(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 230 638**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **86117873.9**

(22) Date of filing: **22.12.86**

(51) Int. Cl.⁴: **F02D 41/04** , F02D 41/34 , F02D 41/24

(30) Priority: **24.01.86 IT 6705586**

(43) Date of publication of application: **05.08.87 Bulletin 87/32**

(84) Designated Contracting States: **DE ES FR GB NL SE**

(71) Applicant: **WEBER S.r.l.**
Corso Marconi, 20
I-10125 Torino(IT)

(72) Inventor: **Scarnera, Michele**
Via IV Novembre, 9
I-40036 Monzuno(IT)
Inventor: **Conticelli, Carlo**
Largo Molina, 4
I-40100 Bologna(IT)

(74) Representative: **Prato, Roberto et al**
c/o Ingg. Carlo e Mario Torta Via Viotti 9
I-10121 Torino(IT)

(54) A system for the rapid correction of the fuel mixture strength supplied to a heat engine having an electronic injection system.

(57) A system for the rapid correction of the fuel mixture strength supplied to a heat engine (101) having an electronic injection system, in particular a sequential and phased system, comprising means - (102) for detecting at each induction stroke of a respective cylinder of the engine (101), differences in the value of the pressure in the induction manifold (107) with respect to the value of the pressure existing at the detection instant for calculation of the normal injection time in relation to the said cylinder, which in dependence on the value of the said difference determines whether or not to enable a supplementary injection of fuel.

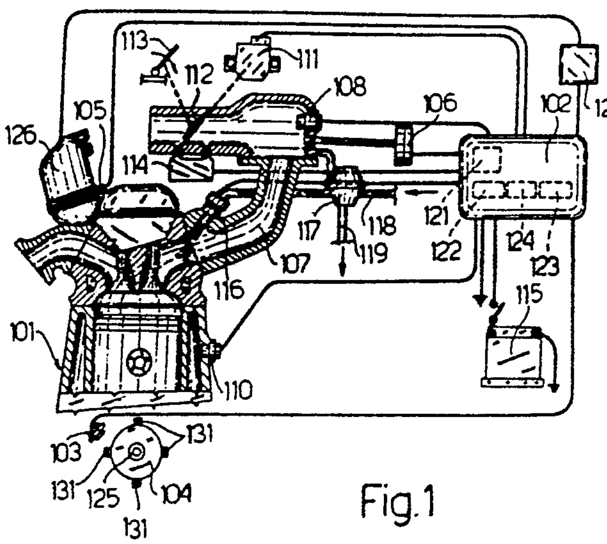

Fig.1

EP 0 230 638 A2

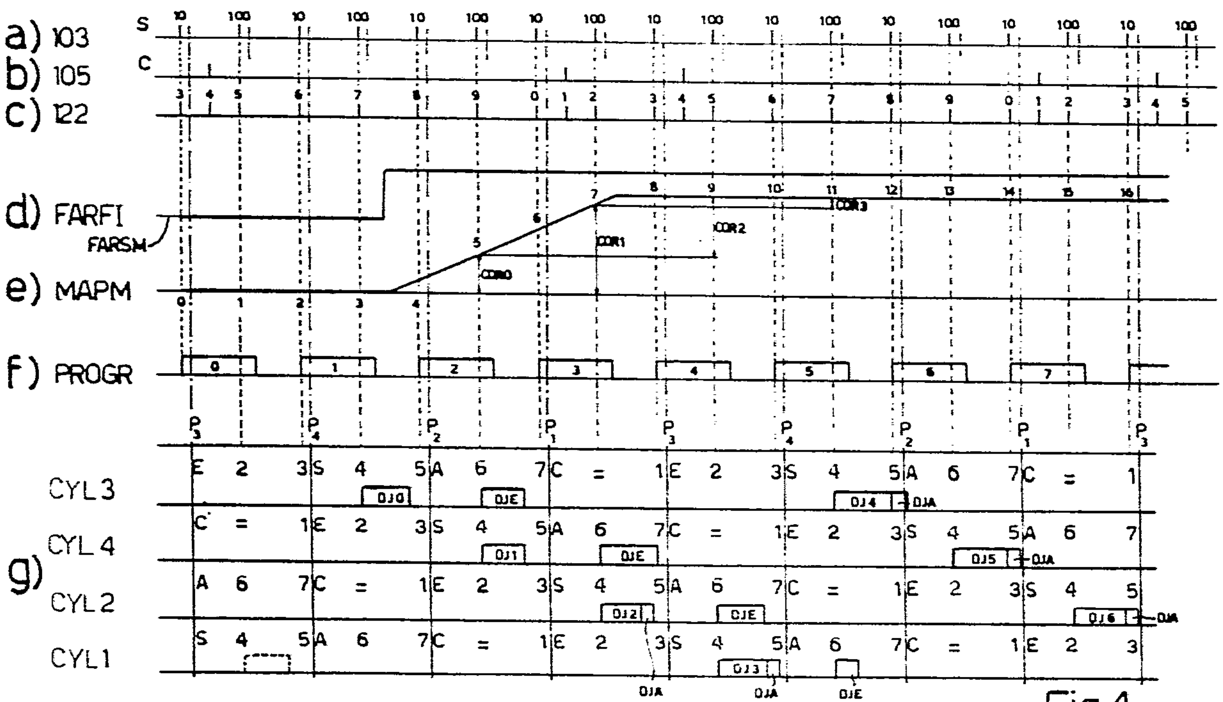
a) 103
b) 105
c) 122
d) FARFI
FARSM
e) MAPM
f) PROGR
g)
CYL3
CYL4
CYL2
CYL1
COR0
COR1
COR2
COR3
OJ0
OJE
OJ1
OJ2
OJ3
OJ4
OJ5
OJ6
OJA

Fig.4

A SYSTEM FOR THE RAPID CORRECTION OF THE FUEL MIXTURE STRENGTH SUPPLIED TO A HEAT ENGINE HAVING AN ELECTRONIC INJECTION SYSTEM

The present invention relates to a system for the rapid correction of the fuel mixture strength supplied to a heat engine having an electronic injection system, in particular a sequential and phased system.

As is known, following variations in the quantity of air inducted into the induction manifold of the engine, mainly because of the variation of the angular position of the butterfly valve connected to the accelerator, it is necessary to correct the fuel mixture strength in that the time for which the injector is open is determined by previously detected parameters which are therefore not the current values, after transients which settle down and which modify the value of the parameters themselves. To improve the speed of correction of the mixture strength there have been used systems which detect the variation in the angular position of the butterfly valve and modify the injection time as a result. Such known control systems are, however, usually unsatisfactory principally because of the requirements for very rapid and precise correction, and this limits the performance during such transient phases of such electronic fuel injection systems which, in general, define a very precise and rapid control strategy for the operation of the engine in that there is an electronic central control unit which, in dependence on signals which it receives from the various sensors (principally sensors detecting the speed of rotation and the phase of the engine, and sensors detecting the pressure and temperature of the inducted air) determines for example the density of the air in the manifold and the speed of rotation of the engine and calculates, by interpolation on associated memorised mappings, the timing and the duration of the fuel injection to the injectors, as well as the ignition advance.

The object of the present invention is therefore that of providing a rapid system for the correction of the fuel mixture strength supplied to a heat engine having an electronic fuel injection system, which allows the mixture strength to be corrected directly in the first induction stroke following a variation in the quantity of air inspired, in the expectation that the correction calculated through the usual measurement of the variation in the butterfly valve be performed.

Other objects and advantages obtained with the rapid correction system of the present invention will become apparent from the following description.

According to the present invention there is provided a system for the rapid correction of the fuel mixture strength supplied to a heat engine having an electronic fuel injection system, characterised by the fact that it includes means for detecting, at each induction stroke of an associated cylinder of the engine, differences in the value of the pressure in the induction manifold with respect to the pressure value existing at the moment of detection for calculation of the normal injection time relating to the said cylinder, and in dependence on the value of the said difference, for determining whether or not to enable a supplementary injection of fuel.

For a better understanding of the present invention a particular embodiment is now described, purely by way of non-limitative example, with reference to the attached drawings, in which:

Figure 1 is a schematic view of an electronic fuel injection system for a heat engine with the rapid fuel mixture strength correction system formed according to the present invention;

Figure 2 is a flow chart illustrating a first part of the correction system of the present invention;

Figures 3a and 3b illustrate flow charts of a second part of the correction system of the present invention;

Figures 4a to 4g illustrate, in schematic form, various signals present in the electronic injection system with the correction system of the present invention; and

Figures 5a and 5b illustrate, in schematic form, other signals present in the correction system of the present invention.

