

[54] FUEL INJECTION CONTROL SYSTEM

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Related U.S. Application Data

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[52] U.S. Cl. 123/32 EA, 123/32 AE

[51] Int. Cl. F02b 3/00

[58] Field of Search..... 123/32 EA

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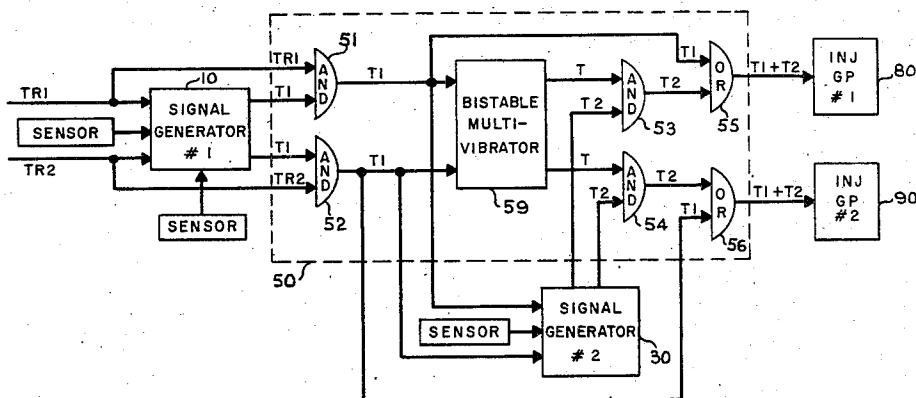
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[57] ABSTRACT

An internal combustion engine fuel injection control system having at least two groups of electrically controlled fuel injector valves which are capable of being operated so that the open time of each group of fuel injector valves may overlap. This is accomplished by a control circuit that produces a pulse train having pulse durations which are capable of being greater than the time required for the engine to complete one engine cycle divided by the number of fuel injector groups that supply fuel to said engine. A switching circuit applies the pulse train, with a phase differential, to the two groups of fuel injector valves so that switching to one injector valve group does not terminate the pulse being supplied to the other injector valve group.

