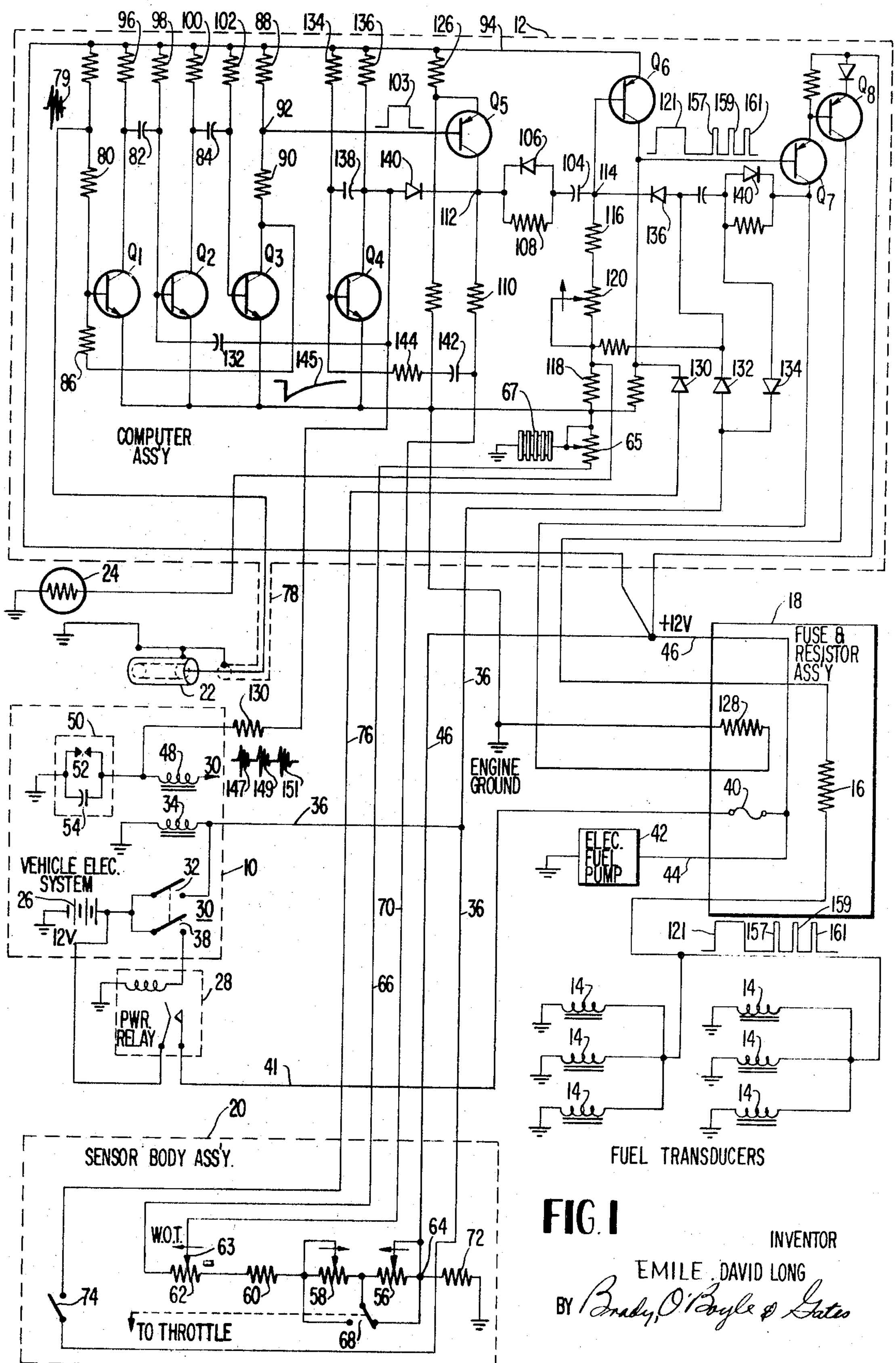


FIG. I

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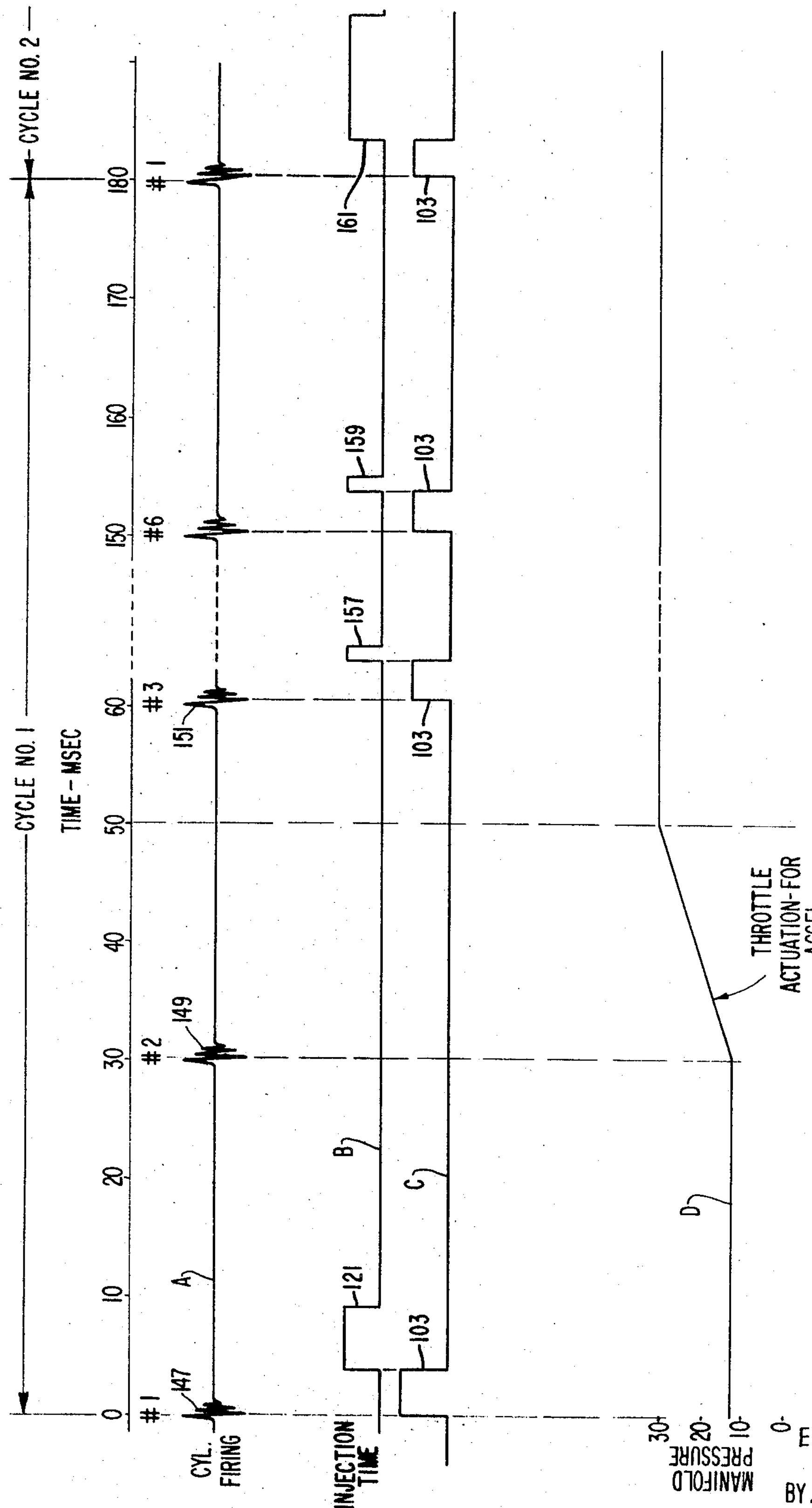

FIG. 2

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PRECISION FUEL METERING SYSTEM HAVING OPERATIONAL MODE CHANGE DURING TRANSIENT INTERVALS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is related to the following applications:

1. "Precision Fuel Metering system," U.S. Ser. No. 650,563, filed Jun. 13, 1967, now U.S. Pat. No. 3,412,718, E. David Long, applicant.

2. "Electronic Modulator Circuit for Precision Fuel Metering Systems," U.S. Ser. No. 653,484, filed Jul. 14, 1967, now abandoned in favor of continuation application U.S. Ser. No. 809,450, filed Feb. 19, 1969, now U.S. Pat. No. 3,493,906, E. David Long, applicant.

3. "Actuator Circuit for Electronic Fuel Metering Systems," U.S. Ser. No. 715,056, filed Mar. 21, 1968, now U.S. Pat. No. 3,500,801, E. David Long and Keith C. Richardson, applicants.

BACKGROUND OF THE INVENTION

This invention is directed to precision fuel metering systems wherein a plurality of fuel metering transducers are employed for delivering, preferably simultaneously, measured amounts of fuel to each of the cylinders of an internal combustion engine, at least once per engine cycle, i.e. the total time required for all the engine pistons to complete their respective cycles of operation, in response to an electronic computer which measures various engine operational and environment parameters, such as engine intake manifold pressure, air temperature, engine temperature, engine speed, throttle position and barometric pressure. The computer generates an energizing pulse for the transducers of a variable pulse width which is a function of the measured parameters. The transducers feeding each of the cylinders is held in the open position for the optimum period of time so that a proper amount of fuel is fed to the cylinders with respect to the air charge for maximum efficiency of operation. Such a system not only provides increased fuel economy and output power but also provides a system which decreases the amount of pollutants dumped into the atmosphere. This latter condition, moreover, far surpasses present minimum U.S. governmental restrictions on air pollution by automobiles.

