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(54) Hardware architecture of a managing system for start-up and injection phase in an internal combustion engine

(57) The invention relates to a hardware architecture of an ignition and/or injection managing system (1) for an internal combustion engine (2), of the type structured to cooperate with an electronic engine control unit (ECU) (3). The managing system comprises:

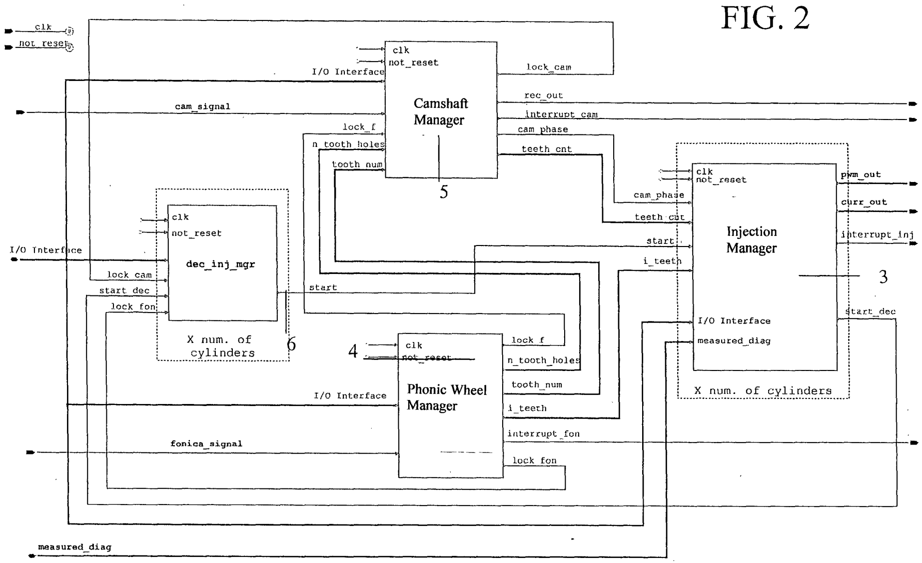
a first module (4) structured to process electric signals from which the angular position of the engine driving shaft can be obtained;

a second module (5) structured to process electric signals from which the cycle phase of the engine (2) can be obtained;

a third module (6) structured to generate suitable signals for driving injector "drivers" (7) such that the injection profile stored inside the module is actuated; and

a fourth module (13) enabling the third module (6) and receiving signals from the first (4) and second (5) modules and from the third module itself (6).

FIG. 2



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Description

Field of Application

[0001] The present invention relates to a hardware architecture of a managing system for the start-up and/or injection phase in internal combustion engines,, particularly for direct injection four-stroke engines with automatic determination of the driving shaft angle and of the operation phase.

Prior Art

[0002] As it is well known in this technical field, the use of electronic units for managing the injection in modern automotive engines is now usual procedure. An example of this is provided by the European Patent Application 01830645.6, to the same Applicant.
[0003] Their use has been dictated by the need to keep certain engine parameters under control so as to diminuish the engine emissions, according to the the close limits set by law in many of the industrialized countries.
[0004] The leading automotive companies are increasing the production of direct injection engines to comply with such restrictive laws, calling for contaminants being released to the environment in ever decreasing amounts, as well as to raise the level of their engine performance. However, these are engines need a more sophisticated and complex control system.
[0005] Recently introduced multiple-injection fuel systems, wherein the parameters to be controlled are characterized by more pressing specifications of time, make the use of a certain number of different-type sensors, whose signals are always processed by current control units, a necessity.
[0006] Thus, nowadays these units, commonly known as ECU (Electronic Control Unit), are now called upon to provide control functions of increasing complexity.
[0007] In the automotive industry it is common practice to use ECUs equipped with a TPU co-processor (Time Processor Unit) which is specifically operative to process signals coming from a sensor of a driving shaft phonic wheel and from a sensor of a camshaft phonic wheel, thereby to determine the angular position of the driving shaft and the operative phase of the engine.
[0008] A big number of parameters must be taken into consideration to carry out the injection process under control by an ECU or a TPU in the best way. This implies a great computational load, both for the ECU and for the co-processor TPU. In fact, both these units handle a large number of signals carrying different priority levels. In all cases, these signals have to be managed by software routine, activated by interrupt signals, in case of the ECU, and by the occurrence of certain events, in case of the TPU.
[0009] In either cases, a discrepancy is bound to exist between an ideal time moment for carrying out the injection and the real time when the injection is actually carried out. This will result in incomplete combustion, generatinglarger pollutant amounts than intended.
[0010] The underlying technical problem of this invention is to provide a new hardware architecture for an ignition and/or injection managing system of internal combustion engines, which architecture should have appropriate structural and functional features so as to allow improved management of the signals coming from the different sensors of the control unit, and therefore, improved control of means provided for the engine ignition and/or injection phase.