15 Claims, 4 Drawing Figures



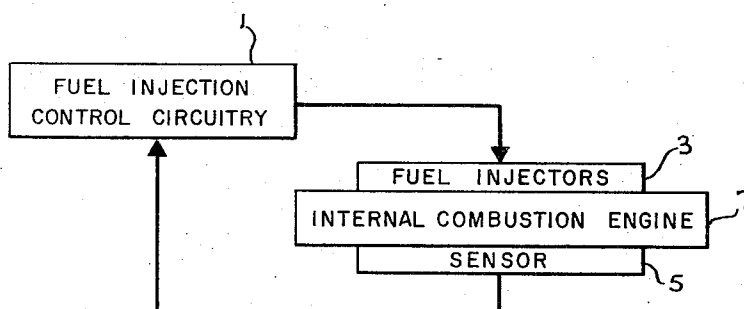


FIGURE 1

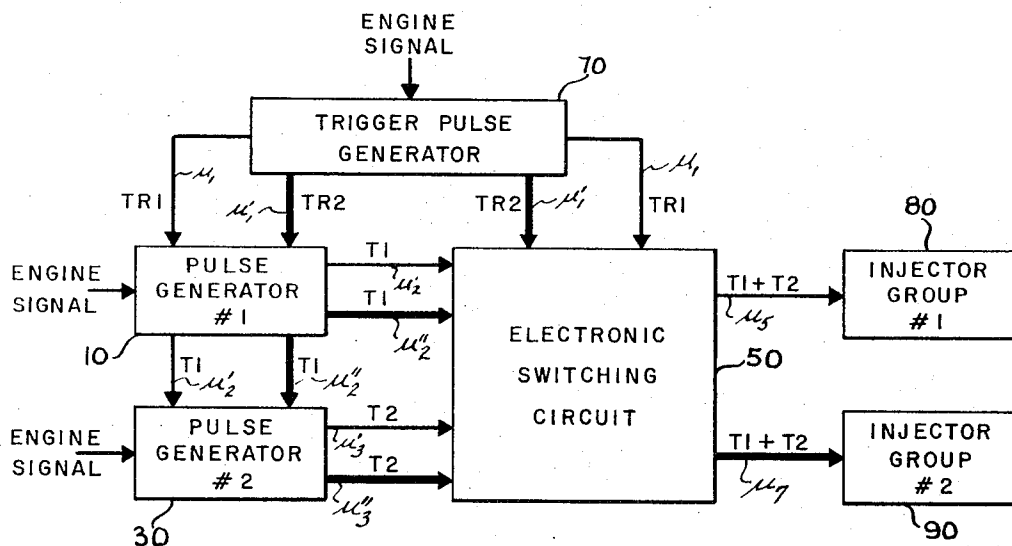


FIGURE 2

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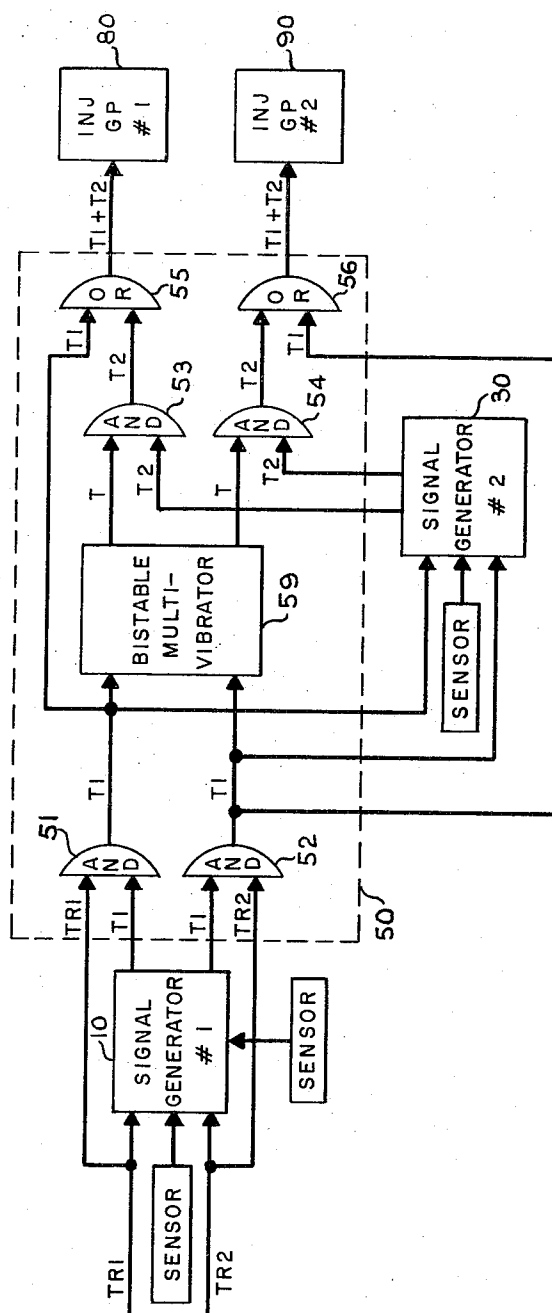