The aforementioned related patent application Ser. No. 650,563, now U.S. Pat. No. 3,412,718, entitled "Precision Fuel Metering System" discloses a system of the type described and teaches the use of extremely fast acting miniature electrically actuated fuel transducers or injectors mounted inside of the engine head adjacent the respective valve port in close proximity thereto. The second aforementioned pending application, U.S. Ser. No. 809,450 entitled "-Modulator Circuit for Precision Fuel Metering Systems " discloses a computer circuit for generating the required energizing pulse for the transducers shown in the first-mentioned application. The third copending application, U.S. Ser. No. 715,056 entitled "Actuator Circuit for Electronic Fuel Metering Systems" discloses a circuit whereby the modulator circuitry described by the third aforementioned application can be controlled in response to energy coupled from a selected spark plug lead thereby obviating the need for mechanical actuation as heretofore been required in such a system. In a spark ignited internal combustion engine, the mass of fuel required is proportional to the mass of air inducted in the combustion chamber, and must be held within certain defined limits for combustion to occur. The absolute mass of fuel required will then be determined by the pressure in the inlet system which in turn may vary as a function of engine load requirements.

During a steady state condition such as, but not limited to the idling condition, the pressure in the inlet induction holds relatively constant. In a "Precision Electronic Fuel Metering System" it is highly desirable to sample the inlet pressure at a rate lower than that established by the basic ignition and induction rate of the individual cylinders. A system such as this will be able to accurately compute the proper fuel requirements during steady state conditions but has the basic limitation that it cannot detect a change in conditions that occurs between computing periods. As an example, consider a precision electronic fuel metering system which has a basic computer sampling rate of once per engine cycle. In a four stroke cycle engine, this would be once every two revolutions of the engine crankshaft. If the inlet pressure were to increase such as, but not limited to, that during the initial period of an acceleration, those cylinders whose intake period occurred after the increase in inlet pressure would receive a greater mass of air and thus for a given fuel/air ratio would require an increased mass of fuel. If the computer sampling period were fixed at the lower once per engine cycle rate the greater mass of fuel required could not be delivered until the next normal computer sampling period occurred. Under these conditions, it is possible then that a number of cylinders would have failed to ignite due to improper fuel to air ratio. To alleviate this fundamental limitation, it is necessary to provide an additional computer sampling interval period upon an upward change in inlet pressure. This additional period would then provide a means of recomputing and supplying the fuel required for the desired fuel/air ratio.

SUMMARY OF THE INVENTION

The system described in this application provides a means of obtaining an additional sampling interval period or periods dependent on the magnitude, rate and duration of a transient in inlet pressure. The additional sampling period is provided by means of an actuation signal processed from the engine ignition system primary at a rate equal to the basic firing rate of the engine and thus in synchronism with the individual cylinder induction rate of the engine. The first ignition signal to occur after the upward transient in inlet pressure will produce a sampling period which will allow for recomputation of engine fuel requirements during transient modes of engine operation and provide the necessary fuel to the engine and comprises a nonregenerative signal generator adapted to generate a transducer energizing signal of variable pulse width, first actuator means coupled to said nonregenerative signal generator circuit for rendering said signal generator operative at least once every engine cycle, and second actuator means coupled to said signal generator for supplementing said first actuator means and operating said nonregenerative signal generator once per every cylinder firing over one or more engine cycles during a transient interval of engine operation such as acceleration. The second actuator means is coupled to the ignition circuit of the engine for receiving a signal in response to each firing of every cylinder and is operated in response to an upward change in engine manifold pressure whereby an increase in vacuum pressure indicative of engine acceleration effects generation and coupling of an actuating signal to the nonregenerative signal generator for causing the fuel transducers to operate for a relatively short period each time a cylinder fires, but becoming inoperative during steady state operation whereupon said first actuator means again controls said nonregenerative signal generator means to operate the fuel transducers once per engine cycle. An engine cycle is defined as the time period required for all the engine pistons to complete respective cycles of operation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an electrical schematic diagram of a precision fuel metering system including the preferred embodiment of the subject invention.

