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(54) **A starter system for an internal combustion engine.**

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EP 0 537 754 B1

Description

The present invention relates to a starter system for an internal combustion engine, and specifically to a system of the type defined in the first part of Claim 1.

A starter system of this type is described for example in EP - A - 0 373 777.

Such a system includes a control circuit preset to supply the winding or solenoid of the electromagnetic control device initially with a dc current, and then with a low average value pulsed current. Commutation of dc current to pulsed current occurs on closing the switch controlled by the said solenoid, which therefore determines the supply of power to the starter motor.

The length of time which lapses between activating the starter system and commuting the current is generally not constant. Furthermore, when the switch closes the translatable pinion does not always mesh effectively with the toothed ring or flywheel of the motor, as the pinion teeth may frontally strike those of the toothed ring. When this happens, the commutation of the current in the said solenoid to the low average value pulsed current determines a reduction in the force with which the pinion is thrust towards the toothed ring. Furthermore, this commutation of current occurs simultaneously with the activation of the starter motor which causes the rotation of the pinion.

This may make it more difficult for the pinion to mesh with the toothed ring and may cause slipping and jumping of the pinion in relation to the toothed ring thereby wearing and deforming both sets of teeth, this in turn making it even more difficult for the pinion to engage with the said toothed ring.

The object of the invention is to provide a starter system which overcomes the above disadvantage.

This object is achieved by the invention with a starter system as described in Claim 1.

In the system according to the invention, commutation of dc current to pulsed current in the said winding or solenoid does not occur when the associated switch is closed but only once it is ascertained that the toothed ring of the motor has actually started to rotate. The threshold for the minimum speed of rotation mentioned in Claim 1 can be, for example, 30-40 rpm.

In this way, the reduction in the force urging the pinion against the toothed ring (this reduction resulting from the passage from dc to pulsed current in the solenoid) occurs safely, only after the pinion has actually meshed with the toothed ring and the ring has been made to rotate.

Further characteristics and advantages of the invention will become clear from the detailed description which follows, with reference to the appended drawings, supplied purely as a non-limitative example, in which:

Figure 1 is a circuit diagram of a starter system according to the invention;

Figure 2 is an exemplary diagram illustrating the voltage applied to the solenoid of the electromagnetic control device of the starter system of Figure 1; and

Figure 3 is a diagram showing, as a function of time t along the abscissa, a different example of the voltage applied to the solenoid of the electromagnetic control device of a starter system according to the invention.

With reference to Figure 1, the battery of a motor vehicle powered by an internal combustion engine (not shown) is indicated 1. In the embodiment illustrated, the negative pole of the battery 1 is grounded while the positive pole is connected to a node 2. Two circuit branches 3 and 4 lead from this node 2. In the branch 3 is a manual switch 5, for example incorporated into a conventional key-operated ignition and starter switch.

In the circuit branch 3, a controlled electronic switch 6, for example a transistor, is arranged in series with the switch 5.

A winding or solenoid 20 is arranged between the commutator 6 and ground.

The solenoid 20 is adapted, in a conventional manner, to control a normally-open contact 11 in the circuit branch 4.

A dc starter motor M is disposed in the circuit branch 4, between the switch 11 and ground. The motor M is intended to drive the pinion 12 to rotate; the pinion is mounted for translation in conventional manner but driven to rotate by the shaft of the said motor.

The solenoid 20 and the associated switch 11 generally form an electromagnetic control device which, when excited, allows current to flow from the battery 1 to the motor M and causes (in a conventional manner) the translation of the pinion 12 towards a working position in which it meshes rotatably with a rotatable toothed member (flywheel) 13 of the internal combustion engine, thereby starting it.

A sensor 14 provides an electrical output signal indicating the speed of rotation (rpm) of the internal combustion engine. This sensor is of a conventional type, for example of the type known as a phonic wheel. This sensor may be, for example, the sensor frequently used to supply information on the engine rpm to the electronic units controlling the ignition and/or fuel injection of the internal combustion engine, or a sensor associated with the flywheel 13 of the engine.

The sensor 14 is connected at its input to a comparison and timing circuit 15, the output of which is connected to the input of a control circuit

17 which controls the electronic switch 6.