With reference to Figure 1, there is - schematically shown an electronic fuel injection system for a heat engine 101, conveniently a four cylinder engine, shown partially and in section. This system includes a central electronic control unit 102 including, in a substantially known way, a microprocessor 121 and registers in which are memorised mappings relating to different operating conditions of the engine 101, as well as various counters, including a counter 122, and various read and write memory registers (RAM), including registers 123 and 124 in particular, each having four memory cells. This central control unit 102 receives signals from:

a sensor 103 detecting the speed of rotation of the engine 101, disposed opposite a pulley 104 having four equally spaced teeth 131 fitted to an engine shaft 125,

a sensor 103 for detecting the phase of the engine 101, positioned in a distributor 126, a sensor 106 for detecting the absolute pressure existing in an induction manifold 107 for the engine 101,

a sensor 108 for detecting the temperature of the air in the manifold 107,

a sensor 110 for detecting the temperature of the water in the cooling jacket of the engine 101,

a sensor 111 substantially constituted by a potentiometer and angular position detector of a butterfly valve 112 disposed in the induction manifold 107 and controlled by the accelerator pedal 113:
between the zones of the induction manifold 107 upstream and downstream of the butterfly valve 112 there is connected a by-pass valve 114 for the introduction of supplementary air, the position of which is controlled by the central control unit 102: in particular this valve 114 can be an electromagnetically controlled valve of the type described in Italian Patent application No. 3386-A/83 filed 12 April 1983 by the same applicant. This electronic central control unit 102 is connected to an electrical supply battery 115, and to earth, and in dependence on signals from the said sensors, the operating conditions of the engine and the density of the air are utilised to determine the quantity of fuel in dependence on the desired mixture strength. This central control unit 102 therefore controls the time for which the electronically controlled injectors 116 disposed in the manifold 107 adjacent the induction valve of each associated cylinder are open to control the quantity of fuel provided to the various cylinders of the engine 101, and controls the timing of the injection to determine the commencement of the delivery of fuel with respect to the stroke (induction, compression, expansion, exhaust) of the engine 101. Each electronically controlled injector 116 is supplied with fuel through a pressure regulator 117 sensitive to the pressure in the induction manifold 107 and having a fuel inlet duct 118 coming from a pump (not illustrated) and a return duct 119 for returning to a reservoir (not illustrated). This central electronic control unit 102 is moreover connected to a unit 120 for controlling the ignition pulses which are supplied to the various cylinders through the distributor 126.

Before describing the operation of the correction system according to the present invention reference will be made to Figure 4 which illustrates at lines a and b the temporal sequence of signals S and C provided by the sensors 103 and 105 the operation of which has been described in detail in Italian Patent application No. 67512-A/85 filed 4 June 1985 by the same applicant, the contents of which are incorporated here simply by reference for the necessary parts. The signals S are therefore provided by the sensors 103 at, respectively, 10° and 100° in advance of the top dead centre point of each cylinder, which are indicated respectively with the letters P_1, P_2, P_3 and P_4 for the cylinders 1, 2, 3 and 4 (as is visible in Figure 4g, in which the associated induction, compression, expansion and exhaust strokes are also indicated with the letters A, C, E, S). In Figure 4b there is indicated the temporal sequence of signals C provided by the sensor 105, and the combination of the signals S and C determines the progressive content from 0 to 9 of a counter 122 the value of which therefore identifies the associated stroke condition of each cylinder. As is visible in Figure 4g, the reference numerals from 0 to 7 indicate the associated conditions of 100° or 10° of the compression, expansion, exhaust and induction strokes, which numbers, for a specific cylinder, correspond unequivocally with two respective predetermined numbers of the counter 122: for example the number 8 in the counter 122 corresponds to the numbers 5, 3, 1 and 7 of the associated cylinders 3, 4, 2 and 1, which indicate that they are at 10° from the end of the respective exhaust, expansion, compression and induction strokes.

In Figure 4f there is further shown, with a box, the calculation time of the main programme of the microprocessor 121, which starting from the detection of the signals from the various sensors, in correspondence with each S10, determines the normal injection time indicated DJi. Indicating with the numbers from 0 to 7 the various updated calculation programmes of the injection times - (Figure 4f), in Figure 4g there are indicated the corresponding injection times (DJ0, DJ1, DJ2, DJ3, DJ4 ...) which start from number 4, corresponding to 100° of the exhaust stroke of each cylinder, supposing this injection phase to be established at an exemplary value of the engine speed of about 1400 revolutions per minute.

The system of the present invention for rapid correction of the fuel mixture strength supplied to the engine 101, made necessary by transient variation conditions of the operating parameters, determined principally by opening or closure of the butterfly valve 112 by the driver, is therefore principally based on the measurement of the difference in the induction pressure existing at the moment in which the injection time is calculated, with respect to the induction pressure present at the moment when the mixture is effectively inspired and burnt; to this correction strategy there is further added a supplementary correction strategy deriving from the measurement of the position of butterfly valve 112 with respect to the position which this valve had in the preceding calculation conditions. The main correction strategy therefore effects a correction of the injection time by means of a supplementary injection of fuel, being based on the measurement of the difference between the value of the absolute pressure in the induction manifold 107 detected in correspondence with the signal S100 subsequent to the signal S10 at which is measured the value of the absolute pressure in the manifold 107 (which is utilised by the programme for calculating the injection time DJi) and the value of the pressure in the manifold 107 measured in correspondence with the signal S100 of the induction stroke of the cylinder involved; this latter value is, in fact, more indicative of the first relative to the calculation of the quantity of inducted air. During the performance of the programme for calculation and actuation of a certain injection time there is therefore memorised in a four cell memory, one for each cylinder, the value of the pressure in the manifold 107 in correspondence with signal S100 subsequent to the signal S10 at the beginning of the calculation programme, that is to say a pressure value very close to that utilised for the calculation of the injection time and can be correlated, for the same conditions, with the value of the pressure which will be measured half way through the induction stroke, also in correspondence with the signal S100; moreover, in the calculation programme there is stored a parameter KAPPAi equal to the calculated injection time DJi divided by the value of the pressure in the induction manifold 107 in correspondence with the signal S10 at the commencement of calculation, this parameter KAPPAi is therefore proportional to the normal injection time in each cylinder, and will be utilised for the effective calculation of the necessary supplementary corrective injection.

Finally, at the moment of normal injection, which with reference to Figure 4 is supposed for example to be in stroke 4, that is half way through the exhaust stroke, the possible supplementary corrective injection is effectively enabled, which will take place half way through the subsequent induction stroke, that is to say in stroke 6, on condition that the normal injection time is reasonably less than the time available before the commencement of stroke 6, for the purpose of avoiding the possibility that at the moment of supplementary injection of fuel the injector may be still open, which would result in an unwanted reduction of the main injection time.

The duration of the supplementary fuel injection is therefore calculated starting from the memorised value KAPPAi relating to that cylinder, and by multiplying it by the difference between the value of the pressure in the induction manifold 107 read half way through the induction stroke, and the value of the pressure memorised at signal S100 indicative of the pressure situation in the induction manifold 107 at the moment when the normal injection time is calculated; to this value there is added a further correction factor depending on the battery voltage necessary to obtain the effective control time for the injector 116 from the calculated supplementary injection time.

The additional correction strategy consists on the other hand in measuring the increment of the angular position of the butterfly valve 112 at each engine stroke, in correspondence with each signal S10, and then calculating a quantity proportional to the required correction, indicated DMAPCi, which modifies the content, (DMAPC) of a memory cell, directly proportional to the correction to be effected, only if it is of greater magnitude. This value DMAPC is decremented by predetermined values (KDR) at each predetermined engine stroke number, for example four, to obtain a decreasing injection enrichment with time in the instants subsequent to the transient. Subsequent transient conditions will replace the present enrichment only if they are of greater magnitude. A deceleration condition (reduction in the angular position of the butterfly valve 112) without this returning to the idling position, will not alter the correction in progress. On the other hand in conditions where the butterfly valve 112 returns to the idling position, any additional injection time is cancelled.