Summary of the Invention

[0011] The solving idea on which the invention stands is that of providing a hardware module, which is operating in a digital logic mode, that could be used as a peripheral unit to the ECU, so as to reduce its computational load.
[0012] This hardware module would have the task of:

calculating the driving shaft angular position, by analysing the signal from a sensor of the driving shaft phonic wheel;

calculating the engine cycle phase, by analysing the signal coming from the sensor of the camshaft phonic wheel; and

actuating the injection process, which is tracking an injection profile stored inside the module.

[0013] Briefly, the idea of the invention is to release the ECU from the task of monitoring the driving shaft angle position, from calculating the engine cycle phase, and from actuating injection and/or ignition.
[0014] On the basis of this idea, the technical problem is solved by a hardware architecture of a managing system of the previously indicated type and as defined in the characterizing part of Claim 1 herewith attached.

[0015] The features and advantages of the architecture according to the invention will be clear from the following description of an embodiment thereof, given by way of non-limitatingexample with reference to the accompanying drawings.

Brief Description of the Drawings

[0016]

Figure 1 shows schematically a endothermic injection engine associated with an ignition and/or injection process control unit.

Figure 2 is a block diagram of the managing system architecture according to the invention.

Figure 3 is a schematic view of a detail of the architecture shown in Figure 2.

Detailed Description

[0017] With reference to the drawings, the hardware architecture of an ignition and/or injection managing system of an IC endothermic engine 2, specifically a direct-injection four-stroke cycle engine with automatic determination of the driving shaft angular position and of the cycle phase, is generally shown with 1 in schematic form.

[0018] The managing system 1 is associated with an ECU 3 (not shown in the figures) as conventionally used in automotive applications for controlling the ignition and/or injection in such engines. The managing system 1 is represented in Figure 1 by a block "Injection Coprocessor".

[0019] The managing system 1 is primarily aimed at releasing the ECU 3 from monitoring the driving shaft angle position, from calculating the engine cycle phase, and from enabling the driving of the engine ignition and/or injection means 2.

[0020] The exact timing moment for actuating ignition or injection is indeed a crucial parameter, because it is responsible for the attainment of optimum combustion conditions in order to generate the smallest amount of pollutants.

[0021] The managing system 1 comprises three modules 4, 5 and 6, each one performing one of the aforementioned functions, as well as a fourth module 13 to be described. The modules 4, 5 and 6 are structurally independent, and each of them can have a respective integrated circuit allocated on a supporting board and standard bus interconnection. The engine ECU may also find place on this board.

[0022] Of course, there is no reason for the modules 4, 5, 6 and 13, and the ECU 3 not to be formed in a unique integrated circuit of the "system-on-chip" type, and still retaining their operational independence.

[0023] A general diagram of the hardware architecture of managing system 1 is given in Figure 2.

[0024] A first module 4, referred to as the "phonic wheel manager" hereinafter, has the task of processing electric signals by means of which it is possible to determine the driving shaft angle position.

[0025] This module 4 is input a signal from a phonic wheel sensor 8, the phonic wheel being rotatively rigid with the driving shaft. The phonic wheels are formed with a predetermined number n of equidistant teeth allocated on the circumference. A small group of m adjoining teeth is omitted to define a reference point on the wheel. The sensor 8 generates a signal, from which module 4 looks for the reference point and issues a signal when it finds the reference point and another signal indicating how many teeth have been passing after the reference point.

[0026] A second module 5, referred to as the "camshaft manager" hereinafter, has the task of processing electric signals that allows the cycle phase of the engine to be determined.

[0027] The phases of a four-stroke engine can be identified through the movement of the piston in its cylinder and through the position of the valves managed by the camshaft. The four phases are: induction, compression, combustion/expansion, and exhaust. The movement of the piston toward the engine head takes place both with all the valves closed (compression phase) and with the exhaust valve open (exhaust phase). The piston will then move in the opposite direction either with both valves closed (combustion/expansion phase) or with the induction valve open (induction phase).

