(12) UK Patent Application (19) GB (11) 2 137 281 A

(43) Application published 3 Oct 1984

(21) Application No 8406745

(22) Date of filing 15 Mar 1984

(30) Priority data
(31) 3310920 (32) 25 Mar 1983 (33) (DE)

(71) Applicant
Robert Bosch GmbH (FR Germany),
Postfach 50, 7000 Stuttgart 1, Federal Republic of Germany

(72) Inventors
Ulrich Steinbrenner
Dieter Gunther

(74) Agent and/or Address for Service
Dr Walther Wolff & Co,
6 Buckingham Gate, London SW1E 6JP

(51) INT CL^3
F02D 5/02 F02M 51/02

(52) Domestic classification
F1B B102 B135 B226 B228 B270 B400 BE

(56) Documents cited
GB 1603501 US 4140084 US 3854458
US 4092717

(58) Field of search
F1B

(54) Adjusting the timing of fuel injection in an internal combustion engine during starting

(57) Under starting conditions of the engine the battery voltage reduces and fluctuates. Thus, in order to improve the operation of the electrically-operated injection valves, means (Figs. 2, 4 and 6 not shown) are provided to adjust the instant of energisation of the injection valves in dependence on engine speed or battery voltage by a predetermined delay time duration or displacement angle, such that the valves are energised at the peaks of the fluctuating battery voltage.