An increased contribution to the injection time equivalent to that caused by an increase in the angular position of the butterfly valve 112 is calculated in the condition in which the idling control strategy of the engine 101 causes an induction of supplementary air through the valve 114 of considerable magnitude, in fact this induction could produce a significant weakening of the mixture, the injection time calculation programme not yet having the power to utilise the new induction pressure values. The normal injection time is therefore corrected in an additive form with an additional injection time calculated starting from the current value of the quantity DMAPC, transformed through suitable scale constants, and corrected in dependence on the water temperature of the engine through respective tabulated coefficients.

With reference to Figure 2, there is shown a block schematic diagram indicating the main correction strategy, which is repetitively performed by means of the microprocessor 121 of the central control unit 102 whenever a signal S provided by the rotation sensor 103 arrives at the central control unit 102 itself. This therefore leads to block 201 which evaluates if the signal S has detected a signal S10: in the positive case the programme leads to a block 202 which tests if there is a cylinder in the stroke established for commencement of the normal injection time. In the negative case this leads to a block 203 which causes continuation of the programme, including calculation of the injection time (DJi) with the parameters detected in correspondence with the signal S10 which has caused commencement of the performance of the calculation programme itself. This block 203 also calculates the coefficient KAPPAi equal to the said injection time DJi divided by the value of the pressure in the induction manifold 107 detected by the sensor 106 in correspondence with the signal S10 upon commencement of the programme for calculation of the injection time and memorises this value KAPPi in a corresponding cell of the memory 124. In the event of a positive condition detected by the block 202 this leads to a block 204 which checks if the previously calculated normal injection time has a duration certainly less than the interval between the current injection stroke and about half of the following induction stroke, so that the injector is certainly closed half way through this induction stroke to allow a possible supplementary injection of fuel in a correct manner, according to the correction system of the present invention, with the characteristics which will be described in more detail below. This block 204 therefore tests if the difference between the supplementary injection stroke (stroke 6) and the current injection stroke (in the specific case stroke 4) multiplied by the interval between the two signals S, is greater than a predetermined safety value at the current injection time. In the positive case this leads to a block 204 which puts the condition EXT = 1, to enable a supplementary injection of fuel, and which memorises the value KAPPAi in a memory cell relating to the cylinder in which the main injection will be controlled to effect, in the case of transients, the calculation of the supplementary injection in that same cylinder; and then leads to a block 206 which controls the normal injection of fuel in the pre-established stroke detected by the block 202; in the case of the negative condition detected by the block 204 this leads instead to a block 207 which puts the condition EXT = 0, that is to say the supplementary injection of fuel is not enabled and then leads to the block 206.

The block 206 leads to the block 203 which has the function of continuation of the calculation programme just described. If the block 201 detects the negative condition, that is to say in the presence of a signal S100, it leads to a block 208 which acquires through the sensor 106 the value of the pressure (MAPM) in the induction manifold 107 in correspondence with this signal S100. This then leads to a block 209 which memorises this pressure value detected by the block 208 in the memory 123 and in the cell TABMAPi corresponding to the cylinder i in which there has been, or there will be, controlled the injection of duration equal to DJi generated by the preceding signal S10.

The block 209 leads to a block 210 which evaluates if EXT is equal to 1: in the negative case (which indicates that there is no enablement for supplementary fuel injection) the programme leads to a block 212 which puts the condition DJE equal to zero, and then leads to block 202, whilst in the positive case it leads to a block 213 which calculates the difference between the current pressure in the induction manifold, detected by the block 208, and the value, still in correspondence with the signal S100, which has been memorised in the register 123 relative to the cylinder which is now in the induction stroke, this difference, indicated CORi is equal to MAPM minus TABMAPi. The block 213 leads to a block 214 which tests if this value CORi is greater than a threshold value DMEX: in the negative case this leads to the block 212, whilst in the positive case it leads to a block 215 which calculates the value DJE which defines the supplementary fuel injection time. This value DJE is equal to the value KAPPAi memorised in the memory 124 and relative to the cylinder which is now in stroke 6 (halfway through the induction stroke) multiplied by the value CORi determined by the block 213, to which is added a value CORVAT which is a function of the voltage of the battery 115. The block 215 then leads to a block 217 which controls the supplementary fuel injection by means of the electronic injector 116 relative to that cylinder for the time DJE calculated by the block 215 in the cylinder in stroke 6. The block 217 leads then to a block 218 which puts DJE equal to zero and then returns to block 202.

As well as the operation determined by the detection of the variations in pressure in the induction manifold 107 described with reference to Figure 2, the rapid fuel mixture strength correction system of the present invention has a further mode of operation in dependence on the detection of the quantity of air provided to the induction manifold 107 through detection of the variation in the angular position of the butterfly valve 112 or the variation in the quantity of air introduced through the supplementary valve 114 which will now be analysed in detail with reference to Figures 3a and 3b. The operating programme of Figure 3 is performed at each signal S10 and leads to a block 250 which, in dependence on the value of the cooling water of the engine 101 detected by the sensor 110 controls the choice of the value of a first coefficient KDER from a respective table of four values memorised in ROM memory, and a coefficient CP from a second table of 16 values memorised in ROM memory. The block 250 leads to a block 251 which, in the associated memory registers which store memorised values of previously calculated parameters, effects the updating of these parameters, in particular, the angular position value -

(FARFI) of the butterfly valve 112 detected in the preceding cycle is updated so that the memorised value FARFI is put equal to FAROLD; the value of a parameter (DUTYT) calculated in the preceding cycle is also updated, which indicates the percentage of the time for which the valve 114 is activated and therefore the quantity of supplementary air supplied through this valve, the test for which has been described in Italian Patent application No. 67544-A/85 filed 11 June 1985 by the same applicant and the content of which is incorporated herein by simple reference for the parts necessary; the block 251 therefore puts the stored value DUTYT equal to DUTYTO.

The block 251 leads to a block 252 which, through the potentiometer 111 acquires a new value (FARFI) of the angular position of the butterfly valve 112, and then leads to a block 253 which evaluates if this new value detected by the block 252 is greater than the value FAROLD) of the preceding cycle memorised in the block 251. In the positive case the programme leads to a block 254 which calculates the difference between the current value of the angular position of the butterfly valve 112 and the value in the preceding cycle, and therefore puts DFARF equal to FARFI minus FAROLD; the block 254 leads to a block 254 which evaluates if this difference DFARF is greater than a threshold value DFS: in the positive case it leads to a block 256 which calculates a parameter DMAPCI as a product of the difference value DFARF and a conversion constant KDALM. From the block 256 the programme leads to a block 257 which evaluates if the value DMAPCI calculated by the block 256 is greater than a current value DMAPC the variability of which will be illustrated further below. In the positive case the programme leads on to a block 258 which evaluates if this value DMAPCI is less than or equal to a maximum limit value KMAPSS: in the negative case it leads to a block 259 which puts this value DMAPCI equal to the limit value KMAPSS and then passes on to a block 260 which puts the value DMAPC equal to the value DMAPCI, whilst in the case of the positive condition the block 258 leads directly to the block 260. From this block 260 it then passes to a block 262 which puts a parameter i equal to 4 and then leads on to a block 263 which calculates an additional injection time (DJA) equal to this value DMAPC times a constant KMPDIN, all multiplied by the parameter CP determined by the block 250. From the block 263 it leads to a block 264 which tests if the starting phase of the engine has finished, that is to say if the current speed of rotation (RPM) is greater than a threshold value (RPM1), and in the positive case leads on to a block 265 which calculates the total normal injection time - (DJi) as a sum of the injection time (DJi) already calculated by the programme and the additional time (DJA) calculated by the block 263. From the block 265 it then leads to a block 266 for continuation of the calculation programme in the microprocessor 121. If the negative condition is detected by the block 264 it leads to a block 268 which puts the condition DMAPC equal to zero and then to a block 269 which consequently puts the additional injection time (DJA) also equal to zero, and then leads on to a block 270 which puts the parameter i equal to 4 and then to the block 265. If the negative condition is detected by the block 255 (Figure 3a) it leads to a block 272 which checks if the value of the parameter DAMPC is equal to zero: in the positive case it leads to the block 269 for cancellation of the additional injection time, whilst in the negative case it leads to a block 274 (Figure 3b) which decrements the parameter i by one unit, putting i equal to i minus 1. From the block 274 it leads to a block 275 which evaluates if the parameter i is equal to zero, and in the negative case leads to the block 263, whilst in the positive case it leads to a block 276 which decrements the value of the parameter DMAPC by the value KDER established by the block 250, thus putting DMAPC equal to DMAPC minus KDER. The block 276 leads to a block 277 which establishes the value of the parameter i equal to 4 and then leads to the block 263. The programme arrives at the same block 274 in the case of a negative condition detected by the block 257 (Figure 3a).