FIG. 2 is a time diagram of waveforms helpful in understanding the operation of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The system disclosed comprises an internal combustion engine electrical system **10** coupled to the present invention which is included in a computer assembly **12** and operates to generate electrical energizing pulse signals of variable pulse width for a plurality of fuel transducers **14**. The energizing pulse is coupled to the fuel transducers **14** via a high power, low value resistor **16** located in a fuse and resistor assembly **18**. The computer assembly **12** is additionally coupled to a sensor body assembly **20** as well as an ignition pulse energy pickup device **22** coupled to a spark plug lead, not shown, and an engine temperature sensing thermistor **24**.

The engine electrical system **10** is comprised of a **12V**. DC battery **26**, the positive terminal of which is coupled to the normally open contacts of a power relay **28** and an ignition switch **30**. The ignition switch contacts **32** embody the starter contacts and are coupled to a starter solenoid **34** and to circuit lead **36** which is connected to the computer assembly **12** and the sensor body **20**. The switch contacts **32** are adapted to be momentarily closed only when starting the engine. The other set of switch contacts **38** of the ignition switch **30** are adapted to be continuously closed when the engine is in operation whereupon the relay coil of the power relay **28** is energized closing the normally open contacts thereof. At such time, the **12V**. battery potential is coupled to the system through the fuse **40** located in the fuse and resistor assembly **18**. From the fuse **40**, the **12V**. battery potential is then coupled to an electrical fuel pump **42** by means of the circuit buss **44** and to the computer assembly **12** and the sensor body assembly **20** by means of the circuit buss **46**.

The engine electrical system **10** additionally is shown comprising an ignition coil **48** coupled in series to the distributor **50** of the engine including the points **52** and the condenser **54**. The opposite side of the ignition coil **48** is adapted to be coupled back to the battery **26** through the ignition switch **30**.

The sensor body **20** comprises, inter alia, a resistive voltage divider network comprised of variable resistors **56** and **58**, the fixed resistor **60** and a potentiometer **62**. The **12V**. DC potential from the battery **26** is applied to one end of the voltage divider network by means of circuit lead **46** which is coupled to the junction **64** at one end of the variable resistor **56**. The other end of the voltage divider network is returned to ground through the variable resistor **65** in the computer assembly **12** by means of the circuit lead **66**. The variable resistor **65** is responsive to atmospheric pressure and forms part of the voltage divider network, being actuated by the element **67**. An idle switch **68** is coupled across the rheostats **56** and **58** so that one or the other is selectively shunted thereby. The armature of the switch **68** is mechanically coupled to the engine throttle, not shown, and is actuated in accordance with throttle position. The variable resistor **56** is adapted to be normally shunted; however, actuation of the throttle will cause rheostat **58** to be shunted.

The potentiometer **62** is referred to as the pressure sensor potentiometer and the movable tap **63** is adapted to be coupled to the engine intake manifold vacuum sensor, not shown. The voltage appearing at the movable tap **63** is a function of the engine operating parameters including manifold pressure. The voltage, moreover, appearing at the tap **63** of the pressure sensor potentiometer **62** is coupled to the computer assembly by means of circuit lead **70**. This voltage is of utmost importance for reasons which will be described subsequently. Additionally, the sensor body assembly **40** includes a fast idle heater resistive element **72** which is connected from the terminal **64** to ground, while a deloader switch **74** is adapted to supply a **12V**. potential momentarily from lead **36** to the computer assembly **12** by means of circuit lead **76**. The operation of the voltage divider, the deloader switch **74**, the fast idle heater, is more fully described in the aforementioned related application Ser. No. 809,450, entitled "Modulator Circuit."

The computer assembly **12**, as noted above, has for its function the generation of the energizing signals for the fuel transducers **14**. It is comprised of a first actuator circuit including transistors Q_1 and Q_2 and Q_3; a second actuator circuit including transistor Q_4, and transistors Q_2 and Q_3; and a nonregenerative variable pulse width signal generator including transistors Q_5, Q_6, Q_7 and Q_8. The first actuator circuit including transistors Q_1 through Q_3 is similar to the actuator circuit shown and described in the above-noted related application Ser. No. 715,056 entitled "Actuator Circuit." The nonregenerative signal generator including transistors Q_5 through Q_8 is similar to, but not identical to, the modulator circuit described in said related application entitled "Modulator Circuit." The present invention is primarily but not exclusively directed to the circuitry of the transistor Q_4 in combination with transistors Q_2 and Q_3 and its operation in combination with the first actuator circuit including transistors Q_1, Q_2 and Q_3 and the nonregenerative pulse generator including transistors Q_5, Q_6, Q_7 and Q_8.