GB 2 137 281 A

FIG. 1

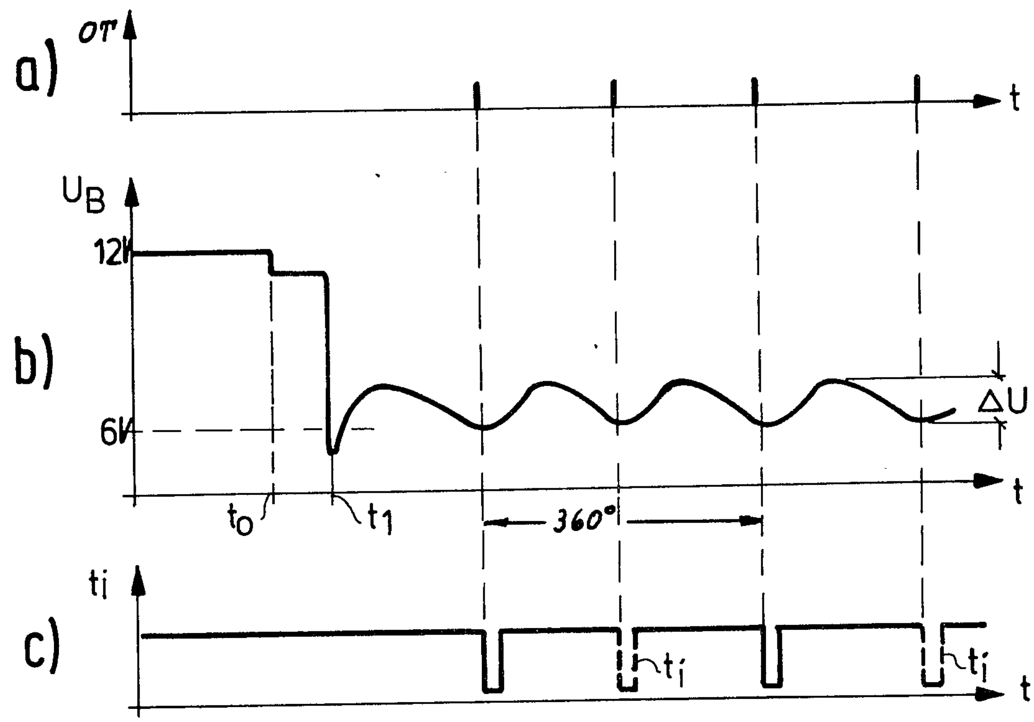


FIG. 2

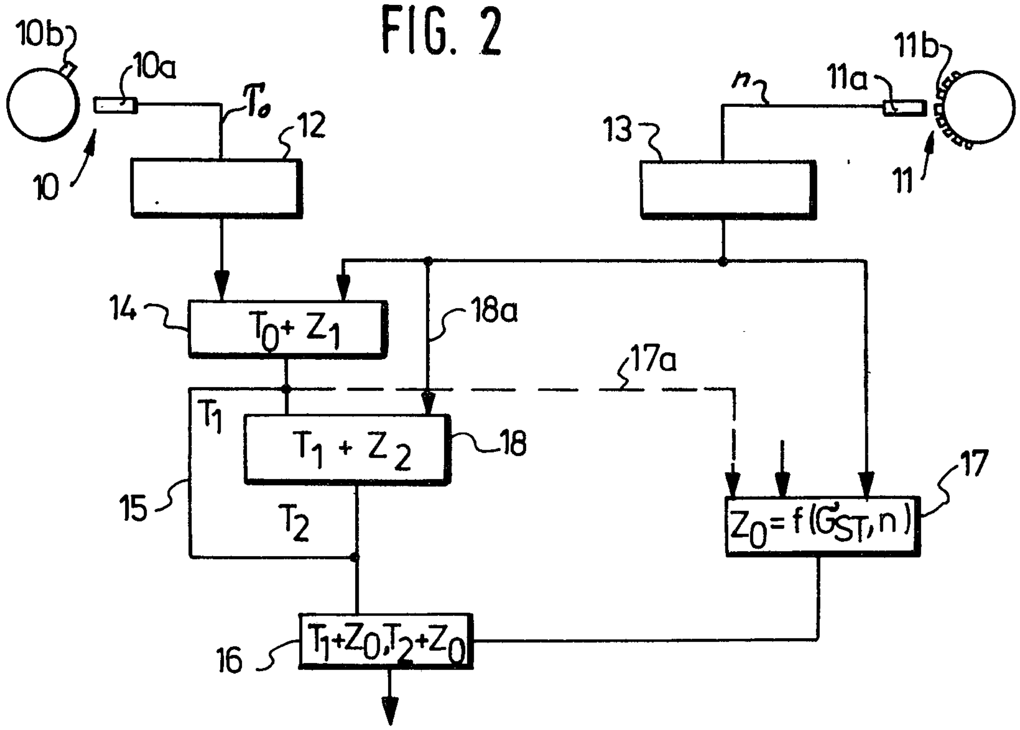

10b
10a
T_o
12
10
13
n
11a
11b
11
14
T_0+Z_1
18a
17a
T_1
T_1+Z_2
18
17
15
T_2
$Z_0=f(G_{ST},n)$
16
T_1+Z_0, T_2+Z_0