FIGURE 3

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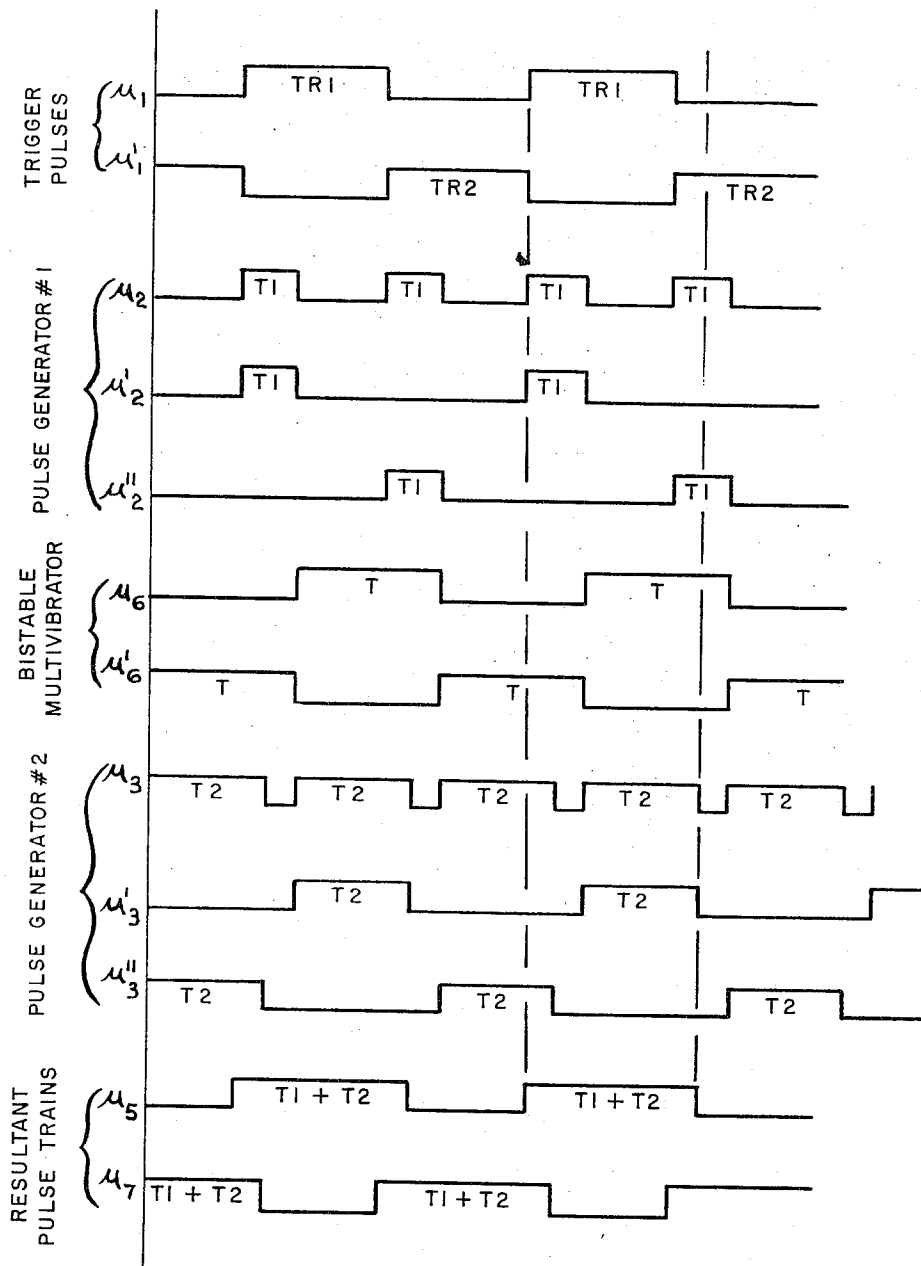


FIGURE 4

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FUEL INJECTION CONTROL SYSTEM

This is a continuation of application Ser. No. 80,861, filed Oct. 15, 1970.

BACKGROUND OF THE INVENTION

This invention relates to an internal combustion engine fuel injection control system of the type having a control circuit to electrically control the open time of two or more groups of fuel injection valves in response to the operating parameters of the engine. This invention is more particularly related to an improved control system that permits the open time of each group of fuel injection valves to overlap.