When the internal combustion engine is stationary, the control circuit 17 applies a signal to the switch 6 allowing it to conduct current. If, in this condition, the switch 5 is closed (time instant t_0 in Figures 2 and 3), a current can flow through the circuit branch 3 and the excitation winding or solenoid 20. In this phase the control circuit 17 causes a dc current to flow through the switch 6 and thereby through the solenoid 20, for a predetermined constant period of time, that is until the time instant t_a in Figures 2 and 3. This dc current may either be constant in time (Figure 2) or variable (Figure 3) as will be explained later.

The time period t_a-t_0 is determined in advance on the basis of the characteristics of the electromagnetic starter motor control device and of the internal combustion engine. This period must be at least equal to the time normally required to close the switch 11, move the pinion 12 into mesh with the toothed ring 13, and to start the rotation of the shaft of the internal combustion engine up to a minimum threshold speed of rotation (for example 30-40 rpm). The flow of current through the winding 20 causes displacement of a moving element or core (not shown) and consequent closure of the contact 11, causing translation of the pinion 12 to engage with the flywheel 13. Following the closure of the contact 11, a high current is supplied to the motor M. The said motor therefore causes the pinion 12 to rotate thereby driving the shaft of the internal combustion engine into rotation.

If in the time period t_a-t_0 the comparison circuit 15 detects that the engine crankshaft speed has not exceeded its minimum threshold, it inhibits the control circuit 17 which in turn inhibits the switch 6. If this happens, the starting operation must be repeated.

If in the time period t_a-t_0 the engine crankshaft speed does pass the said minimum rpm threshold, the comparison circuit 15 sends the control circuit 17 a signal causing this circuit to control the switch 6 in on/off mode, causing a pulsed current, in particular of a pulse width modulated (PWM) current to pass through it. This pulsed current has a low average value so that the corresponding magnetic force developed by the winding 20 is sufficient to maintain the pinion 12 engaged with the toothed ring 13 and to keep the switch 11 closed.

The pulsed current is made to flow through the switch 6 at the most for a predetermined and constant time period t_b-t_a which ends at the time instant t_b in Figures 2 and 3. In this second time period t_b-t_a, as soon as the engine speed exceeds a predetermined value (for example 400 rpm), equivalent to its minimum self-sustaining rate, the circuit 15 inhibits the control circuit 17 which in turn finally inhibits the switch 6.

As a result, the contact 11 opens, the motor M stops and the pinion 12 disengages from the flywheel 13 in a conventional manner. The internal combustion engine is started.

If, on the other hand, in the period t_b-t_a the engine does not reach the said predetermined value, at the instant t_b the comparison circuit 15 finally inhibits the control circuit 17 and the starting operation must be repeated.

The time period t_b-t_a is fixed and is determined in advance on the basis of the characteristics of the starter motor M and of the internal combustion engine. This period must be at least equal to the time normally taken for the speed of rotation of the internal combustion engine to rise from the said minimum threshold (30-40 rpm) to the self-sustaining speed.

As stated earlier, the control circuit 17 may be preset so as to apply to the solenoid 20 a voltage which assumes a constant value over the period t_a-t_0 (Figure 2).

Alternatively, the control circuit 17 may be set to control the conduction of current through the electronic switch 6 so that over the time period t_a-t_0 the voltage between the node 7 and ground and therefore the voltage applied to the solenoid 20, initially assumes a low value V_1 increasing gradually thereafter up to a predetermined final value V_2. Substantially, this occurs in such a way that the voltage between the node 7 and ground increases initially as shown in Figure 3:

- at the time instant t_0 (closure of the switch 5) the voltage V is at an initial value V1 of, for example 4-6 V, and is maintained at this value for a fixed period of time $\Delta t1$; this period of time is predetermined on the basis of the characteristics of the electromagnetic control device 11, 20 and corresponds substantially to the time required for the movable elements of the device to move sufficiently from the rest position to take up all clearances and to engage with the resilient biasing member or members provided to ensure that the said movable elements return to the rest position when excitation of the solenoid 20 ceases; the period of time $\Delta t1$ depends therefore on the characteristics of the electromagnetic control device and is typically of the order of about 10ms;
- starting from the time instant t_1 the switch 6 is controlled so that the voltage V gradually increases from the value V_1 up to a final value V_2 which is reached at a time instant t_2; the time interval $\Delta t2$ between t_2 and t_1 is also appropriately fixed and is determined as a function of the characteristics of the electromagnetic control device used; this time interval, typically about 50ms, is chosen so

that the voltage V increases as slowly as possible, compatible with the absolute need to be able later to return the contact 11 to the closed position; the gradual application of the voltage V makes it possible to reduce the impact speed of the pinion on the flywheel of the heat engine, the speed at which the moving element strikes the fixed element of the electromagnet and the speed at which the movable contact of the contact pair 11 engages against the associated fixed contact, thereby reducing noise.

