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Monpetit

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[54] **ELECTRONIC FUEL INJECTING SYSTEM FOR INTERNAL COMBUSTION ENGINES**

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[58] **Field of Search** .... 123/32 AE, 32 EA, 123/119

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[57] **ABSTRACT**

A fuel injecting system providing an accurate adjustment of the duration of injection, the operative cycle being subdivided into a first stage during which the energy required for injection or the corresponding information is stored in a condenser which is discharged during the second or injection stage. The shifting from one stage to the other is controlled by two switches constituted by transistors acting in alternation so as to energize during a predetermined stage a unijunction transistor controlling the starting and stopping of the injection in conformity with a number of parameters stored in memories. The original signals fed into the system are advantageously produced by an oscillator operating for predetermined angular positions of the crankshaft.

11 Claims, 4 Drawing Figures

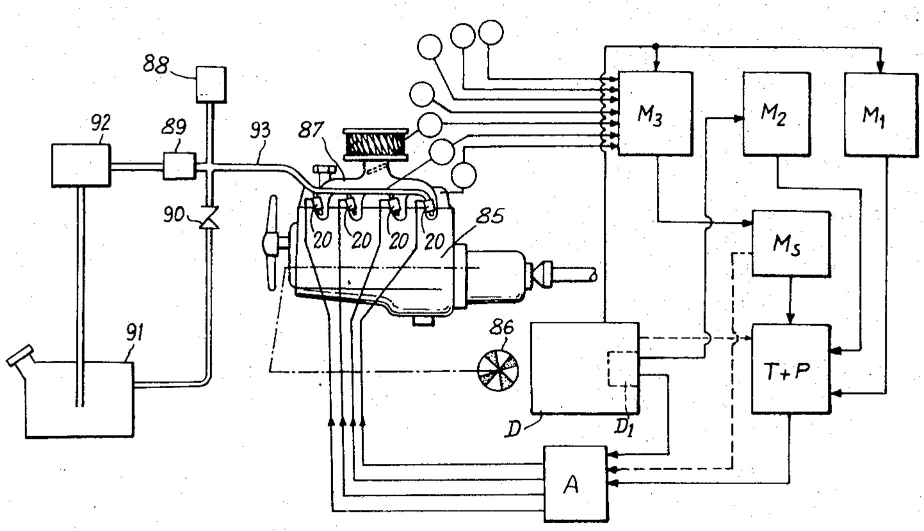

Fig. 1

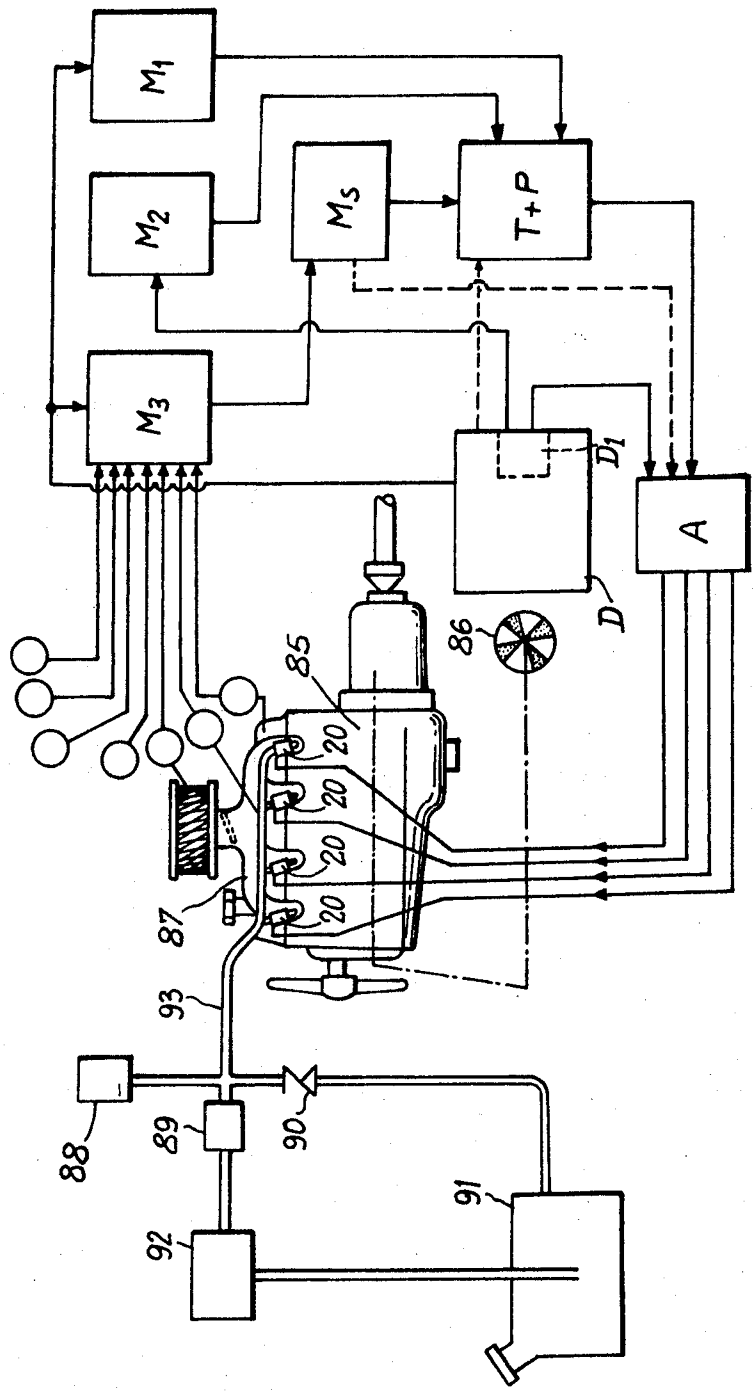

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Fig. 2

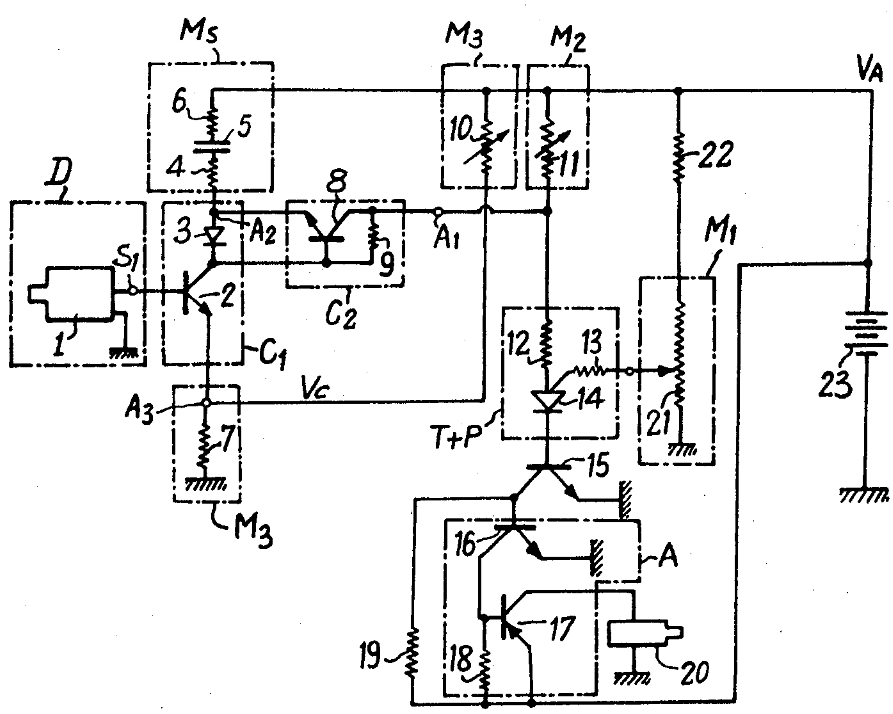

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Fig. 3

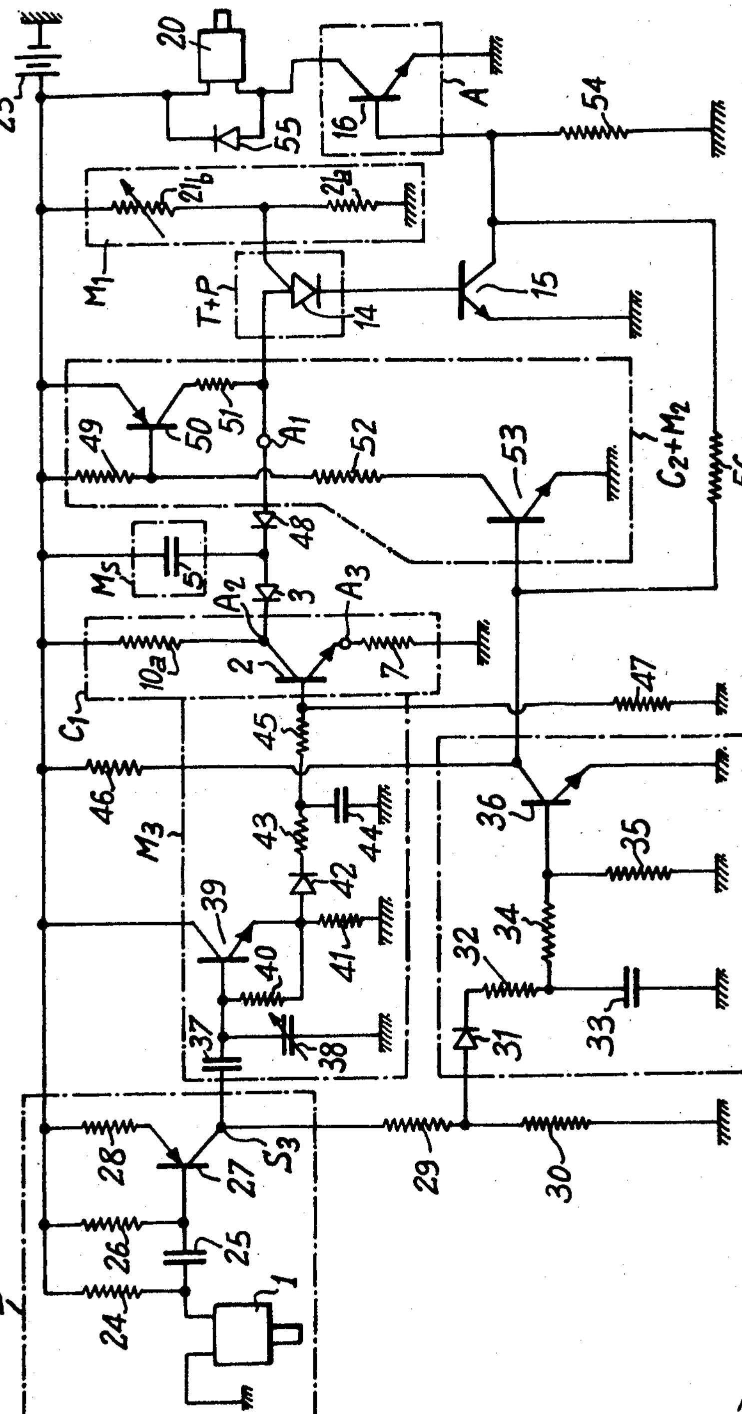

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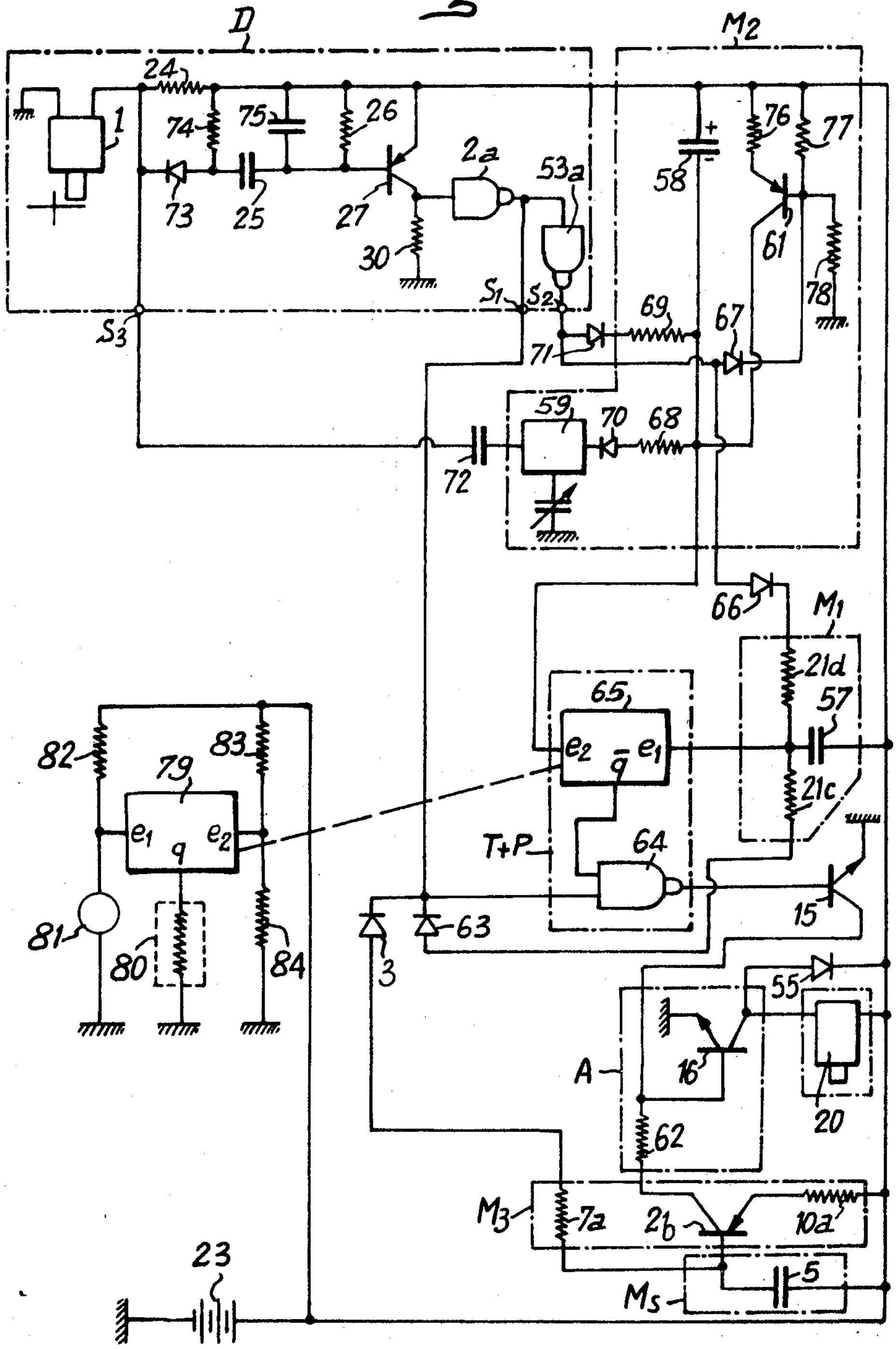
Fig. 4