FIG. 3

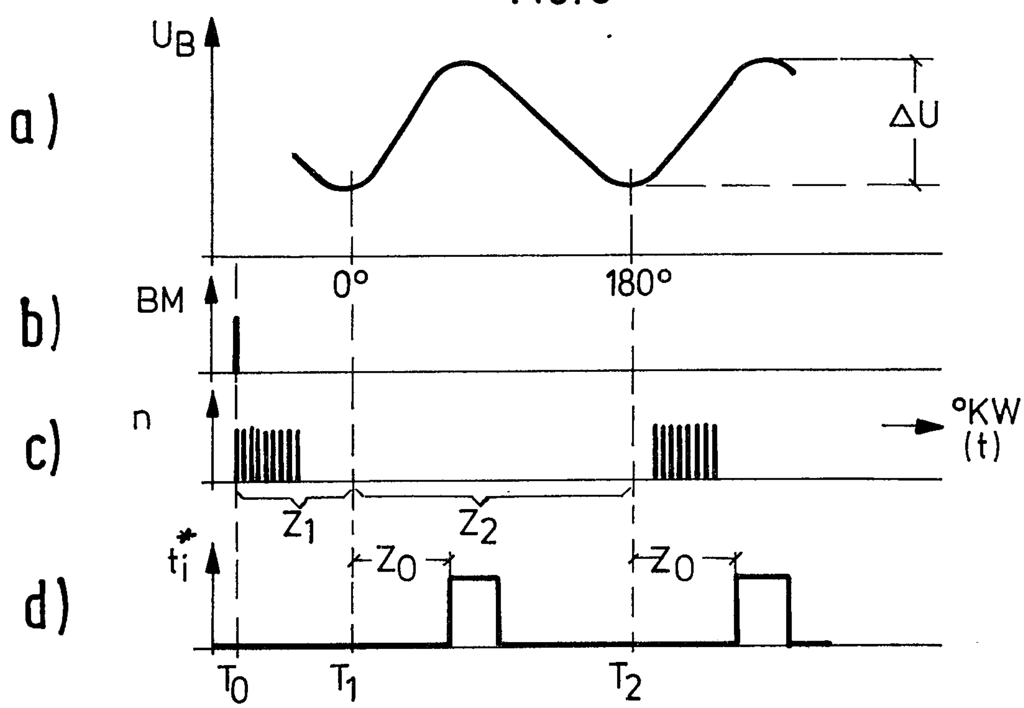

a)
U_B
ΔU
b)
BM
0°
180°
c)
n
°KW
(t)
Z_1
Z_2
d)
t_i^*
Z_0
Z_0
T_0
T_1
T_2

FIG. 4

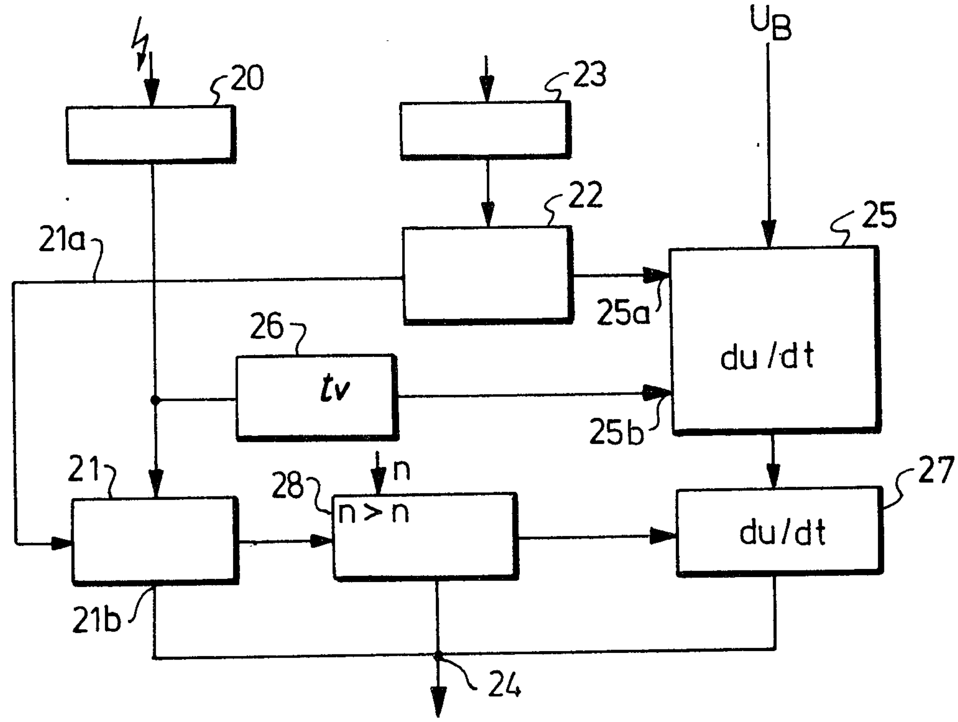

20
23
U_B
22
25
21a
25a
du/dt
26
tv
25b
21
n
28
n > n
27
du/dt
21b
24

FIG. 5

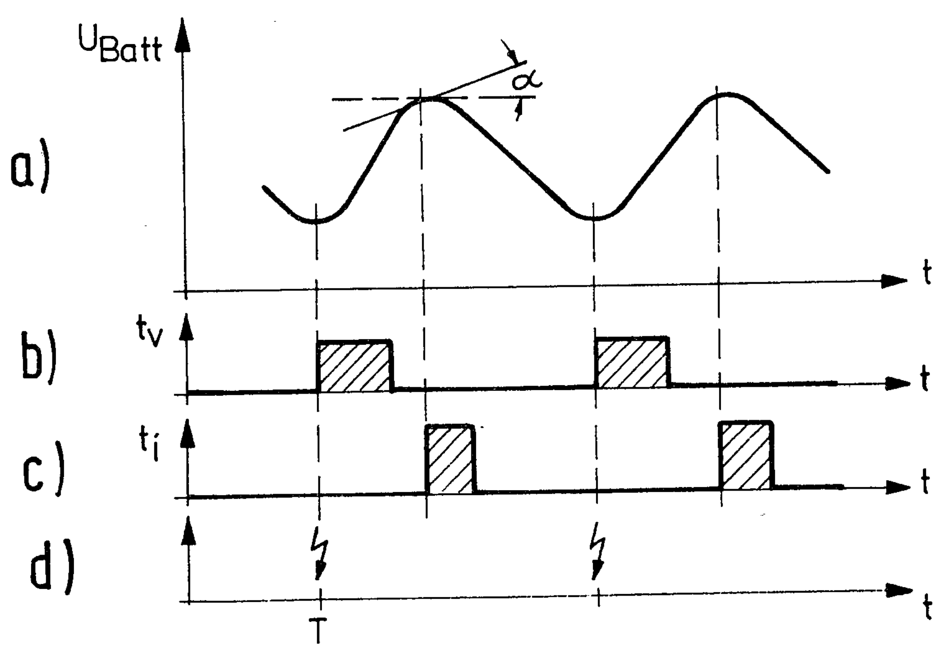

U_{Batt}
α
a)
t
b)
t_v
t
c)
t_i
t
d)
t
T

FIG. 6

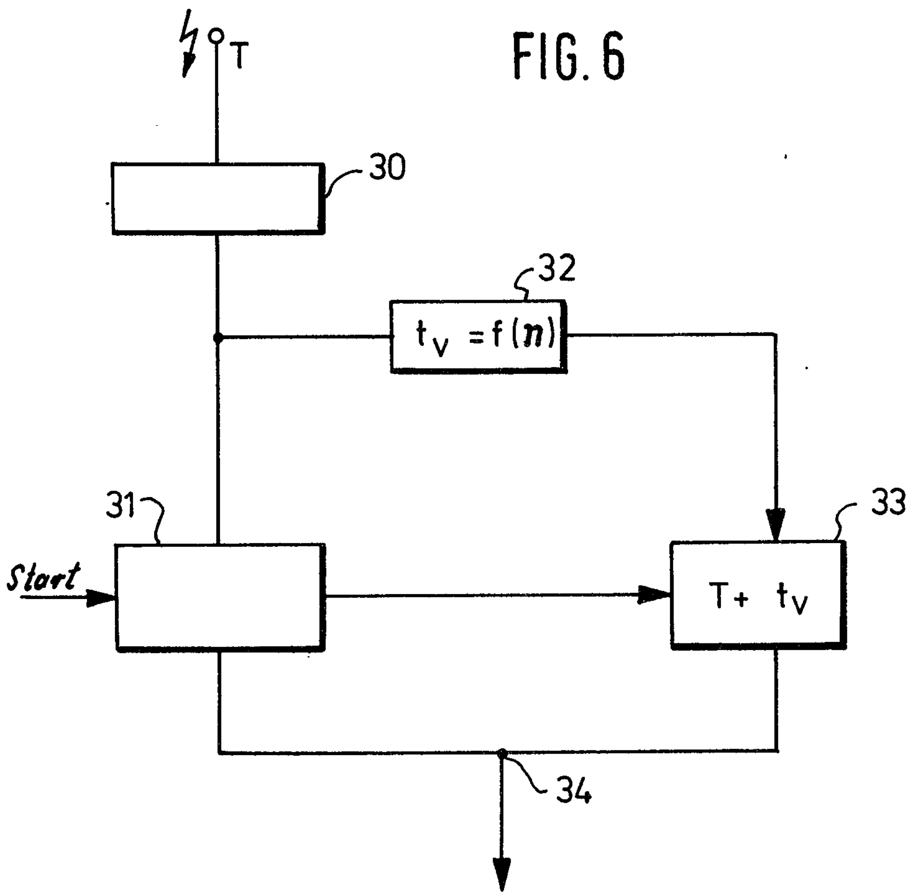
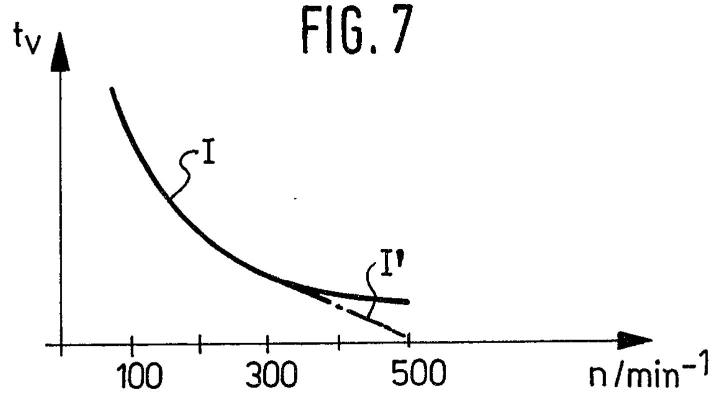


FIG. 7



SPECIFICATION

Method of and apparatus for determining the timing of fuel injection in an internal combustion engine during the starting

The present invention relates to a method of an apparatus for determining the timing of fuel injection by a timed fuel injection system of an internal combustion engine during starting of the engine.

The metering of the quantity of fuel during starting of an internal combustion engine always causes difficulties, particularly when low or very low starting temperatures prevail. On the one hand it is necessary to feed a certain additional quantity of fuel to the engine in order to compensate for condensation at the cold duct and cylinder walls and to ensure as rapid as possible starting of the engine, while on the other hand the mixture must not be made too rich or else the engine might not start at all. In this case, the weakness of the battery at low starting temperatures has to be taken into consideration. It is known to adapt the additional quantities of fuel during the starting operation to the ambient temperature and to operating parameters of the engine, in some cases including its history, which can be made relative, for example in injection systems with intermittent or timed injection, through difficulties connected with electrically actuated valves. This is because the low on-board voltage, due to the appreciable loading of the battery during the starting operation, leads to problems in respect of secure attraction of electromagnetic injection valves and wide scattering of the attraction times.

It would therefore be desirable, during the starting of an engine and in spite of a high loading of the battery, to ensure secure attraction and consistent attraction times of the injection valves in a fuel injection system so as to generally improve starting conditions and to enable advantage to be taken of an exact fuel metering during the starting operation.

According to a first aspect of the present invention there is provided a method of determining the timing of fuel injection by a timed fuel injection system of an internal combustion engine during starting of the engine, comprising the step of displacing the instant of drive for the injection valves under starting conditions through a delay time duration or delay angle, dependent on rotational speed or battery voltage, in such a manner that it is disposed each time approximately in the next following maximum of an on-board mains voltage fluctuating cyclically in dependence on rotational speed.