In the case of a negative condition detected by the block 253, that is, in the case that the angular position of the butterfly valve 112 is constant or decreasing, it leads to a block 280 which evaluates if the position of the butterfly valve 112 (FARFI) is the minimum value (FARSM) in the negative case that is to say, in conditions of a constant angular position of the butterfly valve 112 greater than the minimum, or decreasing to values greater than the minimum, it leads to the block 272, whilst in the positive condition, that is if the butterfly valve 112 is at the minimum, it leads to a block 281 which evaluates if the butterfly valve 112 was also in the minimum position in the preceding cycle, for which it evaluates if FAROLD is equal to FARSM. In the negative case, in which there has been a reduction in the angular position of the butterfly valve 112 to the minimum value from the preceding cycle to the current cycle, it leads to a block 268 for cancellation of the additional fuel injection, whilst in the case of the positive condition, that is to say, maintenance of the minimum position for a certain time, it leads to a block 282 which evaluates a variation in the rate of flow of air through the valve 114 as a difference between the current value of the parameter DUTYT and the value (DUTYTO) calculated in the preceeding cycle, and this difference is put equal to K Q which is then compared in a subsequent block 283 with a threshold value Q_1. If the value detected by the block 282 is less than this threshold value Q_1 no correction on the additional injection time is effected and the programme then leads on to block 272, whilst in the case of a positive condition detected by the block 283 it leads to a block 285 which calculates the value of the correction parameter DMAPCI as a product of the value K Q detected by the block 282 and a transformation coefficient KDUMP, and then from the block 285 leads to the block 257.

A detail of the operating sequence of the correction system according to the present invention will now be described with reference to Figure 4, in which the line d represents a step-like increase in the angular position of the butterfly valve 112 starting from the idling position so there is a corresponding progressive increase in the pressure - (MAPM) in the induction manifold 107, indicated by the line e. Starting, for example, from the signal S10 corresponding to the point 0 of Figure 4e there is the commencement of the ZERO calculation programme (row 4f) and from block 201 (Figure 2) the programme leads to block 202 which, not detecting any cylinder in the established injection phase, sends to the block 203 which proceeds to calculate the injection time DJ0 and the associated coefficient KAPPAi. At the next signal S100 (in the hypothesis of Figure 4 before the end of the calculation of DJ0) it leads from the block 201 to the block 208 which detects the value of the pressure in the manifold 107 and memorises it by means of the block 209 in the memory register cell 123 associated with the injection time DJ0 still in the calcuation phase. It then passes to the block 210 and, supposing that the condition EXT is equal to 1, to the block 213 which calculates the value CORi which, since there is not a pressure transient, is equal to zero. From the block 214 it therefore leads to the block 212 which puts the supplementary fuel injection time equal to zero and then leads to the block 202 which detects if the cylinder 1 is in the established injection phase (stroke 4) from which it leads to block 204 which evaluates on the basis of the normal injection time for the cylinder 1 if this time is certainly less than the achievement of stroke 6 (half induction) for the cylinder 1 itself, and, in this case the positive condition being verified, since the duration of the injection time is indicated in broken lines in Figure 4g, it leads to block 205 which with the condition EXT equal to 1 enables a possible supplementary injection of fuel to the cylinder 1 itself. It then leads to block 206 which controls injection of the fuel for this time calculated in a stroke not present in Figure 4, indicated in broken outline, and then goes to block 203 for the continuation of the calculation programme for the normal injection time DJ0.

At the next signal S10 it goes from the block 201 to the block 202 and from this to block 203 for performance of the calculation programme of the injection time DJ1. At the next signal S100 (point 3 of Figure 4e) it goes to block 208 and then to block 209 which memorises the pressure value read by the sensor 106 in the register 123 associated with the time DJ1, and then from the block 210 goes to block 213 which in this case also calculates the correction value CORi for the cylinder 1 equal to zero, the pressure still being unchanged, so that from block 214 it goes to block 212 and then to block 202 which detects that cylinder 3 is established in the injection phase. The next block 204 with the block 205 enables a possible supplementary injection of fuel into cylinder 3 (in the subsequent induction phase) and then goes on to block 206 which controls the normal injection for the time DJ0 in the cylinder 3, likewise memorising the value of KAPPAi relative to time DJ0 and the pressure value read on the signal S100 (instant 1 of Figure 4a) in memory cells relative to cylinder 3 in which injection has just been taking place. At the next signal S10 which determines initiation of the calculation programme 2, it goes from the block 201 to the block 202 and then to block 203 and then at the following signal S100 it goes from block 201 to block 208 which detects an increased value in the absolute pressure in the induction manifold 107 (instant 5 of Figure 4e) and this new value is memorised by the block 209 in the register cell 123 associated with the calculation time DJ2. The block 210 detects the condition EX2 equal to 1 for the cylinder 3 now in phase 6 (half way through induction) previously determined by the blocks 204 and 205 in that the injection time DJ0 injected in that cylinder was sufficiently limited and therefore lead to block 213 which calculates the value COR0 equal to the difference between the value MAPN at this instant 5 and that memorised in the cell TABMAP 3, read at instant 1 (Figure 4e) corresponding to the consecutive signal S100 after signal S10 which has started the programme for calculation of DJ0. Supposing this value COR0 to be greater than the threshold value DMEX, from the block 214 it goes to block 215 which calculates the duration of this supplementary fuel injection equal to DJE as a product of the coefficient KAPPAi memorised in the calculation of the ZERO programme for the cylinder 3, for this value COR0 and to which is added the corrective coefficient CORBAT. From the block 215 it goes to the block 216 which detects the stroke 6 for the cylinder 3 and then the block 217 controls opening of the injector 116 relating to this cylinder 3 for the calculated supplementary injection time DJE. From the block 217 it then goes to the block 218 which zeros this supplementary injection time, and then to the block 202 which detects the cylinder 4 in the established injection phase 4, for which the duration of the normal injection time DJ1 is controlled through block 206. In this case too, the blocks 204 and 205 enable a possible supplementary injection of fuel in the subsequent induction phase for the cylinder 4 and memorise in cells related to the cylinder 4 the associated values of KAPPAi and pressure at S100 (instant 3 of Figure 4e). Proceeding in a manner similar to that described, for the subsequent sequence of signals S10 and S100, as is visible in Figure 4g, one has that at instant 7 for Figure 4e the magnitude of correction COR1 is calculated as the difference between the pressure signals at the instants 7 and 3 which give rise to the supplementary injection time DJE for the cylinder 4; similarly at instant 9 the pressure difference with respect to instant 5 gives rise to the correction magnitude COR2 for the supplementary injection time DJE at stroke 6 for cylinder 2, and at instant 11 the pressure difference with respect to instant 7, equal to the value COR3, gives rise to the supplementary injection time DJE at stroke 6 for cylinder 1. Subsequently, at instant 13, since there is no longer a pressure difference with respect to instant 9, the block 213 detects the value zero so that the block 214 leads on to block 212 which puts the supplementary injection time equal to zero. On the other hand, if the normal injection time is rather long, so as to terminate almost half way through the induction stroke, the block 204 detects the negative condition so that the block 207, with the condition EXT equals 0, does not enable the supplementary fuel injection and at the subsequent signal S1 the programme transfers from block 210 to block 212.

The intervention of the additional correction strategy, as a function of the detection of the variation in the angular position of the butterfly valve 112, is described in detail with reference to Figures 3a and 3b. At the instants zero and 2 of Figure 4e in which the butterfly valve 112 is maintained in the idling position, from block 253 the programme passes to block 280 and from this to block 281 and 282 which supposes that no variation in the rate of flow of additional air through the supplementary valve 114 is detected. From block 283 it then passes to block 272 which detects the condition DMAPC equal to zero, and from this leads on to block 269 which puts the duration of the additional injection time DJA equal to zero so that the block 265 does not alter the calculated value of the normal injection time DJi. At the next signal S10 (instant 4) the block 252 detects an increased value of FARFI so that from block 253 it leads to blocks 254 and 255 which, supposing that the increment threshold value DFS is exceeded, passes to block 256 for the calculation of the value DMAPCI. From block 256 it leads to block 257 and then to the blocks 258 and 260, and through the block 262 leads to block 263 which calculates the value DJA equal to the additional injection time. Supposing that the starting phase of the engine has passed, from block 264 it leads to block 265 which at the normal injection time (DJ2) relating to programme two in operation at instant 4, adds the additional time DJA calculated by this block 263, as is visible in Figure 4g, for the cylinder 2. Supposing that the butterfly valve 112 remains constantly open at this increased opening value, at each signal S10 the programme leads from the block 253 to the block 280 and then to the block 272 which detects the negative condition so that, through the block 274, there is a progressive reduction in the parameter i at each engine stroke. Since i has been established equal to 4 by the block 262, for three successive strokes the block 275 leads to the block 263 and then to blocks 264 and 265 for the addition of the injection time DJA in the manner already described and is illustrated in Figure 4g for the successive cylinders 1,3 and 4. At the next signal S10 (fifth repetition of the programme) it leads from block 275 to block 276 which decrements the value of the magnitude DMAPC of the quantity KDER so that there is a reduction in the value of the additional injection time DJA calculated by the block 263 and which in the block 265 is added to the normal injection time DJ6 for the total time of injection to the cylinder 2. This new value DMAPC and therefore DJA also remain constant for four strokes, and then decrement again by the quantity KDER as already described.

The operation of this additional correction strategy in dependence on the position of the butterfly valve 112 is further illustrated in a more complete manner for the different possible situations in Figure 5, in which, in Figure a there are indicated various successive butterfly positions, whilst in Figure b there is indicated the temporal progression of the corresponding quantity DMAPC. In the section from zero to 1 in which the butterfly 112 is in the idling position FARSM, the value DMAPC also remains at zero; then, at the instant 1, with the increase in the position of the butterfly valve 112 greater than the threshold value DFS, the control strategy goes from block 253 (Figure 3a) through blocks 254 and 255 to arrive at block 256 which calculates the value DMAPC1. From block 257 it goes to block 258 and then to block 260 which through block 262 goes on to block 263 for the calculation of the additional injection time DJA in the manner already described. As is illustrated in Figure 5b, with reference to what has already been described hereinabove, the value of the magnitude DMAPC reduces by the quantity KDER every four engine strokes until it arrives at the instant 2 in which there is a new increase (5a) in the angular position of the butterfly valve 112. From block 253 it therefore goes to block 254 and then to block 255 which detects the passing of the increasing threshold so that the block 256 calculates a new value DMAPC2. Since the block 257 detects that this new value DMAPC2 is greater than the current value DMAPC (Figure 5b, instant 2) from block 257 it goes to block 258 and then to block 260 and through block 262 causes with block 263 a new calculation of the additional injection time DJA starting from this new value DMAPC2, with the subsequent decrease in the value KDER every four engine strokes as already described hereinabove. At instant 3 in which there is a new increase in the angular position of the butterfly valve 112 (Figure 5a) from block 253 it goes again to blocks 254, 255 and 256 which calculate the value DMAPC3. Since in this case (Figure 5b) the block 257 detects that the value DMAPC3 is less than the current value DMAPC, the performance of the calculation in progress is not altered and therefore from block 257 it goes to blocks 274 and 275 which, every four strokes, through the block 276 cause the value DMAPC to be reduced by the quantity KDER. A reduction in the angular position of the butterfly valve 112 at instant 4 (Figure 5a) causes the strategy to pass from block 253 to block 280 and then to block 272, which detecting a reduction in the value DMAPC does not alter the performance of the calculation in progress so that it returns to the blocks 274 and 275 with the continuation of the progressive decrementing of the magnitude DMAPC until the instant 5 in which the butterfly valve 112 is released at the idling position - (FARSM). In this condition, from block 253 it goes to block 280 and then to block 281 which, in the case of the first detection of the achievement of the idling condition, passes to block 268 which cancels the value of the quantity DMAPC so that the value of the additional injection time DJA is nullified. If at instant 7 (Figure 5a) there is an increase in the angular position of the butterfly valve 112 less than the threshold value DFS, from block 253 it goes to block 254 and then to block 255 which detects the negative condition so that it goes to block 272 which detects in turn the zeroing condition of the magnitude DMAPC, so that it leads to block 269 which maintains the value of the additional injection time at zero. On the other hand, if, for example, at instant 6, in which the butterfly valve 112 is in the idling position, by means of the idling regulation system described in the first specified Patent application by the same applicant, there is controlled an introduction of supplementary air through the valve 114 in a sufficiently high quantity, from block 253 it goes to block 280 and then to block 281 which detecting the positive condition of maintenance of the idling position moves on to block 282 which detects this additional increase in flow rate through the valve 114 and then leads on to block 283 which detects that this flow rate exceeds the threshold value ΔQ, so that it goes on to block 285 which calculates the value DMAPCI indicated in broken outline in Figure 5b; the successive performance of the programme through the blocks 257 and so on is similar to what has already been described hereinabove, with the subsequent decrementing of the magnitude DMAPC every four engine strokes.

The advantages obtained with the rapid correction system of the fuel mixture strength supplied to a heat engine having an electronic injection system, in particular a sequential and phased system, are evident from what has been described, since through the main correction strategy which detects the pressure in the induction manifold 107 during the induction stroke and its variation with respect to the detection for the calculation of the injection time already effected relative to this cylinder, it is possible to effect a correction with a possible supplementary injection of fuel in that induction stroke immediately following the variation in the quantity of air inducted to the engine, generally due to the variation in the angular position of the butterfly valve 112. The additional strategy of increasing the normal injection time by a progressively decremented value as a function of the speed of rotation of the engine (number of engine strokes) is rather useful for improving the precision of correction.

Finally, it is clear that the characteristics of the correction system of the present invention just described can be modified and varied without by this departing from the scope of the invention itself.

Claims

1. A system for the rapid correction of the fuel mixture strength supplied to a heat engine (101) having an electronic injection system, characterised by the fact that it includes means (102) for detecting at each induction stroke of a respective cylinder of the said engine (101) differences (CORi) in the value of the pressure in the induction manifold - (107) with respect to the pressure value existing at the moment of the detection for calculation of the normal injection time (DJi) relating to the said cylinder, and in dependence on the value of the said difference determining whether or not to enable a supplementary injection (DJE) of fuel.

2. A system according to Claim 1, characterised by the fact that the said means include means (213) for comparing the pressure value (MAPM) in the induction manifold (107) at about half way through the said induction stroke with a substantially corresponding pressure value, that is to say about half way through an engine stroke which follows the moment of detection for calculation of the said injection time (DJi).

3. A system according to Claim 1 or Claim 2 characterised by the fact that the said means include means (214) for enabling the said supplementary injection (DJE) in dependence on whether or not a threshold value (DMEX) for the said difference (CORi) between the pressure values is being exceeded.

4. A system according to any preceding Claim, characterised by the fact that it includes means - (215) for calculating the duration of the said supplementary fuel injection (DJE) as a function of the said difference (CORi) between the said pressure values.

5. A system according to Claim 4, characterised by the fact that the said means (215) calculate the duration of the said supplementary injection (DJE) as a function of the ratio (KAPPAi) between the calculated injection time (DJi) and the pressure value (MAPM) detected for the calculation of the said injection time (DJi).

6. A system according to Claim 4 or Claim 5, characterised by the fact that the said means - (215) calculate the duration of the said supplementary injection (DJE) also as a function of a parameter (CORBAT) dependent on the value of a supply battery voltage (115) for the injectors (116) of the said system.

7. A system according to any preceding Claim, characterised by the fact that the said supplementary injection (DJE) of fuel is effected at about half way through the induction phase for the associated cylinder.

8. A system according to any preceding Claim, characterised by the fact that it includes means - (204) for determining if the normal calculated fuel injection (DJi) has terminated with at least a margin of time established before reaching the said half way point in the induction stroke for the associated cylinder, to dtermine whether or not to enable the possible supplementary fuel injection (DJE).

9. A system according to any preceding Claim, characterised by the fact that it includes means - (102) for detecting increases in the quantity of air inducted to the said induction manifold (107) and consequently to correct the said normal injection time (DJi) with an additional time (DJA) the said additional time (DJA) being progressively decremented by an initial calculated value (DMAPCI), in dependence on the speed of rotation of the said engine.

10. A system according to Claim 9, characterised by the fact that the said means (253) for detecting the said increase in the quantity of air, detects a variation in the angular position of a butterfly valve (112) controlled by the accelerator pedal (113), the said means (255) detecting an increase greater than a predetermined threshold value (DFS) to determine whether or not to enable the calculation of the intial value of the said additional time (DJA).

11. A system according to Claim 10, characterised by the fact that the said means - (280,281,282,283) for detecting the said increase in quantity of air further detects an increase greater than a predetermined value in the quantity of air inducted by means of a supplementary valve (114) disposed in parallel with the butterfly valve (112) controlled by the accelerator pedal (113).

12. A system according to Claims 10 or 11, characterised by the fact that the said means include means (257) for enabling the calculation of a new initial value of the said additional time (DJA) in dependence on whether or not the current value - (DMAPC), progressively decremented by a quantity proportional to the said additional time, exceeds the said threshold or not following the said increase in the quantity of air.

13. A system according to any of Claims from 10 to 12, characterised by the fact that it includes means (280,281,268,269) for cancelling the said additional time (DJA) in the event that the said butterfly valve (112) returns to the idling postion - (FARSM).

14. A system according to any of Claims from 9 to 13, characterised by the fact that the said initial calculated value (DMAPCI) and the current progressive values (DMAPC) of a quantity proportional to the said additional time are decremented each time after a plurality of strokes of the said engine (101).

15. A system according to Claim 14, characterised by the fact that the said plurality of strokes is equal to four.

16. A system according to any of Claims from 9 to 15, characterised by the fact that it includes means (264) for disabling the application of the said additional injection time (DJA) if the said engine (101) has not yet passed an initial starting condition.

17. A system according to any preceding Claim, characterised by the fact that the said means (102) include a microprocessor (121) for control of the said electronic injection system.

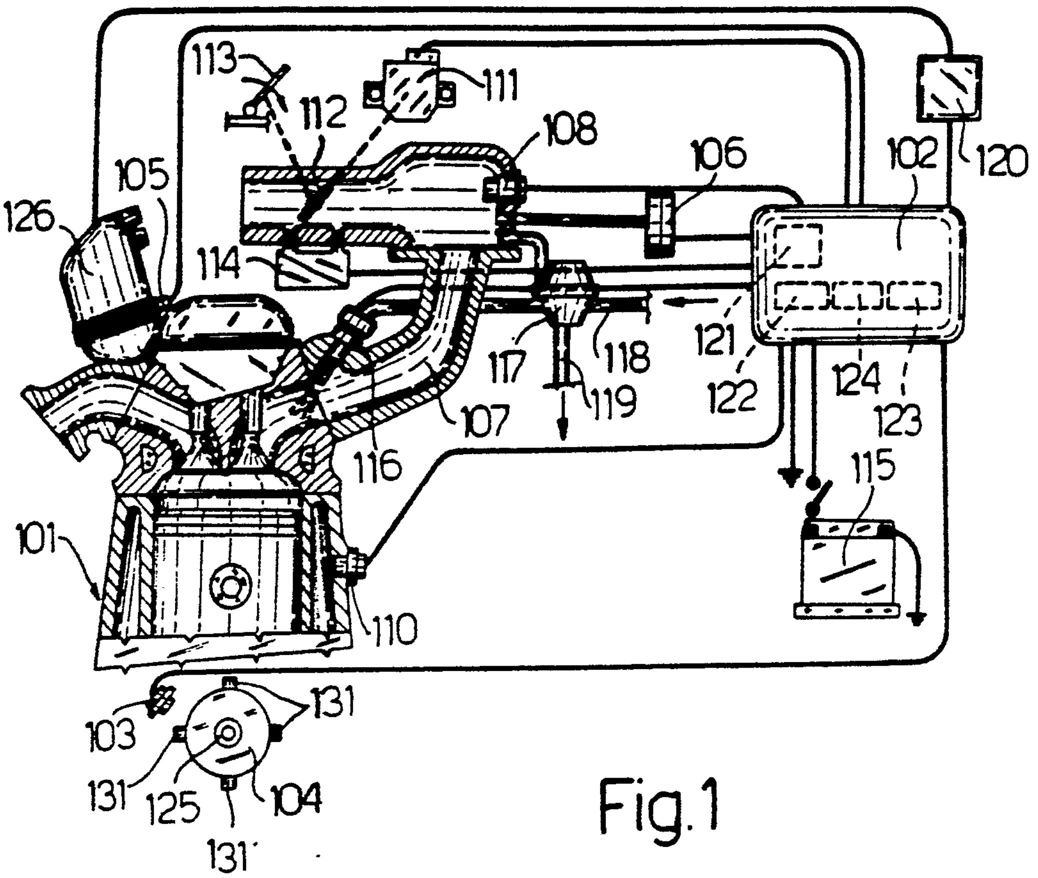
113
111
112
108
106
102
120
105
126
114
121
117
118
122
124
123
119
107
116
115
101
110
103
131
131
125
104
131

Fig.1

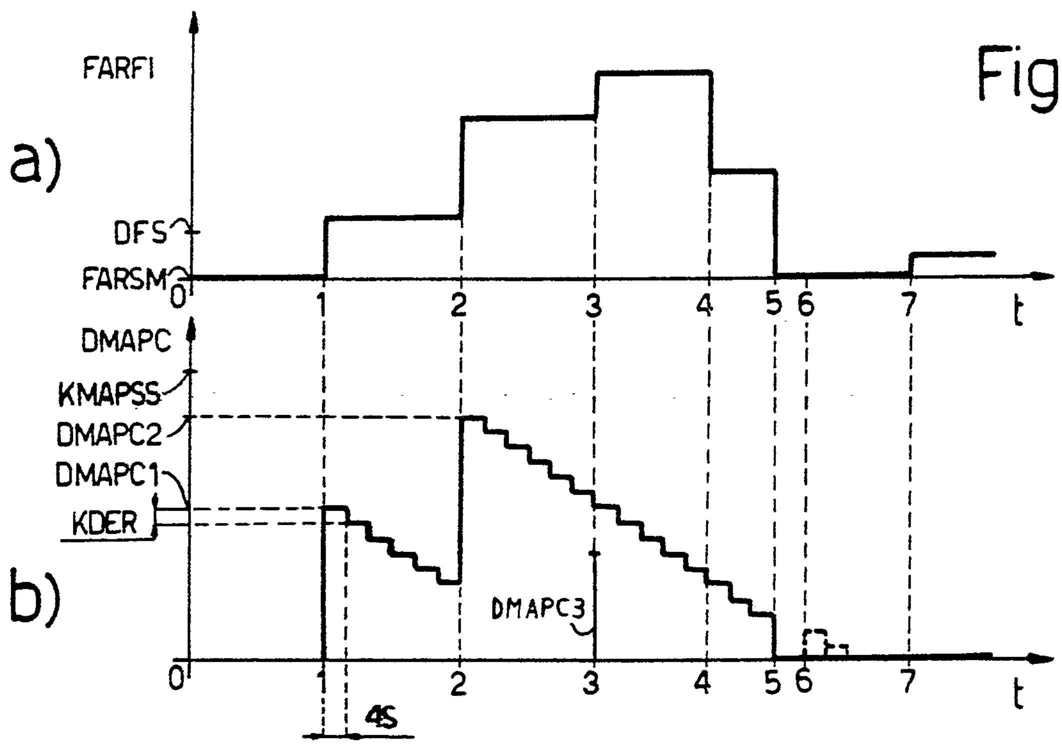
FARFI
a)
DFS
FARSM
0
1
2
3
4
5
6
7
t
DMAPC
KMAPSS
DMAPC2
DMAPC1
KDER
b)
DMAPC3
0
1
2
3
4
5
6
7
t
4S