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ELECTRONIC FUEL INJECTING SYSTEM FOR INTERNAL COMBUSTION ENGINES

The present invention has for its object improvements in electronic control systems for the injection of fuel into internal combustion engines. Such systems, as known hitherto, rely almost all on the principle that the amount of fuel to be defined with reference to the operative conditions of the engine depends on the one hand on the injection pressure, assumed to be constant and on the other hand on the duration of the electric signal transmitted to the electromagnetic solenoid actuated fuel injection valves. To this end, there is provided in the French Pat. No. 1, 172, 680 a monostable flip-flop triggered by a detector pulse generator controlled by the rotation of the engine so as to produce rectangular signals in synchronism with said rotation and the durations of which are adjusted in accordance with the operative conditions of the engine. These signals are then applied to the solenoid-actuated fuel injector valve through amplifier. Such arrangements provide an accurate timing since injection begins when the flip-flop is triggered and the injection duration is determined in accordance with prevailing operative engine conditions.

Although such arrangements seem at first very simple, yet they become very intricate when it is attempted to match accurately the requirements of a particular engine, chiefly with a view to reducing the pollution of the atmosphere by the exhaust gases of the engine. As a matter of fact, the actual fuel requirements are by no means independent of the speed of rotation of the engine and depend in accordance with an intricate law on the rotary speed of the engine, on the extent of the opening of the gas throttling valve and, on the reduction in pressure in the admission manifold. Said law depends also on the ambient temperature, on the temperature of the engine and on the barometric pressure and it varies also according as to whether the engine revolves at a stabilized, accelerated or decelerated speed. Furthermore, since the parameter sensors defining the duration of injection can show only average values corresponding to the duration of injection, it is necessary to make use thereof in a manner such that these average values may correspond to the characteristic properties of the engine prevailing at a well-defined moment of the injection.

It is therefore apparent that it is necessary to provide a multiplicity of auxiliary circuits adapted to ensure the formation of an input signal for the monostable flip-flop which accurately represents the condition of the engine.

On the other hand, U.S. Pat. No. 2 ,018, 159, inter alia, discloses storing, as a first step, of an amount of energy which depends on the operative conditions of the engine, while said energy is released as a second stage step, to control the opening of an electromagnetic injector for a period corresponding to the amount of energy stored. To this end, there is disclosed in said last-mentioned patent a first switch actuated in synchronism with the rotation of the engine so as to charge a variable condenser through a variable resistance while a second switch then connects the charged condenser with the electromagnetic injectors. Obviously, such an arrangement could not operate reliably or durably since the mechanical contact-pieces wear rapidly. Furthermore, the arrangement as designed could not provide a sufficient adjustment of the duration of injection, all the more so since the closing of the injectors was certain by reason of the fact that the limit closing current may vary to a large extent for the different injectors.

The present invention has as its object the elimination of the drawbacks of both above mentioned injection systems by providing an improved arrangement for the electronic control of a fuel injecting system for internal combustion engines including one or more electromagnetic injection valves. The present system is of the type wherein the electric energy controlling the electromagnetic valves and/ or the electric information corresponding to the duration of energization and consequently to the amount of injected fuel, is stored in a suitable circuit section during a first period of the operative cycle of the engine, said energy and/or the information being then released during a further period of the operative cycle in order to control the injection. According to the invention, the arrangement is constituted by a condenser adapted to store the energy required for injection and/or the information and connected between a constant supply voltage and a variable relatively low voltage supply under control of a first switch as provided by a least one memory and as governed by the operative conditions of the engine. This first switch is connected with means sensitive to the angular position of the crankshaft for controlling the charging of the condenser at the low voltage during the storing period. A threshold element provided with a plurality of inputs is also provided, which is connected on the one hand with the condenser and on the other hand with a supply of a variable positive voltage through another memory, under the control of the operative parameters of the engine, last-mentioned said voltage defining the triggering threshold of said element. The condenser is discharged during the injection period by a second switch which is then released and is locked during the storing period. An amplifier is also provided for the control of the electromagnetic valve or valves and is connected with the second switch and with the threshold element, said second switch controlling through this last connection the beginning of the injection while said threshold element controls its end when the condenser is discharged down to a certain voltage corresponding to the triggering threshold of said threshold element.

With such an arrangement, it is possible to utilize simple circuits having the capability to introduce a multiplicity of independent parameters, primarily engine speed, through the use of memories without resort to special circuit elements such as tachometers or centrifugally controlled rheostats. Furthermore, the present invention is particularly suited to the use of integrated circuits for effecting its various functions.

Although the invention is embodied in an arrangement having two stages, one stage for the preparation of the information relating to the injection, and one stage for the actual injection, this results in no disadvantage and in fact results in a number of advantages.

By reason of the rapid response of the electronic circuits, the duration of the storing period is a few microseconds at a maximum as compared with the duration of injection which ranges from 0.5 milliseconds up to about 10 milliseconds. In prior systems incorporating monostable flip-flops, the injection period equally spaced by intervals of the same magnitude, correspond to the duration of deenergization of the injectors at the end of each injection and more particularly to the duration of recovery of the flip-flop. By reason of such intrinsic properties these systems cannot operate again for the next injection before the end of this recovery period.

