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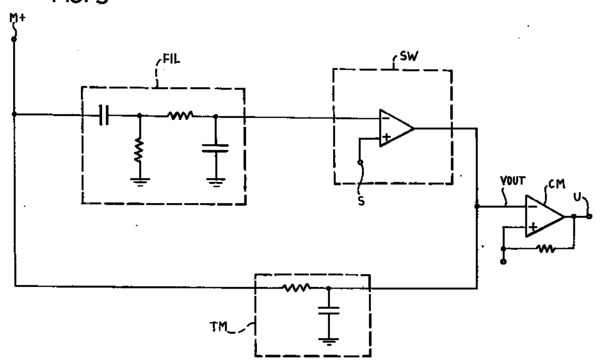
(54) A circuit for detecting the starting of an internal combustion engine

(57) An electronic circuit for detecting the starting of an internal combustion engine, in particular for motor cars, configured to detect the variation in the voltage drop (V) on the supply cable to the starter motor (MA). Starting of the internal combustion engine is detected when the voltage (V) no longer oscillates. The circuit further includes an intrinsic time delay interval for the purpose of discriminating false starts, and a starting memorisation circuit.

FIG. 5



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Description

The present invention relates in general to circuits for detecting the starting of an internal combustion engine, in particular for motor car applications. More specifically the present invention relates to a circuit for detecting the starting of an internal combustion engine by detecting an electrical parameter of an electric starter motor associated with the said internal combustion engine.

The problem of detecting the starting of an internal combustion engine is known in the art. 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 toothed wheels. On the drive shaft of the starter motor is fitted a first toothed wheel, commonly called a pinion, whilst on the crankshaft of the internal combustion engine is fitted a second toothed wheel, called the starter ring, having a significantly greater diameter than that of the pinion.

Upon energising the starter motor this, via the pinion and the starter ring which mesh together, drives the crankshaft of the internal combustion engine thereby permitting starting thereof. The starter motor is provided with a solenoid intended to cause the pinion to engage the starter ring in such a way that the respective teeth mesh only with the starter contact closed and thus with the starter key actuated. It is evident, in fact, that the pinion and the starter ring must be in mesh with one another only for the time necessary for starting of the internal combustion engine in order to avoid excessive wear of the electric starter motor. The starter motor mechanically disengages after starting has occurred thanks to a mechanical device called a "free wheel" but could remain in motion at high speed if the user, the driver in this case, persists in maintaining the starter key actuated.

The prior art system, although tested and universally adopted in the automotive field, does not provide any control for disengaging the supply to the starter motor which can therefore be subject to greater wear than strictly necessary.

It can happen, as noted, that the vehicle's driver, when starting the engine, maintains the starter contacts closed for a longer period of time than necessary. In this case the pinion remains engaged with the starter ring (but mechanically the coupling with the engine is disengaged by the free wheel) and the starter motor remains energised, even though the internal combustion engine has started, until the driver decides to terminate the starting action.

In fact, as anticipated above, a free wheel associated with the pinion is or has been until now universally adopted. This free wheel permits the pinion to rotate at a speed greater than that of the starter motor. In this way, when the internal combustion engine starts, and exceeds the speed at which it is driven by the starter motor, it uncouples from the starter motor thanks to the free wheel. In this case, therefore, the pinion is driven at high speed whilst the starter motor spins with no load.

This arrangement, although it solves the problems of possible "centrifugation" of the starter motor, does not solve the other problems due to excessively prolonged starting operations. These problems consist for example in excessive wear of the starter motor with consequent retirements for a high current from the battery on the vehicle.

In the past there have been proposed devices operable to detect the starting of the internal combustion engine for the purpose of being able to disengage the starter motor and the solenoid. In practice that which is disengaged is the supply to the solenoid which, in the absence of current, disengages the pinion from the starter ring and further interrupts the supply of current to the starter motor.

There are known in the art systems for detecting starting of the internal combustion engine based on processing a phonic wheel signal indicative of the rotation of the internal combustion engine's crankshaft, performed by an electronic central control unit of the internal combustion engine. This arrangement makes it possible to detect starting on the basis for example of a speed of rotation threshold of the internal combustion engine. This system, although effective, does however have the disadvantage of increasing the complexity of the electronics on board the vehicle in that it requires additional connections between the starter control device, typically the ignition key switch, the electronic central control unit of the internal combustion engine and the starter motor. A system of this type is for example described in European Patent Application No. EP-A-0 562 456 and No. EP-A-0 727 577.

There are also known detection systems using a sensor, associated with the starter motor, operable to detect the speed of rotation of the starter motor. Such a system is for example described in Italian Patent Application No. TO94A000917 filed 16 November 1994. Such systems have the advantage of being completely integrated in the starter motor so that the use of additional connections is no longer necessary. Prior art systems of this type have, however, the disadvantage of still being relatively complex to produce.