[0028] Two revolutions of the driving shaft correspond to the four engine phases and to one camshaft revolution. Thus, the rotation ratio between the camshaft and the driving shaft is 1:2. The timing period for the injection to take place is between a compression phase and the next combustion phase, which corresponds to one driving shaft revolution.

[0029] In order to identify properly this period, the camshaft is equipped in turn with a phonic wheel having teeth located on the circumference arranged so that the signal generated by a sensor 9 is different for the two driving shaft revolutions.

[0030] It should be noted that no standard layout of the phonic wheels teeth is provided for the camshaft, and that the second module 5 is flexible enough to be configured for processing a profile whatever. The signal generated by the sensor 9 of the camshaft phonic wheel is, thus, input to the module 5 along with the counter of the phonic wheel teeth coming from the "phonic wheel manager" module 4.

[0031] The "camshaft manager" module 5 processes these signals to generate an appropriate phase signal at each rotation of the phonic wheel. The module 5 may be also programmed by entering a desired phase variation or phase displacement between the camshaft signal and the signal indicating the crankshaft angle position, so that the system can be used with the controllers for variable timing engines.

[0032] A third module 6, referred to as the "injection manager" hereinafter, has the task of generating a series of uesful signals for the "drivers" 7 provided for driving the injectors or actuating the ignition. Because of the many existing types of these "drivers" and of the possible applications for any one "driver", the module 6 may be programmed to generate the driving signals according to a desired timing pattern.

[0033] This makes the module 6 as flexible as possible and also re-usable in different applications. By using a standard input/output interface I/O, the sequence of the output logic states can be stored inside the module 6, which uotputs may be both PWM signals and stable binary logic signals in the '0/1' form. The injection profile thus internally stored may be described according to angles and/or times, allowing the outputs to go from one logic level to another, or when the driving shaft attains a given position (information supplied to the module 6 by the signals tooth_num and i_tooth from module 4, and signal cam_phase from module 5), or after a given lapse from the previous situation. This feature makes module 6 suitable both for use in applications where the amount of fuel to be injected is calculated in terms of time duration, and in applications where it is calculated in terms of the angular position of the driving shaft.

[0034] Briefly, the managing system 1 allows to determine automatically the angular position of the driving shaft and the engine cycle phase, so as to generate, according to theseparameters, a series of signals useful to drive the injectors. All this in order to actuate the injection process exactly at the desired time.

[0035] The functionality of the "Injection Coprocessor" system 1 is obtained by combining together the four modules "phonic wheel manager" 4, "camshaft manager" 5, "injection manager" 6 and "dec_inj_mgr" 13, as illustrated by the architecture depicted in Figure 2. The number of demands of the module 6 and "dec_inj_mgr" module 13 depends on the number of the engine cylinders where the system 1 is to be used.

[0036] As said before, the first "phonic wheel manager" module 4 processes signals from which the driving shaft angular position can be obtained. This module is input the signal from the sensor 8 of the driving shaft phonic wheel. The module flexibility comes from the possibility of programming the values of n and m so as to suit the phonic wheel actually arranged on the driving shaft.

[0037] The second "camshaft manager" module 5 processes signals from which the engine cycle phase can be obtained. This module is input the signal from the sensor 9 of the camshaft phonic wheel. The module flexibility comes from that it can be programmed so as to fit the phonic wheel actually arranged on the camshaft both in fixed and variable timing engines.

[0038] The third "injection manager" module 6 has the task of generating appropriate signals for the injector driving "drivers" in order to actuate the desired injection profile stored inside the module. The module flexibility comes from that it can actuate the injection profile both according to the driving shaft angular position and after given lapses expire.

[0039] Let us now see the structure and function of the fourth module 13 denoted "dec_inj_mgr".

[0040] This module 13 is an enabling module, in the sense that it initiates module 6. Table 2 below shows the input and output signals of module 13. Figure 3 shows the internal architecture of the module.

[0041] The module 13 comprises a network of logic gates inputting signals start_dec, lock_fon and lock_cam, respectively indicating that module 6 is to be initiated and that modules 4 and 5 have detected the respective signals. An output logic gate 12, of the AND type, is input the respective outputs from three logic gates 11 with two inputs, of the AND type.

[0042] Each gate 11 is input a signal that is output by an input logic gate 10, and a signal having a predetermined logic value and being contained in a storage register.

[0043] The input logic gates 10 are of the OR type with two inputs. Each gate 10 receives one of the input signals, and on the other input, receives a signal having a predetermined logic value and being contained in a respective storage register.