It is apparent then, that the storing period in the injection system according to the invention is not lost time as compared with prior systems and that at least the main data relating to the duration of the injections are tapped off the engine during an extremely short time interval. Therefore, in order to sense the reduced pressure in the admission manifold of the engine, use is made of the high speed sensor housed near the admission valve of one cylinder, said collector tapping off the reduced pressure only during a selected fraction of the suction cycle. Thus, it is possible to remove the variations in said reduced pressure during a complete operative cycle and to provide an individual throttling element in the admission pipe of each cylinder. This also results in eliminating the effect of the extent of overlapping of the valves engine on the reduced pressure. This results in a considerable advantage, since engines with a high specific power show generally a large overlapping of the valves which hitherto prevented the use of sensors of reduced pressures for the production of a fundamental regulating parameter and it was necessary to associate said parameter with the opening angle of the gas throttling valve or valves with the consequent necessity of introducing, as a fundamental parameter, the speed of rotation of the engine through intricate means.

According to further developments of the principle of the invention, it is possible furthermore to :

constitute the detector of the angular position of the engine crankshaft by means of an electronic high frequency oscillator positioned in front of an element governed by the rotation of the engine and including one or more metal screens covering a predetermined angular area said oscillator starting the absence of any screen and stopping whenever a screen registers with the oscillator. The oscillator feeds an impedance matching unit with two outputs, the first of which produces a high voltage level and the second of which produces a low voltage level in the absence of oscillations whereas in the presence of oscillations the situation is reversed It is also provided with a direct output for the oscillations;

employ as the threshold element a program-controllable uni-junction transistor, the anode of which is connected with a condenser, the cathode of which is grounded or else connected with the base of a transistor controlling the end of the injection and and the control electrode of which is connected with the middle point of a voltage divider;

employ as the threshold element a trigger with a plurality of inputs, one input being connected with a first memory defining a first reference voltage for said trigger and the other with the input of the second memory defining a second reference voltage while the output of said trigger is connected with the amplifier controlling the electromagnetic injection valve or valves;

utilize switches comprising transistors operating as current generators, which in addition to functioning as switches, also adjust the rate of charging and discharging the condenser;

employ as switches electronic gates of the NAND type;

apply a voltage to the threshold element produced by a potentiometric voltage divider forming a first memory adapted to store the information concerning the operation of the engine;

comprise the first memory of a voltage divider connected through its terminals with the high level and the low level outputs of the crankshaft angular position detector, said voltage divider being connected through its middle point with the voltage supply through a condenser, said first memory being adapted to store information relating to the rotary speed of the engine;

comprise the second memory of a condenser connected between the voltage supply and the output of the detector and further connected with a monostable flip-flop triggered by the oscillations at the output of said detector, the width of the output signals of the monostable flip-flop being adjusted in conformity with the operative conditions of operation of the engine by a variable condenser, the second memory being further connected with the collector of a transistor, the emitter of which is connected with the voltage supply and the base of which is connected with the output of the detector, said second memory storing information relating to the load and speed of rotation of the engine.

generating the voltage on the lower terminal of the energy-and/or information-storing condenser by a voltage divider including resistances and a transistor acting as a current generator;

feeding the base of said transistor a voltage governing the current flowing through the transistor, said voltage being obtained by a capacitory divider including two condensers, one of which varies in accordance with the operative conditions of the engine, said voltage divider being connected with the output of the condenser on the one hand and on the other hand through its middle point with the base of a transistor connected as an emitter follower, the emitter of which is connected with the base of the current-generating transistor through a rectifying diode, filtering resistances and a capacitance, the voltage applied corresponding to the average value of the oscillations, the amplitude of which is defined by the capacitory divider;

connecting the energy and/or information-storing condenser emitter circuit of the current-generating transistor and a resistance between the voltage supply and ground, the detecting oscillator being connected through one of its outputs with the base of said transistor while the charging voltage for said condenser is defined by the voltage divider constituted by a variable resistance and a fixed resistance, a program-controllable uni-junction transistor being connected between the voltage supply through the variable resistance and the fixed resistance, and the base of a transistor, the control electrode of the program-controllable uni-junction transistor being connected with the slider of a potentiometric voltage divider whereas the point through which the resistances are connected is connected with the anode of the diode through the collector-emitter circuit of a transistor, the base of which is connected with the cathode of the diode and also with the collector through a resistance, the electromagnetic injection valve or valves being controlled by an amplifier including transistors connected with the collector of said last-mentioned transistor ;

connecting the energy and/or information storing condenser in series with a diode the collector-emitter circuit of a transistor and a resistance between the voltage supply and ground, the detecting oscillator being connected with the base of said transistor through an impedance adaptor constituted by a condenser, a resistance and a transistor and through a capacitory divider constituted by an fixed condenser and a variable condenser connected between the collector of the transistor and ground, the middle point of said divider being connected with the base of a transistor connected as an emitter follower and the emitter of which is connected with the base of the current generator transistor by a rectifying filter constituted by a diode, resistances and a condenser, a program-controllable uni-junction transistor being connected in series with the emitter-collector circuit of a transistor and a resistance between the voltage supply and the base of a transistor or ground, the control electrode of said program-controllable uni-junction transistor being kept at a predetermined voltage by means of a voltage divider constituted by resistances, variable or fixed, while the anode of said program-controllable uni-junction transistor is further connected with the condenser through a diode, the base of the transistor in series with the uni-junction transistor being connected with the point connecting two resistances with the collector-emitter program-controllable of a further transistor between the feed supply and ground, the base of said further transistor being connected with the collector of a transistor incorporated with rectifying and filtering means constituted by resistances, a condenser and a diode and connected with the detecting unit so as to form a control circuit, controlled by the condenser and resistances of the impedance adaptor;

controlling the electromagnetic injection valve or valves by an amplifier comprising a transistor, the base of which is connected with the collector of the transistor controlling the end of the injection and is grounded through a resistance, the base of said transistor controlling the end of the injection being connected with the cathode of the program-controllable uni-junction transistor while its emitter is grounded.

By way of example and in order to further the understanding of the following description of the invention, the accompanying drawings illustrate said description. In said drawings:

FIG. 1 is a block diagram of the arrangement according to the invention;

FIG. 2 is a schematic diagram of the electronic control circuit according to a first embodiment.

FIG. 3 is a schematic diagram of the electronic control circuit according to a second embodiment;

FIG. 4 is a schematic diagram of the electronic control circuit according to a third embodiment.

Turning first to FIG. 1, it is apparent that the engine **85** provided with an intake manifold **87** is fed with fuel through the injectors **20** comprising by electromagnetic injection valves. In the case illustrated, there is provided an indirect injection into the admission manifold **87**, but obviously, the injection may be provided directly into the combustion chamber of the engine. Furthermore, the injection may be of a mechanical type beyond an electromagnetic injection valve controlled by the amplifier A. Obviously also, the fuel may be injected into the different cylinders of the engine **85** either sequentially in accordance with the sequence of ignitions of the engine with the provision of a suitable distributor which is not illustrated, or else it may be injected simultaneously in all cylinders.

