United States Patent

Monpetit

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[54] METHOD OF REGULATION OF THE DURATION OF REPEATED RECTANGULAR ELECTRIC SIGNAL AND DEVICES FOR THE PRACTICAL APPLICATION OF THE SAME METHOD

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[52] **U.S. Cl.** **307/265,** 123/119, 328/58

[51] **Int. Cl.** **H03k 5/04**

[58] **Field of Search** 123/119; 307/265, 266, 267; 328/58

[56] **References Cited**

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[57] **ABSTRACT**

Method and apparatus are disclosed for varying the width of a rectangular pulse which controls the opening of an electromagnetic fuel injector, in accordance with engine speed. Reference pulses of short duration are generated in synchronism with engine rotation and these pulses are utilized to generate injection pulses, and control pulses. The termination of the control pulse, which is of predetermined width, is utilized to generate a linearly increasing reference voltage which reaches a predetermined voltage level, depending on the spacing between the preceding reference pulse and the following reference pulse. The voltage level reached by the reference voltage is utilized to cut off the injection pulse. The width of the injection pulse, and in consequence the quantity of fuel injected, is thus directly controlled by engine speed, i.e., by the spacing of the reference pulses.

9 Claims, 11 Drawing Figures

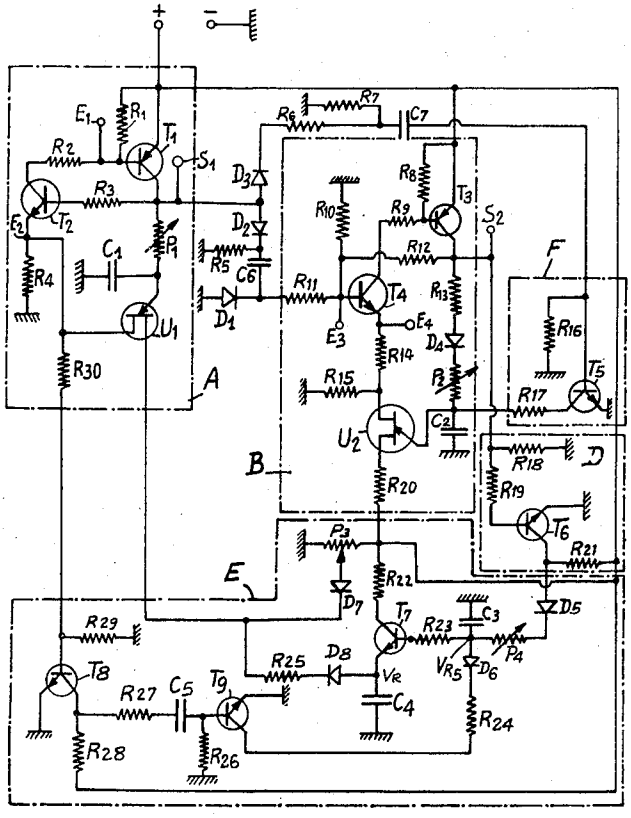

Fig:1

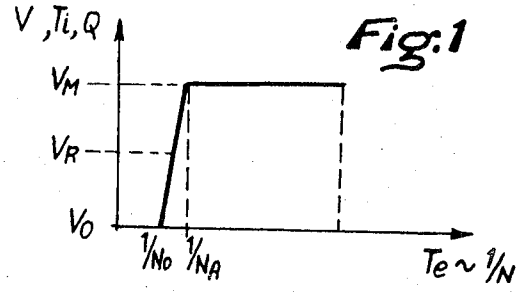

Fig:2

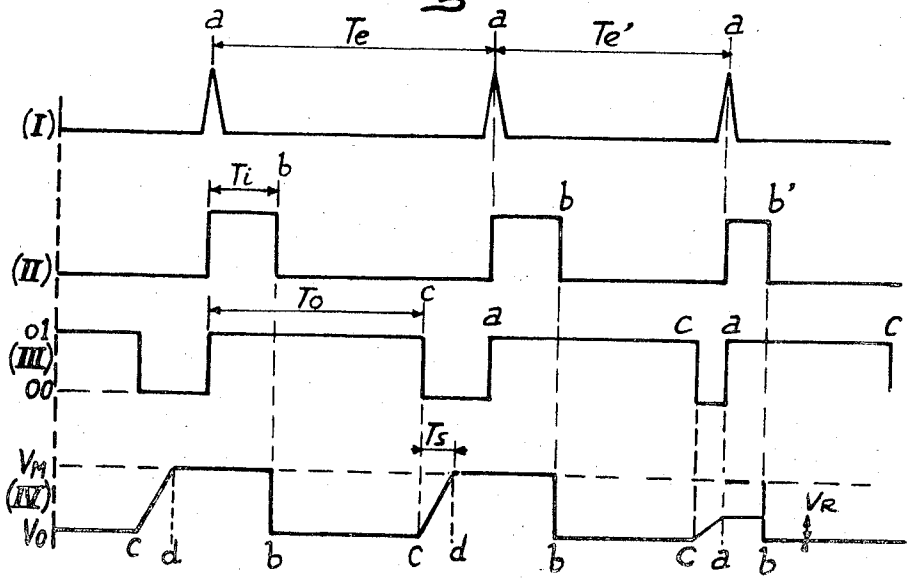

Fig:3

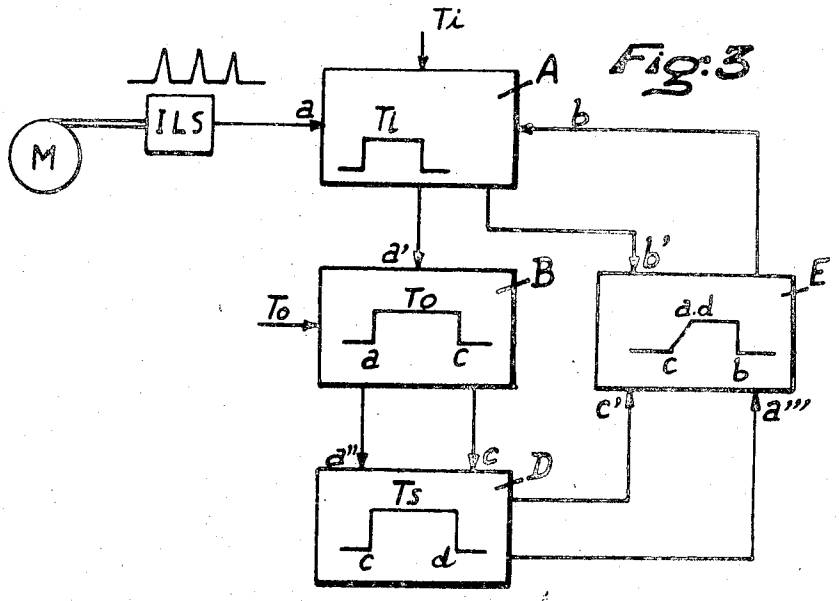

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Fig. 4

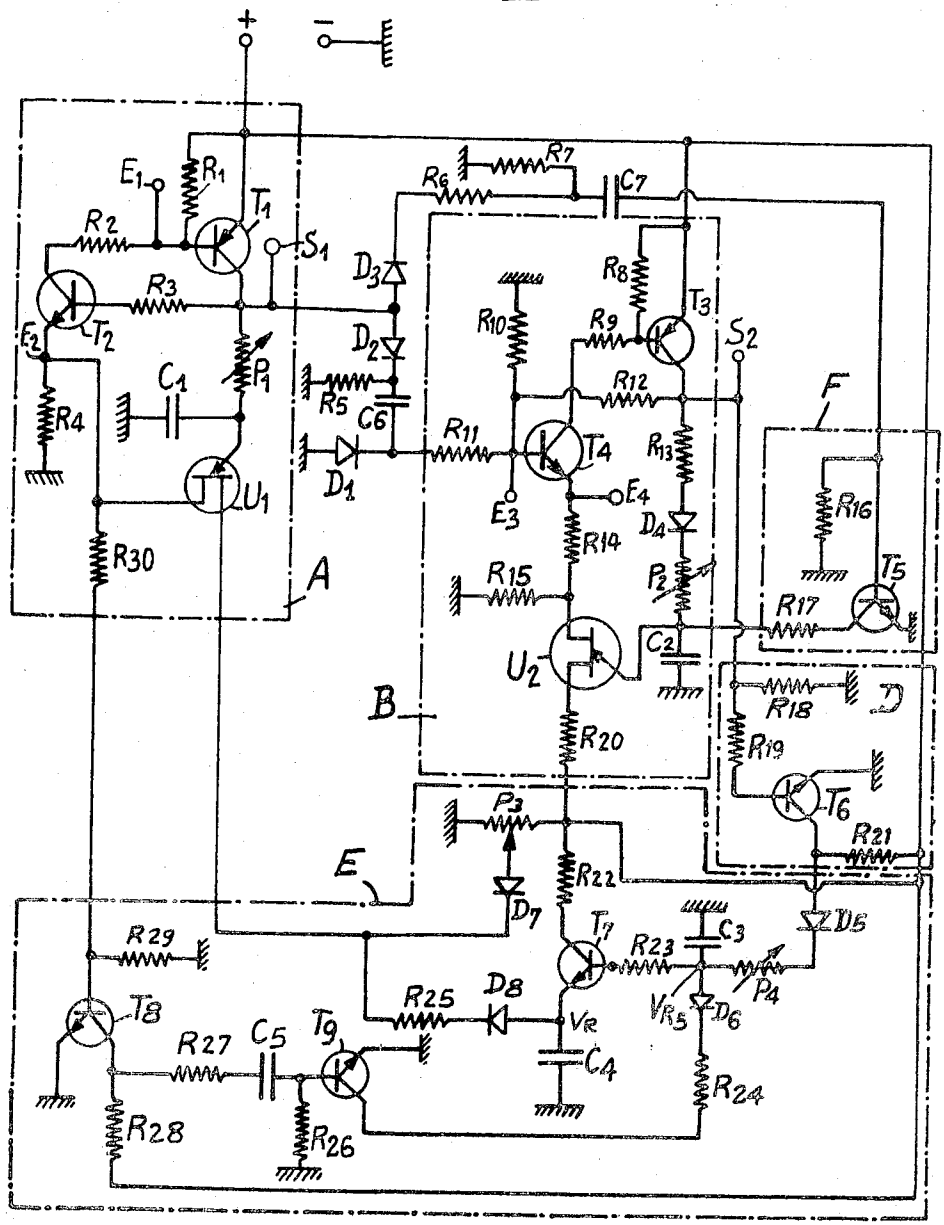

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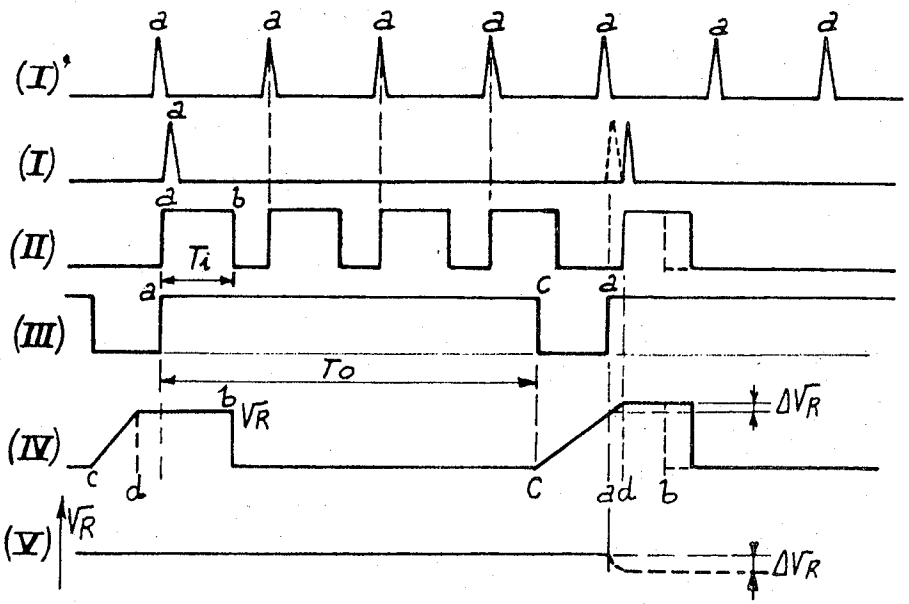
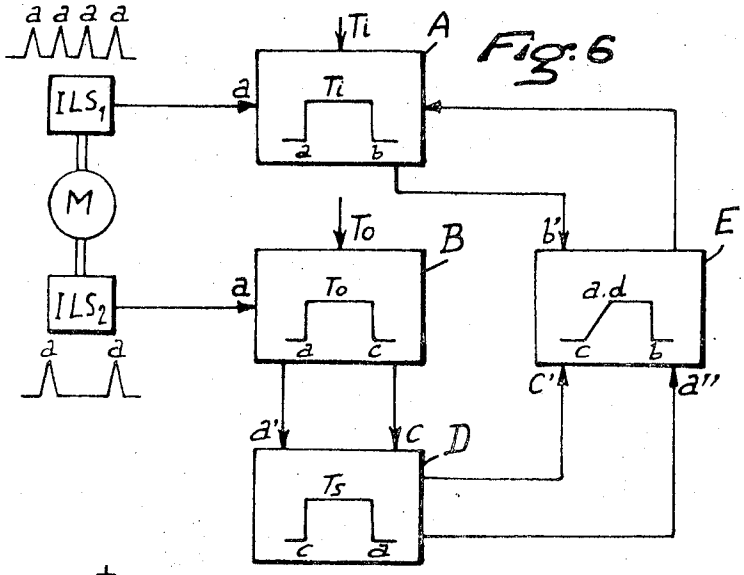
Fig. 5