[0044] The logic network of Figure 3 may be formed of a different number and different types of logic gates. What matters is that the whole logic network can supply a logic signal to enable the module 6 when module 4 finds the driving shaft reference point, module 5 finds the engine cycle phase, and module 6 is ready to execute a sequence of operations stored up therein.

Table 2

Signals	Description
Input	
lock_fon	Indicates that "phonic wheel manager" module 4 has found the reference point.
lock_cam	Indicates that "camshaft manager" module 5 has found the engine cycle phase.
start_dec	Indicates the value of the "start" internal register of "injection manager" module 6.
Output	
start	Indicates if module 6 is to be initiated.

[0045] The framed signals are the internal registers of module 13. By using the standard I/O interface, these signals can be forced to a '0' logic value or to a '1' logic value. The default value for the registers whose name begins with "h" is '0', while for those beginning with "1" it is '1'. Thus, the "start" signal is only activated when the three input signals all have a logic value of '1', indicating that module 4 has found the reference point, module 5 has found the engine cycle phase, and module 6 has been programmed to perform its function only after the determination of the operational condition indicated by modules 4 and 5.

[0046] From the architecture of Figure 3 it is evinced that the module 6 can be initiated to have the "injection coprocessor" module fully available as desired.

[0047] Table 1 below shows the input/output signals of the whole managing system 1. It should be noted that the system interacts outwards through a standard I/O interface, viz. an interface which comprises Control bus, Address bus and Data bus.

Table 1

Signals	Description
Input	
Control_bus Address_bus Data_bus (I/O)	Standard communication interface. Data_bus is bidirectional.
cam_signal	Signal from sensor 9 of camshaft phonic wheel.
fonica_signal	Signal from sensor 8 of driving shaft phonic wheel.
measured_diag	Measured diagnostics signal.
Output	
curr_out	Binary logic signals for power drivers 7.
pwm_out	PWM signals for power drivers 7.
rec_out	Reconstructed camshaft signal.
interrupt_inj	Interrupt signal of module 6.
interrupt_cam	Interrupt signal of "camshaft manager" module 5.
interrupt_fon	Interrupt signal from "phonic wheel manager" module 4.

[0048] Each module, 4, 5, 6, or 13, is configured as desired by means of the standard communication interface. The "phonic wheel manager" module 4 begins to monitor a signal fonica_signal, and after finding the reference point, issues a signal lock_f. The module 4 also generates a signal lock_fon to indicate that the location of the reference point has been verified for a given number of times.

[0049] At this point, the signals tooth_num and i_teeth begin to indicate the driving shaft angular position.

[0050] The signal tooth_num is a counter of the phonic wheel teeth starting from the reference point. The signal i_teeth indicates an estimated position between two teeth of the phonic wheel.

[0051] The signals lock_f and tooth_num are input to the "camshaft manager" module 5, and so is the signal cam_signal. The module 5 processes the signal cam_signal from the activation of signal lock_f, and the process of determining the cycle phase is thus started.

[0052] The identification of the phase is pointed out by activating the signal lock_cam, and from now onwards, the phase indication provided by the signal cam_phase in relation to the signal teeth_cnt is effective.

[0053] The signals cam_phase and teeth_cnt generated by module 5, along with the signal i_teeth generated by module 4, are the primary inputs for module 6, once the latter is enabled by module 13.

[0054] Once initiated, module 6 processes the phase signal and the signals indicating the driving shaft angular position, and is able to carry out independently the injection process, consisting in generating the signals pwm_out and curr_out to drive the injector drivers 7 so as to implement the injection profile internally stored.

[0055] The signal teeth_cnt conveys the same type of information as the signal tooth_num, i.e. is a counter of phonic wheel teeth. The single difference is that the signal tooth_num starts counting afresh at each revolution of the driving shaft phonic wheel, while the signal teeth_cnt starts counting afresh at each revolution of the camshaft, i.e. every two driving shaft revolutions.

[0056] The module 5 is flexible enough to be programmed for the following situations:

1) signal teeth_cnt indicates the same count as signal tooth_num; and

2) signal teeth_cnt indicates a shifted (forwarded or delayed) count with respect to that of signal tooth_num of an amount that can be programmed in a register of module 5.

[0057] Thanks to this feature, the managing system 1 can also be applied to engines in which phase variation system is integrated, and allows extensive flexibility in implementing injection in a wide range of different modes.