Basically, an electrically controlled fuel injection system for an internal combustion engine includes devices for sensing one or more operating parameters of the engine and a control circuit that controls the amount of fuel to the engine in response to the operating parameters sensed. The output of the control circuit is generally in the form of pulses which are applied to electrically controlled fuel injector valves so that the open time of the valves, which inject fuel into the engine cylinder, is determined by the duration of the pulses which are functions of one or more operating parameters of the engine. Therefore, the pulse time, and hence the period during which fuel is injected, may be termed the injection time, can be made dependent on various operating conditions or parameters of the engine, for example, vacuum or absolute pressure in the intake, the speed of the engine, and engine temperature. Other operating conditions of the engine in a prime mover system can also be considered, for example, voltage of the vehicle battery, or special components of the start-up system. In any event, no matter what parameter is chosen to control open time of the fuel injection, the time during which fuel is injected into the engine should be so chosen that the system is optimized under all operating conditions. Thus, best fuel economy can be obtained regardless of the speed of the engine or the load placed thereon; further, pollution caused by exhaust gases from the engine will be a minimum since incomplete combustion can be avoided.

One known approach supplies fuel injection control pulses to more than one injector valve group, for example, two groups, from one composite pulse forming circuit. When a single pulse forming network supplies pulses, for example, to two injector groups, some gating or switching means are provided to divide the total available time in each engine cycle approximately in half so that the control pulse circuit may first serve one injector group and then the other over the total engine operative cycle, one engine cycle being the time required for each piston to travel from the beginning of one power stroke to the beginning of the next power stroke. For a two stroke engine this would be the time required for each piston to complete one cycle.

As a result, the duration of a pulse applied to the injector valves was limited to a duration equal to or less than one-half the time of the total engine cycle as it would then be interrupted by the switching operation to the next group. An example of this known pulse forming and switching approach is disclosed in U.S. Pat. No. 3,483,851 entitled "Fuel Injection Control System", having as an inventor W. Reichardt and assigned to Robert Bosch G. m. b. H., a German company.

Such known systems where a control pulse forming system alternately generates a control pulse to first one

and then another injector valve group over the interval of one complete engine cycle provide good performance and conserve on the cost of the electronic circuit but are limited to energizing an injector valve for a time not exceeding one engine cycle divided by the number of sequentially injected groups or, in the case of two group injection, one-half an engine cycle. This limitation prevents spreading the control pulse and injector valve energization over a greater time base to achieve greater metering accuracy or more fuel for high demand conditions.

SUMMARY OF THE INVENTION

This invention provides an electronic fuel injection control system with the capability of permitting the associated fuel injector valves to remain open for a period greater than the time required for an engine to complete one engine cycle divided by the number of fuel injector groups (one or more injector valves) thereby allowing the open time of two fuel injector groups to overlap.

The invention is an internal combustion engine fuel injection control system characterized by a control circuit which fuel the open time of two groups of fuel injector valves to overlap. In one embodiment of the invention, the control circuit comprises: a network that produces at least one periodic signal having periods and durations which are a function of said engine crank shaft rotation; and a circuit that produces a resultant pulse train having a period dependent upon said engine crank shaft rotation and capable of a maximum pulse duration which is greater than the time required for the engine to complete one engine cycle divided by the number of fuel injector groups that supply fuel to said engine; means for applying said resultant pulse train with a phase differential to said fuel injector groups whereby the open time of one fuel injector group has the capability of overlapping the open time of the other fuel injector group.

Accordingly, it is an object of this invention to provide a fuel injection control system that permits the open time of two groups of fuel injector valves to overlap.

It is another object of this invention to permit the open time of a fuel injector valve to exceed the time required for an engine to complete one cycle divided by the total number of injector groups.

It is still another object of this invention to make the termination of a control pulse to the injector valves independent of the termination of a trigger pulse which is a function of the rotation of the crank shaft.

It is still another object of this invention to produce control pulses that have the capability of exceeding the time required for the crank shaft of a two stroke engine to rotate 180°.

It is still another object of this invention to reduce the number of pulse networks necessary to control the open time of two or more fuel injector groups.

It is still another object of this invention to improve the control of fuel injector valves to obtain better air-to-fuel mixtures.