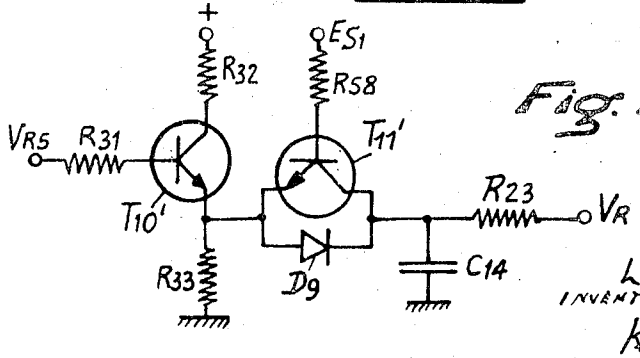


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Fig: 8

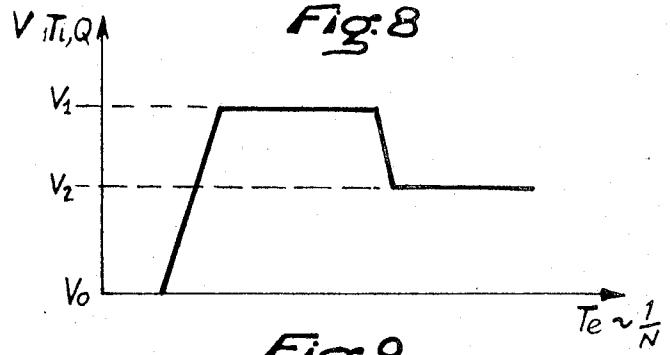


Fig: 9

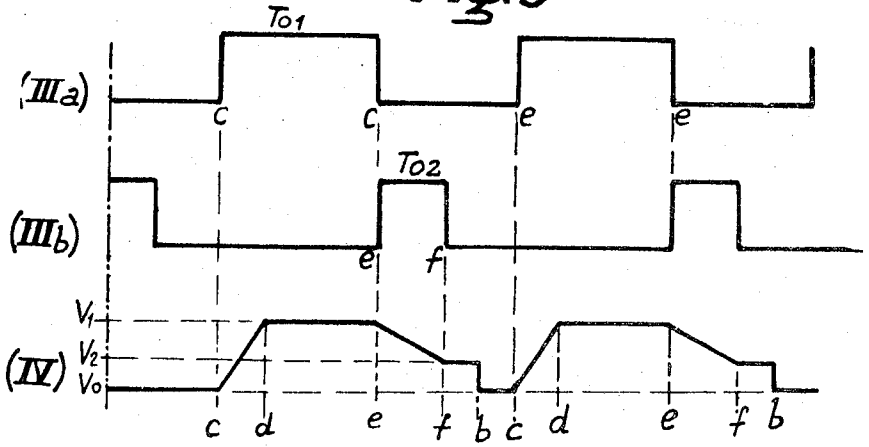
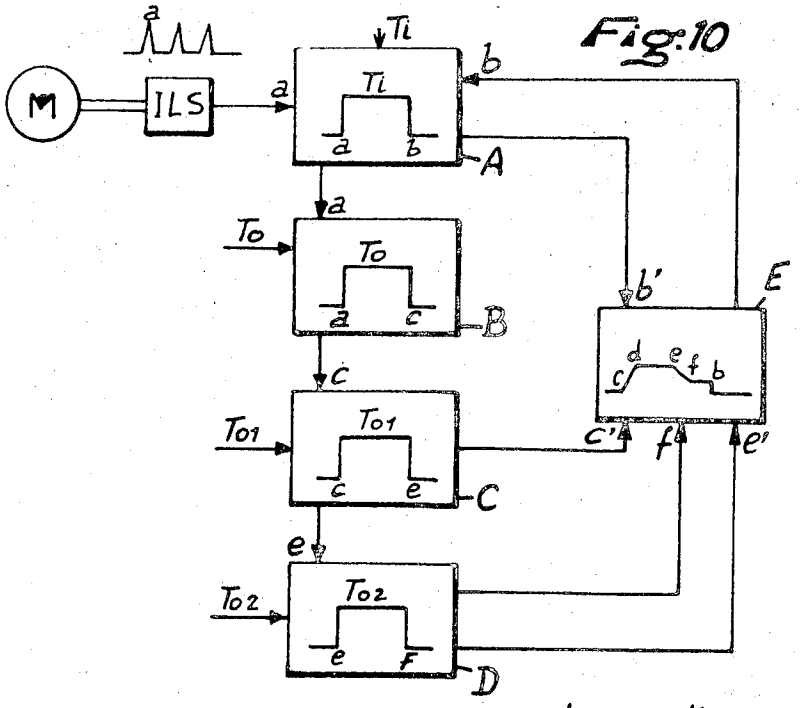