There are also known in the prior art systems for detecting the current in the starter motor so as to determine disengagement of the starter motor when this current no longer oscillates.

In fact, when the starter motor drives the internal combustion engine to rotate the current consumed by the electric motor has an oscillating or pulsing form due to the load variations caused by the compression phases of the various cylinders of the internal combustion engine. When the internal combustion engine starts, the free wheel uncouples the starter motor and therefore this latter starts to run with no load and to consume a substantially constant current without further oscillations.

It is assumed, therefore, that when this condition occurs the internal combustion engine has started; a certain interval of time is nevertheless allowed to pass to ensure that the engine has truly started and there is no false start, after which disengagement of the starter motor takes place. This arrangement has, however, the disadvantage of requiring an intrustive current measurement that is to say a measurement effected by means of a measuring resistor or shunt, or by means of a magnetic field sensor; such systems are complex and of not insignificant cost.

This arrangement, however, is interesting in that it no longer requires a speed sensor positioned within the engine to be started but only a sensor for detecting the current consumed by the starter motor. This arrangement, moreover, no longer requires the detection of the speed of revolution of the internal combustion engine by means of a phonic wheel sensor or other similar devices operable to perform this function.

The object of the present invention is that of providing a device for detecting the starting of an internal combustion engine which allows the above-indicated problems of the prior art arrangements to be resolved in a satisfactory manner.

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

Further advantages and characteristics of the present invention will be evident from the following detailed description given with the aid of the attached drawings provided purely by way of non-limitative example, in which:

- Figure 1 is a schematic representation of a starter motor having a solenoid and using a device according to the present invention;
- Figure 2 is a Cartesian timing diagram illustrating the starting phase of the internal combustion engine;
- Figures 3 and 4 are two Cartesian timing diagrams illustrating the principle of operation of the device according to the invention; and
- Figure 5 is a block schematic representation of the device according to the present invention.

The device according to the invention can advantageously be formed completely within the solenoid of the starter motor. It can therefore be completely integrated into the solenoid therefore allowing a completely self-contained and self-controlled system to be formed.

The idea on which the invention is based is that of detecting the voltage across the terminals of the starter motor rather than the current which flows through it. As can be seen, figure 2 shows the variation in the speed of rotation of the internal combustion engine, indicated RPM, and the current consumed by the starter motor indicated I, during starting. The speed of rotation RPM of the internal combustion engine, initially nil, subsequently increases until it reaches a modest and substantially constant value about the order of 200 revolutions per minute, by the effect of the starter motor. During this phase, in fact, the internal combustion engine is being driven by the starter motor and has not yet started.

The speed of rotation RPM of the internal combustion engine is not constant but oscillates or pulses because of the compressions which arise in the various cylinders. Correspondingly the current I consumed by the starter motor also assumes, after an initial peak in the current through the starter motor, a pulsing variation due to the variable load because of the compressions, which the motor must overcome to drive the internal combustion engine to rotate.

When the internal combustion engine starts it can be seen how the speed of rotation RPM increases significantly and with a decided acceleration. Correspondingly the current I consumed by the starter motor falls and ceases to pulse in that the starter motor is uncoupled from the internal combustion engine by the free wheel associated with the pinion and now runs free.

As previously mentioned, some prior art detection systems use the current I consumed by the starter motor for this purpose by detecting the absence of pulsations in it to determine the starting of the internal combustion engine.

In the case of the device according to the present invention, on the other hand, it is the voltage drop across the supply cables of the starter motor which is detected. More specifically, the voltage on the positive supply terminal of the starter motor is detected.

For a better understanding a starter motor MA using a device according to the present invention will now be described with reference to Figure 1. As can be seen the starter motor MA is provided with a pinion P for the purpose of being able to connect to an internal combustion engine (not illustrated) by means of a ring gear (not illustrated). The starter motor MA has associated with it an electromagnet (or solenoid) EM serving to engage the pinion P on the ring gear and, in an almost simultaneous manner, energising the starter motor MA.

For the purpose of energising the starter motor MA the solenoid EM closes an electrical contact between two terminals. One of these two terminals, indicated V+, is connected by a cable of large dimensions (not illustrated) to the positive battery terminal (not illustrated). The other of these two terminals, indicated M+ is connected to the positive supply terminal of the starter motor MA which naturally is adjacent to it. These connections and the contacts actuated by the solenoid EM are of large cross-section in that the current consumed by the starter motor MA is very high.

During operation of the starter motor MA there is therefore a not insignificant voltage drop on the supply cable which connects the battery to the terminal V+ of the solenoid EM. This voltage drop is significant even though the supply cable has a large cross-section in that the currents which flow are very high, and is of the order of several hundreds of millivolts. The internal resistance of the battery which also generates a voltage drop additional to the voltage drop on the supply cable must also be considered.