According to a second aspect of the present invention there is provided apparatus for carrying out the method of the first aspect of the invention, the apparatus comprising an adding circuit operable, at the instant of the occur rence of an ignition signal or of a reference mark, to add on a delay time duration or delay angle, dependent on rotational speed, in such a manner that each actual injection instant occurs in a voltage maximum of the fluctuating battery voltage.

Alternatively, the apparatus may comprise a differential block to interrogate the battery voltage course directly through formation of the time differential of the battery voltage, and means to free the injection time start with reference thereto in the presence of start conditions.

A method exemplifying the present invention may have the advantage that through displacement of the start of the injection time into a respective voltage maximum of the on-board mains voltage, it is ensured even at very low starting temperatures and correspondingly low on-board voltages that the voltage has a maximum value at each instant of the displaced start of injection, whereby a more than proportionally increasing accuracy in the operation of the injection valves can be achieved. Minima of the on-board voltage can result at very low starting temperatures, which minima, in the case of a 12 volt supply, can lie at only 6 volts, which means an almost irregular operation of the injection valves. If, however, the injection valves are driven at voltage maxima, which in this case can lie at about 8 volts or even more, then attraction problems in electrically actuated injection valves are reduced.

The low on-board voltages which arise during engine starting through the loading of the battery by the starter, particularly at low temperatures, have a pronounced waviness caused by the fact that the starter draws the greatest current from the battery each time a respective piston of the engine is disposed in the region of top dead centre. On the other hand, the instant of injection, thus the driving of the associated injection valve, in principle always takes place when the respective piston is disposed at top dead centre, thus at an instant at which pronounced minima of the supply voltage occur. The problems associated therewith may be eliminated by a method exemplifying and apparatus embodying the present invention, and a secure attraction of the injection valves during starting conditions with shorter attraction time may be achieved. This may enable the introduction of a precise cold start control and thereby make possible a more exact metering of the required quantity of fuel during the starting operation, since the scattering of the attraction times at higher voltages at electromagnetic injection valves may be appreciably smaller.

In addition, the advantage of a better possibility of optimisation at the injection valve in respect of the linearity of small quantities may be achieved, since the minimum attraction voltage does not feature or no longer features critically to the same degree.

The determination of the displacement duration for the start of the injection time from the differential of the battery voltage course during the starting operation on a predetermined minimum slope being exceeded is particularly advantageous. The displacement of the instant of injection as a function of rotational speed is advantageous in this case.

In another connection, a redisposition of the instant of injection in the fuel supply region of an internal combustion engine is known (DE-OS 29 29 516), but for the improvement of exhaust gas composition.

Examples of the method and embodiments of the apparatus of the present invention will now be more particularly described by way of example with reference to the accompanying drawings, in which:

Figures 1a to 1c are diagrams showing the known course of battery voltage during engine starting and fuel injection valve actuation pulses, both as a function of time;

Figure 2 is a schematic circuit diagram of first apparatus embodying the invention;

Figures 3a to 3d are diagrams illustrating operation of the apparatus of Fig. 2;

Figure 4 is a schematic circuit diagram of second apparatus embodying the invention;

Figures 5a to 5d are diagrams illustrating operation of the apparatus of Fig. 4;

Figure 6 is a schematic circuit diagram of third apparatus embodying the invention; and

Figure 7 is a diagram illustrating operation of the apparatus of Fig. 6.

Referring now to the drawings, the basic idea of the examples of the method and embodiments of the apparatus of the present invention as described in the following consists of displacing the start of the injection instant, thus the driving of injection valves in the case of an internal combustion engine equipped with a fuel injection system, to the maximum of the battery voltage, in that a time delay is introduced in dependence on information data from other operating parameters.

By reference to the diagrams of Figs. 1a to 1c, the injection course and the battery voltage curve in an engine equipped with a conventional injection system will now be explained. The occurrence of piston top dead centre (OT) is illustrated as a function of time in Fig. 1a. It can be seen from the battery voltage course illustrated in Fig. 1b that after the beginning of a starting operation and after the starter had engaged, initially an extremely strong battery voltage drop from, for example, 12 volts to about 6 volts occurs at low starting temperatures, with a pronounced waviness ΔU of the battery voltage U_B with minima in the region of each occurence of the TDC point. The short time delay between t_0 (actual beginning of starting) and t_1 is caused by the engagement time of the starter. The pronounced waviness of the voltage results therefrom, but the starter at each piston top dead centre draws the greatest current and the battery is therefore most strongly loaded at the TDC instants, with correspondingly strong dips in the voltage.

As a matter of principle, the injection pulses t_i according to Fig. 1c are provided in known injection systems also during the starting operation at the TDC instants, in a given case with additional injection pulses t_i' at twice the injection frequency, thus at each 180° after a normal injection pulse t_i, wherein the example shown in Fig. 1 relates to a four-cylinder engine.

The circuit diagram illustrated in Fig. 2 shows more exactly what is meant; the diagram comprises individual circuit blocks which fulfil certain functions and in their overall illustration in mutual association represent the basic function of the respective embodiment of the apparatus. It is to be understood that the embodiments shown in Fig. 2, and in the following figures, are merely examples of the basic functions, and the apparatus with inclusion of peripheral signal transmitters can also be realised through computer or electronic logic controls cooperating in the same manner, particularly through the use of microprocessors within the framework of a single purpose computer responsible for the starting operation or within the framework of an overall concept realised by a multi-purpose computer encompassing several individual fields (fuel metering generally, transmission, ignition).

In the first embodiment, illustrated in Fig. 2, for the required crankshaft information data, two transmitter systems are provided, which could consist of a common transmitter fulfilling both functions. This embodiment is particularly suitable for realisation by means of digital component elements and groups. The redisposition of the instant of injection takes place as angular displacement, for example through the counting-down of rotational speed marks (displacement through fixed $\Delta\alpha$-angle). A first transmitter is constructed as a reference mark transmitter 10 and at a predetermined instant t_0 before the top dead centre of the crankshaft position signals a reference mark (BM) through which the further temporal course can be fixed. The reference mark transmitter 10 can consist of, for example, an opti-electrical, inductive or capacitive sensor 10a and a transmitter marking 10b at a part rotating synchronously with the crankshaft, or a sensor that scans a special marking at the second transmitter system 11. According to Fig. 2, the system 11 is constructed as a rotational speed transmitter and, possibly through detection of the movement of starter teeth 11b past the starter gear rim rotating synchronously with the crankshaft, generates rotational speed marks (n-marks) which, appropriately quantised, represent information about the respective crankshaft position. In the curve courses shown in Figs. 3b and 3c, the occurrence of the reference mark is shown as a function of the crankshaft angle (°KW), namely once per crankshaft rotation, as well as the occurrence of the n-marks as a function of the crankshaft angle, for example 120 times per crankshaft rotation, and related in time hereto, the course of the waviness of the battery voltage U_B at Fig. 3a.

Signals indicative of the crankshaft reference mark BM as well as the rotational speed marks are supplied by way of preparatory blocks 12 and 13, connected to outputs of the respective transmitters 10a and 11a, to a first evaluating or computer circuit which adds to the instant T_0, as determined by the occur rence of the reference mark BM, an angular displacement Z_1, which is predetermined, in a given case varying with other operational parameters, but in any case dependent on the rotational speed information of the n-marks, for the normal injection beginning. This computer circuit 14 therefore delivers an output time signal T_1, which is fed through a connecting line 15 initially directly to an adding block 16. The block 16 finally determines the actual injection time start which is either fixed as an instant $T_0 + Z_1$, i.e. T_1, for the normal operation or which undergoes a further angular displacement Z_0 through a block 17. The individual temporal courses are illustrated in Fig. 3d. It can be seen that the additional displacement Z_0 can be dependent at least on rotational speed information and of course on start information stating that a starting operation is indeed in progress. Through this additional displacement, the normally calculated injection instant, referred to the crankshaft rotation, can be displaced out of the region of the top dead centre (minimum voltage) into a region of maximum voltage as the comparison of the curve courses of Fig. 3a and Fig. 3d shows. These injection pulses, displaced in time by reason of the starting information, are designated by t_1^*. The circuit block can be, for example, an n-mark counter which after counting-down a predetermined number of n-mark pulses (fixed $\Delta\alpha$) generates an output signal corresponding to the additional angular displacement Z_0.

If a system with doubled injection frequency during the starting operation is concerned, then an angular displacement Z_2 corresponding to a crankshaft angle of 180° can be added to the instant T_1 through a further adding block 18, wherein the angular displacement Z_2 can be determined from n-mark information fed by way of the addition line 18a directly to the block 18. At the output of the block 18, the second instant T_2 displaced through 180° then results in time raster of the crankshaft division according to Fig. 3, which instant T_2 is augmented, by the corresponding additional angular displacement Z_0 delivered synchronously from the block 17, so as to result in an additional injection pulse $t_1^{*\prime}$.

In fuel metering systems in which crankshaft information data are not available, the time displacements for the injection start can also be derived from available ignition instant information data. A corresponding circuit is shown in Fig. 4 with illustration of the functional course in the diagrams of Figs. 5a to 5d.

An additional signal, after preparation in a block 20, is fed to a first decision circuit 21, which by way of a line 21a interrogates a starting block 22 in the sense of whether a start condition is present; a start signal, for example derived from the rotation of an ignition switch or rotation of the starter, is fed by way of a further preparatory circuit 2 to a starting block 22. If no start signal is present, then the ignition signal is supplied from an output 21b of the decision circuit 21 directly to a circuit point 24 which serves the determination of the instant of injection in the normal case.

If it is evident that a starting operation is present (for example high-lying starting signal at the starting block 20), then the starting block 22 delivers a first release signal to an input 25a of a differential block 25, which forms the differential dU/dt of the battery voltage U_B and to which a further release signal is fed at its input 25b from a delay time circuit 26. The circuit 26 is started each time on the occurrence of the ignition signal (at injection frequency 180°) and after a predetermined delay time tv, which can be determined in dependence on rotational speed or which can be constant, finally frees the formation of the time derivative of the battery voltage as well as the transmission of the formed differential to a comparison circuit 27 connected to the output of the differential block 26. The formation of the differential dU/dt corresponds to a direct interrogation of the battery voltage course.

The comparison of the differential resulting in the time course of the battery voltage is freed by a predetermined threshold differential when a further decision block 28, in the case of the start condition being present, ascertains that, for example, the rotational speed of the internal combustion engine lies below a predetermined threshold rotational speed or, for example, a waviness signal of the battery voltage is evaluated in the sense that this exceeds a predetermined waviness or the absolute value thereof falls below an absolute voltage level which justifies the injection instant redisposition. In this case, a displaced injection instant signal is fed from the comparison circuit 27 to the circuit point 24.

The following functional course thus results: After a predetermined time t_v after each ignition instant (compare the diagram courses of Figs. 5b and 5d), the formation of the derivative of the battery voltage with respect to time is freed and detached, wherein at that instant in which the respective continuously determined derivative of the battery voltage falls below a predetermined lower value (corresponding to angle α in the curve course of Fig. 5a), which value is designated as $dU/dt_{threshold}$, the driving of the injection valve takes place displaced in time. This corresponds to injection approximately at the top dead centre according to voltage maxima of the battery voltage. The time delay t_v predetermined by the delay time circuit 26 with corresponding delayed triggering of the dU/dt detection at the ignition instant is worthy of recommendation for the reason that in the battery voltage minimum, there also occurs a slope value which is smaller than the threshold value of the temporal battery voltage differential. It is to be understood that the freeing of the dU/dt detection or processing can equally well engage at the comparison block 27. This time delay is performed until on average a certain battery voltage is present (U_B of, for example, about 9 volts) or a certain rotational speed of the engine is reached (which corresponds to a higher battery voltage with lower waviness). This is determined by the second comparison block 28, to which corresponding rotational speed and battery voltage signals are fed.

A second possibility for the derivation of the injection instant redisposition from the ignition instant is illustrated in Fig. 6. This embodiment is based on the recognition that the time between the ignition instant and the occur rence of maximum voltage in the wavy course of the battery voltage stands in a fixed connection with the engine speed so that the time-displaced start of injection taking place in the presence of a start condition can generally take place after a certain delay time which is a function of the rotational speed, thus $t_v = f(n)$. According to Fig. 5, the ignition signal after preparation in the block 30 is fed to a first decision circuit 31, which in terms of sense and its construction can correspond to the decision circuit 21 of Fig. 4, as well as to a delay time circuit block 32, which sets up a varying delay time $t_v = f(n)$ according to the curve course of Fig. 7.

On a decision of the circuit block 31 that a start condition is present, an adding block 33 is driven and freed, which adds the delay time t_v dependent on rotational speed to the ignition signal occurring at the instant T and feeds it to a circuit point 34 for the determination of the actual displaced injection time start. For the circuit construction of Fig. 6, the pulse diagram according to Figs. 5a to 5d is applicable in appropriate sense, wherein this simplified embodiment rests on the consideration that the displacement of the injection instant during start conditions need be only such that the driving of the injection valves takes place largely in the region of the voltage maxima of the battery voltage, which after all have a certain width in time. The curve course of Fig. 7 can be realised by appropriately constructed time transmitters in the region of the delay time circuit block 32, for example through the use of a monoflop with a dwell time controlled in dependence on rotational speed. Such a time transmitter as monostable trigger link is started at the instant T. The dwell time of the monoflop is then related to n-mark pulses approximately corresponding to incoming rotational speed information data. The realisation can also take place by way of an integrator (capacitor), which sums the n-marks and the charging level of which is decisive as a measure for the flyback time of the monoflop used. The duration of the metastable state of the monoflop then corresponds to the delay time dependent on rotational speed to that extent. The switching-off of the time delay for the injection start corresponding to Figs. 6 and 7 can then be performed gradually in the sense of the function I stated in the diagram course of Fig. 7 or more than proportionally from a certain rotational speed following the chain-dotted course at I'.