Considering now the computer assembly **12** in greater detail, transistor Q_1 is coupled to the ignition pulse energy coupling device **22** by means of the shielded cable **78**. The device **22** couples a portion of the ignition pulse energy (waveform **79**) appearing on a selected spark plug lead, not shown, to the base of transistor Q_1 by means of the resistor **80**. A capacitor **82** couples the collector of transistor Q_1 to the base of transistor Q_2. Similarly, the collector of transistor Q_2 is coupled to the base of transistor Q_3 by means of the capacitor **84**. A feedback resistor **86** is directly coupled from the collector of Q_3 back to the input of transistor Q_1. The collector load resistor of transistor Q_3 is comprised of the series connected resistors **88** and **90**, having a common connection at the junction **92**. Power supply potential is provided by means of a supply buss **94** coupled to the circuit lead **46** out of the fuse and resistor assembly **18**.

In operation, transistors Q_1, Q_2 and Q_3 are normally biased into conduction so that they operate in the saturation region of their respective current-voltage characteristic. In such operation, the transistors provide a very low impedance or a closed switch condition between their respective collector-emitter junctions. Capacitors **82** and **84** therefore have both their terminals substantially shunted to ground and are completely discharged. Upon the occurrence of a high-voltage ignition pulse, which is a high-energy bipolar waveform having a rapidly decreasing amplitude, the positive swing of the pulse will not affect transistor Q_1 inasmuch as it is already in its conductive state; however, the negative swing will turn transistor Q_1 off. Capacitor **82** begins to charge towards the supply potential through resistor **96** and the conducting transistor Q_2. When the ignition pulse again rises to a value wherein transistor Q_1 is again returned to its conductive state, capacitor **82** will have stored sufficient energy to turn transistor Q_2 "off." The time that transistor Q_2 is in its "off" state is determined by the discharge path of capacitor **82** through the conducting transistor Q_1 and the resistor **98**. When the voltage across capacitor **82** discharges to the point where it can no longer maintain transistor Q_2 in its nonconductive state, transistor **154** again becomes conductive by virtue of the base bias resistor **98**. Meanwhile, the capacitor **84** has charged toward the supply potential through resistor **100** and the conducting transistor Q_3. At the time transistor Q_2 again becomes conductive, the energy stored in capacitor **84** will turn transistor Q_3 "off" for a time interval which will be determined by the discharge path of the conducting transistor Q_2 and the resistor **102**. By selectively choosing the time constants of the charge and discharge circuits for capacitors **82** and **84**, transistor Q_3 is turned "off" and held "off" for a period of, for example, 3 milliseconds giving rise to a positive going rectangular output signal (waveform **103**) of approximately 3 milliseconds in pulse width at the junction **92** at least once per engine cycle.

Considering the nonregenerative variable pulse width signal generator including transistors Q_5, Q_6, Q_7 and Q_8, it is essentially directed to transistor Q_5 and Q_6 and the capacitor **104** coupled between the collector of transistor Q_5 and the base of transistor Q_6. A parallel circuit configuration including diode

106 and resistor 108 is additionally placed in series with the capacitor 104 between the transistor Q_5 and Q_6. The collector of transistor Q_5 is additionally coupled to the tap 63 of the pressure sensor potentiometer 62 located in the sensor body assembly 20 by means of the circuit lead 70 and the resistor 110. The common connection between the collector of transistor Q_5, the resistor 110, and the parallel combination of diode 106 and 108 is identified by the junction 112. The common connection between the capacitor 104 and the base of transistor Q_6 is identified by junction 114. The base of transistor Q_6 and the capacitor 104 is returned to the engine ground through the series combination of fixed resistors 116 and 118 and the variable resistor 120.

Considering the operation of the circuit, transistor Q_5 is operated normally conductive in a saturated state due to the fact that the transistor is a PNP type transistor having its emitter electrode coupled to the positive supply buss 12 by means of the resistor 126 and as a result of the direct connection of the base electrode to junction 92 which is in the collector load circuit of the normally conductive transistor Q_3. Transistor Q_6 is also a PNP type transistor and is also normally conductive in its saturated state by virtue of the direct connection of its emitter electrode to the positive supply buss 94 and the resistive network comprising resistors 116, 118 and 120. When the high voltage ignition pulse (waveform 79) is coupled to the actuator circuit including transistors Q_1, Q_2 and Q_3, a 3 millisecond positive going pulse (waveform 103) appears at junction 92. This actuator signal also appears at the base of transistor Q_5 and drives it nonconductive or "off" for a 3 millisecond interval. During this time interval, capacitor 104 charges to a voltage which is the difference between the potential at junction 112 and 114. Since the transistor Q_6 is still conductive in its saturated state, it acts as a closed switch. Therefore, the potential appearing at junction 114 is the +12V. supply potential appearing on the circuit buss 94. The potential appearing at junction 112, however, is essentially the voltage appearing at the tap 63 of the pressure sensor potentiometer 62 in the sensor body 20 which in combination with the barometric pressure sensor 67 and the idle switch position 68 is indicative of the present engine operating parameters. The diode 106 and the resistor 108 in series with the capacitor 104 provides added noise immunity and stability by virtue of the switching action of diode 90 which provides a low-impedance path for the charging of capacitor 104 while providing a high-impedance path for undesired signals.

At the end of the 3 millisecond actuator pulse (waveform 103) applied to the base of transistor Q_5, transistor Q_5 again becomes conductive and a voltage substantially equal to the +12V. supply potential immediately appears at junction 112 in addition to the voltage already appearing thereat due to the position of the tap 63 of the pressure sensor potentiometer 62. Since the voltage across capacitor 104 cannot change instantaneously, the sudden increase in potential at junction 112 is "seen" at junction 114. When this occurs, transistor Q_6 is immediately driven into its nonconductive state whereupon capacitor 104 begins to discharge through the discharge path comprising resistor 126, the conductive transistor Q_5, resistor 108 and the resistor combination including fixed resistors 116 and 118 and the variable resistor 120. Capacitor 104 discharges until the potential at junction 114 reduces to a voltage sufficient to turn transistor Q_6 "on" again. The voltage at the collector of transistor Q_6 during this time is a rectangular wave (waveform 121) which is variable in pulse width depending upon the voltage appearing at the junction 112 at the time transistor Q_5 is turned "on" and the value of the R-C discharge time constant of capacitor 104.

Transistors Q_7 and Q_8 provide an emitter-follower and an amplification stage, respectively, which are coupled to the fuel metering transducers 14 through the low-impedance resistor 16 in the fuse and resistor assembly 18. The collector-resistor of transistor Q_7 is located in the fuse and resistor assembly 18 and is identified by reference numeral 128. The reason for including the resistor 16 and resistor 128 in a separate assembly is due to the fact that they dissipate relatively more heat than the other load resistors and it is, therefore, desirable to isolate such elements.

The purpose of diodes 130, 132, 134, 136 and 140 is to operate in conjunction with the unloading switch 74 in the sensor body assembly 20 for "unloading" the engine at start up.

What has been described thus far is the generation of a variable pulse width energizing signal in the computer assembly 12 for a steady state mode of operation indicative of constant throttle position of the engine wherein the tap 63 of the pressure sensor potentiometer 62 in the sensor body assembly 20 is relatively stationary. However, during a "transient mode," e.g. acceleration, it is necessary that additional fuel be delivered to the cylinders by means of the transducers 14. This provision is effected by means of the second actuator circuit including transistors Q_4, Q_2 and Q_3 and is operative only during a period of acceleration.

Considering the circuitry in detail, a resistor 130 is connected from the ignition coil 48 directly to the collector of transistor Q_4. Additionally, a coupling capacitor 132 is connected from resistor 130 to the base of transistor Q_2. A base bias resistor 134 is coupled from the positive supply buss 94 to the base of transistor Q_4 while a collector load resistor 136 is connected to the collector of transistor Q_4. A capacitor 138 is connected from the collector to the base of transistor Q_4 and a steering diode 140 is directly connected from the collector of transistor Q_4 to the junction 112. Completing the circuit, a series combination, including capacitor 142 and resistor 144, is coupled from the base of transistor Q_4 to the tap 63 of potentiometer 62 via circuit lead 70.

In operation, transistor Q_4, during steady state operation, is biased into conduction so that it is saturated whereupon transistor Q_4 acts as a closed switch returning resistor 130 substantially directly to ground. Since resistor 130 is connected across the ignition coil 48, a pulse appears thereacross each time a cylinder fires. For example, in a six-cylinder engine, six ignition pulses would appear across resistor 130 per engine cycle, whereas for an eight-cylinder engine, eight ignition pulses would appear. However, since transistor Q_4 is conductive, these pulses are essentially shunted or bypassed to engine ground. When engine manifold pressure suddenly increases upwardly, the tap 63 of the pressure-sensitive potentiometer 62 is moved toward ground potential. A negative going signal (waveform 145) is immediately coupled to the base of transistor Q_4 through the resistor 144 and the capacitor 142 whereupon transistor Q_4 becomes nonconductive. When transistor Q_4 becomes nonconductive, the pulses (waveforms 147, 149, 151,) across resistor 130 are coupled to the base of transistor Q_2 by means of the capacitor 132 whereupon a 3 millisecond actuator pulse 103 is generated each time one of these pulses appears. Transistor Q_5 of the nonregenerative pulse generator is then rendered nonconductive for each cylinder firing and a transducer energizing pulse is produced for each firing of the cylinders as opposed to the steady state mode of operation where an energizing pulse for the transducers is produced only once per engine cycle. In the present instance, however, supplementary actuation takes place and the transducers are energized for a period of time each time a cylinder is fired.

Thus in a six-cylinder four-stroke cycle engine, simultaneous injection to all the cylinders takes place once every two revolutions of the engine crankshaft during the steady state mode; however, during a sudden increase in manifold pressure, simultaneous injection to all the cylinders takes place as often as three times per crankshaft revolution, depending upon the point in time of the engine cycle that the increase in manifold pressure takes place.

It is not desirable, however, that the transducers 14 remain open for the same length of time as the steady state mode of operation due to the fact that engine "flooding" would take place. A smaller injection time period is desirable such as 1 or 2 milliseconds per pulse. This is achieved by the steering diode

140 and the resistor 136. When transistor Q_4 becomes nonconductive the steering diode 140 is biased into conduction and a new voltage divider providing a new voltage reference level occurs at junction 112. The significant increase of the potential at junction 112 results in a comparatively lesser charge accumulation on capacitor 104 during the interval of the actuator pulse (waveform 103) applied to the base of transistor Q_5. This produces a comparatively narrower pulse width output (waveforms 157 and 159) from the collector of transistor Q_6. After a predetermined time, transistor Q_4 is again rendered conductive according to the charging time constant of resistor 144 and capacitor 142 which is dependent on the direction, magnitude and rate of manifold pressure change due to change of voltage which appears at the tap 63 of the pressure sensor potentiometer 62 and the pulses across resistor 130 are again shunted to ground. When this occurs, the first actuator circuit under the influence of a single ignition pulse per engine cycle coupled to transistor Q_1 takes over and simultaneous injection of all the cylinders takes place again once per engine cycle with an updated computation of the pulse width as shown by waveform 161.

The operational sequence as described can be more fully understood by reference to FIG. 2 which is a time diagram of the operation of a six-cylinder engine. It should be pointed out, however, that this is illustrated by way of example only and is not meant to be interpreted in a restrictive sense since an eight or even a four-cylinder engine would operate substantially the same. All of the waveforms of FIG. 2 are under a common time scale and waveform A illustrates a six-cyclinder firing cycle with each cylinder firing at substantially 30 millisecond intervals. This corresponds to a speed of approximately 666 r.p.m. Waveform B of FIG. 2 is illustrative of the time that the transducers are energized. Curve C, on the other hand, is illustrative of the actuator pulse applied to the base of transistor Q_5 during a first and second steady state condition and an intervening transient condition whereupon a mode change occurs and waveform D is illustrative of an upward increase in intake manifold pressure over one engine cycle during which throttle actuation takes place for acceleration. The waveforms indicate that the system disclosed in FIG. 1 is adapted to operate in two modes. The first mode is the steady state mode where a variable pulse width energizing pulse, waveform 121, in the order of 5 milliseconds is generated after a 3 millisecond computing period, waveform 103, after the firing of cylinder No. 1. The manifold pressure is in the order of 13 -in. Hg. indicative of for example "idle" operation. After cylinder No. 2 fires, however, the manifold pressure increases to 30 -in. Hg. at the occurrence of throttle actuation and acceleration of the engine is desired. At this time, the system switches into the second mode of operation involving the transistor Q_4 in the computer assembly 12 and an energizing pulse, waveform 103, is generated each time a cylinder (No. 1—No. 6) fires for delivering fuel simultaneously to each of the cylinders each time a cylinder fires over the remainder of the engine cycle. As shown by waveform B and waveforms 157 and 159 thereof, the energizing pulses generated during the second mode of operation are relatively shorter in pulse width than that for steady state operation.

After one or more additional engine cycles, the second or transient mode is interrupted and the system reverts back to an updated first mode of operation indicative of a new steady state condition as shown by waveform 161. FIG. 2 illustrates that the steady state mode takes over on the next succeeding cycle following the transient mode.

What has been shown and described, therefore, is a precision fuel metering system adapted to operate in two different modes depending upon its state of operation. During periods of nonacceleration, the system operates to deliver measured amounts of fuel to each of the cylinders simultaneously once per engine cycle but during the period of an upwardly changing or transient condition of intake manifold pressure caused by throttle actuation, the system switches into a mode whereby fuel is delivered each time a cylinder is fired over an engine cycle, i.e. a plurality of times per engine cycle. Such a system provides faster response for throttle actuation and removes the "dead time" interval which can occur without supplementary injection and control for acceleration.

I claim:

1. In a precision fuel metering system for internal combustion engines of the type described wherein a plurality of fuel metering transducers are energized by means of signals produced by circuit means responsive to varying engine operating conditions and actuated in accordance with the engine ignition circuit, including a distributor, for delivering measured amounts of fuel to each of the cylinders, the combination of:

first circuit means for generating an energizing signal of predetermined time duration when an actuation pulse is coupled thereto for operating said fuel metering transducers for a period substantially equal to said predetermined time duration;

first actuator circuit means coupled to said engine ignition circuit for producing an actuation signal once per engine cycle for said first circuit means under a first mode of engine operation indicative of a steady state condition of engine operation; and

second actuator circuit means coupled to said engine ignition circuit and responsive to a change in intake manifold pressure for supplementing said first actuator circuit means and producing an actuation signal at a rate equal to once per each cylinder firing which is coupled to said first circuit means under a second mode of engine operation indicative of said change of intake manifold pressure for at least a portion of one cycle of engine operation after which said first actuator circuit means again produces an actuation signal once per engine cycle indicative of a new steady state condition of engine operation.

2. The invention as defined by claim 1 and additionally including means coupled to and actuated by said second actuator circuit means for causing said circuit means for generating said energizing signal to generate an energizing signal of a comparatively lesser predetermined time in said second mode of operation.

3. The invention as defined by claim 2 wherein said circuit means for generating an energizing signal comprises a controlled variable pulse width signal generator.

4. The invention as defined by claim 3 wherein said variable pulse width signal generator comprises an externally controlled nonregenerative signal generator.

5. The invention as defined by claim 4 and wherein said first actuator circuit at least means comprises a pulse signal generator including means for being triggered by an ignition pulse from said engine ignition circuit once per engine cycle.

6. The invention as defined by claim 4 and wherein said second actuator circuit means comprises a pulse signal generator including means for being rendered operative only during transient intervals corresponding to an upward change or increase in intake manifold pressure and including means for being triggered once per each cylinder firing during an engine cycle from said engine ignition circuit, thereby producing an actuation signal for said first circuit means once per each cylinder firing.

7. The invention as defined by claim 6 wherein said second actuator circuit means comprises a substantially constant pulse width signal generator and additionally including means for coupling said signal generator to the distributor of said engine ignition circuit.

8. The invention as defined by claim 6 wherein said second actuator circuit means includes switch means normally conductive and operative to substantially ground the input of said second actuator circuit means for rendering it inoperative during said first mode of engine operation but becoming nonconductive during transient intervals, thereby allowing said second actuator circuit means to become operative to

produce an actuation pulse once per cylinder firing, and wherein said means coupled to and actuated by said second actuator circuit means includes circuit means coupled between said switch means and said nonregenerative signal generator for establishing a new voltage reference level in said nonregenerative signal generator for producing relatively shorter pulse width energizing signals for said transducers during the transient interval.

9. The invention as defined by claim **8** wherein said switch means comprises an electronic switch normally conductive and operative to substantially ground the input of said second actuator circuit means for rendering it inoperative during said first mode of engine operation but becoming nonconductive during transient intervals, thereby allowing said second actuator circuit means to become operative to produce an actuation pulse once per cylinder firing, and wherein said means coupled to and actuated by said second actuator circuit means includes circuit means coupled between said electronic switch and said nonregenerative signal generator for establishing a new voltage reference level in said nonregenerative signal generator for producing relatively shorter pulse width energizing signals for said transducers during the transient interval.

10. The invention as defined by claim **9** wherein said last-mentioned circuit means comprises a voltage divider and a steering diode, said steering diode adapted to become conductive when said electronic switch means becomes nonconductive for inserting said voltage divider in said nonregenerative signal generator.

11. The invention as defined by claim **9** wherein said electronic switch means comprises a transistor.

12. The invention as defined by claim **1** wherein said first actuator circuit means additionally includes an ignition pulse energy pick up device coupled to a selected spark plug lead of said engine ignition circuit, and wherein said second actuator circuit means additionally includes impedance means coupled to the distributor of said engine ignition circuit.

13. The invention as defined by claim **12** wherein said impedance means comprises resistor means.

14. The invention as defined by claim **12** and additionally including means coupled to said circuit means for generating an energizing signal for energizing all said fuel metering transducers simultaneously during both said first and said second mode of operation.

15. The invention as defined by claim **8** and additionally including a resistance-capacitance circuit combination having a predetermined time constant coupled between said switch means and a voltage indicative of said upward change in intake manifold pressure to render said switch means nonconductive for a predetermined time for at least a portion of one cycle of engine operation.

16. The invention as defined by claim **15** wherein said resistance-capacitance circuit combination comprises a series circuit.