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H. SCHOLL

3,315,134

CLUTCH

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FIG. 2

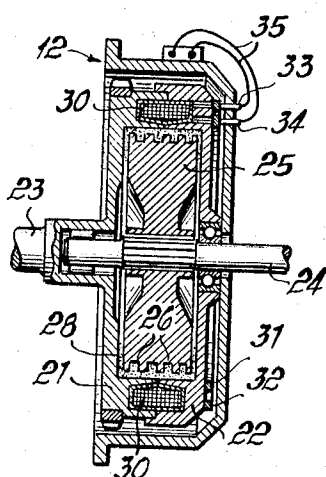


FIG. 1

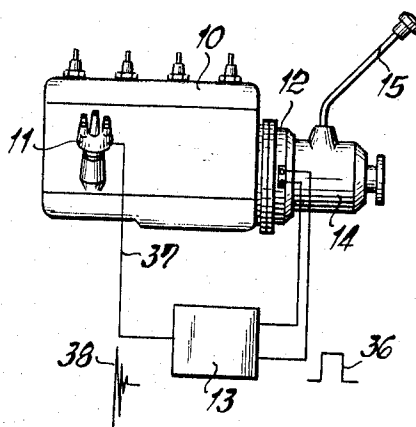


FIG. 3

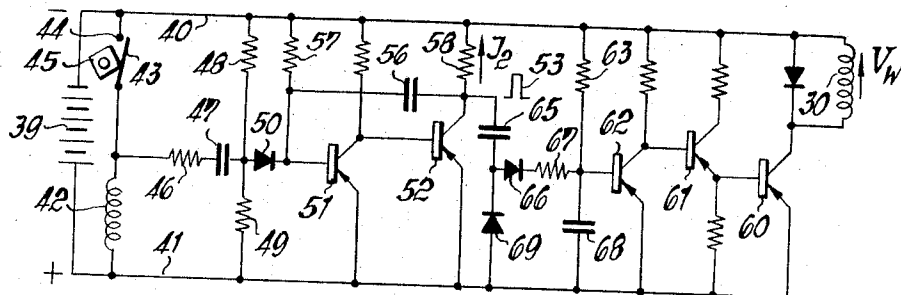


FIG. 4

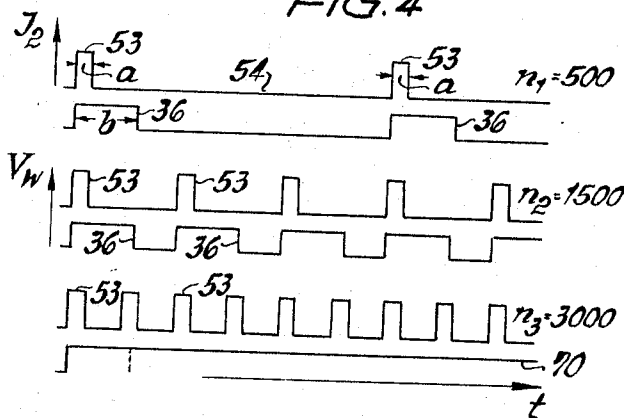
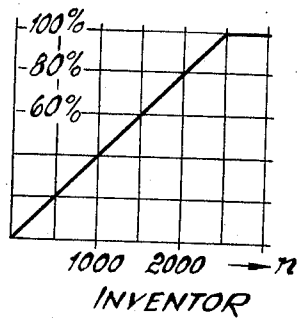


FIG. 5



1

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CLUTCH

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B 73,667

5 Claims. (Cl. 317-148.5)

The present invention relates to a control device for operating an electromagnetic device, particularly a starting and shifting clutch of an automobile, which clutch is electromagnetically engageable and disengageable. The electromagnetic device includes a magnetic winding which is fed with so-called working current pulses of at least approximately equal duration. These working current pulses come from a D.C. source and have a pulse repetition frequency which is synchronized with a control magnitude, and they are fed via a power transistor operating in on-off manner, i.e., a transistor which is either in conductive or non-conductive state. This power transistor is controlled by an input transistor operating in phase opposition; ahead of this input transistor there is connected a control transistor which switches back and forth between current-conducting and blocked condition in synchronism with the beat of the control value.

In starting and shifting clutches of this type which are intended for the operation of automobiles, an electromagnetic force is to be produced in the clutch by the control device, which force continuously increases with the increasing rotational speed of the internal combustion engine serving as the drive means. The control pulses which are in synchronism with the revolutions of the crankshaft of the engine can be derived, for example, from the high-voltage ignition system of the engine and be fed to the control device. The driving torque of the internal combustion engine which the clutch is to transmit must, in this case, be capable of increasing from as small a value as possible at the idling speed, to the maximum value determined by the size of the clutch, this maximum value being reached at about one-third of the highest engine r.p.m.