[0058] The managing system 1 can be adapted for the widely different types of driving- and cam-shaft phonic wheels, as well as of automotive injector drivers, thanks to the extensive configurability of parameters afforded by the modules 4, 5, 6 and 13. This makes the system of this invention the more flexible and re-usable in different applications as possible.

Claims

1. A hardware architecture of an ignition and/or injection managing system (1) for an internal combustion engine (2), adapted to cooperate with an electronic engine control unit (ECU) (3), **characterized in that** it comprises:

a first module (4) structured to process electric signals from which the angular position of the engine driving shaft can be obtained;

a second module (5) structured to process electric signals from which the cycle phase of the engine (2) can be obtained;

a third module (6) structured to supply the "drivers" (7) with suitable signals for driving the injectors so as to actuate the desired injection profile stored inside the module; and

a fourth module (13) enabling the module 6 and receiving signals from said first (4) and second modules (5) and from the module 6 itself.

2. Architecture according to Claim 1, **characterized in that** said first module (4) is input a signal from a sensor (8) of a phonic wheel made rotatively rigid with the engine driving shaft (2).

3. Architecture according to Claim 1, **characterized in that** said second module (5) is input a signal from a sensor (9) of a phonic wheel made rotatively rigid with the engine camshaft (2).

4. Architecture according to Claim 1, **characterized in that** said third module (6) is input a pair of signals (cam_phase; teeth_cnt) from the second module (5), said signal pair relating to the engine cycle phase and to the number of teeth of said phonic wheel, and an additional signal (i_teeth) from the first module (4), said additional signal relating to the angular position of the engine driving shaft (2).

5. Architecture according to Claim 1, **characterized in that** said fourth enabling module (6) is input a first signal (lock_fon) relating to said angular position of the engine driving shaft, a second signal (lock_cam) relating to said cycle phase of the engine (2), and a third signal (start_dec) indicating the operational state of said third module (6).

6. Architecture according to Claim 2, **characterized in that** said phonic wheel has a predetermined number (n) of equidistant teeth arranged on the circumference, a small group (m) of adjoining teeth being missing to define a reference point on the wheel detectable by said sensor (8).

7. Architecture according to Claim 6, **characterized in that** the number (n) of teeth of the phonic wheel and the number (m) of missing teeth are programmable.

8. Architecture according to Claim 1, **characterized in that** said first (4), second (5) and third (6) modules are structurally and functionally independent.

9. Architecture according to Claim 3, **characterized in that** said second module (5) is input a signal of a teeth counter (n) of said driving shaft phonic wheel from said first module (4), and that a predetermined amount of phase displacement may be provided between said signal and the signal from the sensor (9) associated with the camshaft in order to control the cycle phase of variable timing engines.

10. Architecture according to Claim 1, **characterized in that** said fourth module (13) is a logic network.

11. Architecture according to Claim 3, **characterized in that** said phonic wheel has a non-standard arrangement of teeth along its circumference.

12. Architecture according to Claims 3 and 11, **characterized in that** the module may be programmed so as to be adapted to different camshaft phonic wheels.

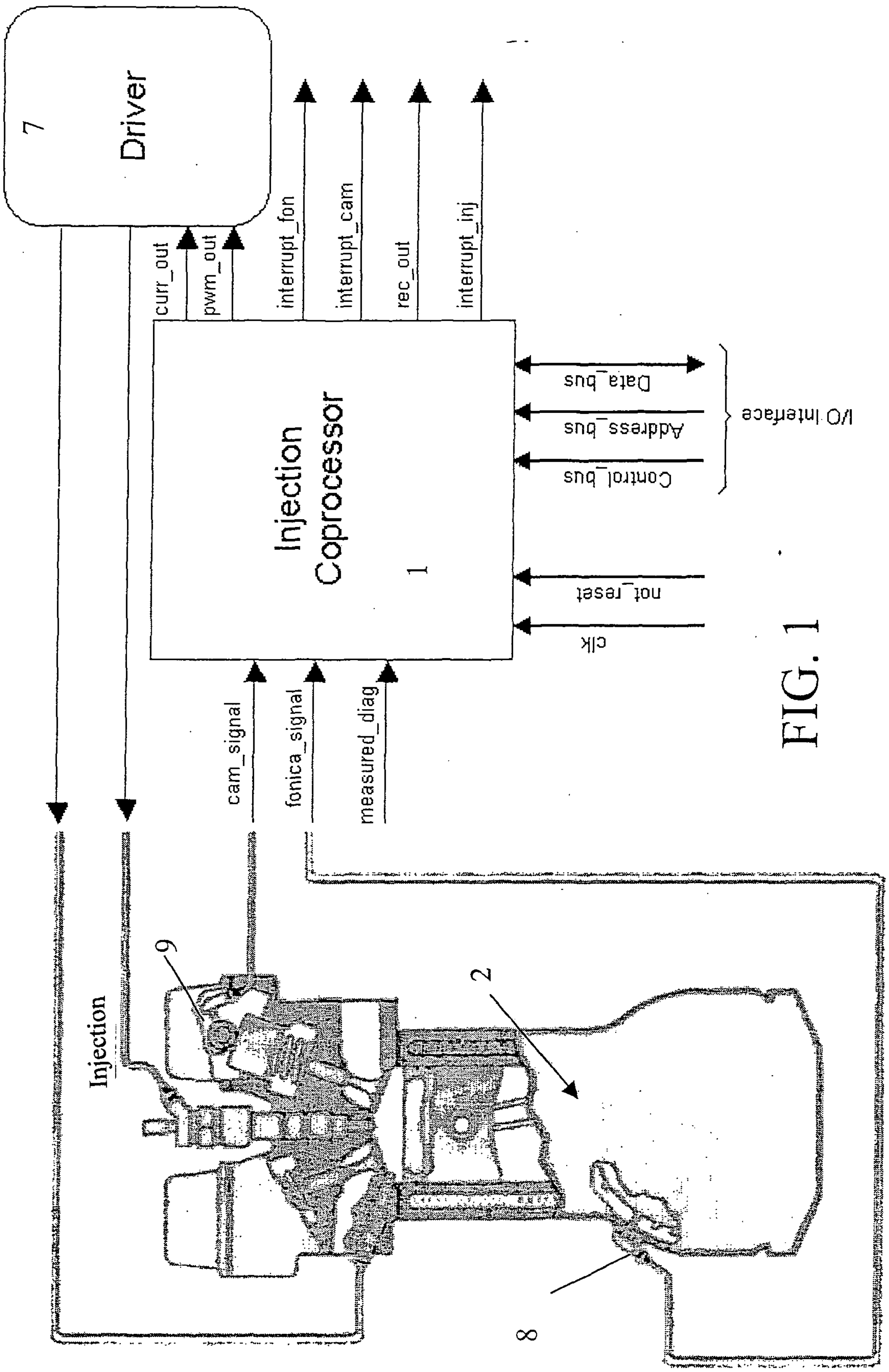
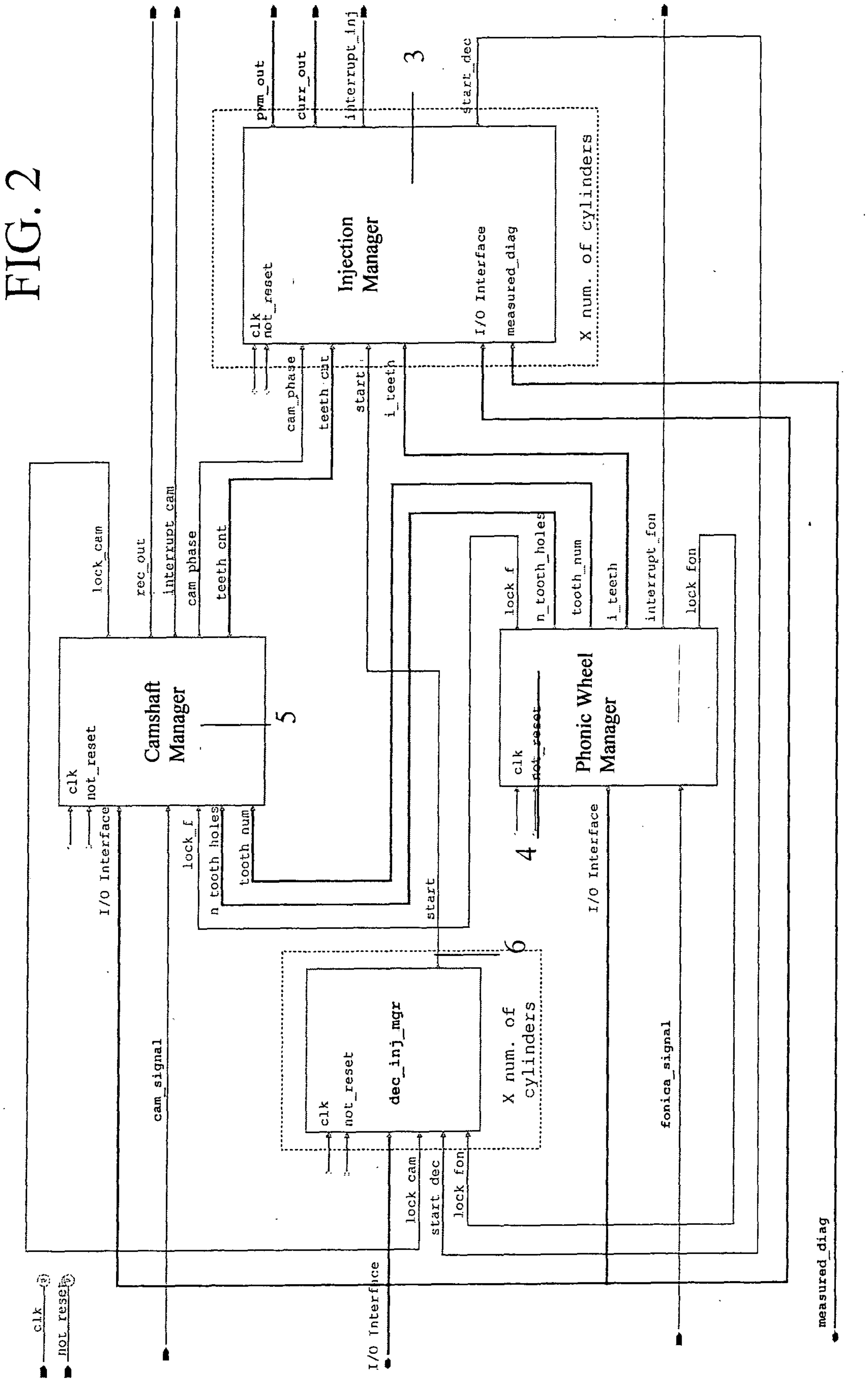

Driver
7
curr_out
pwm_out
interrupt_fon
interrupt_cam
rec_out
interrupt_inj
Injection Coprocessor
1
Data_bus
Address_bus
Control_bus
I/O Interface
not_reset
clk
cam_signal
fonica_signal
measured_diag
Injection
9
2
8

FIG. 1

FIG. 2


Injection Manager
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I/O Interface
measured_diag
X num. of cylinders
pwm_out
curr_out
interrupt_inj
start_dec
cam_phase
teeth_cnt
start
i_teeth
3
Camshaft Manager
5
lock_cam
rec_out
interrupt_cam
cam_phase
teeth_cnt
lock_f
n_tooth_holes
tooth_num
Phonic Wheel Manager
4
lock_f
n_tooth_holes
tooth_num
i_teeth
interrupt_fon
lock_fon
dec_inj_mgr
X num. of cylinders
6
lock_cam
start_dec
lock_fon
cam_signal
fonica_signal
measured_diag
I/O Interface
clk
not_reset

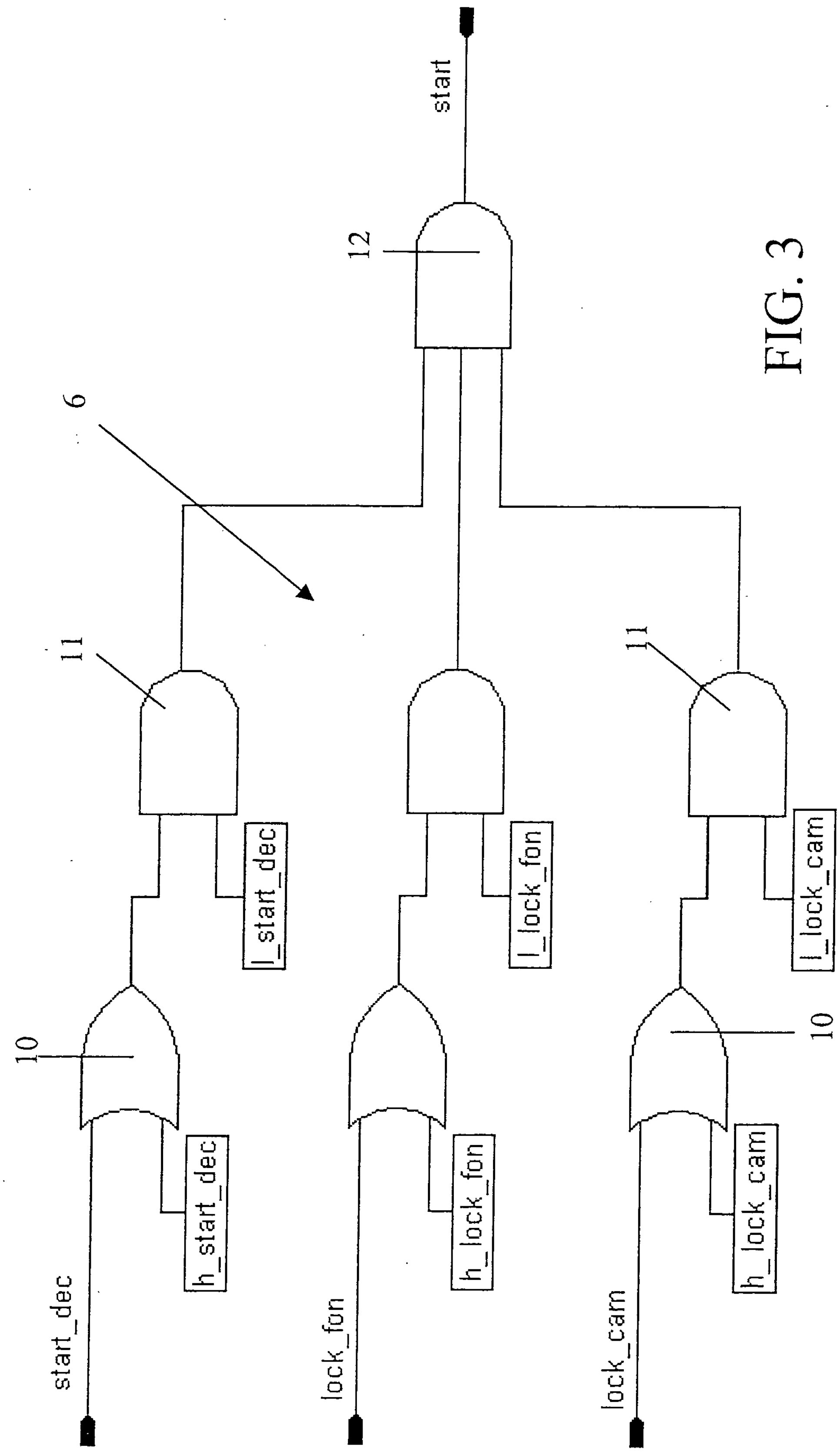
start
12
6
11
11
10
10
start_dec
h_start_dec
l_start_dec
lock_fon
h_lock_fon
l_lock_fon
lock_cam
h_lock_cam
l_lock_cam

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 42 5731

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	US 5 794 592 A (FUKUI WATARU) 18 August 1998 (1998-08-18) * column 6, line 58 - column 11, line 27; figures 1,2 *	1-5,8, 10-12 6,7,9	F02D41/34 F02D41/24 F02D41/30
X Y	US 5 860 406 A (STAHL WENDELL D ET AL) 19 January 1999 (1999-01-19) * the whole document *	1-4,6-8, 10-12 6,7	
X Y	US 6 109 224 A (ISOBE DAIJI ET AL) 29 August 2000 (2000-08-29) * column 4, line 45 - column 10, line 53; figures 1,2 *	1-5,8-12 9	
A	EP 0 582 430 A (FORD WERKE AG ;FORD FRANCE (FR); FORD MOTOR CO (GB)) 9 February 1994 (1994-02-09) * the whole document *	1-12	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	25 April 2003	Aign, T

CATEGORY OF CITED DOCUMENTS

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25-04-2003

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5794592	A	18-08-1998	JP	3264850	B2	11-03-2002
			JP	10220333	A	18-08-1998
			DE	19730970	A1	13-08-1998
US 5860406	A	19-01-1999	DE	19714963	A1	30-10-1997
			GB	2346932	A	23-08-2000
			GB	2312017	A	15-10-1997
			JP	10037792	A	10-02-1998
US 6109224	A	29-08-2000	JP	11159356	A	15-06-1999
			DE	19843665	A1	25-03-1999
EP 0582430	A	09-02-1994	US	5245968	A	21-09-1993
			DE	69306057	D1	02-01-1997
			DE	69306057	T2	20-03-1997
			EP	0582430	A1	09-02-1994
			JP	6173730	A	21-06-1994

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