For the purposes of the present invention, however, it is not of interest to detect this voltage drop in an absolute manner; what is of interest is essentially its variation, that is to say the variations in the voltage drop. This voltage drop is therefore detected by sensing the voltage present on the supply terminal of the starter motor MA, for example the terminal M+.

In all current systems there is, moreover, a further terminal, indicated C in the drawing, disposed on the solenoid EM. This terminal C is the terminal by means of which the winding of the solenoid EM is supplied, which must obviously be separated from the supply cable connected to the terminal V+ of the starter motor MA.

The device according to the invention therefore detects the voltage present on the terminal M+. This voltage on the terminal M+ has a variation substantially corresponding to the variation of the voltage drop due to the supply cable of the starter motor MA and to the internal resistance of the battery. The variation of this voltage, indicated V, is shown in Figures 3 and 4 which illustrate two starting operations. As will be noted, the voltage drop, and therefore the voltage V, during the starting phase has a characteristic variation and is consistent with the variation of the current I.

Before starting the voltage V is nil in that the supply contact of the starter motor MA is open. Upon closure of this contact the voltage V assumes a certain value given by the battery voltage less the voltage drop, this voltage V subsequently falls in that the current I diminishes as does the associated voltage drop. Further, when the starter motor MA starts to turn the voltage V assumes a pulsing variation exactly corresponding to the pulsing variation of the current I. This occurs because: $\Delta V = \Delta IR$ where R is the resistance of the supply cable plus the internal resistance of the battery. These pulsations have an amplitude of the order of hundreds of millivolts. Initially the current I is of the order of 100 or 200 Ampère upon closure of the contacts and subsequently, with the internal combustion engine started, the current falls to values of about 40 Ampère.

The variation of the voltage V can be utilised very advantageously to detect the starting. In fact, as mentioned, on the solenoid EM there is available the contact or rather the positive supply terminal M+ of the starter motor MA at which it is possible to effect a measurement of the voltage V. This contact M+ is, moreover, already available outside the solenoid EM in that it serves to determine the holding current of the solenoid EM at the end of the stroke. This contact thus costs nothing and makes it possible to achieve a device completely contained within the solenoid EM.

An embodiment of electronic circuit forming the device according to the present invention will now be described with reference to Figure 5 for a better understanding.

As can be noted, the circuit of the device according to the invention is very simple and comprises three fundamental blocks. These blocks are essentially constituted by a filter FIL, a threshold comparator SW and a timer or rather a circuit TM operable to form a voltage ramp.

The operation of this electronic circuit is very simple. In substance it effects detection of the pulsation of the voltage V. This voltage V is sent to a filter FIL which serves to eliminate disturbances. This filter FIL is constituted by a high-pass filter connected in series with a low-pass filter and therefore is, in practice, a band-pass filter. The output of the filter FIL is sent to an operational amplifier configured as a threshold comparator SW which functions as a switch. This comparator SW is configured to switch its output to ground when it detects a pulsation in the input signal V greater than a predetermined threshold S. This input voltage V is used, moreover, to command a timer TM formed with a circuit of RC type. This voltage V then goes, for example, to charge a capacitor of the RC circuit of the timer TM with a time constant greater than the period of the minimum starting frequency.

In this way, when the comparator SW commutes to ground, that is to say connects its output to earth, it discharges the capacitor of the RC circuit which was partially charged and therefore zeros the timer TM. In practice, upon each oscillation of the input voltage V, the comparator SW discharges the timer TM zeroing it. The timer TM therefore continually tries to charge itself and is discharged by each oscillation received on the input signal V. When the oscillations on the input signal V cease the timer TM is then no longer zeroed or discharged by the comparator SW and can therefore become fully charged.

The voltage at the output of the comparator SW and the timer TM, indicated VOUT, therefore rises in value because of the absence of the oscillations of the input signal V. Because of this, when the oscillations cease the voltage VOUT, increased by the timer TM, rises until it reaches a predetermined threshold (for example 4 volts) to which an output comparator with memory CM is sensitive and which therefore commutes its output U which is also the output of the circuit. This configuration makes it possible to obtain a delay time interval, mentioned above, which is needed in order to be certain that starting of the internal combustion engine has effectively taken place and that it is not a false start.

The time delay interval is therefore intrinsic to the circuit according to the invention and is given by the time constant of the timer TM. The output threshold comparator CM, receiving at its input the voltage VOUT at the output of the timer TM and the comparator SW, therefore makes it possible to generate the output signal U which is indicative of the starting of the internal combustion engine.

This output signal U is locally memorised by the comparator CM, which is configured with a positive feedback, and therefore evidently can be utilised to disconnect the supply from the solenoid EM as previously mentioned.

This positive feedback on the output comparator CM is essential in that it serves to ensure that the disconnection of the starter motor MA is stable. If, in fact, this positive feed back were not there, upon exceeding the predetermined threshold value for the output voltage VOUT the comparator CM would, as envisaged, cause disengagement of the supply to the starter motor MA. However, disconnection of the supply would mean that the supply terminal M+ of the starter motor MA would no longer be supplied. This would mean that the timer TM, also supplied via the terminal M+, would discharge causing lowering of the output voltage VOUT. Consequently the output comparator CM would again switch and this would mean that the starter motor MA would be again supplied.

It is therefore necessary to insert a positive feedback on the output comparator CM which ensures that when the comparator CM commutes because the output voltage VOUT exceeds the threshold, this condition remains stable and can no longer be modified by variations of the output voltage VOUT.

This memorisation is cancelled when the driver of the vehicle releases the ignition key therefore cutting off supply to the whole circuit thereby returning it completely to the initial conditions in which it is supplied, as seen, by the terminal C.

Note therefore how the circuit just described is very simple and of low cost to perform the desired function in a very reliable and precise manner.

Naturally, the principle of the invention remaining the same, the details of construction and the embodiments can be widely varied with respect to what has been described and illustrated, without by this departing from the ambit of the present invention as defined in the attached claims.

Claims

1. A device for detecting the starting of an internal combustion engine having an associated electric starter motor (MA) and a device operable automatically to uncouple the said internal combustion engine from the said starter motor (MA) when the said internal combustion engine, having started, exceeds the speed at which it is driven by the said starter motor (MA), the said device comprising:

    - sensor means (FIL, SW) operable to detect the presence of oscillations of a voltage (V) on a supply terminal (M+) of the said starter motor (MA),
    - switching means (TM, CM) operable to generate an output signal (U) indicative of the starting of the said internal combustion engine, which acts to switch off the said starter motor (MA) in the absence of the said oscillations in the said voltage (V).

2. A device according to Claim 1, characterised in that:

    - the said switching means (TM, CM) comprise a timer circuit (TM) operable to generate the said output signal (U) for switching the said starter motor (MA) off after a predetermined time interval and activated upon supply of the said starter motor (MA),
    - the said sensor means (FIL, SW) are configured in such a way as to zero the said time circuit (TM) at each detected oscillation of the said voltage (V).

3. A device according to Claim 2, characterised in that the said sensor means (FIL, SW) comprise a filter (FIL) and a first comparator circuit (SW).

4. A device according to Claim 3, characterised in that the said filter (FIL) is a band-pass filter.

5. A device according to Claim 3 or Claim 4, characterised in that the output of the said first comparator circuit (SW) commutes in the presence of each oscillation of the said voltage (V).

6. A device according to Claim 5, characterised in that the output of the said first comparator circuit (SW) switches its output in the presence of each oscillation of the said voltage (V) having an amplitude greater than a first predetermined threshold value (S).

7. A device according to any of Claims from 2 to 6, characterised in that the said timer circuit (TM) comprises a circuit operable to generate a ramp voltage (VOUT) and in that the said sensor means (FIL, SW) are configured in such a way as to discharge to earth the said voltage (VOUT) generated by the said ramp generator circuit.

8. A device according to Claim 7, characterised in that the said switching means (TM, CM) comprise a second comparator circuit (CM) configured to emit the said output signal (U) acting to turn off the said starter motor (MA) when the said voltage (VOUT) generated by the said ramp generator circuit exceeds a second predetermined threshold value.

9. A device according to Claim 7 or Claim 8, characterised in that the said ramp generator circuit is an RC circuit.

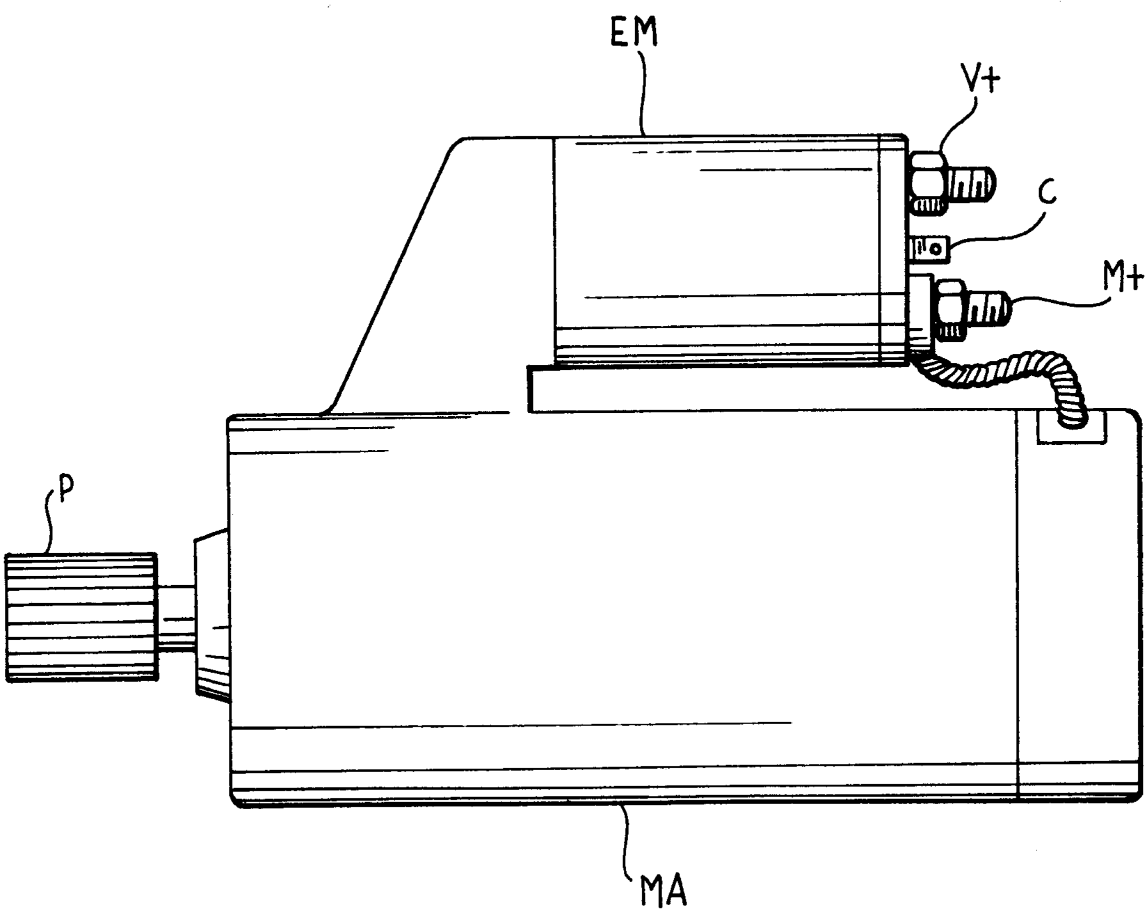
10. A device according to any of Claims from 1 to 9, characterised in that it is configured so as to memorise the said output signal (U) in a stable manner after starting of the internal combustion engine has taken place.

11. A device according to Claim 10, characterised in that the said comparator circuit (CM) is configured with a positive feedback to memorise the said output signal (U), indicative of the starting of the said heat engine, when the said voltage (VOUT) generated by the said ramp generator circuit exceeds the said second predetermined threshold value.

12. A device according to Claim 10 or Claim 11, characterised in that the memorisation of the said output signal (U) indicative of the starting of the said internal combustion engine is cancelled when a user of the said internal combustion engine interrupts supply to a solenoid (EM) associated with the said starter motor (MA).

13. A device according to Claim 12, characterised in that it is integrated and contained within the said solenoid (EM).

FIG. 1



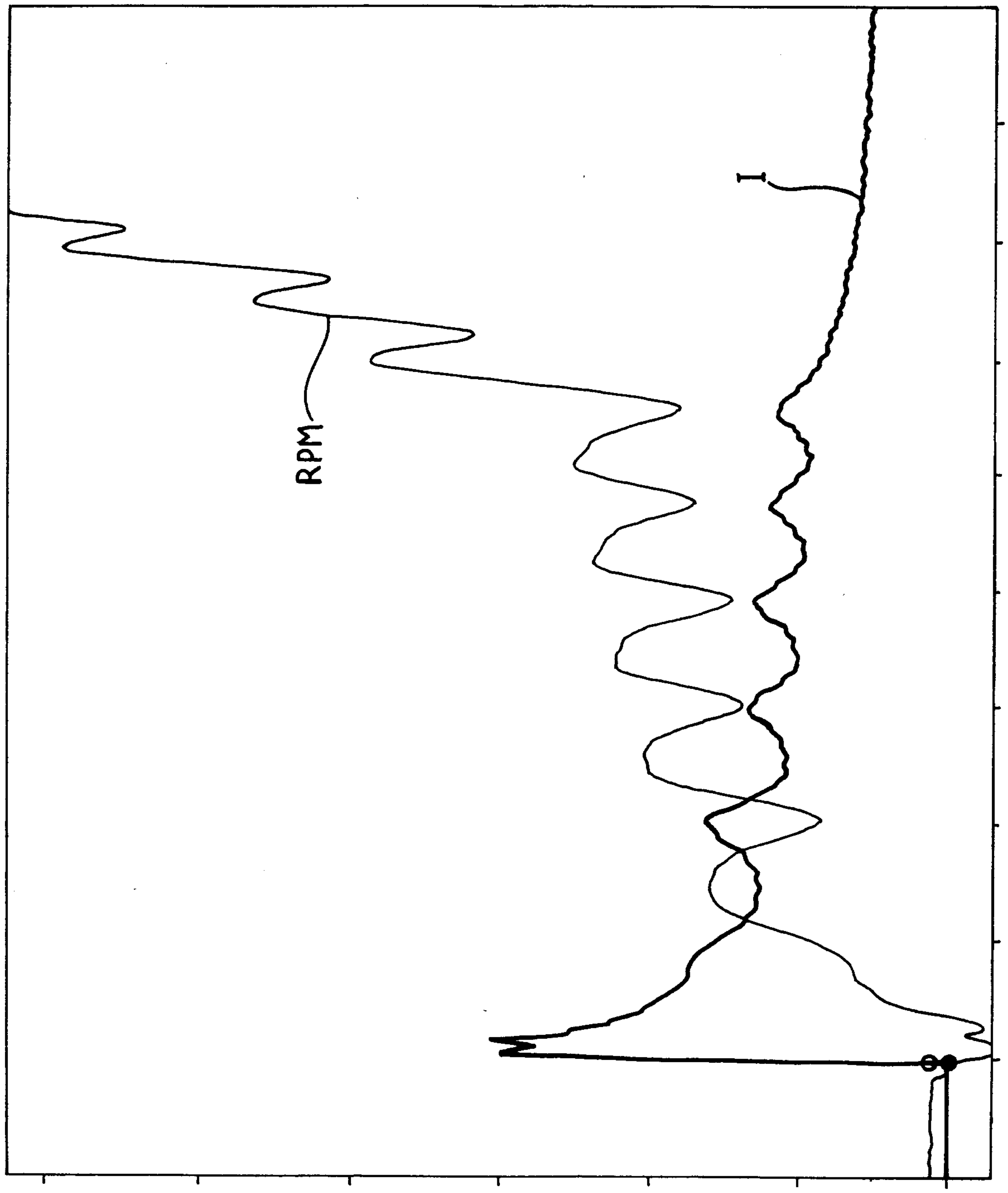


FIG. 2

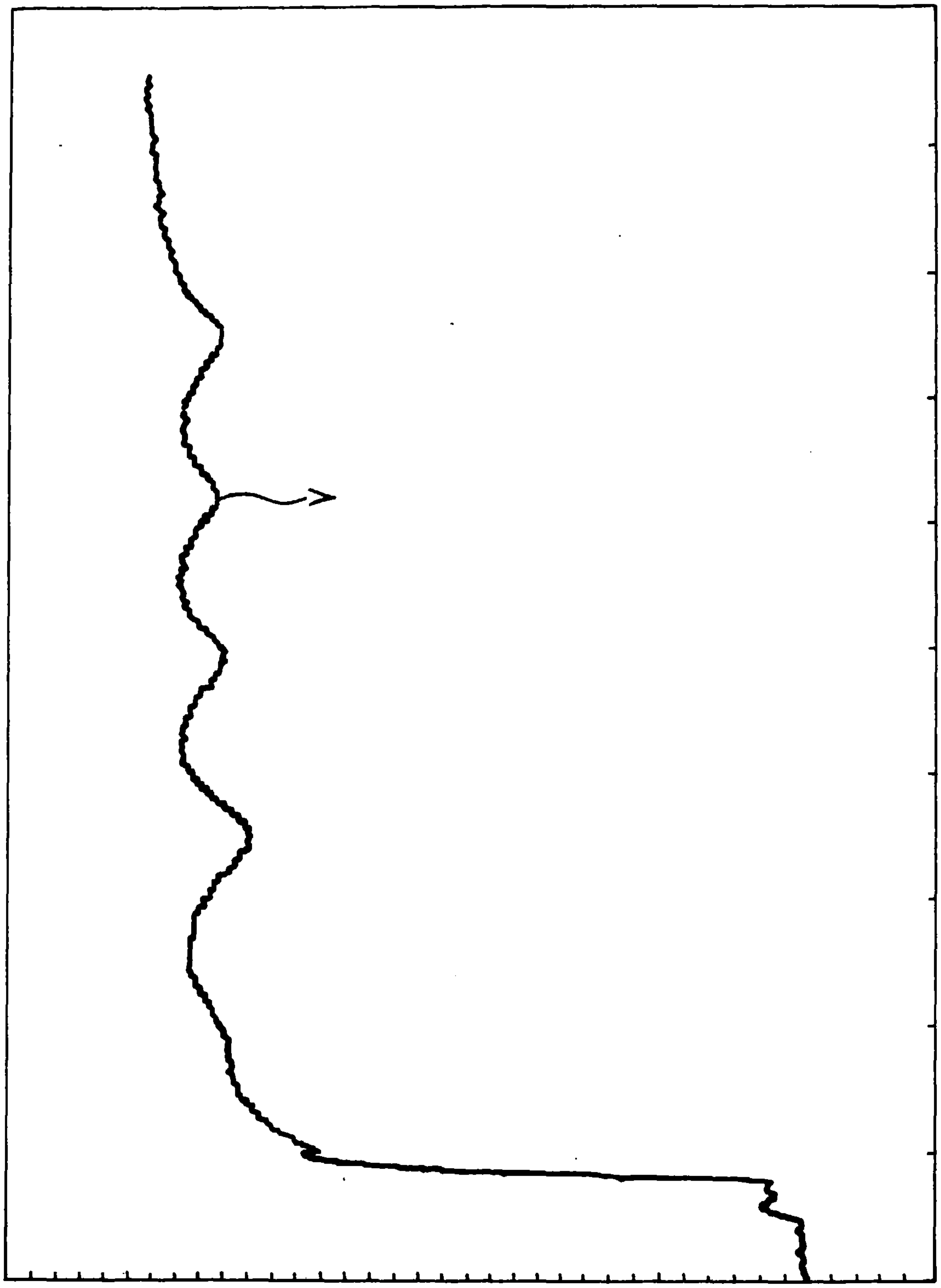


FIG. 3

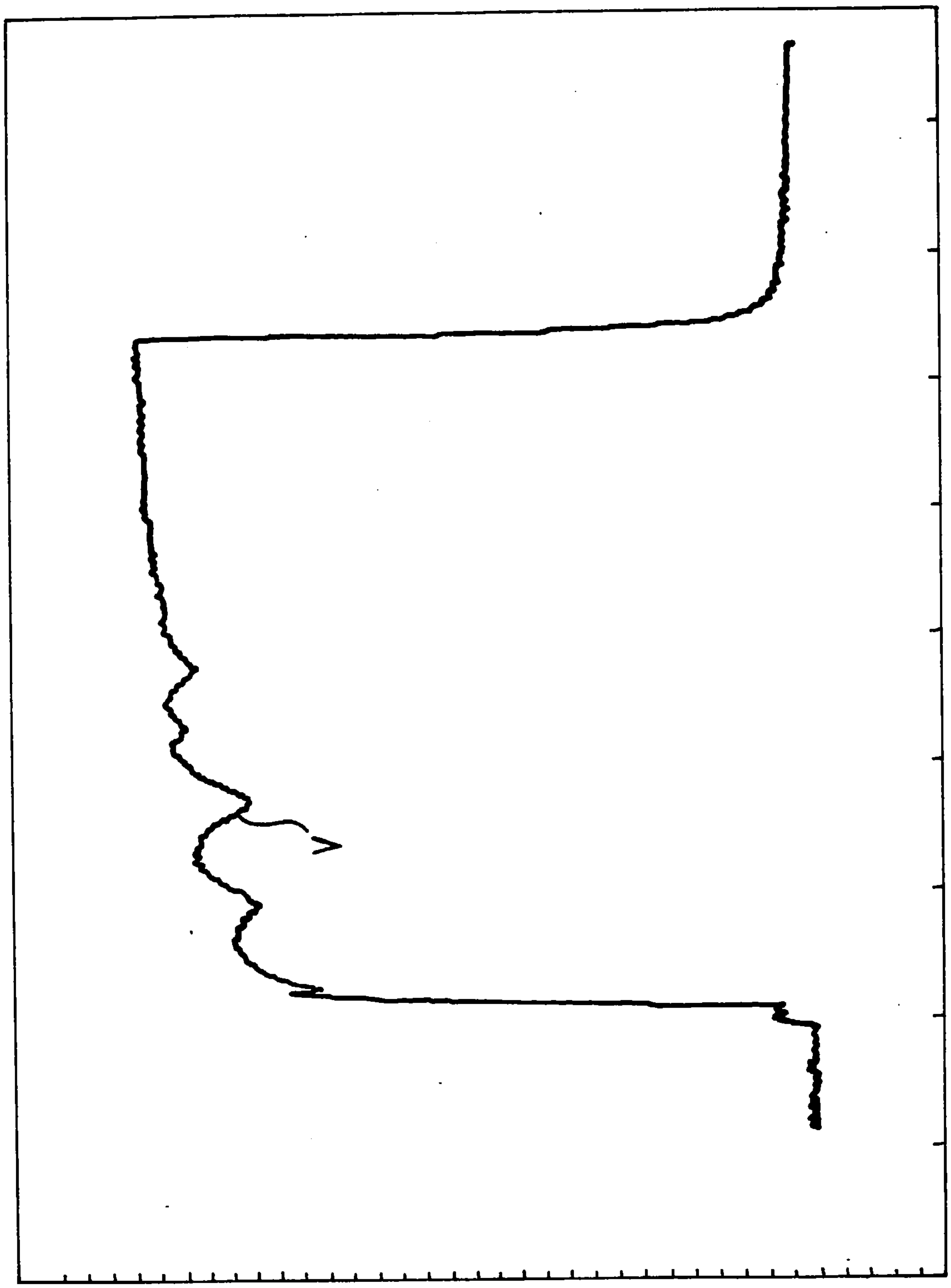
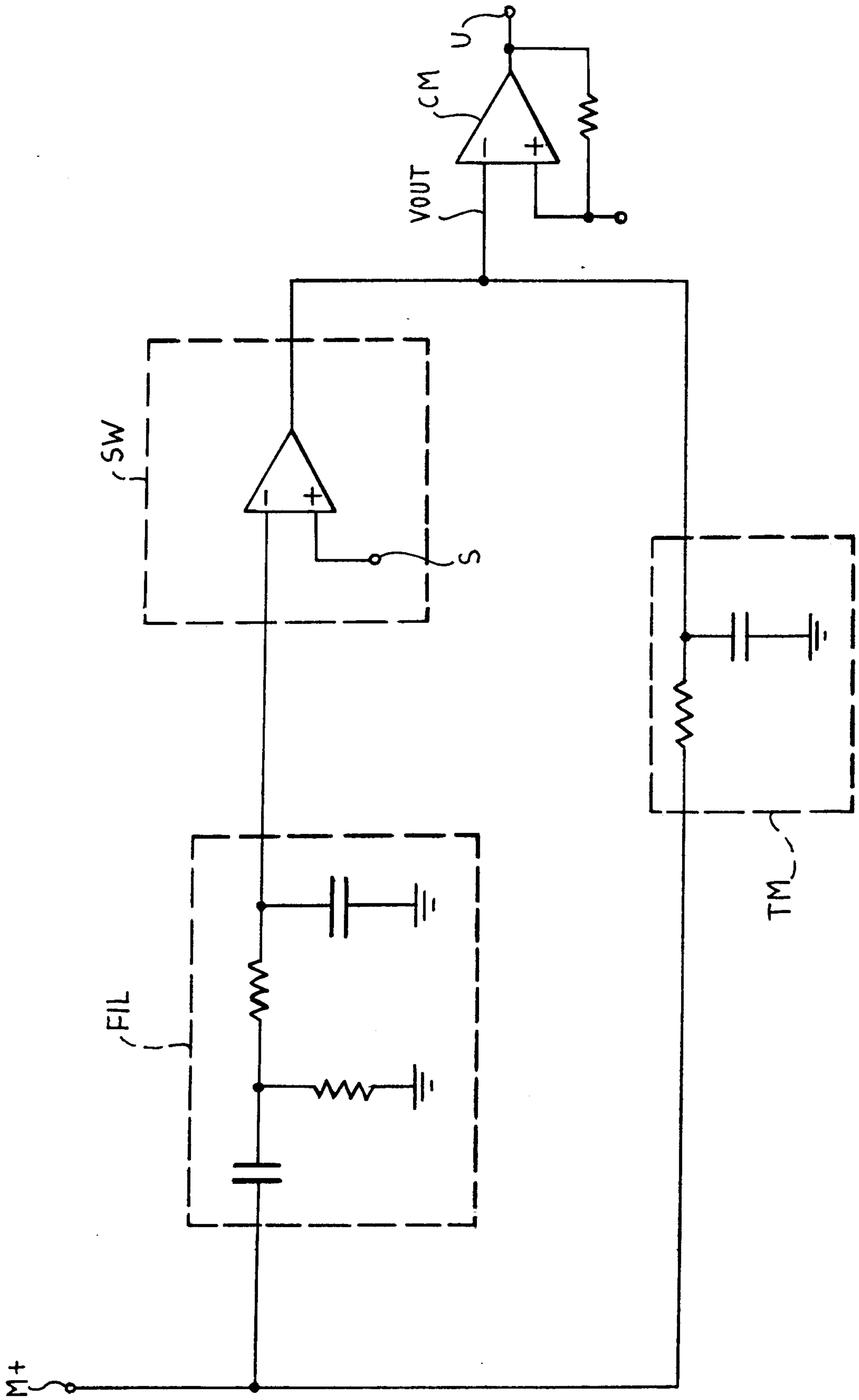


FIG. 4

FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 97 10 3097

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)
X	PATENT ABSTRACTS OF JAPAN vol. 010, no. 014 (M-447), 21 January 1986 & JP 60 175765 A (NIPPON DENSO KK), 9 September 1985, * abstract *	1	F02N11/08
A	FR 2 626 417 A (MITSUBISHI ELECTRIC CORP) 28 July 1989		
A	DE 33 22 209 A (ROBERT BOSCH) 3 January 1985		
D,A	EP 0 562 456 A (IND. MAGNETI MARELLI) 29 September 1993		
D,P,A	EP 0 727 577 A (IND. MAGNETI MARELLI) 21 August 1996		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F02N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 May 1997	Bijn, E

CATEGORY OF CITED DOCUMENTS

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