Fig: 10



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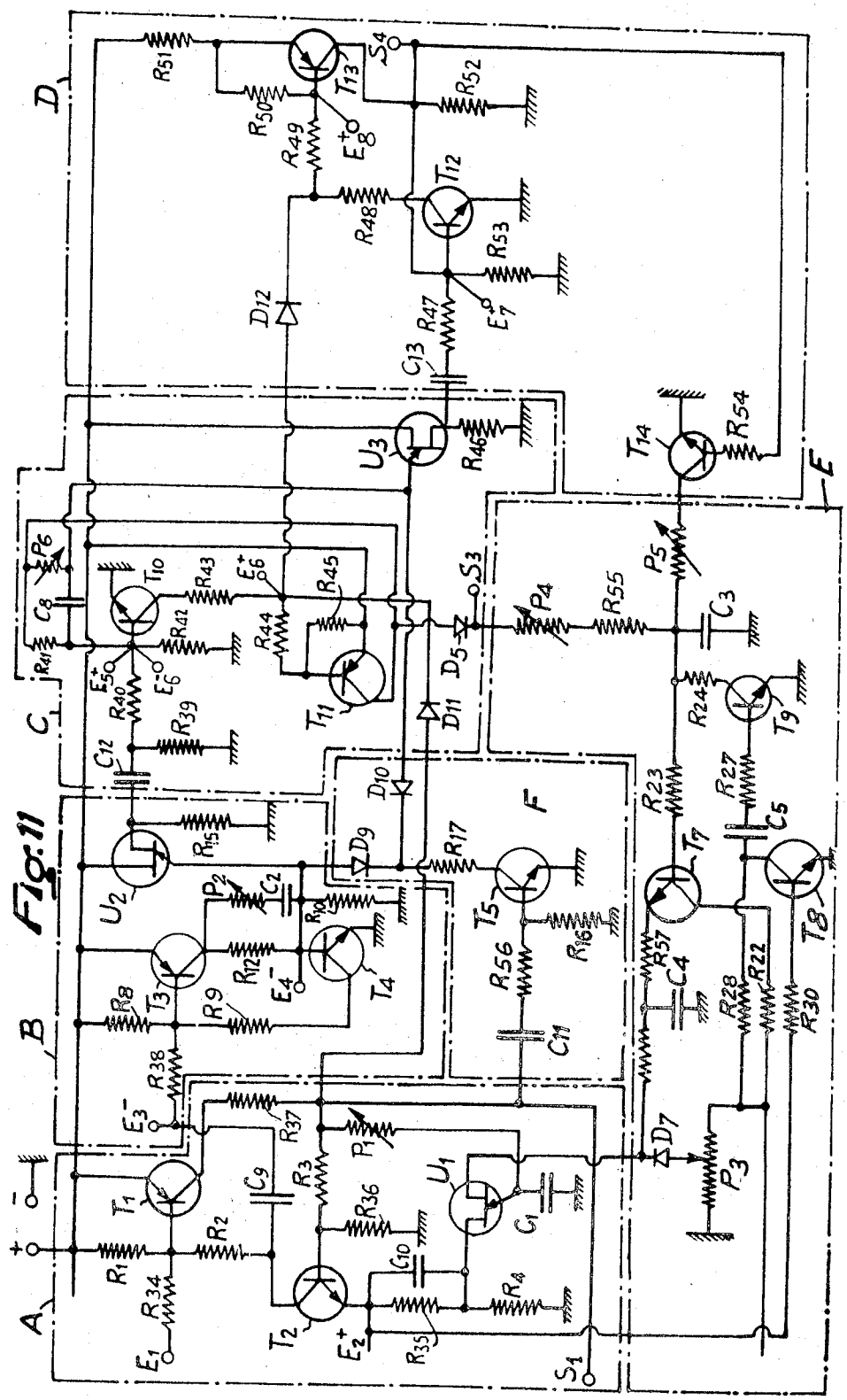
A
B
C
D
E
F
Fig. 11
R51
T13
S4
R52
R50
R49
E8+
T12
R48
R53
D12
R47
E7
C13
U3
R46
T14
R54
P6
C8
T10
R43
E6+
R45
S3
P4
R55
P5
C3
R41
R44
T11
D5
E5+
E6-
R40
R39
D11
R24
T9
C12
D10
R23
R27
C5
R15
D9
R17
F
U2
P2
C2
T5
T7
T8
R10
R16
R57
C4
R12
E4-
T4
T3
R56
R28
R22
R30
R8
R9
C11
R38
E3-
R37
P1
D7
P3
T1
C9
R3
U1
C1
R36
R1
R2
R34
C10
R4
E1
T2
E2+
R35
S1
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METHOD OF REGULATION OF THE DURATION OF REPEATED RECTANGULAR ELECTRIC SIGNAL AND DEVICES FOR THE PRACTICAL APPLICATION OF THE SAME METHOD

The present invention relates to a method of regulation of the duration of a repeated rectangular electric signal, the duration of said rectangular signal being regulated as a function of the repetition time. Said method is applicable in particular to the regulation of the injection time of electromechanical injectors or transducers which are controlled by said rectangular signal as a function of speed of rotation in internal combustion engines. The invention is also concerned with devices for carrying out said method.

In some electronic injection systems, the quantity of fuel injected per cycle is a simple and usually linear function of the duration of a voltage signal which is applied to an injector or transducer. In the case, for example, of overspeed regulation, it accordingly follows that the regulation of injection entails the maintenance of a constant duration of the electric signal at any speed below a predetermined limit, above which said duration is progressively reduced to a sufficiently small value which, at a given moment, is such that the quantity injected is reduced to zero.

In order to obtain a regulation of this type, it is known to make use of devices for producing a voltage which is a function of the engine speed. This voltage can be supplied, for example, by a Tacho-generator which is driven by the engine. As a rule, said voltage is directly proportional to the speed of rotation and has to be transformed in order to provide a reduction of the injection time. In French Pat. application No. 89,547 filed on 30th Dec., 1966 in the names of Messrs. Bassot and Montpetit, there was described another device constituting a frequency-voltage converter which is integrated with the electronic injection-control system. The device referred-to makes it possible to obtain a voltage which increases with the speed of rotation of the engine and the integration of the signals which initiate the commencement of the injection is carried out by suitable electronic means.

However, in the case of known devices, it is necessary to transform a voltage which increases with the speed of rotation into a voltage which decreases with over-speed in order to reduce the time-duration of injections. In addition, the voltage variation is small in respect of small variations in the speed of rotation, the precision of regulation being consequently affected.