As previously stated, the electronic switch 6 may appropriately be a transistor.

The control circuit 17 of Figure 1 is easily made from control stages of conventional type, able to make the transistor operate in a substantially linear manner and in an on/off mode.

It is useful, though not necessary, if the starter system described above with reference to Figure 1 also includes an electrical temperature sensor 18, preferably arranged adjacent the electromagnetic control device 20, 11. In this case, the control circuit 17 has a further convenient input connected to this sensor. Such a control circuit is able to control the electronic switch 6 so as to modify the average value of the current flowing through the solenoid in dependence on the temperature measured by the sensor 18. In particular, when the sensor 18 signals increasing (decreasing) temperatures, the circuit 17 controls the electronic switch 6 so that it supplies increasing (decreasing) average current to the solenoid 20.

This arrangement enables any increase/decrease in the electrical resistance of the solenoid 20, as a result of any increase/decrease in temperature, to be compensated.

The pulse width modulation (PWM) control of the electronic switch 6 in the time period t_b-t_a means less power is dissipated in the excitation solenoid 20. For the same volume of copper used, that is for the same overall dimensions of the winding, this solenoid may be made with fewer turns, each having a greater cross-section. This means that for the same voltage supplied the ampere-turns can be increased, thereby increasing the power of the electromagnetic control device.

Claims

1. A starter system for an internal combustion engine, comprising

a d.c. voltage source (1),

an electric starter motor (M) operable to cause rotation of a translatable pinion (12),

an electromagnetic control device (20; 11) which includes at least one winding (20) operable, when current flows through it, to cause the pinion (12) to translate towards a working position in which the said pinion (12) is able to mesh with a rotatable member (13) of the internal combustion engine, and to cause the closure of a contact (11) interposed in a connection (4) between the voltage source (1) and the starter motor (M); and

control means (14-18) operable to control the coupling of the electric motor (M) and the solenoid (20) of the electromagnetic control device (20; 11) to the voltage source (1);

the said control means comprising

electrical sensor means (14) operable to provide electrical signals indicative of the speed of rotation of the crankshaft (13) of the internal combustion engine;

switch means (6) interposed between the said voltage source (1) and the said solenoid (20) of the electromagnetic control device (20; 11), and

monitoring circuit means (15) connected to the said sensor means (14) and to the said switch means (6); the said monitoring circuit means (15) being operable, when activated, to cause dc current to flow through the said solenoid (20) for a first period of time and then pulsed current to flow through the said solenoid (20) for a second period of time;

characterised in that the said control means (14-18) are preset to

- cause dc current to pass through the said solenoid (20) for a first fixed period of time of constant duration (ta-t_0);
- cause, after the said first period of time (t_a-t_0), a pulsed current to pass through the said solenoid (20) when, within the said first period of time (t_a-t_0), the signals provided by the said sensor means (14) indicate that the speed of rotation of the engine crankshaft (13) has exceeded a predetermined minimum threshold;
- interrupt the passage of current through the said at least one solenoid (20) at the end of the said first time period (t_a-t_0) if the speed of rotation of the said crankshaft (13) has not exceeded the said minimum threshold in this time period (t_a-t_0);
- interrupt the passage of pulsed current through the said solenoid (20) in a second period of time (t_b-t_a) as soon as the speed of the said crankshaft (13) reaches a predetermined value higher than the said threshold, or at the end of the said second period of time (t_b-t_a) if in the said second period (t_b-t_a) the speed or rotation of the said crankshaft (13) does not exceed the said predetermined value;

said first (t_a-t_0) and second (t_b-t_a) time periods being determined in advance on the basis of the characteristics of the internal combustion engine and respectively of the electromagnetic starter motor control device (20, 11) and of the starter motor (M).

2. A starter system according to Claim 1, characterised in that the said control means also include control circuit means (17) adapted to vary the current flowing through the said at least one solenoid (20) during the said first time period (t_a-t_0); the said control circuit means (17) being adapted to cause the application to the said at least one winding (20) of

- an initial low voltage (V_1) for a first predetermined period of time (Δt1);
- a voltage increasing from the said low voltage (V_1) up to a predetermined final voltage (V_2) for a second predetermined time period (Δt2), and thereafter
- a voltage equal to the said final voltage (V_2).