It is still a further object of this invention to improve the versatility of existing electronically controlled fuel injection systems.

The above and other objects and features will become apparent from the following detailed description

taken in conjunction with the accompanying drawings and claims which form a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a fuel injection control system.

FIG. 2 is a block diagram of a control circuit for a fuel injection control system which utilizes the principles of this invention.

FIG. 3 is a logic diagram of the control circuit shown in FIG. 2.

FIG. 4 is a timing diagram illustrating the operation of the system.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, FIG. 1 illustrates a control system for an internal combustion engine 7 wherein the control circuitry 1 obtains its control signals from sensors 5 to control the operation of the fuel injectors 3.

The sensors 5 include one or more devices for sensing engine crank shaft angle, the pressure in the intake manifold or other operating engine parameters.

The fuel injectors 3 are comprised of electromagnetically operated fuel injection valves which are generally located immediately adjacent the inlet valve to the engine cylinders (not shown). Fuel is supplied under pressure to each of the injector valves so that when a valve is opened fuel will be provided for a cylinder of the engine 7.

FIG. 2 is a block diagram which illustrates how the control circuitry reacts to trigger pulses TR1 and TR2 which are synchronized with the rotation of the engine to open each group of fuel injector valves 80, 90. Trigger pulse TR1 initiates the pulse that opens the fuel injector valves for Group 1 and trigger pulse TR2 initiates the pulse that opens the fuel injector valves for Group 2. The control circuitry includes a first pulse generator 10 and a second pulse generator 30 whose output pulses are connected to an electronic switching circuit 50 which applies the pulses in a predetermined manner to two groups of injector valves 80 and 90. A trigger pulse generator 70 is connected to the first pulse generator 10 and the electronic switching circuit 50.

The trigger pulse generator 70 is synchronized with the rotation of the engine so that the output pulses of the trigger pulse generator 70 (TR1 and TR2), the first pulse generator 10 (T1), the second pulse generator 30 (T2), and the electronic switching circuit 50 (T1 + T2) have a period which is a function of the rotation of the engine.

While the trigger pulse generator may be implemented in many different mechanical or electronic forms, for functional analysis of this invention it may be thought of as a simple bistable flip-flop which in response to an engine triggering signal produces TR1 signal for one-half an engine operating cycle and a TR2 signal for the other half of the cycle.

The inputs to the first pulse generator 10 are the trigger pulses from generator 70 and an engine signal from a sensing device (not shown) which senses an operating parameter of the engine. The output of the pulse generator 10 is a pulse train that has a period which is a function of the engine rotation with pulses having durations which are a function of the sensed engine operating parameter.

The inputs to the second pulse generator 30 are the pulses from the first pulse generator 10 and an engine signal from a sensing device which senses an operating parameter of the engine. The output of the second pulse generator 30 is a pulse train that has a period which is a function of engine rotation with pulses having durations which are a function of the sensed engine operating parameter. The engine signals that are supplied to the pulse generators 10, 30 may be the same although they may differ. For example, the engine signal to the first pulse generator 10 may be a function of absolute pressure in the intake manifold while the engine signal to the second pulse generator 30 may be a function of the differential pressure in the intake manifold. Other engine operating parameters may also be used to control the pulse durations of the pulse generators 10, 30.

The electronic switching circuit 50 receives the pulse trains from the pulse generators 10 and 30, adds them together and produces resultant or composite pulse trains having a period which is dependent in frequency upon the rotation of the engine and having durations which are equal to the sum of the duration of a pulse from the first and second generators. In the preferred embodiment the output of the electronic switching circuit 50 is two pulse trains which are applied, with a phase differential, to each of the injector groups 80, 90.

The pulse trains generated by the control circuitry are indicated generally by the symbol u , and shown in detail in FIG. 4.

FIG. 3 illustrates in logic form the control circuitry shown in FIG. 2. The dotted lines encompass the logic which comprises the electronic switching circuit 50.