The object of the present invention is to circumvent the disadvantages noted above and is therefore intended to provide :

a. A method of regulation of the duration of a repeated rectangular electric control signal, characterized in that a signal corresponding to the beginning of the first rectangular signal of the series of control signals initiates a rectangular reference signal of externally variable duration, the end of said reference signal being utilized to initiate a variation of a regulation voltage, said regulation voltage being utilized to vary following the end of a rectangular control signal in order to modify the duration thereof.

b. A device for the practical application of the method in accordance with paragraph a) hereinabove, characterized in that said device comprises a first flip-flop having two transistors and a timing element having a variable resistor, a capacitor and a unijunction transistor, said first flip-flop having a first input for the signal which releases the rectangular control signal and a second input for the signal corresponding to the end of the rectangular control signal and coupled with the timing element ; that said device further comprises a second flip-flop having two transistors and a timing element with a variable resistor, a capacitor and a unijunction transistor, said second flip-flop having a first input for the signal which releases the rectangular reference signal induced by the beginning of a given rectangular control signal and a second input for the signal corresponding to the end of the rectangular reference signal and coupled with the timing element of said second flip-flop ; that said device further comprises a device for producing a variation in the regulation voltage which is applied to the base of the unijunction transistor of the first flip-flop, said device being made up of a first capacitor which is charged from a voltage source through a diode and a variable resistor, the terminal voltage of said first capacitor being applied to the base of a transistor whose collector is connected to a voltage source and whose emitter is connected to a second capacitor as well as to the base of the unijunction transistor of the first flip-flop through a diode and a resistor, a voltage which can be varied by means of a voltage divider and which is either lower than or equal to the regulation voltage being also applied via a diode to the base of the unijunction transistor of the first flip-flop, the charge on the first capacitor being controlled by a device constituted by a transistor whose base is connected to the output of the second flip-flop and whose emitter is connected to ground whilst the collector is connected to the supply of said first capacitor upstream of the diode so that when said charge-control transistor is saturated, no supply voltage is applied any longer to said first capacitor, said first capacitor being discharged at the end of each rectangular control signal by means of a signal delivered by the timing element of the first flip-flop and applied to a first transistor which in turn drives a second transistor into saturation through a resistor and a capacitor, the emitter of said second transistor being connected to ground and the collector being connected to the terminal of said first capacitor through a resistor and a diode.

The invention additionally comprises all or a part of the characteristics mentioned hereinafter and considered either separately or in combination. Reference is made to the accompanying drawings which are given by way of example in order that the description may be more readily understood, and in which :

FIG. 1 is a simple example of the progressive variation of the regulation voltage as a function of the recurrence time ;

FIG. 2 is a representation of the different electric signals which are produced in order to obtain a regulation in accordance with the invention ;

FIG. 3 is a block diagram of a regulation device in accordance with a first embodiment ;

FIG. 4 is a detailed circuit diagram of a regulation device in accordance with a first embodiment ;

FIG. 5 is a representation of the different electric signals which are produced in order to obtain a regulation in accordance with another embodiment ;

FIG. 6 is a block diagram of a device for obtaining a regulation in accordance with FIG. 5 ;

FIG. 7 is a detailed circuit diagram of an element to be inserted in the diagram of FIG. 4 in order to obtain a regulation according to FIG. 5 ;

FIG. 8 is an example of progressive variation of the regulation voltage as a function of the recurrence time in the case of an engine with controlled ignition ;

FIG. 9 is a representation of some of the electric signals which are produced in order to obtain a regulation according to FIG. 8 ;

FIG. 10 is a block diagram of a device for obtaining a regulation according to FIG. 8 ;

FIG. 11 is a detailed and complete circuit diagram for obtaining a regulation according to FIG. 8.

Referring to FIG. 1 there is shown the fuel injection characteristic for a constant-speed Diesel engine. The quantity of fuel Q which is injected during each cycle is proportional to the injection time T_i and to the regulation voltage V_R and does not vary in the case of a speed of rotation which is lower than N_A (as shown in FIG. 1). Said speed N_A is a reference value for the regulation of fuel injection. If for any reason the speed of rotation becomes higher than N_A, the injection is progressively decreased with a certain static stability of regulation which is

defined by the difference between the speed N_o at which the injection becomes zero and the reference value N_A.

In FIG. 2, there are shown at (I) the signals for triggering the injection having a repetition period T_e. These signals are derived from a pulse emitter ILS (FIG. 3) with flexible-blade switches, for example, said emitter being driven in rotation by the motor M (FIG. 3), and are directed into a device A. There are shown at (II) in FIG. 2 the rectangular signals which control the injection time T_i and which also have a repetition period T_e. The beginning *a* of the signal is synchronous with the speed of rotation whilst the end *b* is varied in accordance with engine speed. At the time a of triggering of an injection, an electronic device B changes from a state **OO** to a state 01 (line III, FIG. 2) and returns to state **OO** at the point marked *c* at the end of a time T_o which can be varied externally. At the time c, a device E receives a signal and the regulation voltage begins to vary progressively, this variation being represented in the present instance by the terminal voltage of a capacitor which is charged through a resistor. Said regulation voltage changes in a time T_s from a variable value V_o to a maximum value V_M as represented by the point *d* of line IV in FIG. 2 if the time interval T_e between two subsequent injections is longer than the added time intervals $T_0 + T_s$Said voltage retains this value until the end *b* of the second injection and is caused to revert to the value V_o by a signal which is transmitted to the device E from the device A at the end of said injection. If, on the contrary, the time interval ($T_{e'}$), FIG. 2 line I, between two subsequent injections is shorter than the added time intervals ($T_o + T_s$), the voltage rise is stopped at the value V_R by a signal derived from the device D and corresponding to the beginning of the following injection and the reduced regulation voltage accordingly acts on the device A so as to cutoff the injection at *b'*.

As a result of this arrangement, the value of the regulation voltage is located and stabilized at the beginning of an injection at a value which is comprised between V_o (variable) and V_M.

In the case of a given value of T_o and of T_s, said value is equal to V_M if T_e is than $T_o + T_s$, that is to say if the speed of rotation of the engine is lower than a reference value. If I_e becomes shorter, that is to say if the speed increases, the value of the regulation voltage will decrease from the moment when $T_e = T_o + T_s$ and will drop from V_M to V_o when (T_o) equals ($I_e$that, if the value of the regulation voltage is employed at the moment of triggering of the injection so as to control the duration of this latter, the quantity of fuel will change from the value corresponding to V_m to that which corresponds to V_o in respect of a variation in the engine period equal to T_s which is as small as may be desired.