The injectors **20** are fed with fuel under constant pressure conditions by the pump **92** drawing the fuel out of the tank **91** and delivering it into the pipe **93** through the filter **89**. The pipe **93** is provided with a pressure accumulator **88** and with a pressure regulator **90**.

The injection-control signals are generated starting from a detector D actuated by a pulse generator **86** controlled by the rotation of the engine. Said pulse generator **86** produces a signal of a predetermined duration controlling the storing of the information concerning the injection in the memories M_1, M_2 and M_3 which control the storing of injection energy in the memory M_s. Said pulse generator further produces a signal of a predetermined duration during which the injection takes place, said signal being transmitted to the amplifier A. The threshold element T +P is connected with the memories M_1, M_2, M_3 and M_s and may also be connected with the detector controlling the end of the injection through operation of the amplifier A. The unit D, is an adaptor shaping the signals, and is used only in conjunction with the embodiment of FIG. 3 and the connections drawn in dashed lines are not essential for all embodiments. In FIG. 1, there is illustrated inputs of all the operative parameters into the memory M_3. But, obviously, said parameters may be introduced into any one of the memories or into all three memories to be distributed in accordance with practical requirements.

In FIG. 2, there is illustrated a first practical embodiment of the control arrangement wherein the detector D is constituted by a unit **1** provided with an output S_1, on which a positive voltage appears during the storing period. Said signal is applied to the base of a transistor **2** forming a first switch C_1 and the collector-emitter circuit of which is connected in series with a resistance **6**, a condenser **5** comprising the unit M_s, a resistance **4**, a diode **3** and another resistance **7** between the voltage supply **23** and ground. The terminal A_3 of the emitter of the transistor is connected with the voltage supply through the variable resistance **10** forming the memory M_3 defining the charging level of the condenser **5** when the transistor **2** is conductive whereby the terminal A_3 is kept at a voltage V_c which varies in accordance with the operative conditions of the engine. The point A_2 between the diode **3** and the resistance **4** is connected with a point A_1 through the emitter-collector circuit of a transistor **8** forming a second switch C_2. Said point A_1 is connected with the base of the transistor **8** and with the collector of the transistor **2** through a resistance **9**, with the voltage supply **23** through the variable resistance **11** and with the anode of a program-controllable uni-junction transistor or threshold unit T + P through a resistance **12**. The variable resistance **11** forms the memory M_2 controlling the charging of the condenser **5** in accordance with the operative condition of the engine. The control electrode of the program-controllable uni-junction transistor **14** is connected with the slider of a potentiometric voltage divider **21** through a resistance **13**, said voltage divider being connected between ground and the resistance **22** connected with the voltage supply **23**. This voltage divider forms the memory M_1 depending also on the operative condition of the engine. The cathode of the programme-controllable uni-junction program-controllable is connected with the base of a transistor **15** the emitter of which is grounded and the collector of which is connected on the one hand with the base of the transistor **16** forming part of the amplifier A and on the other hand with the voltage supply **23** through resistance **19.**

The amplifier A further includes transistor **17** connected through its base with the collector of the transistor **16** and also with the voltage supply through resistance **18.**

The electromagnetic injection valves **20** are connected in series with the emitter-collector circuit of the transistor **17** between the voltage supply and ground. The emitter of transistor **15** is also grounded.

The operation of the arrangement is as follows :

During the storing period a high level signal appears at the output S_1 of the detector **1** and renders the transistor **2** conductive. Consequently, the condenser **5** is charged under a voltage corresponding to the difference between the voltage V_A of the supply of current and the voltage V_c defined by the voltage divider constituted by the resistances **7** and **10.** The charging time constant depends on the resistances **4** and **6** and on the capacity of the condenser **5.** During this time, transistor **8** is cut off since the voltage on its base is lower than that on its emitter.

When the detector enters its injection position, the signal at the output S_1 returns to its low level, which cuts off transistor **2.** Therefore, transistor **8** becomes conductive since the voltage on its base may rise to the value of the voltage at the point A_1. The program-controllable uni junction transistor which had been conductive is then cut off and condenser **5** discharges. The transistor **15** is also cut off which renders the transistor **16** and **17** conductive and triggers the injection. The condenser **5** during its discharge causes the voltage at the point A_2 and consequently at the point A_1 to rise at a rate which depends chiefly on the value of the resistance **11.** When the voltage at A_1 reaches a predetermined value with reference to the voltage applied to the control electrode of the transistor **14,** said program-controllable uni-junction transistor **14** again becomes conductive which renders the transistor **15** conductive and cuts off transistors **16** and **17,** ending the injection.

The programme controllable single junction transistor then remains conductive until the next injection is initiated after a further storing period.

The duration of the injections thus depends on the charging voltage V_c of the condenser **5,** as defined by the resistance **10,** the discharge speed defined by the resistance **11** and by the reference voltage applied to the control electrode of the programme-controlled uni-junction transistor **14,** which voltage is adjusted by the voltage divider **21.** It is apparent that the resistance **10** acts on the very short storing period, while the resistance **11** and the potentiometer **21** are adapted to act during the injection period. It is therefore possible to select the moment at which the engine parameters are introduced applied according to whether it is preferable to cause their effect during the storing period or during the injection period.

It should be noted that engine speed produces its effect in the case illustrated during the charging of the condenser. As a matter of fact, if the duration of the storing signal, which is inversely proportional to the speed of rotation of the engine, is larger than about three times the time constant of the circuit charging condenser **5,** said condenser is allowed a sufficient for reaching the asymptotic charging value. The charge consequently decreases when the speed of rotation rises above a predetermined limit while the duration of injection is reduced in accordance with the speed of rotation beyond a predetermined threshold.

Obviously, the use of variable resistances for the adjustment of the duration of injection is not an optimum solution when it is desired to execute speedy adjustments as simply as possible.

FIG. **3** illustrates a more complete, entirely transistorized circuit. It should be remarked that the unit **1** of the detector D comprises more particularly here a conventional electronic high frequency oscillator with the original feature being that it oscillates only when no metal member is to be found in its vicinity. This feature is made use of by providing in front of said unit **1,** a rotary unit **86** (FIG. **1**) controlled by the rotation of the engine and provided with alternating metallic and non-metallic sectors. Over a predetermined angular area, the non-metallic sector or sectors cause the unit **1** to oscillate in conformity with the storing period while the metallic sector or sectors produce a stopping of the oscillations during a period corresponding to the injection period.

In the case of FIG. **3,** the unit **1** is fed through the resistance **24,** the resistances **26, 28,** the condenser **25** and the transistor **27** forming an impedance matching adaptor provided on the collector of said transistor **27** with an output terminal S_3 on which the oscillations of the unit **1** are repeated with a difference in phase.