The electronic switching circuit 50 includes AND and OR gates 51, 52, 53, 54, 55, 56 which react to the trigger pulses (TR1 and TR2) and the pulses (T1 and T2) of the first and second pulse generator 10, 30. Each of the AND and OR gates has two inputs and when the proper control signals are applied to the AND and OR gates, output signals will be produced as shown in the drawing.

Located between each pair of AND gates is a bistable multivibrator 59 which produces gating pulses (T) which are applied to the AND gates 53, 54.

FIG. 4 is a timing diagram which illustrates graphically the inputs to and the signals of the fuel injection circuitry.

The trigger pulse trains u_1 and u'_1 are comprised of a series of pulses having a duration TR1 and TR2 which vary in duration as a function of the rotation of the engine. As the rotation of the engine increases, the duration of the pulse TR1 and TR2 decreases.

The pulse trains u_2 , u'_2 and u''_2 are the pulse trains from the first signal pulse generator 10 and have durations which are a function of a sensed engine operating parameter. For instance, the duration of the pulses T1 may be a function of intake manifold pressure.

The pulse train u_6 and u'_6 are the pulse trains generated by the bistable multivibrator 59. The duration of the pulses T from the bistable multivibrator corresponds to pulses TR1 and TR2 but is delayed by a time T1.

The pulse trains u_3 , u'_3 and u''_3 are the pulse trains from the second pulse generator 30. The duration of the pulses (T2) of the second pulse generator 30 is a function of a sensed operating parameter of the engine.

For instance, the input signal to the second pulse generator 30 may be a function of the differential pressure in the intake manifold of the engine. The pulse train u_3 is synchronized with pulse train u_2 so that a pulse (T2) is initiated when a pulse (T1) in pulse train u_2 terminates.

The pulse trains u_5 and u_7 represent the output pulse trains from the electronic switching circuit 50. Pulse train u_5 is the result of adding the pulses of pulse train u'_2 to the pulses of pulse train u'_3 . Therefore, the duration of the pulses of pulse train u_5 is equal to the duration of a pulse T1 from pulse train u'_2 and a pulse T2 from pulse train u'_3 . Similarly, pulse train u_7 is a result of adding the pulses of pulse train u''_2 and u''_3 . Therefore, the duration of the pulses of pulse train u_7 are also equal to the duration of a pulse T1 from pulse train u''_2 and a pulse T2 from pulse train u''_3 .

When there are two groups of injector valves, pulse train u_5 (associated with trigger pulse TR1) is applied to the first group and pulse train u_7 (associated with trigger pulse TR2) is applied to the second group. Since the pulse trains u_5 and u_7 are out of phase with each other and the durations exceed the phase differential, the open times of the injector valves in each group will overlap.

Operation

Referring now to the drawings, and more particularly to FIGS. 2, 3 and 4, the control system operates as follows. A sensing device which senses the rotation of the engine and absolute pressure in the intake manifold transmits a signal to the first pulse generator 10 and the trigger pulse generator 70. These pulse generators then produce pulse trains (u_1 , u'_1 and u_2) having a period which is a function of engine rotation. The duration of the pulses TR1 and TR2 (u_1 and u'_1) is a function of rotation of the engine and is equal to the time required for the engine to complete one engine cycle divided by the number of fuel injector groups that supply fuel to the engine. The duration of the pulses T1 (u_2) is a function of the absolute pressure in the intake manifold. Another sensing device senses the differential pressure in the intake manifold and sends a signal to the second pulse generator 30 which produces a pulse train (u_3) having a period dependent upon rotation of the engine and the duration of the pulses of pulse train u_2 . The duration (T2) of the pulses of pulse train u_3 is a function of the differential pressure in the intake manifold. The output pulse trains of the trigger pulse generator 70 (u_1 , u'_1) the pulse generator 10 (u_2) and the pulse generator 30 (u_3) are applied to the electronic switching circuit 50.

The output of the electronic switching circuit 50 is pulse trains u_5 , u_7 having a phase differential and periods which are a function of the rotation of the engine with pulse durations (T1 + T2) which are a function of the absolute and differential pressure in the intake manifold and the rotation of the engine. The duration of the pulses (T1 + T2) of the pulse trains u_5 and u_7 is capable of a maximum duration which is greater than the time required for the engine to complete one engine cycle divided by the number of fuel injector groups that supply fuel to said engine. The electronic switching circuit 50 applies the resultant pulse trains, with a phase differential, to two groups of injector valves to control the open time thereof. When a pulse is applied to an injector valve it is opened and the valve

closes when a pulse is removed. Therefore, it can be seen from the timing diagram, FIG. 4, that the durations and periods of the resultant pulse trains (u_5 and u_7) are such that the open time of each group of valves may overlap when the duration of a maximum pulse from pulse trains u_5 , u_7 is greater than the duration of a pulse from pulse train u_1 , u'_1 .

While a preferred embodiment of the invention has been disclosed, it will be apparent to those skilled in the art that changes may be made to the invention as set forth in the appended claims, and, in some cases, certain features of the invention may be used to advantage without corresponding use of other features. For example, the magnitudes, durations, and polarities of the pulses shown in the timing diagram may be varied in different ways to achieve the object of the invention. Further, the circuitry may be modified so that more than two groups of injector valves can be controlled. Accordingly, it is intended that the illustrative and descriptive materials herein be used to illustrate the principles of the invention and not to limit the scope thereof.

Having described the invention, what is claimed is:

1. In an internal combustion engine fuel control system of the type having trigger signal generating means for generating a signal indicative of engine speed, a plurality of engine parameter sensors, a first pulse generator means responsive to the trigger signal generating means and to a first sensor operative to generate a first generator signal, a second pulse generator means responsive to the first generator signal and to a second sensor operative to generate a second generator signal, each of the first and second generator signals having frequencies dependent upon the triggering frequency and pulse durations dependent upon the sensor inputs, and a plurality of sequentially actuated injector valve means, the improvement comprising switching means for applying the first and second generator signals to the plurality of injector valve means in a sequence whereby the open times of consecutive injector valve means in the sequence may overlap comprising:

first gating means responsive to the first and second pulse generator means, operative to apply consecutive first and second pulse generator means pulses to selected injector valve means;

further pulse generator means responsive to said first pulse generator means operative to generate signals having at least one frequency dependent upon the triggering frequency and a pulse duration substantially corresponding to the time interval between the terminations of consecutive first generator signal pulses; and

second gating means responsive to said further pulse generator means pulses operative to apply second generator signal pulses to said first gating means in a manner determined by said further pulse generator means signal.

2. The system as claimed in claim 1 wherein said first gating means comprise OR gates in one-to-one relationship with the plurality of injector valve means.

3. The system as claimed in claim 1 wherein said further pulse generator means comprise means for generating signals substantially equal to the trigger signal generating means signal but delayed in time relative thereto by a duration substantially equal to the duration of the pulses of the first generator signal.

4. The system as claimed in claim 1 wherein said further pulse generator means comprise means for generating a plurality of pulse train pulses having a frequency dependent upon the triggering frequency and a pulse duration substantially equal to the reciprocal of the frequency divided by the number of injector valve means in the sequence.

5. The system as claimed in claim 4 wherein said further pulse generator means comprise a bistable device.

6. The system as claimed in claim 5 wherein said bistable device is switched between stable modes after an interval following initiation of the first generator signal pulses.

7. An internal combustion engine fuel control system comprising in combination:

triggering means for cooperative association with an engine operative to generate a plurality of pulse train signals each signal having a frequency and a pulse duration indicative of engine speed, the beginning of a pulse of one triggering means signal substantially corresponding to the termination of a pulse of another triggering means signal;

a plurality of engine sensors for cooperative association with an engine operative to generate signals indicative of engine operating conditions;

first pulse generator means mutually responsive to said triggering means and at least one of said sensors operative to generate a first output signal pulse train having a frequency dependent upon said triggering signal frequency and pulse durations determined by said at least one sensor;

second pulse generator means mutually responsive to said first pulse generator means and a second of said sensors operative to generate a second output signal pulse train having a frequency dependent upon said first signal frequency and pulse durations determined by said second sensor;

fuel delivery means, including a plurality of injector valve means arranged in a plurality of sequentially actuated injector valve members, responsive to said first and second signals operative to deliver quantities of fuel substantially in proportion of the duration of said first and second signal pulse durations; and

switching means including third pulse generator means responsive to said triggering, first and second signals operative to apply said triggering, first and second signal pulses to said injector valve means in a predetermined manner, said third pulse generator being responsive to the first signal pulses and being operative to generate a third signal having a frequency and pulse durations substantially equal to the frequency and pulse durations of said triggering signals but delayed in time relative thereto by a predeterminable amount of time.

8. The system as claimed in claim 7 wherein said third pulse generator means are arranged to be responsive to the termination of said first signal pulses.

9. The system as claimed in claim 8 wherein said third pulse generator means comprise bistable multivibrator means.

10. The system as claimed in claim 7 wherein said switching means further include first gating means responsive to said triggering means for applying said first

signal to a selected injector valve means, the selection being determined by said triggering means signal.

11. The system as claimed in claim 7 wherein said switching means further include second gating means responsive to said third signals for applying said second signal to a selected injector valve means, the selection being determined by said third signals.

12. The system as claimed in claim 10 including further second gating means responsive to said third signals for applying said second signal to a selected injector valve means, the selection being determined by said third signals and corresponding to the selection made by said triggering means signals.

13. In an engine having an operating cycle, an electrically controlled fuel injection system, comprising, in combination:

at least two injection means adapted to inject fuel sequentially at predetermined time instants in said operating cycle, each for a length of time dependent upon the duration of an activation signal;

first signal generator means for furnishing first control signals at said predetermined time instants, said first control signals having a duration varying in response to at least one engine parameter;

second signal generating means connected to said first signal generating means adapted to furnish a second control signal for each of said first control signals, the termination of each of said second control signals following the termination of the corresponding first control signals in said operating cycle by a first time interval, the duration of said first time interval being a function of a second engine parameter;

third signal generating means connected to said first signal generating means for generating further signals having a frequency dependent upon engine speed and pulse durations equal to the period of the signal divided by the number of injection means in the sequence;

means for combining said first and second control signals comprising first and second gating portions, said first gating portion being connected to said second and third signal generating means for generating a gated second control signal only in the presence of a said second control signal and a said further signal and said second gating portion being connected to said first signal generating means and said second gating portion to form said activation signals in such a manner that the beginning of each of said activation signals is dependent upon the termination of the corresponding second control signal; and

means for applying said activation signals to each of said injection means at the corresponding predetermined time instant.

14. The system as claimed in claim 13 wherein said means for generating the further signal are arranged to initiate respective pulses of said further signal at a point in time following said predetermined time instants by a predeterminable interval.

15. The system as claimed in claim 14 wherein said predeterminable time interval is substantially equal to the duration of said first control signals.

* * * * *

**UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION**

Patent No. 3,854,458 Dated December 17, 1974

Inventor(s) Junuthula N. Reddy

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

IN THE SPECIFICATION

Column 2, Line 22 - delete the word "guel" and insert therefor

--fuel--;

Column 2, Line 24 - after "which" delete "fuel" and insert therefor

--permits--;

IN THE CLAIMS

Claim 4, Column 7, Line 6 - delete the word "frequency" and insert therefor

--frequency--;

Claim 7, Column 7, Line 43 - after "proportion" delete "of" and insert

therefore --to--.

Signed and sealed this 27th day of May 1975.

(SEAL)

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks