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

(11) EP 0 727 577 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.08.1996 Bulletin 1996/34

(51) Int. Cl.[6]: **F02N 11/08**

(21) Application number: **96102242.3**

(22) Date of filing: **15.02.1996**

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

(30) Priority: **17.02.1995 IT TO950116**

(71) Applicant: **INDUSTRIE MAGNETI MARELLI S.p.A.**
I-20145 Milano (IT)

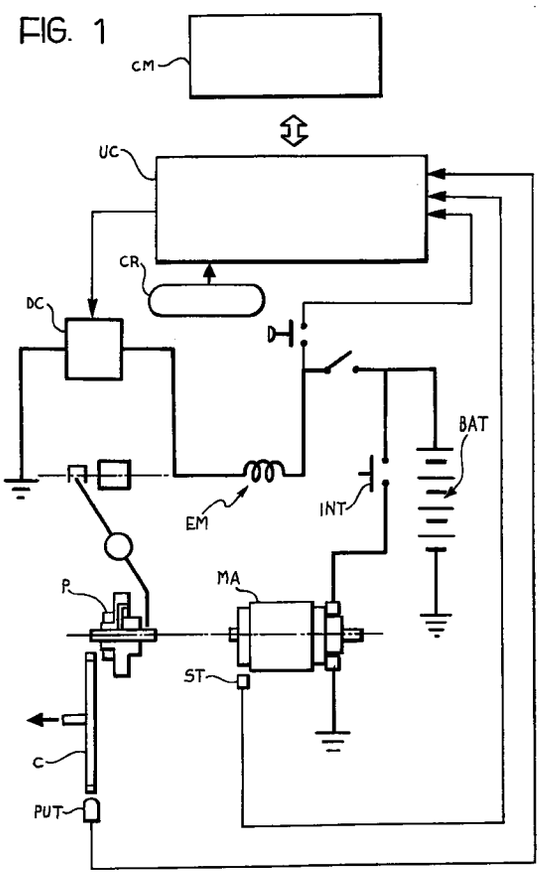
(72) Inventors:
- **Casellato, Giancarlo**
  I-10141 Torino (IT)
- **Rodari, Gianpiero S.**
  I-20060 Gessate (Milano) (IT)
- **Palazzetti, Mario**
  I-10051 Avigliana (Torino) (IT)

(74) Representative: **Quinterno, Giuseppe et al**
c/o JACOBACCI & PERANI S.p.A.
Corso Regio Parco, 27
10152 Torino (IT)

(54) A device for the electronic control of a coupling electromagnet, particularly for a starter motor

(57) A device for controlling a coupling electromagnet (EM), particularly for a starter motor (MA) of a motor vehicle, can regulate the speed at which the pinion (P) engages the ring gear (C) so as to prevent stresses, wear and noise due to excessive speed of engagement in the initial stage of the starting operation. The device operates with a closed loop, with a signal generated by a tachometric sensor (SENS) associated with the electromagnet (EM).

FIG. 1



EP 0 727 577 A1

Description

The present invention relates in general to coupling devices and, more specifically, relates to a device for controlling a coupling electromagnet for association with starter motors used to start internal combustion engines.

As is known, the use of electric motors for starting combustion engines, particularly internal combustion engines, is very widespread. In the case of motor-vehicle internal combustion engines, this starting system has in fact now become standard.

In order to start an internal combustion engine by means of an electric starter motor, the motor and the engine are coupled by means of gears. A gear commonly known as a pinion is keyed to the shaft of the starter motor and a gear known as a ring gear and having a markedly larger diameter than the pinion is keyed to the engine shaft.

When the starter motor is supplied, it sets the engine shaft in motion by means of the meshed pinion and ring gear, starting the engine. Clearly, however, the pinion and the ring gear cannot be meshed permanently. In fact, if this were the case, once the engine had started, it would rotate the starter motor at high speed certainly damaging the two gears and/or the starter motor. For this reason, the starter motor therefore has an electromagnet for bringing about the meshing of the axially-slidable pinion with the ring gear so that their respective teeth mesh solely during the starting stage.

Although this system is approved and universally used in the automotive field, it is not without disadvantages. Starting systems according to the prior art do not in fact provide for any control of the supply to the electromagnet so that the pinion and the ring gear are subject to large stresses due to the excessive speed with which the pinion comes into contact with the ring gear. This excessive speed also causes an annoying noise particularly when the teeth of the pinion strike those of the ring gear. Moreover, since the engine tends always to stop in certain positions, the same teeth of the ring gear tend always to be affected by these impacts, resulting in localized wear.

Further problems may occur, for example, if, in operating the starter, the user keeps the starting contact closed for a longer period of time than necessary, thus causing the starter motor to be driven at high speed by the engine which, by that time, has started.

The object of the present invention is to provide a device for controlling a coupling electromagnet which solves all of the problems indicated above in a satisfactory manner.

According to the present invention, this object is achieved by virtue of a control device having the characteristics indicated in the claims which follow the present description.

Further advantages and characteristics of the present invention will become clear from the following detailed description, given with the aid of the appended drawings, provided purely by way of non-limiting example, in which:

Figure 1 is a block diagram of a starting system comprising a device according to the present invention,

Figure 2 is a functional diagram of a component of the device according to the invention,

Figure 3 is a functional diagram of an alternative embodiment of the component of Figure 2,

Figure 4 is a functional diagram of a further alternative embodiment of the component of Figure 2.

The present invention thus consists essentially of a device for controlling a coupling electromagnet and having the function of controlling the speed of operation of the electromagnet in order to eliminate the problems described above. Figure 1 is a block diagram of a starting system for a combustion engine comprising a control device of the type according to the present invention.

Naturally, the system comprises an electric starter motor MA to the shaft of which a pinion P is keyed. The pinion P can slide along its axis so as to be meshed with or disengaged from a ring gear C. The ring gear C is connected to the shaft of the engine to be started (not shown). Normally, the pinion P and the ring gear C are connected, that is, are meshed with one another, solely during the starting stage whereas, for the rest of the time, they are disconnected, that is, they are not meshed.

Typically, the pinion P is slid along its axis so as to mesh with the ring gear C by means of a lever operated by an electromagnet EM. The electromagnet EM is usually of the type with a drawn-in movable core. The movable core of the electromagnet EM also operates a switch INT by means of which the starter motor MA is supplied. After it has brought about the working travel with possible meshing of the pinion P with the ring gear C, the electromagnet EM thus also causes the starter motor MA to be supplied. Naturally both the electromagnet EM and the starter motor MA, like all of the components of the starter system, are supplied by an electrical storage battery BAT. This type of starting system is widely known and is conventional for vehicles driven by internal combustion engines.

In the case of the present invention, the electromagnet EM is no longer supplied, as in the prior art, simply by the closing of a switch, for example, by means of the ignition key of the vehicle, but is supplied by means of an operating device DC. The operating device DC, which is controlled by an electronic control unit UC, has the function of controlling the current supplied to the electromagnet EM. The control unit UC can thus control the speed of operation of the electromagnet EM and

consequently the operation of coupling the pinion P with the ring gear C.

In the present embodiment, the control unit UC is constituted by an electronic circuit and the operating device DC is constituted by a semiconductor switch device, for example a MOSFET.

In the specific embodiment, the control unit UC is configured so as to implement a closed-loop control system. The control unit UC therefore has to have a module CR for supplying a feedback signal indicative of the speed of operation of the electromagnet EM. The purpose of the control unit UC is, in fact, to control the speed of movement of the movable core of the electromagnet EM and the feedback signal supplied by the module CR therefore has to be a signal indicative of the speed of movement of the movable core.

In a currently-preferred embodiment, the control unit UC is also connected to a sensor PUT which can provide a signal indicative of the speed of rotation of the engine. The sensor PUT may, for example, be an electromagnetic sensor associated with a phonic wheel which, typically, is already present in engines fitted in vehicles currently in production. This signal enables the control unit UC to detect the starting of the engine which can be considered to have occurred when the speed of rotation exceeds a predetermined threshold value, for example 1000 revolutions per minute, for a certain period of time. Once it has detected the starting of the engine, the control unit UC cuts off the supply to the electromagnet EM to de-activate the starter motor MA and to disengage the pinion P from the ring gear C. Risks of damage owing to spinning of the starter motor are thus excluded.

Moreover, in a currently-preferred embodiment, there is a further sensor ST which measures the temperature of the starter motor which is considered to be the most important temperature, for example, that of the brush-holder plate. This measurement serves to disengage the motor, as in the previous case, to prevent thermal damage in the event of excessively prolonged starting and, at the same time, prevents the battery from being completely discharged in the event of difficulty in starting the engine, for example, because of carburation anomalies and persistent excessive starting by the user.

The control unit UC may also be interfaced with an engine management unit CM. This connection can serve for various purposes, for example, for the exchange of signals and data between the management unit CM and the unit UC in order to automate the starting operation, in order to implement diagnostic functions, to integrate the management unit CM and the unit UC, etc.

The control unit UC will now be described in greater detail. As stated above, the control unit UC operates with a closed loop. In the simplest case, the control unit UC regulates the current through the electromagnet EM in a manner such that its movable core moves at a constant predetermined speed. This type of closed-loop control is well known in the art and, as already stated, requires a signal indicative of the actual speed of the movable core of the electromagnet EM. The actual speed of the movable core may be measured (by means of a sensor), or estimated (by means of a model). Figure 2 is a functional block diagram of an embodiment of the device according to the present invention using a sensor.

In this embodiment, the control unit UC comprises a voltage-control module CDT which is supplied with the battery voltage VBAT and can control the supply voltage V of the winding A of the electromagnet EM. The voltage-control module CDT operates on the basis of an error signal ER generated by a subtraction node SUB. The subtraction node SUB receives an input signal SI indicative of the desired constant speed of the movable core from which a feedback signal SE, indicative of the actual speed of the movable core, is subtracted. The signal SE is generated by a tachometric sensor SENS associated with the electromagnet EM. This type of control system, which is known in the art, thus allows the desired speed of the movable core (the signal SI) to be set, the system then providing for this speed to be reached and maintained.

Figure 3 shows an alternative embodiment in which a model is used to estimate the actual speed of the movable core instead of a measurement sensor SENS. In Figure 3, parts and elements already described with reference to Figure 2 have again been given the same alphanumeric symbols. As can be seen from Figure 3, the embodiment shown therein differs essentially in the way in which the feedback signal SE indicative of the actual speed of the movable core is generated.

A measurement resistor RMIS (also called a shunt) in series with a winding A of the electromagnet EM can pick up a signal I indicative of the current through the winding A. This signal I is supplied to the input of an estimator module MOD, together with a signal V indicative of the supply voltage of the winding A. The estimator module MOD uses a model of the electromagnet EM and is configured to calculate the actual speed of the core from the signals I and V. The estimator module MOD thus generates a signal SE indicative of the actual speed of the core. This signal SE is supplied to a subtraction node SUB. As can be seen from Figure 3, the rest of the system is as described with reference to Figure 2 and operates in essentially the same way.

As a result of experimental tests carried out by the Applicant, the embodiment using the tachometric sensor SENS is considered preferable. In fact, it is possible to use a tachometric sensor which is extremely simple and cheap and, at the same time, has good performance suitable for achieving the desired aims.

In a currently-preferred embodiment, the tachometric sensor SENS, which can be seen in Figure 4, is constituted by a small permanent magnet MAG associated with the movable core of the electromagnet EM and cooperating with a winding W carried by a fixed support. The movement of the permanent magnet MAG produces an electrical voltage at the ends of the winding W

and this can be used as a signal indicative of the speed of movement of the movable core.

A possible embodiment of the tachometric sensor SENS which can be used advantageously in association with the control device according to the invention is described in a corresponding patent application filed in the Applicant's name simultaneously with the present application.

The control device according to the invention may conveniently be formed so as to operate with pulse amplitude modulation. Figure 4 shows an embodiment using precisely this type of technique. As can be seen, the current in the winding A of the electromagnet EM is controlled by a MOSFET transistor T. The transistor T is driven by a hysteretic comparator circuit AMP which provides for the pulse amplitude modulation control. Naturally, the comparator AMP operates on the basis of an error signal ER derived from a constant signal SI indicative of the desired speed set and from a signal SE indicative of the actual speed of the core generated by the tachometric sensor SENS described above.

The embodiment of the device according to the invention shown in Figure 4 also provides for the use of differential feedback to improve the control of the speed of the movable core. For this purpose, a signal DER indicative of the differential of the current passing through the winding A is picked up from the winding A. In practice, this signal DER is produced by the measurement of the differential of the instantaneous magnetic flux which passes through the winding of the sensor SENS as the leakage flux from the main solenoid of the electromagnet EM, which is indicative of the current. The differential of the flux is obtained simply from the voltage induced in the sensor SENS.

The main function of this signal DER is to limit the rise or fall of the current in the transistors to corrected values, preventing undesired oscillations of the control system. The signal DER thus passes through a first subtraction node SUB1 together with the signal SE indicative of the actual speed of the movable core. In practice, the subtraction node SUB1 is formed in the structure of the sensor SENS itself.

The resulting signal generated by the subtraction node SUB1 is then sent to the input of a second subtraction node SUB2 which also receives an input signal SI indicative of the speed set. As described above, the subtraction node SUB2 generates an error signal ER on the basis of which the comparator AMP regulates the supply current in the winding A.

The device according to the invention may also be formed so as to control the speed of movement according to a predetermined curve with the speed being variable over time rather than at a constant speed, for example, if the mechanical characteristics of the starting system make this appropriate. In this case, it suffices to form the sensor SENS in a manner such that the signal generated by the sensor SENS is not linear. This can be achieved by means of a non-linear configuration of the sensor SENS achieved, for example, by tapering or shaping of the core on which the winding W of the sensor SENS is wound.

The use, described with reference to the present embodiment, of a logic signal MAN generated by means of the switch INT for the supply of the starter motor MA is also advantageous. The signal MAN indicates that the starter motor has been supplied and consequently that the pinion P has completed its travel. In practice, this means that the movable core of the electromagnet EM has reached the end of its travel. The detection of this condition is useful since, once the core has reached the end of its travel, it suffices for the control device to keep the movable core in the position reached by controlling the current in the winding A and limiting the power dissipation therein, particularly during prolonged starting.

The signal MAN therefore has the effect of modifying the operating condition of the control device and hence the reference for the control unit UC which, in this case, will be a speed of zero. This is advantageous since it permits the use of electromagnets EM with single windings instead of the electromagnets with double windings used in the prior art, in which the second winding intervenes upon completion of the travel with a holding force corresponding to a relatively low current (and hence dissipation).

As stated above, moreover, the device according to the invention can be configured so as to cut off the supply to the electromagnet EM when it detects that the engine has started. In order to detect this condition, as disclosed above, the device may use a sensor PUT for detecting the speed of rotation of the engine.

The device according to the invention thus achieves many advantages, the main advantage being the low speed of impact of the pinion P on the ring gear C. This consequently limits noise and mechanical wear of these components, improving the overall reliability and life of the starting system.

The device according to the invention also enables the starting operation to be automated with a consequent overall improvement in product image and technical advantages due, for example, to the reduction of emissions caused by false starts which were possible with systems of the prior art. The device according to the invention also enables diagnostic functions of the starting system to be implemented, for example, by making use of the data obtained by the tachometric sensor SENS.

As already stated, the device according to the invention simplifies the production of the winding A of the electromagnet EM by eliminating the holding winding commonly used for keeping the movable core in its travel limit position. This reduces the cost of the electromagnet EM and, moreover, makes it less sensitive to production parameters by virtue of the fact that larger holding currents can be used.

Naturally, the principle of the invention remaining the same, the details of construction and forms of embodiment may be varied widely with respect to those

described and illustrated, without thereby departing from the scope of the present invention.

Claims

1. A device for controlling the speed of a coupling electromagnet (EM) for bringing about the meshing of a first gear (P) with a second gear (C) by means of a translational movement of the first gear (P), characterized in that it comprises:

   - sensor means (CR) for generating a signal (SE) indicative of the actual speed of movement of the first gear (P) or of the electromagnet (EM),
   - processing means (UC) receiving, as inputs, the signal (SE) indicative of the actual speed of movement and a signal (SI) indicative of a predetermined reference speed of movement,
   - switch means (DC) driven by the processing means (UC) for controlling the passage of current through the electromagnet (EM),

   the processing means (UC) being configured for regulating the supply current of the electromagnet (EM) so as to render the actual speed of movement substantially equal to the predetermined reference speed.

2. A device according to Claim 1, characterized in that the sensor means (CR) comprise a tachometric sensor (SENS) for generating a voltage signal (SE) indicative of the actual speed of movement of a movable core of the electromagnet (EM).

3. A device according to Claim 1, characterized in that the sensor means (CR) comprise a sensor (SENS) associated with the electromagnet (EM) for generating a signal (DER) indicative of the differential of the current passing through the winding (A).

4. A device according to Claim 3, characterized in that the processing means (UC) are configured so as to implement a differential control on the basis of the signal (DER) indicative of the differential of the current passing through the winding (A).

5. A device according to any one of Claims 1 to 4, characterized in that it is configured so as to operate with pulse amplitude modulation.

6. A device according to Claim 5, characterized in that it comprises a comparator circuit (AMP) for driving the switch means (INT) with pulse amplitude modulation.

7. A device according to Claim 6, characterized in that the comparator circuit (AMP) is a hysteretic comparator circuit.

8. A device according to any one of Claims 1 to 7, characterized in that the sensor (SENS) is configured so as to generate the voltage signal (SE) indicative of the actual speed of movement of the movable core of the electromagnet (EM) in a non-linear manner.

9. A device according to any one of Claims 1 to 8, in which the electromagnet (EM) is a coupling electromagnet for a starter motor (MA) for a combustion engine, characterized in that the processing means (UC) receive an input signal indicative of the fact that the combustion engine has started and are configured to cut off the supply of the electromagnet (EM) when this situation occurs.

10. A device according to Claim 9, characterized in that the signal indicative of the fact that the engine has started is a signal indicative of the speed of rotation of the combustion engine and in that the processing means (UC) are configured so as to detect the exceeding of a predetermined threshold value of the speed of rotation.

11. A device according to Claim 9 or Claim 10, characterized in that the processing means (UC) receive an input signal indicative of the temperature of the starter motor (MA) and are configured to cut off the supply of the electromagnet (EM) when the temperature exceeds a predetermined threshold value.

12. A device according to Claim 11, characterized in that the temperature is detected by means of a temperature sensor associated with a brush-holder plate of the starter motor (MA).

13. A device according to any one of Claims 1 to 12, characterized in that the processing means (UC) receive an input signal (MAN) indicative of the fact that a travel limit position of the first gear (P) has been reached and are configured to control the supply of the electromagnet (EM) so as to keep the first gear (P) in that position when this condition occurs.

14. A device according to Claim 13, characterized in that the signal (MAN) indicative of the fact that the travel limit position has been reached is a signal indicative of the fact that the starter motor (MA) has been supplied.

FIG. 1

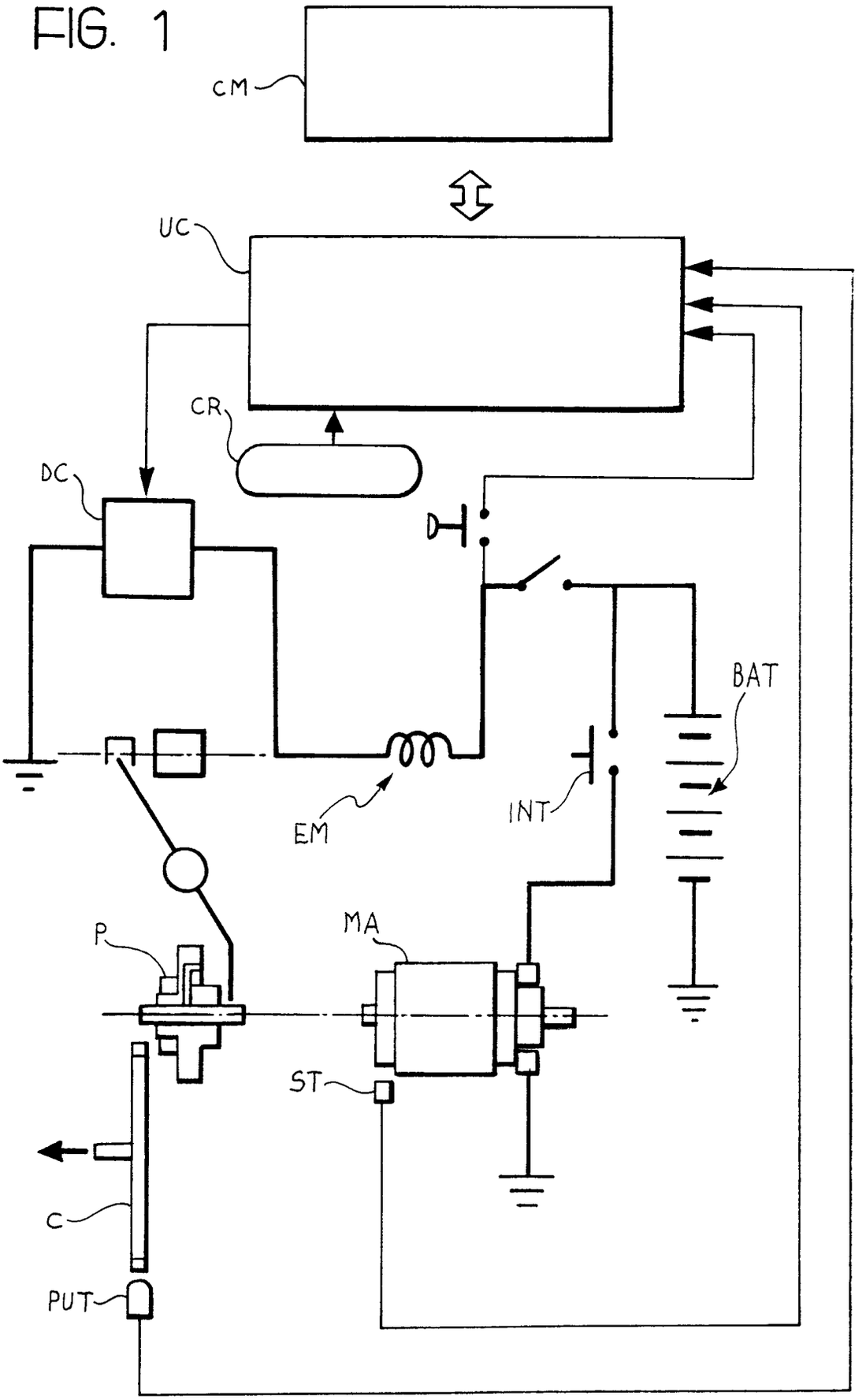


FIG. 2

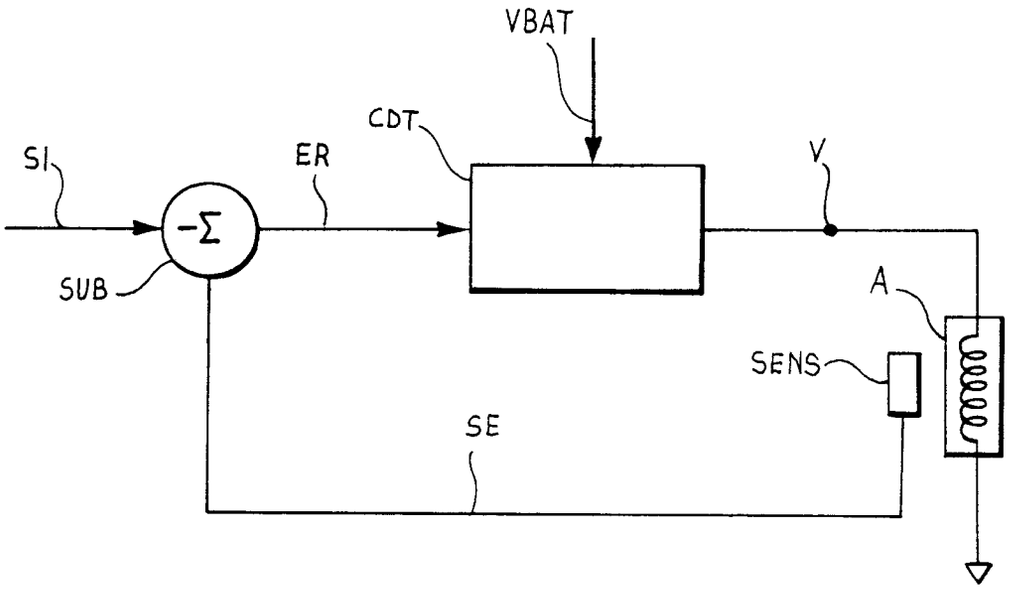
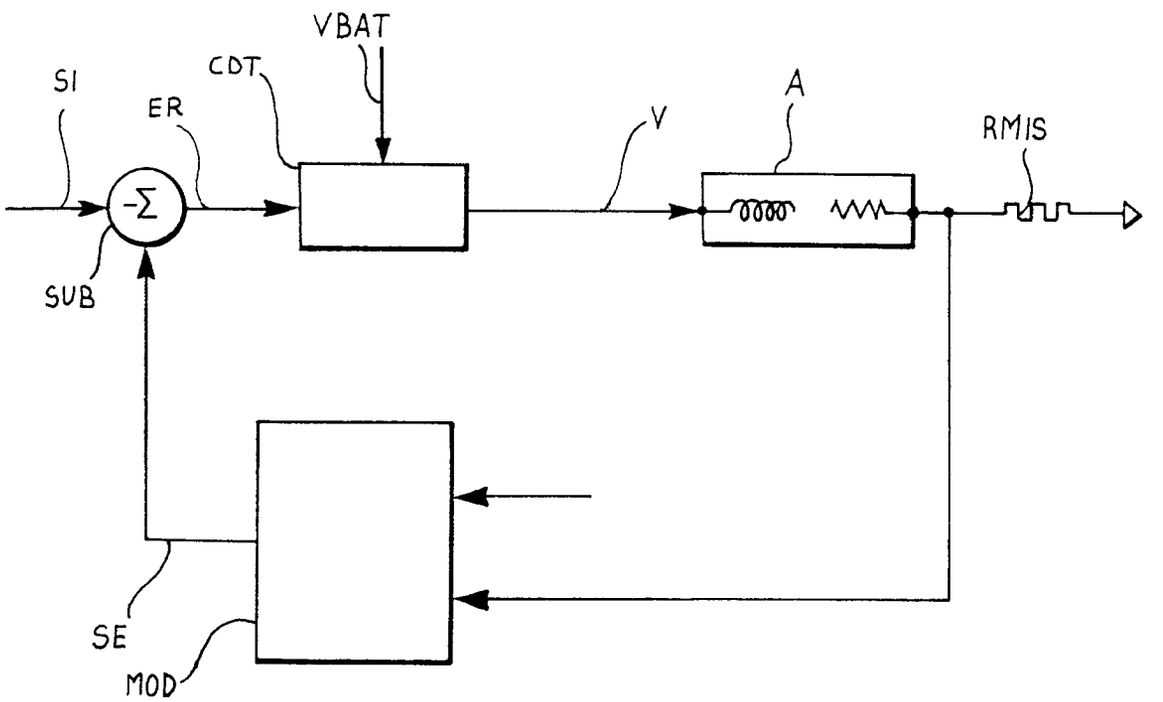


FIG. 3



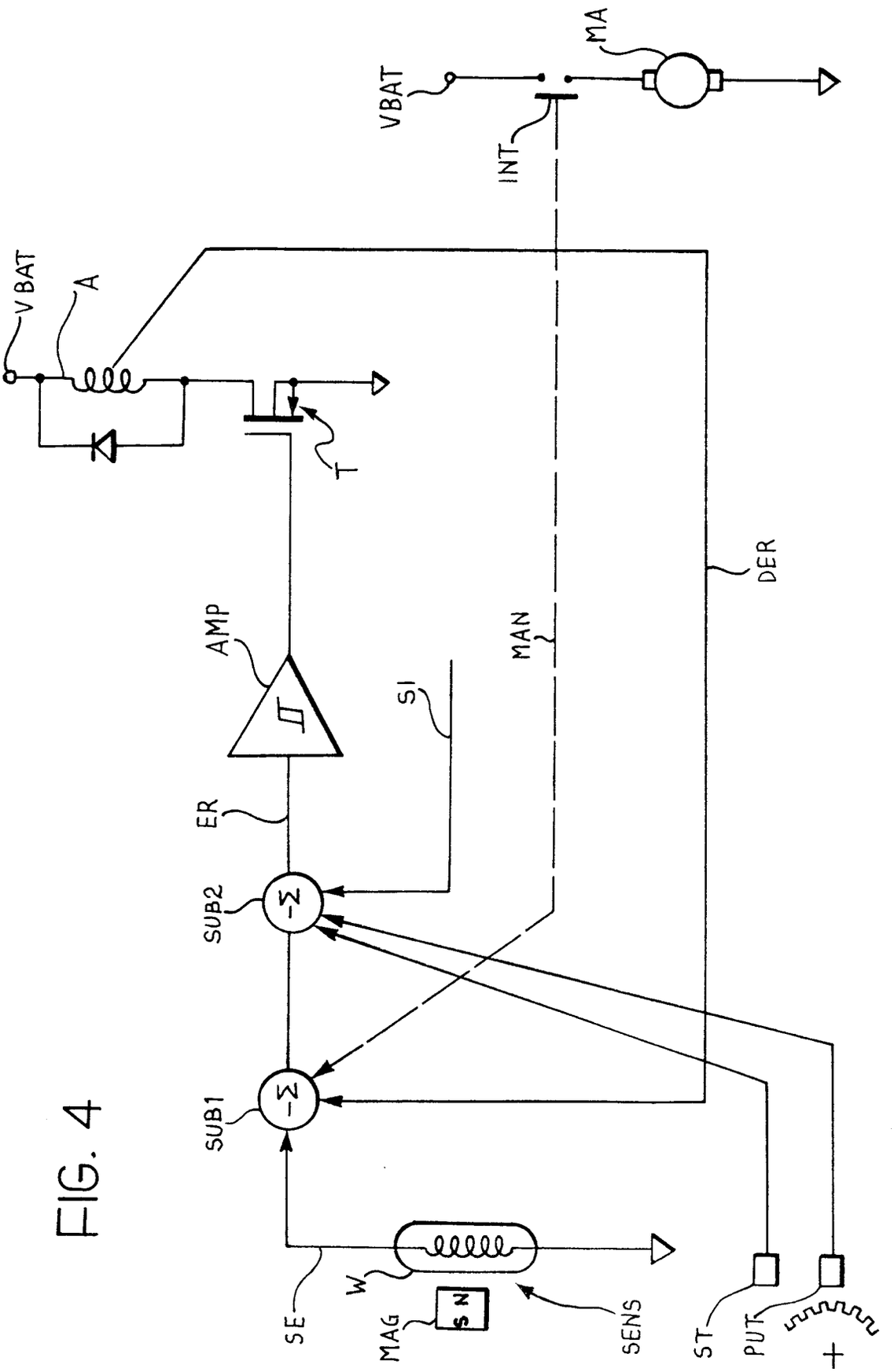

VBAT
MA
INT
V BAT
A
T
DER
AMP
MAN
SI
ER
SUB2
SUB1
SE
W
MAG
SENS
ST
PUT
+

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 2242

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.6)
Y	EP-A-0 562 457 (MAGNETI MARELLI SPA) 29 September 1993	1,2	F02N11/08
A	* column 4, line 43 - column 5, line 16; figure 2 *	13,14	

Y	PATENT ABSTRACTS OF JAPAN vol. 004, no. 145 (E-029), 14 October 1980 & JP-A-55 095306 (MARANTZ JAPAN INC), 19 July 1980,	1,2	
A	* abstract *	8	

A	WO-A-93 11369 (CATERPILLAR INC) 10 June 1993 * abstract *	3,4	

A	US-A-4 917 410 (CUMMINS DONALD L ET AL) 17 April 1990 * abstract *	5	

A	US-A-4 862 010 (YAMAMOTO KYOHEI) 29 August 1989 * column 8, line 32 - line 56; figure 1 *	9,10	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
	---		F02N H01F
A	EP-A-0 246 140 (VALEO) 19 November 1987 * abstract *	12,13	

A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 014 (M-108), 27 January 1982 & JP-A-56 132461 (TOYOTA MOTOR CORP), 16 October 1981, * abstract *		

A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 066 (E-1034), 15 February 1991 & JP-A-02 290142 (HITACHI LTD;OTHERS: 01), 30 November 1990, * abstract *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 May 1996	Marti Almeda, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)