3. A starter system according to Claim 1, characterised in that it also includes temperature sensor means (18), preferably arranged adjacent the said electromagnetic control device (20; 11), and in that the said control circuit means (17) are preset to modify the average value of the current flowing through the said excitation winding (20) in dependence on the temperature measured by the said temperature sensor means (18), so that the said average value is increased/decreased with any increase/decrease in the said temperature.

4. A starter system according to Claim 1, characterised in that the said switch means (6) include a transistor, and in that the said control circuit means (17) are preset to control the said transistor, in the said first predetermined time period (t_a-t_0), so that the said transistor (6) operates in a linear manner.

5. A starter system according to Claim 1, characterised in that the said switch means include a transistor (6), and in that the said control circuit means (17) are preset to control, the said transistor (6) in a pulsed mode, by pulse width modulation (PWM) in the second time period (t_b-t_a).

Patentansprüche

1. Anlaßvorrichtung für einen Verbrennungsmotor, wobei die Vorrichtung enthält:
eine Gleichspannungsquelle (1),
einen Anlaß-Elektromotor (M), der dazu dient, um ein verschiebbares Ritzel (12) in Drehung zu versetzen,
eine elektromagnetische Steuervorrichtung (20; 11), die zumindest eine Wicklung (20) aufweist, die beim Durchfluß eines Stroms dazu dient, um das Ritzel (12) zu veranlassen, sich zu einer Arbeitsstellung zu verschieben, in der das Ritzel (12) in ein drehbares Element (13) des Verbrennungsmotors eingreifen kann, und das Schließen eines Kontaktes (11) zu bewirken, der zwischen einem Anschluß (4) zwischen der Spannungsquelle (1) und dem Anlaßmotor (M) liegt; und
eine Steuerstufe (14-18), die dazu dient, um das Kuppeln des Elektromotors (M) und der Zylinderspule (20) der elektromagnetischen Steuervorrichtung (20; 11) mit der Spannungsquelle (1) zu steuern; wobei die Steuerstufe enthält:
einen elektrischen Fühler (14), der dazu dient, um elektrische Signale zu liefern, die die Drehzahl der Kurbelwelle (13) des Verbrennungsmotors anzeigen;
einen Schalter (6) der zwischen der Spannungsquelle (1) und der Zylinderspule (20) der elektromagnetischen Steuervorrichtung (20; 11) liegt, und
eine Überwachungsstufe (15), die mit dem Fühler (14) und dem Schalter (6) verbunden ist; wobei die Überwachungsstufe (15), wenn sie in Betrieb steht, dazu dient, um durch die Zylinderspule (20) in einem ersten Zeitintervall einen Gleichstrom und daraufhin in einem zweiten Zeitintervall einen gepulsten Strom fließen zu lassen;
dadurch gekennzeichnet, daß die Steuerstufe (14-18) so voreingestellt wird, um:

- durch die Zylinderspule (20) in einem ersten festen Zeitintervall mit konstanter Dauer (t_a-t_0) einen Gleichstrom fließen zu lassen;
- nach dem ersten Zeitintervall (t_a-t_0) durch die Zylinderspule (20) einen gepulsten Strom fließen zu lassen, wenn im ersten Zeitintervall (t_a-t_0) die vom Fühler (14) gelieferten Signale anzeigen, daß die Drehzahl der Motorkurbelwelle (13) einen vorgegebenen Minimalschwellwert überschritten hat;
- den Stromfluß durch die zumindest eine Zylinderspule (20) am Ende des ersten Zeitintervalls (t_a-t_0) zu unterbrechen,

wenn die Drehzahl der Kurbelwelle (13) den Minimalschwellwert in diesem Zeitintervall (t_a-t_0) nicht überschritten hat;

- den Stromfluß des gepulsten Stroms durch die Zylinderspule (20) in einem zweiten Zeitintervall (t_b-t_a) zu unterbrechen, sobald die Drehzahl der Kurbelwelle (13) einen vorgegebenen Wert erreicht, der größer als der Schwellwert ist, oder am Ende des zweiten Zeitintervalls (t_b-t_a) zu unterbrechen, wenn im zweiten Intervall (t_b-t_a) die Drehzahl der Kurbelwelle (13) den vorgegebenen Wert nicht überschreitet; wobei das erste (t_a-t_0) und zweite (t_b-t_a) Zeitintervall vorher aufgrund der Kennlinien des Verbrennungsmotors beziehungsweise der elektromagnetischen Steuervorrichtung für den Anlaßmotor (20; 11) sowie des Anlaßmotors (M) festgelegt werden.

2. Anlaßvorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daS die Steuerstufe weiters einen Steuerkreis (17) aufweist, der dazu dient, um den durch die zumindest eine Zylinderspule (20) während des ersten Zeitintervalls (t_a-t_0) fließenden Strom zu verändern; wobei der Steuerkreis (17) so aufgebaut ist, um an die zumindest eine Windung (20) zu legen:

- in einem ersten Zeitintervall (Δt1) eine anfangs niedrige Spannung (V_1);
- in einem zweiten vorgegebenen Zeitintervall (Δt2) eine Spannung, die von der niedrigen Spannung (V_1) bis zu einer vorgegebenen Endspannung (V_2) ansteigt, und nachher
- eine Spannung, die gleich der Endspannung (V_2) ist.

3. Anlaßvorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß die Vorrichtung weiters einen Temperaturfühler (18) aufweist, der vorzugsweise neben der elektromagnetischen Steuervorrichtung (20; 11) angeordnet ist, und daß der Steuerkreis (17) voreingestellt wird, um den Mittelwert des durch die Erregerwicklung (20) fließenden Stroms in Abhängigkeit von jener Temperatur zu ändern, die mit dem Temperaturfühler (18) gemessen wird, so daß der Mittelwert mit jedem Ansteigen/Fallen der Temperatur angehoben/abgesenkt wird.

4. Anlaßvorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß der Schalter (6) einen Transistor aufweist, und daß der Steuerkreis (17) voreingestellt wird, um den Transistor im ersten vorgegebenen Zeitintervall (t_a-t_0) so zu steuern, daß der Transistor (6) im linearen Betrieb arbeitet.

5. Anlaßvorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß der Schalter einen Transistor (6) aufweist, und daß der Steuerkreis (17) voreingestellt wird, um den Transistor (6) im zweiten Zeitintervall (t_b-t_a) in einem Impulsbetrieb mit einer Pulsbreitenmodulation zu steuern.

Revendications

1. Système de démarrage pour un moteur à combustion interne, comprenant

une source de tension de courant continu (1),

un moteur de démarreur électrique (M) servant à provoquer la rotation d'un pignon déplaçable (12),

un dispositif de commande (20; 11) électromagnétique comprenant au moins un enroulement (20) servant, lorsqu'un courant le traverse, à forcer le pignon (12) à se déplacer vers une position de travail dans laquelle ledit pignon (12) peut engrener avec un organe rotatif (13) du moteur à combustion interne, et à provoquer la fermeture d'un contact (11) disposé dans une connexion (4) entre la source de tension (1) et le moteur de démarreur (M); et

des moyens de commande (14 à 18) servant à commander le couplage du moteur électrique (M) et du solénoïde (20) du dispositif de commande (20; 11) électromagnétique à la source de tension (1);

ledit moyen de commande comprenant

un moyen formant capteur électrique (14) servant à fournir des signaux électriques indicatifs de la vitesse de rotation du vilebrequin (13) du moteur à combustion interne;

un moyen de commutation (6) disposé entre ladite source de tension (1) et ledit solénoïde (20) du dispositif de commande (20; 11) électromagnétique; et

un moyen formant circuit de surveillance (15) connecté audit moyen formant capteur (14) et audit moyen de commutation (6); ledit moyen formant circuit de surveillance (15) servant, lorsqu'il est activé, à provoquer le passage d'un courant continu dans ledit solénoïde (20) pendant une première période de temps et a provoquer ensuite le passage d'un courant pulsé dans ledit solénoïde (20) pendant une deuxième période de temps;

caractérisé en ce que lesdits moyens de commande (14 à 18) sont préréglés pour

- provoquer un passage de courant continu dans ledit solénoïde (20) pendant une

période déterminée de temps d'une durée constante (t_a-t_0);

- provoquer, après ladite première période de temps (t_a-t_0), le passage d'un courant pulsé dans ledit solénoïde (20) lorsque, dans ladite première période de temps (t_a-t_0), les signaux fournis par ledit moyen formant capteur (14) indiquent que la vitesse de rotation du vilebrequin de moteur (13) a dépassé un seuil minimal prédéterminé;
- interrompre le passage de courant dans ledit au moins un solénoïde (20) à la fin de ladite première période de temps (t_a-t_0), si la vitesse de rotation dudit vilebrequin (13) n'a pas dépassé ledit seuil minimal lors de cette période de temps (t_a-t_0);
- interrompre le passage de courant pulsé dans ledit solénoïde (20) dans une deuxième période de temps (t_b-t_a), dès que la vitesse dudit vilebrequin (13) atteint une valeur prédéterminée supérieure audit seuil, ou à la fin de ladite deuxième période de temps (t_b-t_a) si, lors de ladite deuxième période de temps (t_b-t_a), la vitesse de rotation dudit vilebrequin (13) ne dépasse pas ladite valeur prédéterminée; lesdites première (t_a-t_0) et deuxième (t_b-t_a) périodes de temps étant déterminées à l'avance sur la base des caractéristiques du moteur à combustion interne et, respectivement, du dispositif de commande de moteur de démarreur (20, 11) électromagnétique et du moteur de démarreur (M).

2. Système de démarrage selon la revendication 1, caractérisé en ce que lesdits moyens de commande comprennent également un moyen formant circuit de commande (17) adapté à faire varier le courant passant dans ledit au moins un solénoïde (20) durant ladite première période de temps (t_a-t_0); ledit moyen formant circuit de commande (17) étant adapté à provoquer l'application sur ledit au moins un enroulement (20),

- d'une faible tension initiale (V_1) pendant une première période de temps ($\Delta t1$) prédéterminé;
- d'une tension, augmentant depuis ladite faible tension (V_1), jusqu'à une tension finale (V_2) prédéterminée, pendant une deuxième période de temps ($\Delta t2$) prédéterminée, et ensuite
- d'une tension égale à ladite tension finale (V_2).

3. Système de démarrage selon la revendication 1, caractérisé en ce qu'il comprend également un moyen formant capteur de température (18), disposé de préférence adjacent audit dispositif de commande (20; 11) électromagnétique, et en que lesdits moyens formant circuit de commande (17) sont préréglés pour modifier la valeur moyenne du courant passant dans ledit enroulement d'excitation (20), en fonction de la température mesurée par ledit moyen formant capteur de température (18), de manière que ladite valeur moyenne soit augmentée/réduite conjointement avec une augmentation/réduction quelconque de ladite température.

4. Système de démarrage selon la revendication 1, caractérisé en ce que lesdits moyens de commutation (6) comprennent un transistor et en ce que lesdits moyens formant circuit de commande (17) sont préréglés pour commander ledit transistor, pendant ladite première période de temps (t_a-t_0) prédéterminée, de manière que ledit transistor (6) fonctionne de manière linéaire.

5. Système de démarrage selon la revendication 1, caractérisé en ce que lesdits moyens de commutation comprennent un transistor (6) et en ce que lesdits moyens formant circuit de commande (17) sont préréglés pour commander ledit transistor (6) de manière pulsée, par une modulation de largeur d'impulsion (PWM) pendant la deuxième période de temps (t_b-t_a).

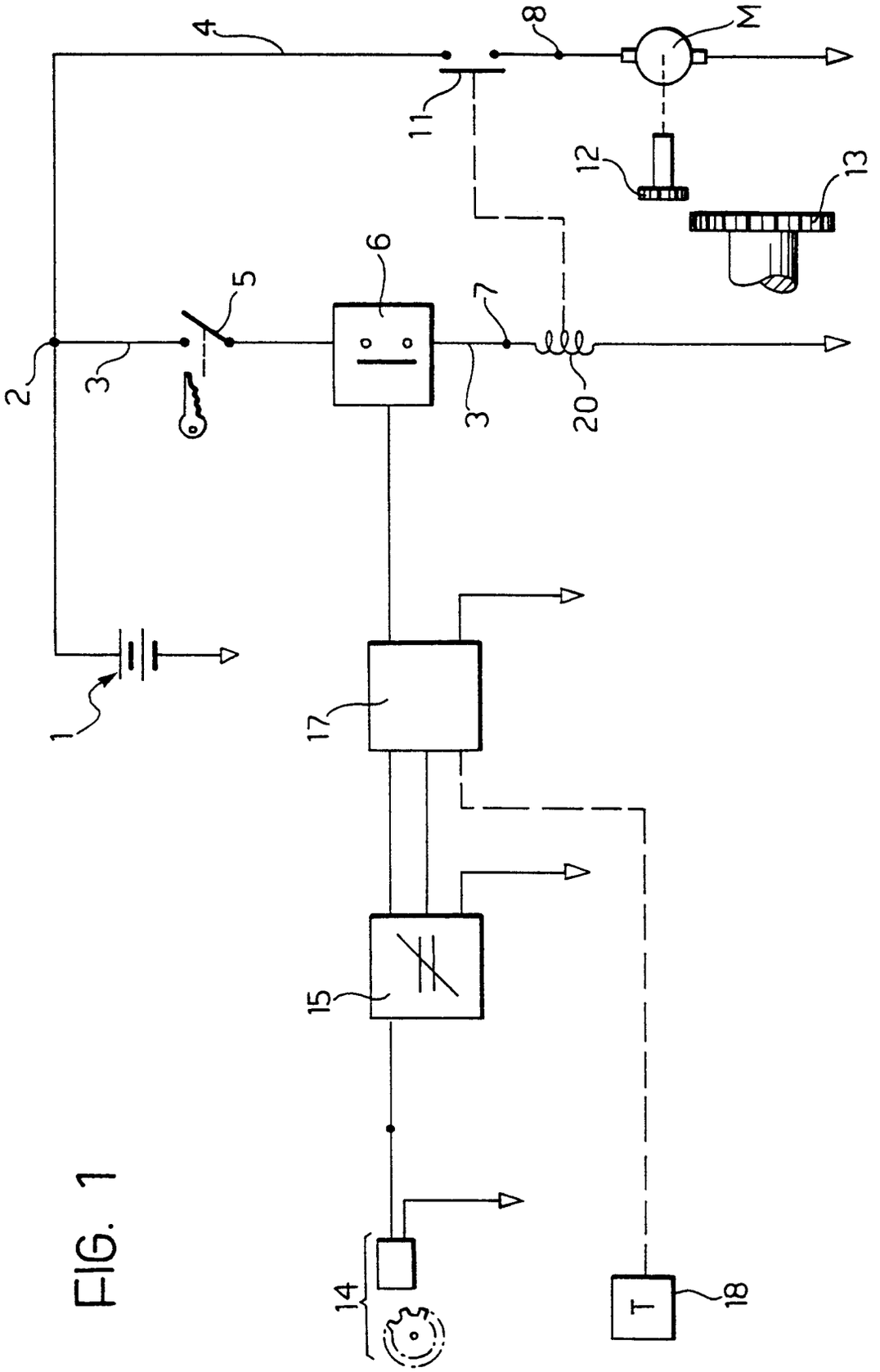


FIG. 1

FIG. 2

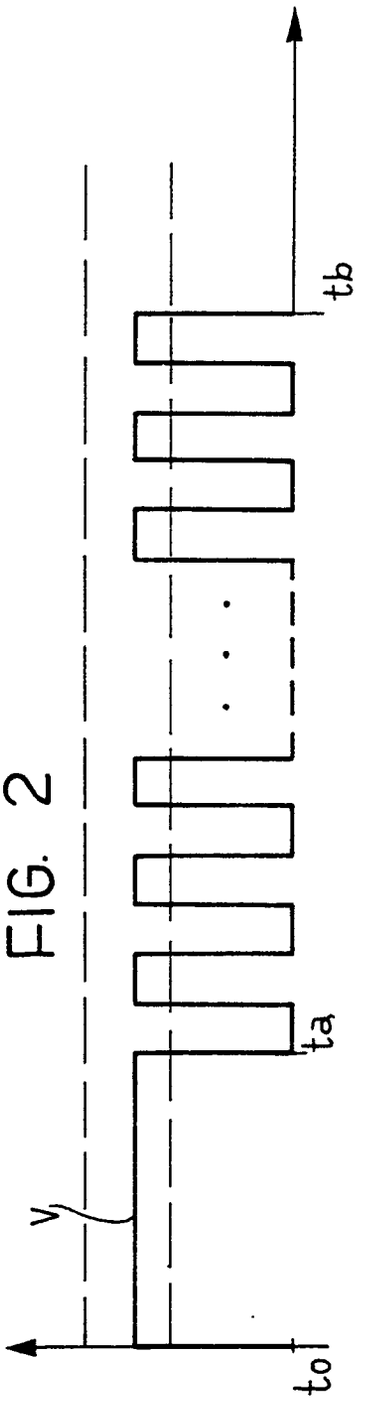


FIG. 3