It is to be understood that the time displacement of the injection pulses can also take place only once.

CLAIMS

1. A method of determining the timing of fuel injection by a timed fuel injection system of an internal combustion engine during starting of the engine, comprising the step of displacing the instant of drive for the injection valves under starting conditions through a delay time duration or delay angle, dependent on rotational speed or battery voltage in such a manner that it is disposed each time approximately in the next following maximum of an on-board mains voltage fluctuating cyclically in dependence on rotational speed.

2. A method as claimed in claim 1, wherein in the presence of reference mark information referring to piston top dead centre as well as crankshaft angle information, the normal state of injection is determined initially by the addition of a first time duration dependent on the crankshaft angle information or fixed crankshaft angle to the reference mark instant and subsequently a further delay time duration or delay angle, dependent on rotational speed, is added for determination of the displaced start of injection time.

3. A method as claimed in claim 2, wherein, when the injection frequency is double, a time duration, corresponding to a predetermined crankshaft angle according to the

number of cylinders of the engine, is constantly added to the normal injection instant for the determination of a second normal injection instant with corresponding addition of delay time duration or delay angle dependent on rotational speed.

4. A method as claimed in claim 1, wherein, in the absence of information referring to crankshaft angle, the temporally displaced injection instant is determined from ignition instant information.

5. A method as claimed in claim 4, wherein a detection of the time differential of the battery voltage or a comparison of this differential with a given threshold differential is freed after a given internal delay time, which in a given case is dependent on rotational speed, and the drive of the injection valves takes place after decision checking for the presence of start conditions as well as further presence of certain rotational speed conditions as well as on-board mains voltage conditions.

6. A method as claimed in claim 4, wherein a delay time block for the setting-up of a delay time dependent on rotational speed is started up at the instant of the occurrence of the ignition signal and the addition of the delay time to the ignition is freed in the presence of a start information for the displacement of the injection instant into the battery voltage maximum.

7. A method as claimed in claim 6, wherein the delay time follows a given course of curve in dependence on rotational speed and only a single displacement of the injection pulses is also undertaken in a given case.

8. A method substantially as hereinbefore described with reference to Figs. 2 and 3a to 3d of the accompanying drawings.

9. A method substantially as hereinbefore described with reference to Figs. 4 and 5a to 5d of the accompanying drawings.

10. A method as hereinbefore described with reference to Figs. 6 and 7 of the accompanying drawings.

11. Apparatus for carrying out the method claimed in claim 1, comprising an adding circuit operable, at the instant of the occurrence of an ignition signal or of a reference mark, to add on a delay time duration or delay angle, dependent on rotational speed, in such a manner that each actual injection instant occurs in a voltage maximum of the fluctuating battery voltage.

12. Apparatus for carrying out the method claimed in claim 1, comprising a differential block to interrogate the battery voltage course directly through formation of the time differential of the battery voltage, and means to free the injection time start with reference thereto in the presence of start conditions.

13. Apparatus as claimed in claim 11, wherein after preparation of a reference mark information top dead centre and information data proportional to crankshaft angle in decision blocks, a first adding circuit is provided which adds a given time duration, referring to crankshaft and in a given case dependent on further operating parameters, to the reference symbol instant for obtaining a second instant, which refers to the crankshaft position and is fed as starting point for the redisposition of injection instant to a second adding circuit, which receives the delay time duration or displacement angle, dependent on rotational speed, from a circuit block, which in the presence of a start information sets up the delay time duration or delay angle from a rotational speed signal.

14. Apparatus as claimed in claim 12, wherein an ignition instant signal is, after preparation in a circuit block, fed to a delay time circuit block, which sets up a delay time in correspondence with a given course of curve in dependence on rotational speed and feeds it to an adder, which for the freeing of the injection instant is driven by a decision circuit in the presence of a start information.

15. Apparatus as claimed in claim 12, wherein for the direct interrogation of the battery voltage signal, a differential block is provided, which is freed – in a given case delayed in time to the ignition instant – for the formation of the time derivative of the battery voltage and to the output of which a comparison circuit is connected, which compares the battery voltage differential with a predetermined threshold differential and on agreement generates a drive signal delayed in time for the injection valves.

16. Apparatus as claimed in claim 15, wherein a start block is provided, the output signal of which is fed to a start decision circuit, which in the presence of start conditions drives a second decision circuit, which frees the differential comparison circuit for the generation of an injection instant when a predetermined threshold rotational speed is not exceeded or until a certain mean battery voltage is present.

17. Apparatus substantially as hereinbefore described with reference to Figs. 2 and 3a to 3d of the accompanying drawings.

18. Apparatus substantially as hereinbefore described with reference to Figs. 4 and 5a to 5d of the accompanying drawings.

19. Apparatus substantially as hereinbefore described with reference to Figs. 6 and 7 of the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1984, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.