There is shown in FIG. 4 one non-limitative example of arrangement of an electronic circuit which carries out a regulation of the injection time according to FIGS. 1 to 3. The assembly A is constituted by a flip-flop formed by two transistors T_1, T_2 and the resistors R_1, R_2, R_3, R_4 and a timing element constituted by a relaxation oscillator which acts on the input E_2 of said flip-flop and comprises a unijunction transistor U_1, a capacitor C_1 and a variable resistor R_1. A negative pulse applied to the input E_1 of the flip-flop causes the appearance of a rectangular signal having a duration T_i at the output S_1. The output S_1 is coupled with the input E_3 of an assembly B via the diode D_2, the capacitor C_6 and the resistor R_1 and the diode D_{11} and the resistor R_5 have the function of discharging the capacitor after the passage of a pulse. The assembly B is also a flip-flop which is similar to that in A. Said flip-flop is made up of the transistors T_3, T_4 and the resistors R_8, R_9, R_{10}, R_{12}, R_{14}, R_{15} and a timing element which produces action on the input E_4 of said flip-flop with a unijunction transistor U_2, a capacitor C_2 and a variable resistor P_2 in series with a diode D_4 and a resistor R_{13}. A positive pulse applied to the input E_3 causes the appearance of a rectangular signal having a duration T_o at the output S_2. Said output S_2 is connected to an assembly D which controls the increase in the voltage V_R. Said assembly D is constituted by the resistors R_{18}, R_{19}, R_{21} and the transistor T_6, said transistor being saturated during the time T_o of the signal at the output S_2 of the second flip-flop. Said assembly D which serves to control the voltage rise is coupled with the assembly E via the diode D_5. The assembly D comprises a first portion which has the function of increasing the regulation voltage V_R and transmitting this latter to the unijunction transistor of the assembly A. Said first portion is constituted by the capacitor which is charged from the resistor R_{21} through the variable resistor P_4. The voltage V_{R5} which is developed across the terminals of the capacitor C_3 is applied to the base of the transistor T_7 via the resistor R_{23}. The base regulation voltage V_o is taken from the voltage divider P_3 and transmitted via the diode D_7 to the base 2 of the unijunction transistor U_1, the voltage V_R is delivered from the transistor T_7 via the diode (D_8) and the resistor R_{25} and corresponds to the terminal voltage of the capacitor (C_4) which is dependent on the voltage V_R which is applied to the base of the transistor T_7. The second portion of the assembly D carries out the discharge of the capacitor C_3 at the end of each injection having a duration T_i. To this end, a transistor T_8 is connected at its base to the input E_2 of the first flip-flop in the assembly A, the emitter of said transistor being connected to ground and the collector being connected to the base of a transistor T_9 through a resistor R_{27} and a capacitor C_5 as well as to a voltage source through the resistor R_{28}. The emitter of the transistor T_9 is connected to ground and its collector is connected to the terminal of the capacitor C_3 through the diode D_6 and the resistor R_{24}. Finally, a resistor R_{26} is connected to the base of the transistor T_9 and the capacitor C_5 is connected to ground. In order to prevent any troublesome occurrences at the time of a sudden reduction in the time T_o when modifying the variable resistor P_2 in the assembly B, provision is accordingly made for an assembly F consisting of a transistor T_5 the collector of which is connected to the capacitor C_2 through the resistor R_{17} and the emitter of which is connected to ground. Said transistor is saturated at the beginning of each injection by a signal which is transmitted from the output S_1 of the assembly A via the diode D_3, the resistor R_6 and the capacitor C_7 to the base of said transistor I_5, the resistors R_7 and R_{16} being intended to discharge the capacitor C_7.

The operation of the device is as follows:

A negative pulse which is applied to the input E_1 of the assembly A initiates a change of state and the appearance of the rectangular signal for controlling the injection having a duration T_i at the output S_1. This pulse is transmitted to the input E_3 of the assembly B and initiates a change of state and the appearance of the rectangular reference signal having a duration T_o at the output S_2. The same pulse at S_1 is also transmitted to the base of the transistor T_5, thereby driving said transistor into saturation for a very short time, with the result that the capacitor C_2 can discharge. This is carried out in order to ensure that said capacitor C_2 is fully discharged as each cycle of operation begins again. The signal which appears at the output S_2 of the assembly B is applied to the base of the transistor T_6 and drives this latter into saturation. As a result, the point of connection of the diode D_5 and resistor R_{21} is grounded and no charge voltage is therefore applied any longer to the terminals of the capacitor C_3 and this latter accordingly remains at the voltage V_{R5} which it had reached at the moment of saturation of the transistor T_6. The voltage V_{R5} is applied to the base of the transistor T_7, with the result that the capacitor C_4 is charged to a regulation voltage V_R which is dependent on the voltage V_{R5} which is developed across the terminals of the capacitor C_3. The regulation voltage V_R is applied to the base 2 of the unijunction transistor U_1 and initiates a reversal of state of the assembly A when the terminal voltage of the capacitor (C_1) is approximately equal to the regulation voltage V_R thereby turning transistor T_2 on and causing the appearance of a positive signal at the input E_2 of the flip-flop. At the end of the injection, the signal produced at the input E_2 is transmitted to the device for discharging the capacitor C_3 which device is constituted by the transistors T_8 and T_9 which, being saturated by the end-of-injection pulse, through the re-

sistor R_{30} permit the discharge of said capacitor C_3. The capacitor C_4 then discharges at a slower rate through the unijunction transistor U_1 until the voltage V_o which is obtained from the voltage divider P_3 is reached. The assembly B changes state again at the end of a time T_o which is determined in a similar manner by the timing element U_2, C_2, P_2 and the transistor T_6 changes to the blocked state so that the capacitor C_3 begins to charge again at a rate which is dependent on the resistor P_4. If the following injection occurs at the end of a time interval T_e which is longer than the added time intervals $T_o + T_s$, the capacitor C_3 will be fully charged to the maximum voltage and the duration of the injection corresponds to the application of the maximum voltage V_M to the base 2 of the unijunction transistor U_1 and there is no decrease in the quantity of fuel injected.