The output terminal S_3 is connected with a memory M_3 constituted by a capacitory divider including a constant condenser **37** and an adjustable condenser **38** connected in series between the output S_3 and ground, the connecting point between the condensers being connected with the base of transistor **30** connected as an emitter follower grounded through resistance **41** while its collector is connected with the voltage supply **23.** The emitter of the transistor **39** is further connected with the filtering and rectifying circuit constituted by the diode **42,** the resistances **43, 45, 47** and the condenser **44,** the point connecting the resistances **45** and **47** being connected with the base of the transistor **2** forming the first switch C_1 controlling the condenser **5.** Said condenser **5** is charged through the diode **3,** the transistor **2** and the resistance **7** while the charging voltage is defined by the voltage divider constituted by the resistances **7** and **10***a* and by the voltage applied to the base of the transistor **2** which thus forms the memory M_3 with said voltage divider **7–10***a* . The condenser **5** is discharged through the transistor **50** connected between the voltage supply **23** and the lower terminal of the condenser, together with the resistance **51** and the diode **48.** Said transistor **50** is controlled by the transistor **53** the collector of which is connected with the base of the transistor **50** through the resistance **52,** the end of which connected with the base of the transistor **50** is also connected with the voltage supply through the resistance **49.** The arrangement including elements **49** and **53** forms the switch C_2 and the memory M_2. The emitter of said transistor **53** is grounded whereas its base is connected with the filtering and rectifying unit D_1 forming part of the detector D. Said unit D_1 is connected with the point connecting the resistances **29** and **30** which are connected respectively with the output S_3 of the detector D and with ground. A conventional filtering and rectifying unit constituted by the diode **31**, the resistances **32**, **34** and **35** and the condenser **33** is adapted to saturate the transistor **36**, the emitter-collector circuit of which is connected with the resistance **46** between the voltage supply **23** and ground each time the unit **1** in the detector D oscillates. The collector of the transistor **36** is connected with the base of the transistor **53** and, through the resistance **56**, with the collector-base connection between the transistors **15** and **16**.

The program-controllable uni-junction transistor **14** of the threshold unit T + P is connected through its anode with the point A_1, through its cathode with the base of the transistor **15** and through its control electrode with the point connecting the resistance **21a** and **21b** connected in series between the voltage supply **23** and ground so as to form a voltage divider constituting the memory M_1. The electromagnetic injection valves **20** are connected in parallel with the protecting diode **55** in the collector-emitter circuit of the transistor **16** forming the amplifier A, between the voltage supply and ground. The base of the transistor **16** in addition to its connection with the collector of the transistor **15** is connected with ground through the resistance **54**.

The operation of the circuit illustrated in FIG. **3** is similar to that illustrated in FIG. **2**. As a matter of fact when the unit **1** oscillates, that is during the storing period, the oscillations after a phase shift appear at the output terminal S_3 of the detector D. The capacitance voltage divider constituted by the condensers **37** and **38** transmits these oscillations to the transistor **39** connected as an emitter follower and the amplitude of these oscillations is adjusted by the variable condenser **38** in accordance with the operative condition of the engine. After the oscillations have passed through the rectifying and filtering unit **42–43–44–45**, an average voltage appears on the base of the transistor **2** connected as a current generator. The condenser **5** is then charged through transistor **2** at a rate which depends on the voltage on the base of said transistor **2** and at a level which depends on said base voltage and on the resistances **10a** and **7** in the collector-emitter circuit of the transistor **2**.

At the same time, the oscillations at the output terminal S_3 of the detector D are transmitted to the rectifying and filtering means **31, 32, 33, 34, 35** forming the unit D_1 in a manner such that the transistor **36** is saturated. Consequently the transistor **53** is cut off and so is the transistor **50**. Furthermore transistor **16** is cut off by reason of its connection with the unit D_1 and therefore no injection can take place.

When the oscillations stop, that is during the injection period, the transistor **2** is again cut off as is transistor **36** and the latter ensures conductivity for the transistor **53** and consequently for the transistor **50** connected as a current generator and controlling the discharge of the condenser **5** at a rate depending on the current flowing through transistor **50**.

Simultaneously, transistor **16** is saturated by reason of its connection with the unit D through the resistance **56** and this produces injection. The voltage at the point A_1 rises until it reaches a predetermined value with reference to the voltage applied on the control electrode of the program-controllable uni-junction transistor **14**, which triggers said transistor **14** and stops the injection since the transistor **15** becomes then conductive and cuts off transistor **16**. The transistor **14** remains conductive since the transistors **53** and **50** remain conductive up to the moment at which further oscillations appear at the output terminal S_3 and cause the transistors **53** and **50** to be cut off which cuts off the transistor **14**.

In the case considered, the fundamental regulating parameter such for instance as the reduction in pressure in the admission manifold is transmitted to the condenser **38** which may be of a small capacity and be designed so as to vary in accordance with a suitable law with reference to the reduction in pressure. Such a condenser has rapid response and is suitable therefore for the detection of rapid modifications of a parameter. The memory M_3 introduces again a speed effect as in the case of FIG. **2**. The parameters which vary more slowly such as temperature or atmosphere pressure are introduced into the memories M_1 and/or M_2.

It should be noted that the amplifier A may be collected also by means of a connection between the base of the transistor **16** and the middle point of the voltage divider **21a–21b** of the memory through a resistance and by replacing the resistance **56** by a diode.

FIG. **4** illustrates a control circuit constituted by integrated circuits. In fact, there is provided a unit with four electronic gates of the NAND type, of which only three gates are made use of in association with a double trigger and a monostable flip-flop. In this case, the circuit connections are as follows :