Fig.5

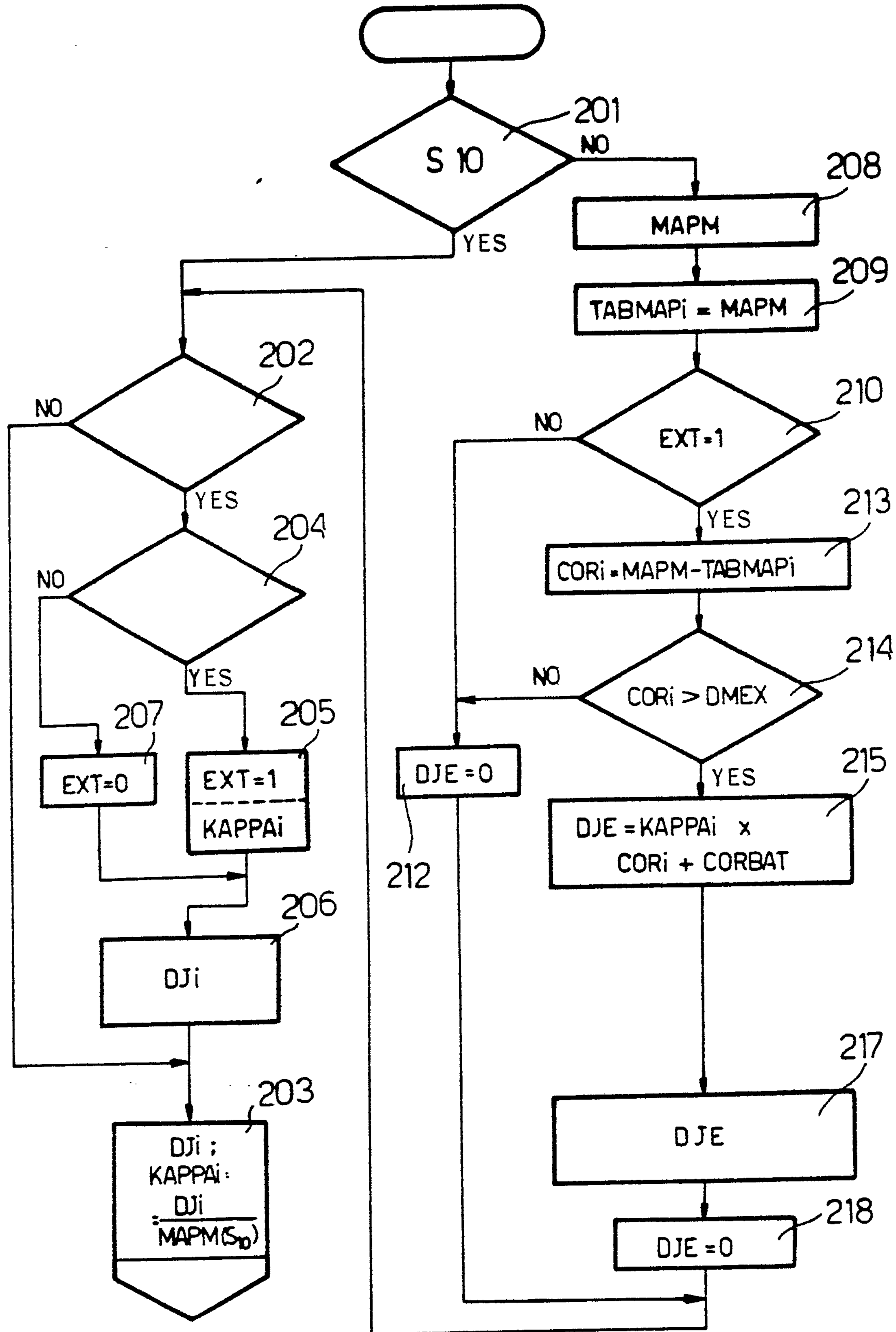
201
S 10
NO
YES
208
MAPM
209
TABMAPi = MAPM
202
NO
YES
210
EXT=1
NO
YES
213
CORi = MAPM-TABMAPi
204
NO
YES
214
CORi > DMEX
NO
YES
207
EXT=0
205
EXT=1
KAPPAi
DJE=0
212
215
DJE = KAPPAi x
CORi + CORBAT
206
DJi
203
DJi ;
KAPPAi = DJi / MAPM(S10)
217
DJE
218
DJE = 0

Fig.2

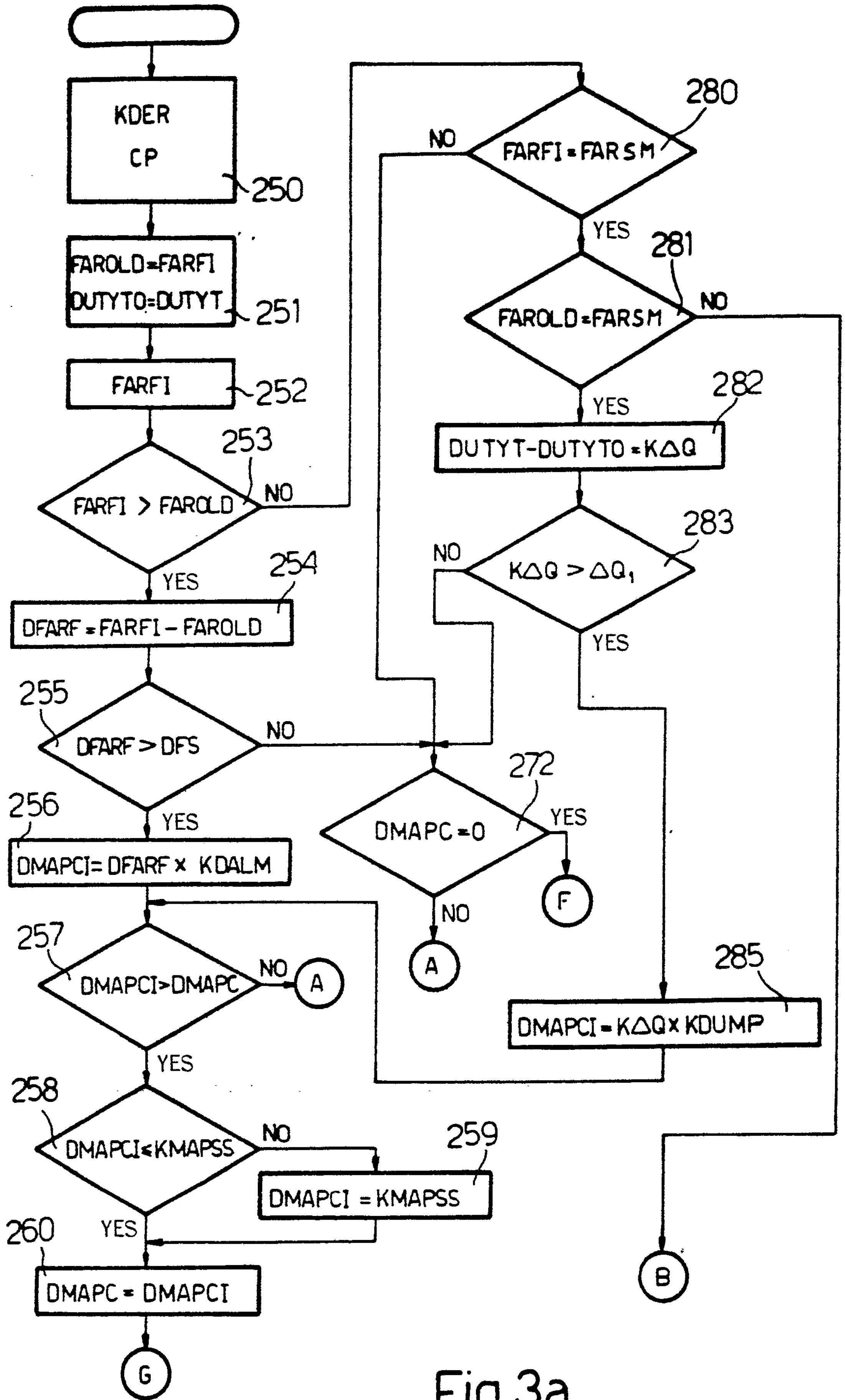
KDER
CP
250
FAROLD=FARFI
DUTYTO=DUTYT
251
FARFI
252
253
FARFI > FAROLD
NO
YES
254
DFARF = FARFI – FAROLD
255
DFARF > DFS
NO
256
YES
DMAPCI = DFARF × KDALM
257
DMAPCI>DMAPC
NO
A
YES
258
DMAPCI≤KMAPSS
NO
259
DMAPCI = KMAPSS
260
YES
DMAPC = DMAPCI
G
280
NO
FARFI = FARSM
YES
281
FAROLD = FARSM
NO
YES
282
DUTYT-DUTYTO = KΔQ
283
NO
KΔQ > ΔQ1
YES
272
DMAPC = 0
YES
F
NO
A
285
DMAPCI = KΔQ × KDUMP
B