On the other hand, if the subsequent injection occurs at the end of a time interval $T_{e'}$ which is shorter than the added time intervals $T_o + T_s$, the charge on the capacitor C_3 is stopped at a lower value owing to the saturation of the transistor T_6 and a regulation voltage V_R which is lower than the maximum voltage V_M is applied to the base 2 of the unijunction transistor U_1 and, as a consequence, the injection time is reduced in proportion.

Should it not be desired to initiate the formation of the regulation voltage V_R at each injection, for example in the event that the injections to be carried out are not uniformly spaced as is occasionally the case with some types of V-engines, it is possible to employ for the purpose of forming said regulation voltage V_R only a part of the injection trigger signals or even one of these latter, and in fact one or a number of independent pulse emitters ILS_1, ILS_2 which are coupled, for example, with the camshaft of the engine M.

In this case, two successive pulses *a* for producing the regulation voltage V_R are separated by the time interval corresponding to two engine revolutions or only one revolution if the pulse emitter is coupled with the crankshaft and not with the camshaft.

The principle of formation of the voltage then remains substantially the same. A value To is assigned to a flip-flop B which is triggered by said pulse emitter ILS_2 and an injection flip-flop A is triggered by the pulse emitter ILS_1.

A regulation voltage V_R is then formed as in the previous instance and will be stored from one engine revolution to the next in order to ensure regulation.

In FIG. 5, there is accordingly shown the voltage diagram in which :

line I' represents the usual injection pulses,

line I represents the articular regulation forming pulses,

line II represents the injection signals corresponding to the time interval T_i,

line III represents the reference signal having the duration To,

line IV represents the regulation voltage formed by the two above-mentioned devices in accordance with the process which has been explained earlier and

line V represents the value of the stored regulation voltage V_R.

It is thus possible to employ a device as shown in FIGS. 3 and 4, with the modifications indicated in FIGS. 6 and 7 the output S_1 of the assembly A is no longer connected either to the input E_3 of the assembly B or to the assembly F. In this case, the triggering operation will be carried out by a pulse emitter ILS_2 as shown in FIG. 6. Provision must also be made for a storage device which is connected between one terminal of the capacitor C_3 in FIG. 4 and the base of the transistor T_7. This circuit shown in FIG. 7 is constituted by a first transistor T_{10}, the base of which is supplied through a resistor R_{31} at the value of voltage V_{R5} which is reached by the capacitor C_3. As a result, the capacitor C_{14} is charged in proportion to said voltage V_{R5} by said transistor T_{10} through the resistor R_{32} and the diode D_9. A second transistor T_{11} is also provided for the purpose of discharging the capacitor C_{14} through the resistor R_{33} when the voltage V_{R5} is lower than that which is stored in the capacitor C_{14}. The voltage of the output S_1 of the assembly A is accordingly applied to the base of the second transistor T_{11} through a resistor R_{58}.

The method and devices hereinabove described are primarily employed with Diesel engines but it is apparent that they also have application to gasoline engines. In this case, however, it is sometimes useful to endow the regulation voltage with a more complex waveform as shown in FIG. 8. From this figure, it is apparent that in the case of a short time interval T_e, that is to say in the case of a high speed of rotation, the regulation voltage V_R decreases from the maximum value V_1 to the value V_0 and that in the case of a long time interval T_e, that is to say with a low speed of rotation, the regulation voltage V_R also decreases from the maximum value V_1 to an intermediate value V_2. The signals employed then have the waveform shown in FIG. 9. The signal shown in line III*a* of the figure is formed in an assembly C and the signal of line IIIb is formed in the assembly D of FIG. 10. The signals of assemblies A and B remain the same. The regulation voltage V_R formed in the assembly E then has the waveform shown in line IV. The voltage rises between the points *c* and *d* and is maintained up to point *e*, then falls between points *e* and *f* down to the level stage *f* – *b*. At *b*, the voltage V_R drops to the value Vo.

Referring now to FIGS. 10 and 11, the injection control device is accordingly constituted in one non-limitative example of construction by an assembly A for setting up T_i which is formed by a flip-flop with two transistors T_1, T_2, the resistors R_1, R_2, R_3, R_4, R_{34}, R_{35}, R_{36}, R_{37} and the capacitors C_9 and C_{10}, as well as by the timing element with the unijunction transistor U_1, the capacitor C_1 and the variable resistor P_1. The assembly B which sets up To is connected at its input E_3 to the assembly A and is triggered at the same time as this latter. The assembly B comprises another flip-flop with the two transistors T_3, T_4, its resistors R_8, R_9, R_{10}, R_{12}, R_{38} and its timing element formed by the unijunction transistor U_2, the capacitor C_2, the variable resistor P_2 and the resistor R_{15}. Another assembly C which sets up To_1 is coupled with its input E_5 to the assembly B through a capacitor C_{12}. Said assembly C being made up of a third flip-flop with its two transistors T_{10}, T_{11}, its resistors R_{39}, R_{40}, R_{42}, R_{43}, R_{44}, R_{45} and its timing element formed by the unijunction transistor U_3, the capacitor C_8, the variable resistor P_6 and the fixed resistors R_{41}, R_{46}. The assembly C is additionally coupled with its input E_6 to the output S_1 of the assembly A through the diode D_{11}. Finally the input E_7 of a fourth assembly D is connected to the assembly C through the capacitor C_{13} and the input E_8 is connected to the output S_1 of the assembly A through the diodes D_{11} and D_{12}. Said assembly D is formed by a fourth flip-flop with its two transistors T_{12}, T_{13} and its resistors R_{47}, R_{48}, R_{49}, R_{50}, R_{51}, R_{52}, R_{53}. The output S_4 of said assembly B drives the base of the transistor T_{14} through the resistor R_{54}. The assembly E corresponds to that of FIG. 4 : it is composed of the capacitor C_3 which is charged from the output S_3 of the assembly C through a diode D_5, a variable resistor P_4 and a resistor R_{55}. Said capacitor C_3 can be discharged through the variable resistor P_5 and the transistor T_{14} when this latter is saturated but is also discharged through the resistor R_{24} and the transistor T_9 when this latter is saturated by a pulse derived from the transistor T_8 via the capacitor C_5 and the resistor R_{27}, the base of the said transistor T_8 being connected to the input E_2 of the assembly A. The supply voltage is applied to the collectors of the transistors T_7, T_8 via the resistors R_{22}, R_{28} and to a voltage divider P_3 which supplies the voltage Vo to the base 2 of the unijunction transistor U_1 via the diode D_7. The voltage developed across the terminals of the capacitor C_3 is applied to the base of the transistor T_7 via a resistor R_{23}. Said voltage again has the form of a regulation voltage V_R at the terminals of the capacitor C_4 which is charged by the transistor T_7 through the resistor R_{57}. The voltage V_R is also transmitted to the base 2 of the unijunction transistor U_1 via the resistor R_{25}. Finally, the assembly F serves to discharge the capacitor C_2 of the assembly B and the capacitor C_8 of the assembly C through the diodes D_9, D_{10}, the resistor R_{17} and the transistor T_5 when this latter is saturated