The detector D includes the oscillator **1** fed through the resistance **24** followed by the filtering and rectifying means constituted by the resistances **26–30–74**, the condenser **25-75**, the transistor **27** and the diode **73**. The electronic gate 2a forming the switch C_1 is connected through its input with the collector of the transistor **27**, while its output is connected with the input of the second electronic gate **53a** forming the second switch C_2. The output S_1, of gate **2a** and the output S_2 of the gate **53a** form the detector outputs. The level of the output S_1 is low in the presence from oscillations of the oscillator **1** and the level of the output S_2 is then high whereas, in the absence of oscillations, the conditions are reversed. The output S_3 of the detector D provides a direct connection for the oscillations of the oscillator **1**. The output S_1 is connected to one of the inputs of a third gate **64** forming part of the threshold unit T + P which further includes a trigger **65** the output *g* of which is connected with the other input of the gate **64** whereas the inputs *e*, and e_2 of said threshold unit are connected with the memories M_1 and M_2 respectively. The memory M_1 is constituted by the resistances **21c** and **21d** connected in series between the outputs S_1 and S_2 of the detector D with the interposition of the corresponding diodes **63** and **66**. Said memory M_1 further includes condenser **57** connected between the voltage supply **23** and the point connecting the resistances **21c** and **21d** with one another. The memory M_2 comprises integrated bistable flip-flop **59** fed with triggering pulses to form the output S_3 of the detector D and through the condenser **72** during the oscillations of the oscillator **1**. The width of the rectangular signals at the output of said flip-flop **59** is adjusted by the variable condenser **60** in accordance with the fundamental regulating parameter of the engine. The flip-flop **59** is connected with a condenser **58** through the diode **70** and the resistance **68**, said condenser **58** being further connected with the output S_2 of the detector D through the resistance **69** and the diode **71** and with the collector of the transistor **61** while its other terminal is fed by the voltage supply **23.** The transistor **61** is connected through its emitter with the supply **23** through the resistance **76** and through its base with a voltage divider constituted by the resistances **77–78** connected between the voltage supply **23** and ground, said base being further connected with the output S_2 through the diode **67.** The energy-storing condenser **5** is connected between the voltage supply **23** and the output S_1, said connection being provided through a resistance *7a* and the diode **3.** Said resistance *7a* forms with the resistance **10***a* and the emitter-base circuit of the transistor **2***b* the memory M_3 which is a voltage divider defining the lower charging voltage of the condenser **5.** The resistance **10***a* is connected with the voltage supply **23** and with the emitter of the transistor **2***b* the base of which is connected with the point joining the condenser **5** with the resistance *7a*. The collector of the transistor **2***b* is connected through a resistance **62** with the base of the transistor **16** forming the amplifier A. transistor **16** has its collector emitter circuit connected in series with the electromagnetic injection valve **20** between the voltage supply **23** and ground. A protecting diode **55** is connected in parallel with the electromagnetic injection valve. A transistor **15** connected through its base with the output of the gate **64** has its collector-emitter circuit connected between the base of the transistor **16** and ground.

The integrated trigger **63** is associated with an identical independent trigger **79,** the latter ensuring constancy of the temperature of the circuit. To this end, the inputs e_1 and e_2 of said trigger **79** are provided with voltage dividers comprising the resistance **82** and the thermistance **81** for e_1 and two resistances **83–84** for e_2. The output **8** of the trigger **79** is grounded through a heating resistance **80** fitted on the frame enclosing the circuits so as to heat them throughout when the thermistance has caused the trigger to change its condition to a temperature below a predetermined limit.

It should be noted that all the units provided with an integrated circuit are fed with current by means which are not illustrated.

The operation of the injection-controlling system is as follows:

When the oscillator **1** oscillates during the storing period, the output S_1 is at a low level and the output S_2 at a high level. Further, the monostable flip-flop **59** produces rectangular signals. Consequently, the transistor **61** of the memory M_2 is cut off and the condenser **58** is charged through the voltage applied to its lower terminal, as defined on the one hand by the voltage divider constituted by the resistances **69** and **68** and on the other hand by the rectangular signals produced by the flip-flop **59.** The charge on the condenser **58** depends therefore on the number of signals produced by said flip-flop **59** and on their width. A voltage is applied to memory M_1 during this time which corresponds to the charge on the condenser **57** and depends on the duration of the storing period. Consequently, after a predetermined time trigger **65** changes its condition, and produces at its output *q* a high level signal.

Since the gate **64** receives from the output S_1 a low level signal its output is at a high level which renders the transistor **15** conductive and cuts off transistor **16.**

Simultaneously, the condenser **5** is charged at a rate defined by the transistor **2***b* and the resistance *7a* at a voltage level defined by the voltage divider constituted by the resistances *7a* and **10***a*.

At the beginning of the injection period, the output S_1 rises to a high level while the output S_2 falls to a lower level. The output S_3 no longer feeds any pulses to the flip-flop **50** so that its output remains at a high level which biases diode **3** and stops the charging of condenser **5B** if this charging has not ceased previously. This further results in gate **64** receiving a high level signal which acts in association with the high level signal output of trigger **65** so as to make a low level signal appear at the output of gate **64,** which signal cuts off transistor **15.** Therefore, transistor **16** becomes conductive and initiates the injection since its base is fed by the transistor **2***b* which has also become conductive by reason of the lower voltage applied to its base.

During this time, condenser **58** is discharged through the transistor **61** which has been rendered conductive by the low level signal applied to its base. The voltage applied to the input e_2 of the trigger **65** consequently rises whereas the voltage applied to the input e_1 does not vary. This results in trigger **65** returning to its prior condition, which causes a low level signal to appear at its output *q* and a high level signal to appear at the output of the gate **64.** The injection which is taking place is stopped by transistor **15** which becomes conductive and cut off base of the transistor **16.**

It should be noted that in the FIG. **4** embodiment memories M_1 and M_2 and the unit M_3 act on the injection as a function of engine speed. It is therefore possible, by a suitable selection of the various circuit components, to obtain a duration of injection which increases first with low rotary speeds of the engine, remains at a predetermined level in the middle of the range of speeds and decreases for high speeds of rotation.

As a matter of fact, for low speeds of rotation, condenser **57** is discharged more slowly than the condenser **58** and there is obtained a positive speed effect, that is, the duration of the injection increases. In contradistinction for high rotary speeds, condenser **57** can no longer be charged and a negative speed effect is obtained.

It should be further noted that the current passing through the injector is governed by the amplifier A, that is by the transistor **16** the base of which is fed by a current depending on the charge of the condenser **5** by reason of the connection between the base of the transistor **2***b* and condenser **5.** The end of injection is however defined by the output signal of gate **64** and consequently no difficulty can arise as far as the closing of the injection valve **20** is concerned.

What I claim is:

1. A fuel injection system for an internal combustion engine adapted to operate over a range of speeds and having an electrically actuable fuel metering valve, said system comprising:

a. a capacitor;

b. a charging circuit connected to said capacitor including:

i. a power source having a substantially uniform output voltage connected to said charging circuit for charging said capacitor,

ii. a first switch in said charging circuit which when closed enables charging of said capacitor, the level of said charging being a function of the duration of closure of said first switch, and

iii. first means for regulating the charging of said capacitor by said charging circuit when said first switch is closed as a function of a first engine operating parameter,

c. means synchronized with engine rotational position for controlling said first switch means to close during a first predetermined portion of the engine cycle and to open said first switch means during a second predetermined portion of the engine cycle, the duration of the closing of said first switch by said controlling means varying as an inverse function of the engine rotational speed, the duration of the closing of said first switch at the higher engine rotational speed being insufficient to enable said first switch to charge said capacitor fully and causing the charging of said capacitor to vary as an inverse function to the engine rotational speed in at least a portion of the range of engine rotational speeds;

d. a discharging circuit connected to said capacitor including:

i. a second switch the closing of which permits discharging of said capacitor through said discharging circuit,

ii. a reference point in said discharging circuit, said discharging causing the voltage at said reference point in said discharging circuit to change to a predetermined reference voltage in relation to the extent of the discharging, said second switch being closed in response to the opening of said first switch and opened in response to the closing of said first switch by said first switch controlling means,

iii. second means for regulating the discharging of said capacitor by the discharging circuit as a function of a second engine parameter,

e. threshold means connected to said reference point in said discharging circuit and being responsive to the voltage at said reference point for actuating the fuel metering valve only when said reference voltage is in a predetermined relationship with respect to a threshold level, the value of the

threshold being determined by said threshold means, whereby the duration of both the discharging of said capacitor to the predetermined reference voltage and the actuating of the fuel metering valve are a function of a level of charge obtained during the charging, the extent of discharging, and the value of the threshold level.