Fig.3a

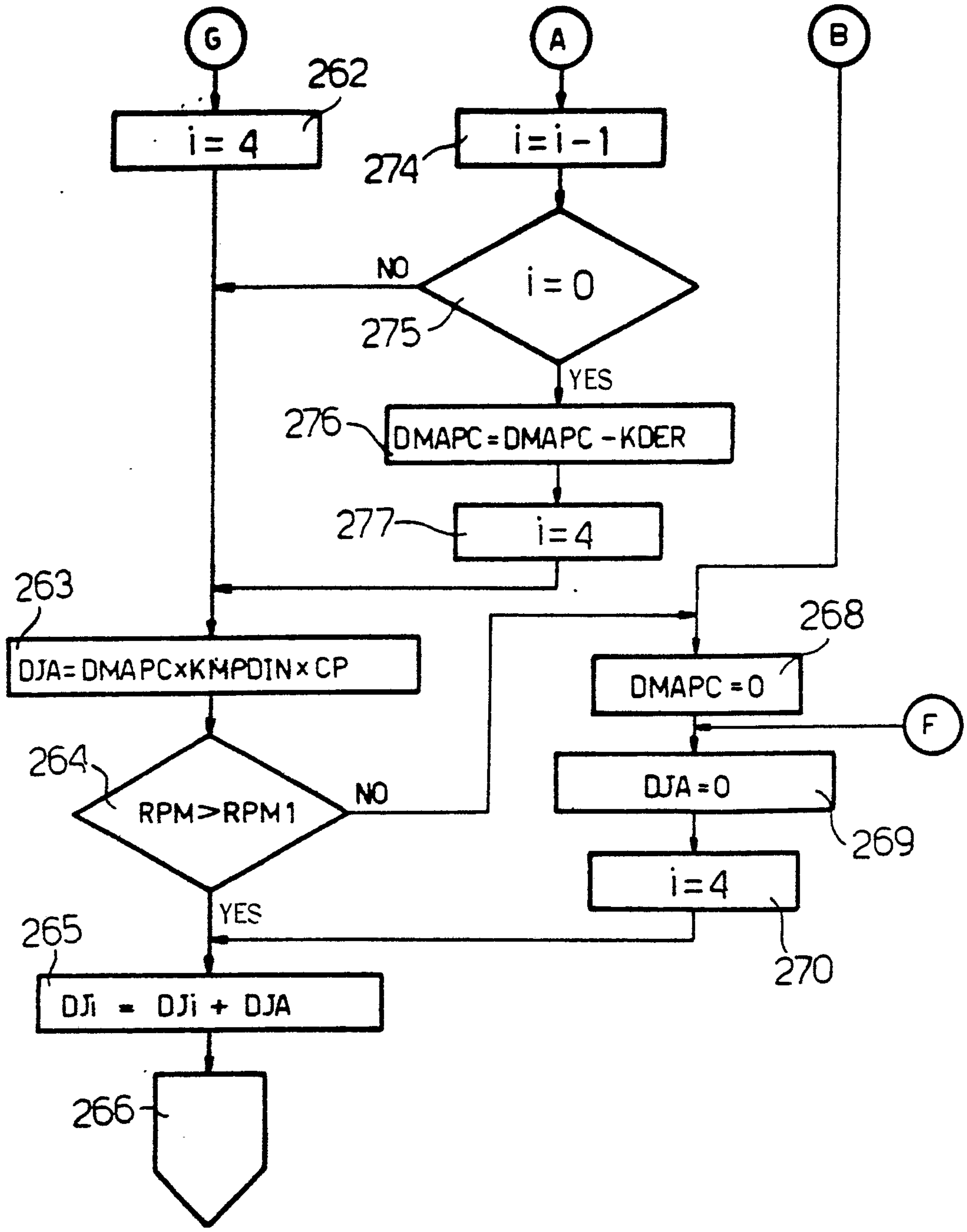
G
A
B
262
i= 4
i=i-1
274
NO
i=0
275
YES
276
DMAPC=DMAPC-KDER
277
i=4
263
DJA=DMAPCxKMPDINxCP
268
DMAPC=0
F
264
RPM>RPM1
NO
DJA=0
269
i=4
YES
265
270
DJi = DJi + DJA
266

Fig.3b

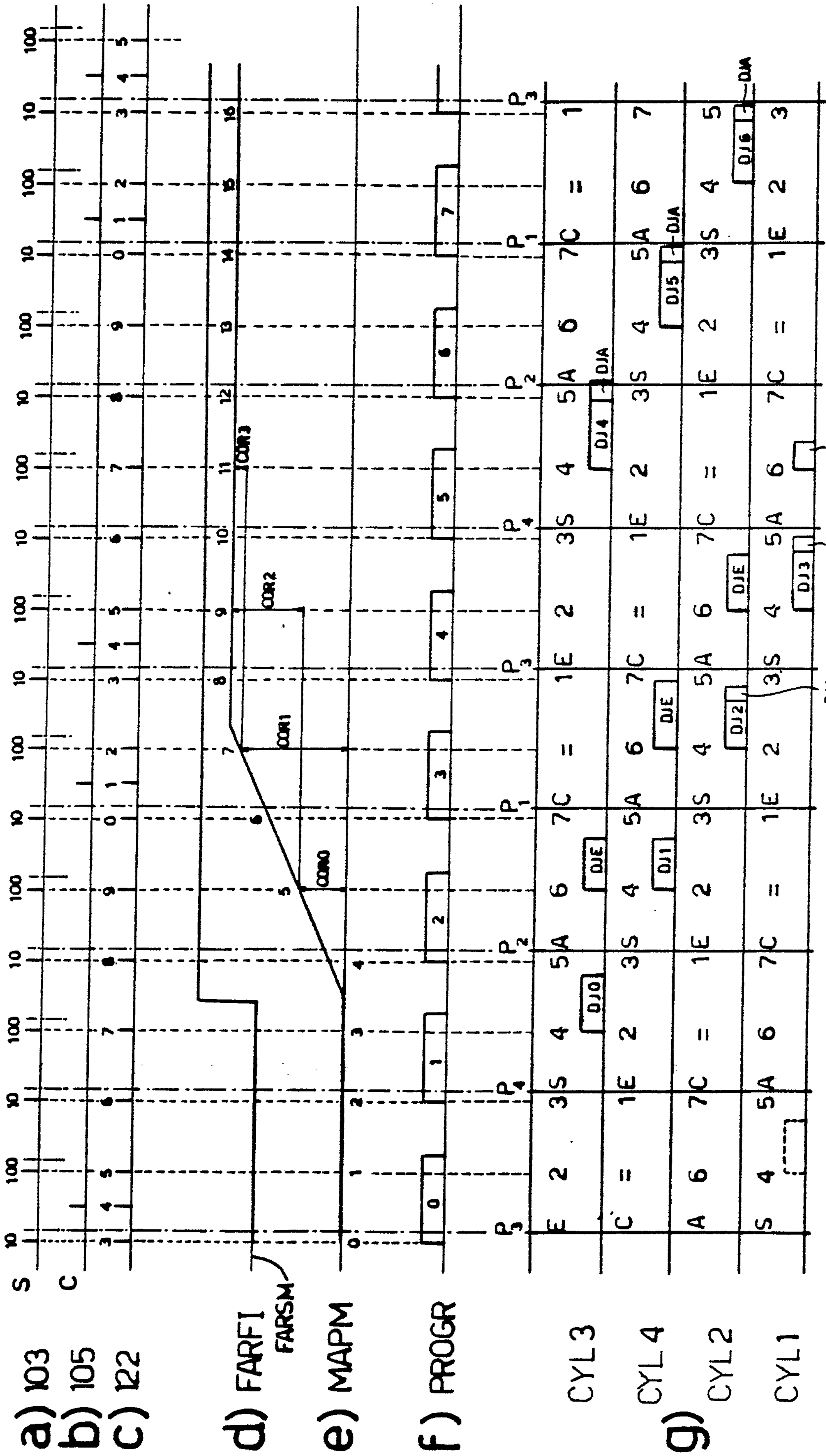
a) 103
b) 105
c) 122
d) FARFI
FARSM
e) MAPM
f) PROGR
g)
CYL 3
CYL 4
CYL 2
CYL 1
S
C
COR0
COR1
COR2
COR3
DJ0
DJ1
DJ2
DJ3
DJ4
DJ5
DJ6
DJE
DJA

Fig.4