for a short time by a pulse derived from the output S_1 of the assembly A via the capacitor C_{11} and the resistor R_{86}. The resistor R_{16} serves to discharge the capacitor C_{11}.

The operation is accordingly as follows : the pulse applied to the input E_1 triggers the assembly A for a period T_i and triggers the assembly B via the input E_3 for a period To. The end of the signal of assembly B is transmitted to the assembly C via the input E_5 and triggers this latter for a period To_1. At this moment, the capacitor C_3 of the assembly E is charged through the transistor T_{11} of assembly C. The charge is stopped when assembly C again changes state, namely either at the end of a time interval To_1 which corresponds to the relaxation time of its timing element or at the beginning of the following injection by means of a signal which is derived from the output S_1 of assembly A and transmitted to the input E_6 of assembly C. A reversal of state of assembly C has the effect of triggering assembly D through the input E_7, thereby saturating the transistor T_{14} which is connected to the output S_4 of assembly D and the capacitor C_3 discharges at a predetermined rate through the resistor P_5 and said transistor T_{14}. The discharge is stopped at the beginning of the following injection by a reversal of state of assembly D which is initiated in the case of the injection-commencement signal which is transmitted from the output S_1 of assembly A to the input E_8 of assembly D. Full discharge is carried out as in the previous instance by the injection-completion pulse from the input E_2 of the assembly and the transistors T_8, T_9.

The result achieved by this arrangement is that, when the time interval T_e is shorter than the added time intervals To + I_{01}, the duration of the injection is progressively decreased to zero and that, when the time interval Ie is longer than the added time intervals To + To_1, the duration of the injection is also reduced, in proportion, to a predetermined value corresponding to the voltage (V_2) of the level stage *f–b*.

It is readily understood that the invention is not limited to the exemplified embodiments hereinabove described but that the method can be employed with other equivalent electronic circuits. It is apparent in particular that the progressive variation of the regulation voltage V_R could take place either upwards or downwards in order to obtain a variation of the injection time.

What is claimed is:

1. A method of controlling the width of a rectangular pulse in response to a series of reference pulses of variable spacing, comprising the steps of:
   a. generating a first pulse of variable width commencing with a pulse in said series of reference pulses;
   b. generating a rectangular control pulse of predetermined duration commencing with said pulse in said series of reference pulses;
   c. generating a reference voltage, the voltage level of which is dependent upon the spacing of said reference pulses in comparison to the duration of said control pulse; and
   d. modifying the duration of said first pulse as a function of the voltage level of said reference voltage.

2. The method set forth in claim 1 wherein said reference voltage is generated in response to the termination of said control pulse.

3. The method set forth in claim 2 wherein said reference voltage is generated from an initial level, linearly up to a predetermined maximum level when the spacing of said reference pulses bears a predetermined relationship to the width of said control pulse and up to a value lower than said predetermined maximum level when the spacing of said reference pulses varies from said predetermined relationship.

4. The method set forth in claim 3 including the further step of returning said reference voltage to said initial level in response to the termination of a second pulse of variable width generated after said first pulse.

5. The method set forth in claim 1 wherein the duration of said rectangular control pulse is greater than the spacing between two pulses in said series of reference pulses and further including the step of storing said reference voltage for modifying the duration of at least two pulses of variable width.

6. The method set forth in claim 1 further including the steps of:
   a. generating a second rectangular control pulse of predetermined duration in response to the termination of said first rectangular control pulse;
   b. modifying the voltage level of said reference voltage in accordance with the duration of said second rectangular control pulse; and
   c. modifying the duration of said first pulse of variable width in accordance with the modification in said voltage level when the spacing between two reference pulses exceeds the pulse widths of said first and second rectangular control pulses.

7. A circuit for modifying the width of a rectangular pulse in response to a series of reference pulses of variable spacing, comprising:
   a. means responsive to a reference pulse in said series of reference pulses for generating a first pulse of variable width;
   b. means for generating a rectangular control pulse of predetermined duration at the same time said first pulse of variable width is generated;
   c. means for generating a reference voltage having a value dependent upon the spacing of said reference pulses in comparison to the duration of said control pulse; and
   d. means for modifying the duration of the rectangular pulse of variable width following said first pulse as a function of the value of said reference voltage.

8. The combination set forth in claim 7 further including means for storing said reference voltage so that the duration of more than one pulse of variable width may be modified thereby.

9. The combination set forth in claim 7 further including:
   a. means for generating a second rectangular control pulse in response to the termination of said first rectangular control pulse;
   b. means for modifying the voltage level of said reference voltage in accordance with the duration of said second rectangular control pulse; and
   c. means for modifying the duration of said pulse of variable width as a function of the modification in said voltage level, when the spacing between two reference pulses exceeds the pulse width of said first and second rectangular control pulses.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,651,343 Dated March 21, 1972

Inventor(s) Louis A. Monpetit

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

In column 3, line 41, "I_e" should be -- T_e --.

In column 3, line 45, "I_e" should be -- T_e --.

Column 3, line 45 "(I_e that," should be -- (T_e). It is clear that, --

Column 3, line 63, "R_1" should be -- R_{11} --.

Column 3, line 64, "D_{11}" should be -- D_1 --.

Column 4, line 40, "I_5" should be -- T_5 --.

Column 4, line 75, after "being" insert -- momentarily --.

Column 5, line 50, "articular" should be -- particular --.

Column 7, line 31 "I_{01}" should be -- T_{01} --.

Column 7, line 32 "I_e" should be -- T_e --.

Signed and sealed this 3rd day of October 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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