2. The apparatus of claim **1**, in which said synchronized control means comprises:

a. an oscillator responsive to an input to produce a signal,

b. a detector responsive to rotation of the engine to produce said input only during said first portion of the cycle, and

c. means connecting said oscillator to said first and second switches to apply said signal to close said first switch and open said second switch responsive to the presence of said signal and to close said second switch and open said first switch responsive to the absence of said signal during said second portion of the cycle.

3. the apparatus of claim **1** in which said threshold means comprises:

a. an amplifier connected to the fuel valve for actuating the valve in response to an input to said amplifier,

b. a three-terminal semiconductor gating element having two main terminals between which current easily passes in a forward direction only when said gating element is fired, and a gate terminal for controlling the firing point of said gate element, the main terminals of said gating element being connected in said forward direction between said reference point and said amplifier for providing said input only when said gating element is firing, and

c. a variable output voltage divider having its output connected to the gate terminal of said gating element for controlling its firing point, the value of said variable output being dependent on the value of a third engine operating parameter,

whereby the duration of actuation of the fuel valve is further dependent on the output value of the voltage divider which is in turn dependent on said third parameter.

4. The apparatus of claim **1**, in which said threshold means comprises:

a. an amplifier for actuating the fuel valve in response to an input,

b. a trigger connected between said reference point and said amplifier to provide said amplifier input when said reference voltage is less than said threshold level, and

c. threshold-setting means connected to said trigger and responsive to a third engine parameter for determining said threshold level.

5. The apparatus of claim **1** in which each of said first and second switches comprise a transistor, which transistors are connected as current generators to control said rates of charging and discharging, respectively.

6. The apparatus of claim **1**, in which each of said first and second switches comprises an electronic NAND gate.

7. The apparatus of claim **3**, in which said voltage divider comprises a potentiometer.

8. The system of claim **4**, in which said threshold-setting means comprises a voltage divider connected between the output of said detector and a low voltage point, the midpoint of said voltage divider connected between said trigger and a source of electric potential via a capacitor.

9. The system of claim **1**, in which said second means comprises:

a. a flip-flop connected at its input to the output of said synchronized control means said flip-flop being adapted to produce a square wave output having a frequency equal to that of said synchronized control means output,

b. means including a variable capacitor connected to said flip-flop, the value of said variable capacitor determining the breadth of said square waves, the value of said variable capacitor being dependent on said second parameter,

c. a fixed capacitor connected between the output of said flip-flop and said power source, and

d. a transistor having its collector-emitter circuit connected between said power source and the output of said flip-flop and its base connected to the output of said synchronized control means,

whereby the voltage on said fixed capacitor is a function of engine speed and of the value of said second parameter.

10. The system of claim **1**, in which:

a. said first switch comprises a first transistor, and

b. said first means comprises a voltage divider connected between said power source and ground, the midpoint of said voltage divider being connected to the terminal of said capacitor nearest ground.

11. The system of claim **1**, in which:

a. said first switch comprises a first transistor,

b. said first means comprises:

i. a capacitive voltage divider connected between the output of said synchronized control means and ground,

ii. an emitter-follower transistor having its base connected to the midpoint of said capacitive voltage divider, and

iii. a rectifier-filter circuit connected between the emitter of said emitter-follower transistor and the base of said first transistor.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,744,460 Dated July 10, 1973

Inventor(s) Louis Monpetit

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

Column 1, line 12, change "solenoid actuated" to -- solenoid-actuated --.

Column 1, line 20, change "solenoid-actuated fuel injector valve" to -- solenoid-actuated fuel injection valves --.

Column 1, line 21, insert -- an -- before "amplifier".

Column 1, line 21, delete [an] before "accurate".

Column 1, line 36, change "admission" to -- intake --.

Column 1, line 57, delete [stage] before "step".

Column 1, line 59, delete [said].

Column 2, line 35, change "last-mentioned said" to -- said last-mentioned --.

Column 2, line 67, change "period" to -- periods --.

Column 3, line 48, after "reversed" insert a -- . --.

Column 3, line 50, change "program" to -- programme --.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,744,460 Dated July 10, 1973

Inventor(s) Louis Monpetit

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

Column 4, line 32, change "transistor a voltage" to read -- transistor with a voltage --.

Column 4, line 47, after "condenser" insert -- in series with resistances, a diode, the collector-emitter --.

Column 4, line 57, change "program" to -- programme --.

Column 5, line 15, change "program" to -- programme --.

Column 5, line 27, after "two" insert -- series --.

Column 5, line 28, change "program" to -- programme --.

Column 5, lines 28 and 29, change "program-controllable of a further transistor between the feed supply and ground, the base of said further" to -- circuit of a further transistor between the voltage supply and ground, the base of said further --.

Column 5, line 42, change "program controllable" to -- programme-controllable -- .

Column 5, line 42, change "program" to -- programme --.

Column 5, line 19, change "program" to -- programme --.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,744,460 Dated July 10, 1973

Inventor(s) Louis Monpetit

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

Column 5, line 23, change "program" to -- programme --.

Column 6, line 54, change "program" to -- programme --.

Column 6, line 59, change "program" to -- programme --.

Column 6, line 67, change "program" to -- programme -- .

Column 6, line 67, cancel "program-" .

Column 7, line 1, change "controllable" to -- transistor --.

Column 7, line 31, change "program" to -- programme --.

Column 7, line 32, change "uni junction" to -- uni-junction --.

Column 7, line 41, change "program" to -- programme --.

Column 7, line 45, change "single" to -- uni- --.

Column 7, line 59, delete [introduced].

Column 8, line 37, change "30" to -- 39 --.

Column 9, line 11, change "program" to -- programme --.

Column 9, line 64, change "program" to -- programme --.

Column 10, lines 17 and 18, change "collected" to -- controlled --.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,744,460 Dated July 10, 1973

Inventor(s) Louis Monpetit

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

Column 10, line 32, change "2a" to -- 2^a --.

Column 11, line 2, before "supply" insert -- voltage --.

Column 11, line 28, change "63" to -- 65 --.

Column 12, line 4, change "50" to -- 59 --.

Column 12, line 25, change "cutoff base of the" to -- cuts off transistor 16.--.

Signed and sealed this 22nd day of January 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents