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[54] **TIMING CIRCUIT FOR OPENING FUEL-INJECTION VALVES**

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[51] **Int. Cl.** **F02d 5/00**

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

[56] **References Cited**

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[57] **ABSTRACT**

A fuel-injection arrangement for internal combustion engines with electromagnetically actuated fuel-injection valves and intake manifold. A monostable multivibrator provides output pulses having a duration dependent on at least one operating parameter of the engine, such as the suction pressure within the manifold behind the throttle valve. A pulse-extending stage connected to the monostable multivibrator emits an extending pulse adjoining each pulse from the multivibrator and having a duration which depends on the duration of the preceding pulse from the multivibrator. A second monostable multivibrator has an unstable state duration beginning with the extending pulse and lasting for a fraction of the duration of the extending pulse. A compensating network connected to the pulse-extending stage influences the duration of the extending pulse by either increasing or decreasing the duration of the extending pulse.

8 Claims, 2 Drawing Figures

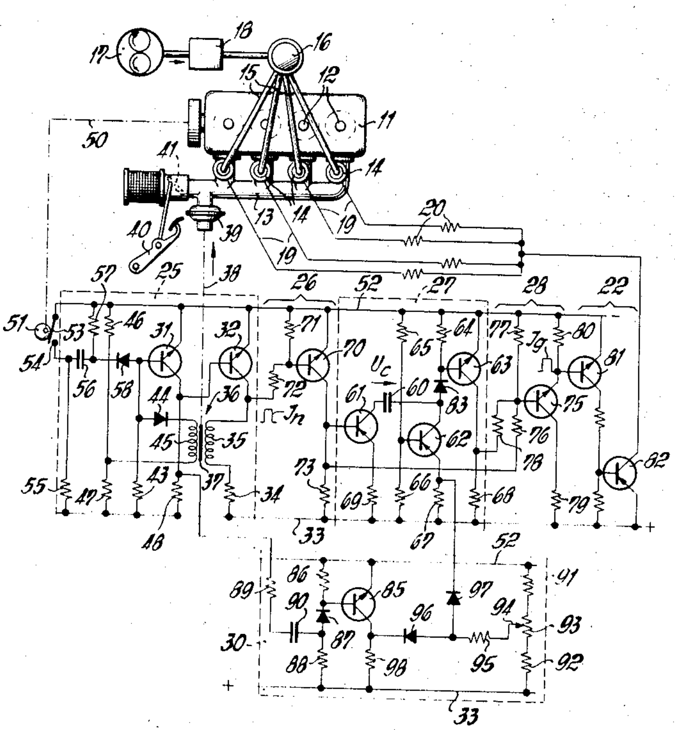


FIG. 1

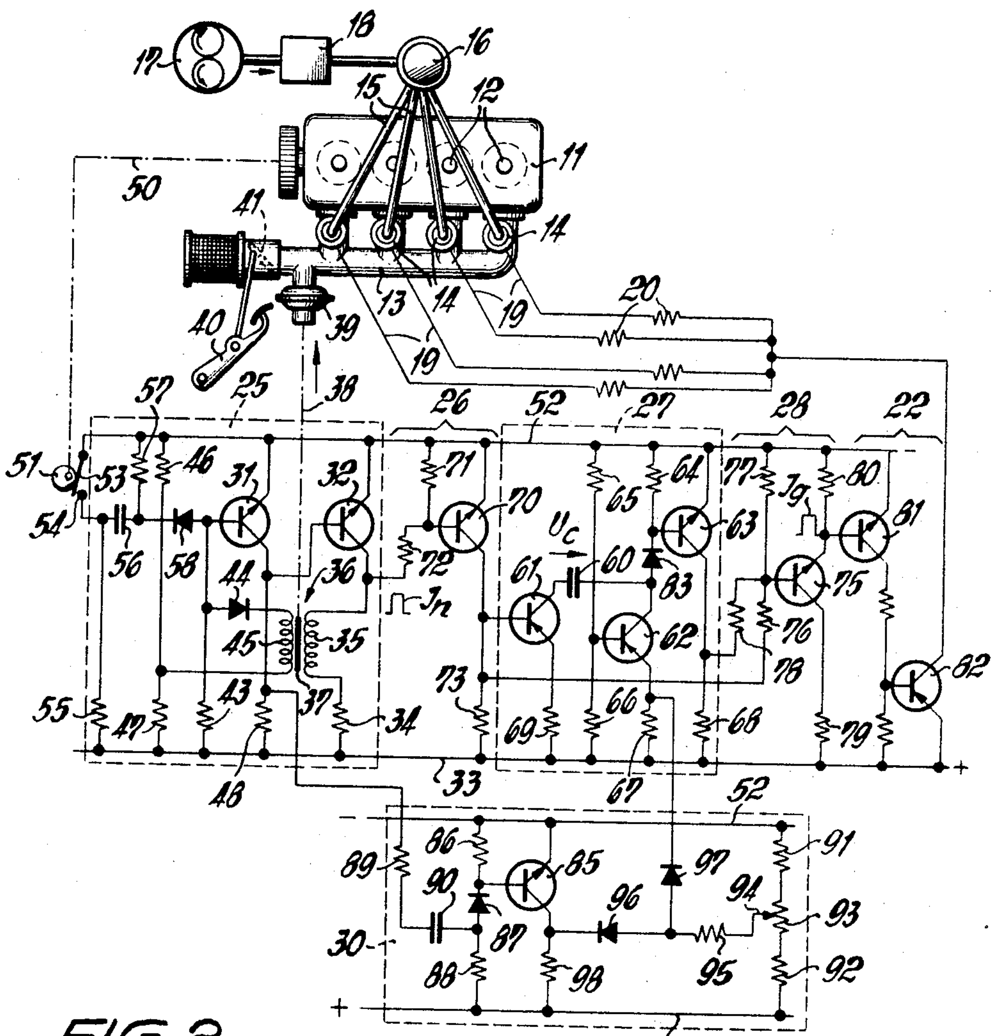
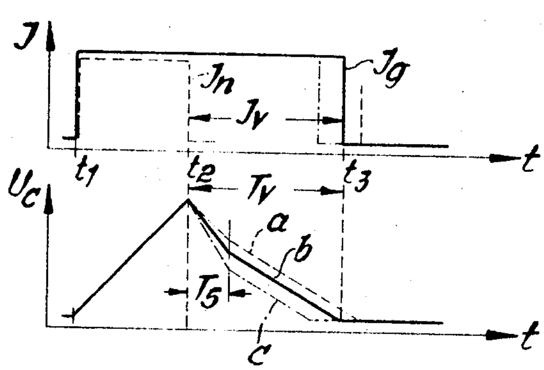


FIG. 2



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TIMING CIRCUIT FOR OPENING FUEL-INJECTION VALVES

BACKGROUND OF THE INVENTION

The present invention relates to a fuel-injection arrangement for an internal combustion engine which is equipped in particular with intake manifold injection. A control arrangement determines the opening duration of at least one electromagnetically actuated fuel-injection valve. This control arrangement is preferably constructed of a monostable multivibrator having output pulses with duration made dependent on at least one operating parameter of the engine. Such a parameter is preferably the suction pressure within the intake manifold prevailing behing the throttle valve. An electronic pulse-extending stage is connected to the monostable multivibrator and provides an output pulse adjoining the pulse emitted by the multivibrator. The duration of the pulse from the pulse extender is dependent upon the duration of the output pulse from the monostable multivibrator immediately beforehand. A second monostable multivibrator which is connected to the first multivibrator has an unstable state which begins with the pulse from the extending stage and has a duration which is a fraction of the pulse from the extended stage.

In fuel-injection arrangements of the above species, the quantity of fuel injected can be made particularly precise in relation to the speed and load of the engine, for every suction cycle in a cylinder of the engine. This has the advantage above all that injurious exhaust gases from the engine may be held at a minimum. In order to fit the opening duration of the injection valves to the prevailing operating condition, the fuel-injection arrangements known in the art use different devices which provide the required electrical information as a function of the operating conditions, for the control purposes. These devices, however, cannot be mass-fabricated while maintaining the required narrow tolerances at economical costs. The present invention, therefore, has as its basic object to provide an arrangement through which the tolerances of the individual devices as well as the tolerances of the engine are compensated through a correcting or compensation control device. This correction is superimposed so that the magnitude of the opening duration is either shortened or extended and remains constant over the entire speed range. This is made so that too large an influence is avoided at high speeds or high suction pressure. To provide the desired correction, an adjustable voltage divider is provided in conjunction with the fuel-injection arrangement. This adjustable voltage divider influences the pulse-extending stage in a decreasing or increasing sense. In particular, two diodes are provided at a movable contact of the adjustable voltage divider, and these two diodes have both of their same electrodes connected to this movable contact. One of these diodes is connected to the emitter of a transistor within the pulse-extending stage, whereas the other diode is connected to the collector of a switching transistor within the compensating stage.

SUMMARY OF THE INVENTION

A fuel-injection arrangement used for internal combustion engines provided with intake suction manifold and electromagnetically actuated injection valves. A first monostable multivibrator provides output pulses having a duration made dependent on at least one operating parameter of the engine, such as the suction pressure within the intake manifold behind the throttle valve. A pulse-stretching or extending stage is connected to the first monostable multivibrator and emits an extending pulse adjoining immediately the pulse from the first monostable multivibrator. The duration of the extending pulse is made dependent upon the preceding output pulse from the first monostable multivibrator. A second monostable multivibrator is connected to the first monostable multivibrator and has an unstable state duration which begins with the extending pulse and lasts for a fraction of the duration of this extending pulse. A compensating network is connected to the first monostable multivibrator and the pulse-extending stage for influencing the duration of the extending pulse.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an electrical circuit diagram of the fuel-injection arrangement for an internal combustion engine, in accordance with the present invention;

FIG. 2 is a pulse-timing diagram of pulses prevailing in the circuit shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, and in particular to FIG. 1, the fuel-injection arrangement shown therein is intended for operating a four-cylinder internal combustion engine **11**. The sparkplugs **12** of this engine are connected to a high-voltage ignition arrangement, not shown. An electromagnetically actuated injection valve **14** is provided for each cylinder branch leading from the intake manifold **13**. These valves **14** are located directly in proximity of the individual cylinders of the internal combustion engine, and in particular in proximity to the inlet valves, not shown. Fuel from a distributor **16** is transmitted to each injection valve through a fuel line **15**. The fuel pressure within the distributor **16** and the fuel lines **15** is maintained at approximately 3 atm. through means of an electrically motor-driven pump **17** and a pressure regulator **18**.

Each injection valve **14** possesses an electromagnetic coil, not shown. One end of each coil is connected to ground potential, whereas the other end of each coil is connected through one of the interconnecting lines **19**, with one of the four resistors **20**. In the embodiment shown, all injection valves are simultaneously operated in synchronous manner relative to the crankshaft rotations of the engine to actuate them to their open positions. This occurs through the application of an electrical opening pulse J_g. The duration of this pulse determines the duration of the fuel injection period. The power stage **22** is used for actuating the injection valves, and is described in further detail below.

The electronic control arrangement controls as an essential part, a monostable multivibrator **25**, an inverting stage **26**, a pulse-extending stage **27** connected to the stage **26**, and an OR gate **28** to which the power stage 22 is connected. A correction circuit or compensation circuit 30 is, furthermore, provided.

The monostable means 25, have a multivibrator includes an input transistor 31 and an output transistor 32 having its base connected to the collector of the transistor 31. From the collector of the output transistor 32, leads a series circuit to the positive supply line 33, through a primary winding 35 of a transformer 36, and a resistor 34. The transformer 36 has an adjustable core 37. The core 37 of this transformer is mechanically coupled, through linkage 38, with the membrane (not shown) of a pressure sensor 39. This pressure sensor 39 is connected to the intake manifold 13 of the engine, and is located after the throttle valve 41 which is actuated by the accelerator, when viewed in the direction of intake in the manifold 13.

The input transistor 31 of the multivibrator 35 is maintained conducting in its inoperative state, through a resistor 43 which is connected between the base of this transistor and the positive supply line 33. A diode 44 is, furthermore, connected between the base of transistor 31 and the primary winding 35 of the transformer 36. The other terminal of this primary winding of the transformer is connected to the junction of two resistors 46 and 47 which serve as a voltage divider.

The crankshaft 50 of the engine is coupled to a triggering means cam 51 comprising a which actuates a switching arm 53 connected to the negative voltage supply line 52 of a power supply not further shown. The actuation of the switching arm 53 produces pulses J_n for switching the multivibrator 25 to its unstable state, in a synchronous manner relative to the crankshaft rotations. A charging resistor 55 is connected to the fixed contact 54 associated with the switching arm 53, and one electrode of a coupling capacitor 56 is connected to the junction of the terminal 54 and the resistor 55. The other electrode of this capacitor 56 leads to the negative voltage supply line 52 through a resistor 57. At the same time, a diode 58 is connected between the base of transistor 31 and the junction of the capacitor 56 and resistor 57. As long as the switching arm 53 is in the open position shown in FIG. 1, the capacitor 56 can charge through the two resistors 55 and 57 and acquire the voltage determined from that prevailing across voltage supply ines 52 and 33. When the switching arm 53 is actuated by the cam 51 so that it becomes pressed against contact 54, the positively charged electrode of the capacitor 56 becomes connected with negative potential. As a result, the base of the input transistor 31 strongly acquires negative potential so that the transistor 31 becomes turned off and the output transistor 32 becomes turned on.

The collector current of the output transistor 32 which flows through the primary winding 35, induces a voltage within the secondary winding 45, so that the input transistor 31 is further held turned off. The duration of the time during which the transistor 31 is thus turned off, is thereby determined by the pressure prevailing within the intake manifold 13 of the engine. When this pressure drops considerably below the outer atmospheric pressure when the throttle valve 41 is either closed or almost closed, then the pressure sensor 39 lifts the core 37 in the direction of the arrow in the drawing, and increases thereby the air gap in the transformer 36. The inductance of the primary winding 35 is thereby considerably decreased. In view of such decreased induced voltage, the input transistor 31 then turns rapidly to its initial conducting state, and the output transistor 32 becomes turned off anew. The pulse J_n appearing at the collector of the output transistor 32 has, thereby, a short duration of approximately 1.2 msec.

When, however, the accelerator or gas pedal 40 is depressed and the throttle valve 41 is thereby moved into its open position, the air pressure behind the throttle valve is only slightly below that of the outer atmospheric air, even when the speed of the engine is substantially high. Since under these circumstances the core 37 can only be lifted slightly, the primary winding 35 has a substantially high inductance, and this leads to a slow rise of the collector current in the primary winding 35. The pulse J_n has an accompanying larger pulse duration, thereby, of approximately 4.2 msec.

In the embodiment shown, the pulse J_n is taken from the inverting stage 26 of the output transistor 32, and is applied to the pulse-stretching or extending stage 27. This stage 27 produces directly an extended pulse J_v connected to the pulse J_n. The duration of the pulse J_v is larger than the duration of the pulse J_n by an adjustable factor. This factor can be made dependent on different operating conditions of the engine, as shown in the art. Such operating conditions of the engine can be, for example, the cooling water temperature.

In particular, the pulse stretcher 27 contains a storage capacitor 60, a charging transistor 61, a discharging resistance means have in form of a transistor 62, and a switching transistor 63 which has its emitter directly connected to the minus voltage supply line 52. The base of this transistor is connected through a resistor 64 to this minus voltage supply line, and at the same time, to one electrode of the capacitor 60, through a diode 83. The collector of the switching transistor 63 is connected with its base to the collector of the transistor 62, through the diode 83. The base of the discharge transistor 62, on the other hand, is connected to the junction of two resistors 65 and 66 forming a voltage divider. The emitter of transistor 62 leads to the positive supply line 33 through a resistor 67.

The collector of the charging transistor 61 is connected to the other electrode of the storing capacitor 60. This transistor is connected as an emitter follower, since its emitter leads to the positive supply line 33 through the resistor 69, and its base is directly connected to the collector of the inverting transistor 70 of the inverting stage 26. A resistor 73 is connected between the collector of the transistor 70 and the positive supply line 33. A resistor 71, furthermore, is connected between the base of transistor 70 and the voltage supply line 52. A resistor 72 is connected between the collector of the output transistor 32 and the base of transistor 70.

The collector of the transistor 70 leads to the base of transistor 75, through a resistor 76. The transistor 75 belongs to an OR gate 28. A resistor 77 is connected between the base of the transistor 75 and the negative supply line 52. A coupling resistor 78 is, furthermore, connected between the base of this transistor 75 and the collector of the transistor 63. A resistor 68 is connected between the junction of resistor 78 and the collector of transistor 63, and the positive supply line 33. The collector of transistor 75 leads to the positive supply line 33 through a resistor 79, whereas a resistor 80 is connected between the emitter of transistor 75 and the negative supply line 52. The base of a transistor 81 is directly coupled to the emitter of transistor **75**. This transistor **81** is of the npn type, and forms a power stage **22** together with the pnp power transistor **80**.

The principle of the circuit described thus far is known in the art. The operation of this circuit can, therefore, be described as follows: When the engine operates the switching arm **53** and closes it through the cam **51** during each rotation of the crankshaft, the input transistor **31** becomes turned off, and the pulse J_n is generated in the manner described above. The duration of this pulse depends upon the rotational speed of the engine and the throttle valve position. During the interval or duration of this pulse, the transistor **70** of the AND gate **26** is turned off, so that the transistor **75** belonging to the OR gate **28** becomes conducting through the first coupling resistor **76**. As a result, the transistor **81** and the power transistor **82** are also turned on. In the initial state or in the inoperative state, the collector potential of the charging transistor **61**, as well as the collector potential of the conducting inverting transistor **70** are substantially at the potential of the negative supply line **52**. The voltage U_c across the storage capacitor **60** is then substantially zero. As soon as a pulse J_n begins, however, the base potential of the charging transistor **61** acquires a magnitude which is intermediate the voltage between the line **33** and the negative line **52**, in view of the base current flowing through the resistor **73** of the OR stage **75**. The charging transistor **61**, consequently, can deliver a constant charging current for the storage capacitor **60**. Within the duration of the pulse J_n, the voltage U_c rises across the capacitor **60** in a linear manner, as shown in FIG. **2**. This linearizing votlage takes place from the instant of time t_1 to the terminal instant t_2 of the pulse J_n. However, as soon as the end of this pulse is reached and the inverting transistor **70** becomes again conducting, the collector of this transistor receives a substantially large negative potential, as does also the collector of the charging transistor **61**. As a result, the charge accumulated in the meantime on the capacitor **60** causes the base of the switching transistor **63** to be also strongly negative, so that the transistor **63** becomes turned off until the charge disappears through the discharge transistor **62**.

Under the conditions determined by FIG. **2**, the discharge process takes place from the instant of time t_2 until the instant t_3. During this time interval the switching transistor **63** is again conducting. Since the OR transistor **75** can be held turned on through the second coupling resistor **78** and the collector resistor **68** while the switching transistor **63** is turned off, an extended pulse J_v becomes joined to the pulse J_n. These two pulses together form a pulse J_g which determines the opening duration of the fuel injection valves, and therefore the quantity of fuel injected.

As shown in the lower parts of FIG. **2**, the discharge of storage capacitor **60** occurs during the interval of the extended pulse J_v, in a manner which is not constant, and the discharge takes place through the transistor **62**. The correcting or compensation circuit **30** provides that for the entire engine speed range as well as load range, the extended pulse is compensated or corrected so that it remains constant. In particular, the compensation arrangement **30** has a monostable stage which has a constant time interval of approximately **1** millisecond. The monostable stage consists of a transistor **85** which is of the npn type and has its base connected to the negative supply line **52**, through a resistor **86**. The base of this transistor **85** is also connected to the cathode of a diode **87**, while the anode of this diode leads to the positive supply line **33** through a resistor **88**. This resistor **88** maintains the transistor **85** conducting during its initial or inoperative state. In order that the transistor is switched to its unstable, non-conducting state through the pulse J_n provided by the multivibrator **25**, the base of transistor **85** leads to the collector of the input transistor **31** of the multivibrator **35**, through a resistor **89** and capacitor **90**. The time constant of this series RC circuit is approximately **1** millisecond. A voltage divider is, furthermore, provided within the circuit **30**. This voltage divider forming part of an adjustment means consists of fixed resistors **91** and **92**, and a potentiometer **93** between them. The movable contact **94** of the potentiometer is connected to the anodes of two diodes **96** and **97**, through a resistor **95** which serves as a limiting resistor. The diode **96** leads to the positive supply line **33** through a resistor **98**, and to the collector of transistor **85**. The cathode of the other diode **97** is connected to the emitter of the discharge transistor **62** of the pulse-extension stage **27**. During the correcting or compensation interval T_s which adjoins directly the time instant t_2, the switching transistor **85** is turned off. Since the diode **96** is then also non-conducting, auxiliary current can be applied to the collector of transistor **62**, through the diode **97**. This transistor **62** provides an essentially larger discharge current from the capacitor **60** during the time interval T_s. The discharge current of the capacitor **60** determines substantially the duration T_v of the stretched or extended pulse of the stage **27**. Since the auxiliary current flows only for 1 millisecond as a result of the time interval T_s determined by the capacitor **90**, the injection duration can be varied only by the amount attained during the duration T_2.

The broken line in FIG. **2** represents the function of the capacitor voltage U_c across the storage capacitor **60**. This capacitor voltage is determined by the position of the movable contact **94** of the potentiometer **93** when it is substantially near the negative potential. In this case, an extension of the injection duration occurs. The dash-dot line *c* is applicable when the movable contact **94** of the potentiometer is near the positive potential, whereby a shortening of the injection duration can be achieved. The solid line *b* in FIG. **2** is applicable for the center position of the contact **94**, at which time the compensating or correcting arrangement **30** is ineffective.

The particular advantage of the compensating or correcting arrangement described above resides in the condition that the correction or compensation is independent of the operating conditions as, for example, speed, manifold pressure, etc. Thus, the fuel injection duration is independent of these operating conditions. IN a simple manner, the influence of the additional equipment, for example the manifold pressure sensor becomes compensated through the present invention. The pressure sensor **39** can be considered as representing numerous other elements which can be compensated against their manufacturing tolerances through the correcting arrangement **30**, and as a result the fuel-injection arrangement can be compensated through installation of the present invention, in an electrical manner.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can be applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended

1. In a fuel-injection system for an internal combustion engine of the type including at least one electrically controlled fuel-injection valve having an electrical input, an arrangement for generating electrical valve-opening pulses, comprising in combination triggering means for generating triggering signals synchronized with engine rotation; monostable means having an input connected to said triggering means and having an output connected to said electrical input of said valve, and operating upon receipt of a triggering signal for generating a first valve-opening pulse having a duration dependent upon at least one variable engine operating condition; and pulse-extending means having an input connected to said monstable means and having an output connected to said electrical input of said valve, and operative upon termination of said first pulse for generating a second pulse having a duration dependent upon the duration of said first pulse and forming with said first pulse a longer composite valve-opening pulse, said pulse-extending means including timing means for determining the duration of said second pulse, said timing means comprising an energy-storing timing component so connected to said monostable means as to undergo a first change of stored energy during said first pulse and an opposite second change of stored energy which commences upon termination In said first pulse and whose completion results in termination of said second pulse, resistance means connected to said timing component and having a value causing said second energy change to ordinarily proceed at a first rate, and compensating means connected to said pulse-extending means and automatically operative after termination of said first pulse and during an initial portion of said second energy change, for causing said second energy change to proceed during said portion thereof at a different second rate, and thereafter at said first rate upon termination of operation of said compensating means.

2. An arrangement as defined in claim **1**, wherein said compensating means comprises adjusting means for selectably changing said second rate.

3. An arrangement as defined in claim **1**, wherein said initial portion of said second energy change commences at the time of termination of said first pulse.

4. An arrangement as defined in claim **1**, wherein said compensating means includes a timing circuit for maintaining said compensating means operative for a fixed time period independent of the duration of said first pulse.

5. An arrangement as defined in claim **1**, wherein said timing component is a timing capacitor, and wherein said compensating means comprises means operative for establishing a flow of current through said capacitor during said initial portion of said second energy change superimposed upon the component of capacitor current determined by the RC-time-constant of said capacitor and said resistance means.

6. An arrangement as defined in claim **2**, wherein said selecting means comprises adjustable voltage divider means so connected to said pulse-extending means as to be capable of changing said second rate.

7. An arrangement as defined in claim **1**, said engine having an air intake passage and a throttle valve located in said passage, and wherein said engine operating condition is the pressure prevailing in said passage downstream of said valve.

8. An arrangement as defined in calim **1**, wherein said timing component is a timing capacitor, and wherein said compensating means includes a timing circuit connected to said monostable means and commencing operation upon termination of said first pulse and comprising a switching circuit including a switching transistor for initiating operation of said compensating means upon termination of said first pulse and for terminating operation of said compensating means in dependence upon operation of said timing circuit, and wherein said compensating means further includes adjusting means for changing said second rate, said adjusting means comprising an adjustable voltage divider having a mid-tap, further including a diode having one electrode connected to said mid-tap and another electrode connected to said timing component for carrying current between said mid-tap and said timing component, and another diode having one electrode connected to said mid-tap and another electrode connected to the collector of said switching transistor.

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