In conventional control devices, a monostable flip-flop circuit is used for producing the working current pulses of approximately uniform duration, this duration or so-called pulse width not being dependent upon the rotational speed. The control pulses derived from the ignition device are applied to this flip-flop circuit. Such circuits contain at least one time member, the so-called RC-element, which consists of a capacitor and a charging or discharging resistor whose capacitance and resistance, respectively, determine the pulse width. This time member, however, must be designed to afford a rather large time constant so as to produce sufficiently long working current pulses capable of producing a starting torque which, at a starting r.p.m. that is just above the idling r.p.m., will be sufficient in spite of the pulse repetition rate which, at this time, is still very slow. However, the greater the pulse width of the working current pulses, the lower will be the r.p.m. at which the pauses between the individual control pulses become shorter than the width of the working current pulses, and the flip-flop circuit then can no longer follow the frequency of the control pulses but jumps to half the control frequency.

It is, therefore, the object of the present invention to provide a control device which yields a torque, in the lower r.p.m. range, which increases continuously with the r.p.m. but which, when high rotational speeds are reached, allows a smooth transition of the working current pulses into an uninterrupted direct current, and, with this object in view, the present invention resides, mainly, in a control device in which a series-circuit made up of a first capacitor

2

connected with the collector of the control transistor, a first rectifier and a first resistor is provided between the collector of the control transistor—the same being connected to one terminal of the D.C. source via a resistor, and the base of the input transistor; in which a second resistor leads from the base of the input transistor to the same D.C. terminal; in which a second capacitor is connected between this base and the other terminal of the D.C. source; and in which a second rectifier is connected between this other D.C. source terminal and the juncture of the first capacitor and the first rectifier, the polarity of the two rectifiers being such that they pass current in the same direction.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIGURE 1 shows the internal combustion engine of the automobile with the electromagnetic clutch, as well as a control device pertaining thereto.

FIGURE 2 shows the electromagnetic clutch in longitudinal section.

FIGURE 3 is a circuit diagram of the control device for actuating the clutch.

FIGURE 4 shows three plots which will be referred to for explaining the mode of operation of the clutch at different speeds of the engine.

FIGURE 5 is a graph illustrating the percentage clutch torque as a fraction of the engine r.p.m. (n).

Referring now to the drawings, and first to FIGURE 1 thereof, the same shows an internal combustion engine 10 intended for driving an automobile (not shown), this engine having associated with it a high-voltage ignition system whose distributor is indicated at 11. The housing 12 of the magnetic powder clutch is mounted to the engine by means of a flange-connection; this clutch is automatically engaged, by means of an electric control device indicated at 13, to be described in more detail in FIGURE 3, when the r.p.m., i.e., the rotational speed of the engine is increased to a predetermined minimum value above the idling speed. A conventional transmission 14 is flanged to the housing of the magnetic powder clutch; the individual gears of the transmission can be selectively engaged by a gearshift lever 15.

As shown in FIGURE 2, the magnetic powder clutch contains, in its housing 12, a cage composed of two shells 21 and 22 which are fixedly connected to the crankshaft 23 of the engine, this cage forming at the same time the flywheel of the engine. This housing 12 furthermore contains a rotor 25 seated on a driven, i.e., output, shaft 24, this rotor being provided on its outer surface with several, axially adjacent peripheral grooves 26. Between the outer surface of the rotor and the inner walls of the cage, there is, in practice, an annular gap of approximately 1 to 2 mm., the same containing magnetizable powder 28. The front surfaces of the cage shells 21 and 22 facing each other are each provided with one annular groove for receiving a magnetic winding 30. The ends of the magnetic winding are connected to respective slip rings 31 and 32 which are seated, insulated from each other, on the outer front surface of shell 22 and which cooperate with two brushes 33 and 34 which themselves are mounted in housing 12 and are insulated therefrom. The brushes are connected to a junction box 35 provided on the outside of housing 12, it being through this junction box that the magnetic winding 30 of the clutch is connected to the control device 13.

When a torque is to be transmitted between shafts 23 and 24, the magnetic powder 28 is magnetized by means of square pulses 36 which are delivered by the control device 13 at a pulse repetition frequency which is in synchronism with the revolutions of the crankshaft of the engine. For producing these pulses, the input side of the control device 13 is connected with the distributor 11 of the high-voltage ignition device by means of a cable 37 so that, with each ignition, a short control pulse, indicated at 38, is applied.

Referring now to FIGURE 3, the control device is supplied with current from a D.C. source such as a 12 volt battery 39 which powers the high-voltage ignition system, via a negative line 40 and a positive line 41, the same being connected to the negative and positive terminals of the battery 39, respectively. The primary winding 42 of the ignition coil of the high-voltage ignition system, which is otherwise not illustrated, is connected in series with the interrupter arm 43 of the ignition interrupter provided in the housing of distributor 11, between the negative line 40 and the positive line 41. The interrupter arm co-operates with a stationary contact 44 connected to the negative line 40 and is lifted from the stationary contact 44 twice during each crankshaft revolution, this lifting being done by a four-lobed cam 45 which is likewise provided in the distributor housing. Every time the switch 43, 44 is opened, there is produced a switching-off voltage at the primary winding 42, this voltage generating the control pulse 38. The control pulse 38 is fed to a voltage divider consisting of two resistors 48 and 49, via a resistor 46 of 15 kilo-ohms and a capacitor 47 of 20,000 picofarads; from there, the control pulse is delivered, via a rectifier 50, to the base of a transistor 51.

This transistor constitutes together with a further transistor 52 a monostable multivibrator which is intended for supplying a narrow rectangular pulse 53 every time the interrupter arm 43 is lifted off contact 44. For this purpose, the transistor 52 is made to occupy its current-conducting condition for a period of time corresponding to the short duration of the rectangular pulse 53, whereupon the collector current I_2 of this transistor 52 increases suddenly, and is then blocked again.

In the plots illustrated in FIGURE 4, the line 54 represents the curve of the collector current I_2 for a rotational speed $n_1=500$ r.p.m. of the engine 10, the same being, by way of an example, assumed to be a four-cylinder, four-cycle engine. At this rotational speed, the interrupter arm 43 is lifted 1000 times in one minute. At this speed, the pulse repetition frequency of the rectangular pulses 53 is thus 1000 cycles per minute. The pulse width is, however, chosen to be so short that, at the maximum engine r.p.m. expected during operation of the automobile, i.e., approximately 7500 r.p.m., there is still a short, current-less pause between the individual successive rectangular pulses 53, this pause being at least so large that the capacitor 56 connected between the collector of the transistor 52 and the base of transistor 51 and serving as energy storage means, can be charged, via the resistor 57 connected between the base of transistor 51 and the positive line 40, to the battery voltage of battery 39. In the example on which FIGURE 3 is based, the individual rectangular pulses 53 have a duration a of 0.003 sec.=3 milliseconds. This duration is determined by the size of the resistor 57, the capacitor 56, as well as the collector resistor 58 connected between the collector of transistor 52 and the negative line 40, and thus remains the same at all engine speeds.

In contradistinction to the previously known arrangements, however, these rectangular pulses 53 which occur in synchronism with the crankshaft revolutions of the engine do not determine the duration of the working current pulses 36 effective in the magnetic winding 30. Rather, they serve, according to the present invention, for making available a charging energy, which is independent

of the r.p.m., for an additional capacitor which determines the duration of the working current pulses 36. By means of this charging energy, a power transistor 60 is kept in its conductive state, the transistor itself operating in the on-off manner. The emitter-collector path of transistor 60 is connected to the winding 30. The input circuit of transistor 60 is connected to a transistor 61 serving merely for in-phase current amplification. The transistor 61 is connected to the emitter of transistor 60. Also shown is an input transistor 62 which operates in phase-opposition to the two transistors 60, 61. The collector of this transistor 62 is connected with the base of transistor 61. This transistor 62 has its base connected, via a resistor 63, to the negative line 40, and thus seeks to return to its conductive state, thereby to block the power transistor 60. Furthermore, according to the invention, there is provided a series-circuit, consisting of a first capacitor 65 connected with the collector of transistor 52, a first rectifier 66, and a resistor 67, this series-circuit being connected between the collector of the control transistor 52, which collector is connected, via resistor 58, to the negative line 40, and the base of the input transistor 62. Further, a second capacitor 68 is connected between the base of the transistor 62 and the positive line 41 and a second rectifier 69 is connected between the juncture of the first rectifier 66 with condenser 65, and the positive line 41. As shown in FIGURE 3, the polarity of the rectifiers 66, 69, is such that they pass current in the same direction, the two rectifiers having respective dissimilar electrodes connected to each other.

The significance of this arrangement will be appreciated from the following description of the operation of the device. As long as the engine runs at low speeds which, for reasons set forth below, will be considered to be speeds below 2500 r.p.m., the transistors 51 and 62 are, immediately prior to each opening movement of the interrupter arm 43, in their conductive state and thus block the transistors 52, 60 and 61, respectively, which are connected behind the first-mentioned transistors. At the instant of interruption which results in ignition, the positive control pulse 38 reaches the base of transistor 51, this pulse bringing the transistor 51 into its non-conductive state and consequently bringing the transistor 52 into its conductive state. As the capacitor 65 was, during the time interval prior to this instant, able to charge up to battery voltage via the rectifier 69 and the resistor 58, and in view of the fact that this voltage is maintained by capacitor 65 at the instant of interruption, the base of the previously current-conducting transistor 62 is raised above the potential of the positive line 41 and becomes positive. This renders transistor 62 non-conductive and simultaneously, a large proportion of the previous charge of capacitor 65 is transferred, via the low-ohmic resistor 67, to capacitor 68. The voltage which is thus made to appear across the capacitor 68 maintains the base of transistor 62 positive for a considerable period beyond the instant at which the control transistor 52 returns, at the end of the rectangular pulse 53, into its blocked condition; thus, this voltage ensures that the working current pulse 36 can be maintained via the transistor 60, which is still conductive so long until the capacitor 68 has discharged, and the transistor 62 thus returns to its quiescent, conductive state. The return of the control transistor 52 to its current-less condition has, therefore, no influence on the capacitor 68 because the rectifier 66 allows the charge to flow from capacitor 65 into capacitor 68, but blocks such a charge flow in the opposite current direction. Instead, the capacitor can discharge only via the relatively high-ohmic resistor 63. This resistance of resistor 63 is chosen so large, in conjunction with the capacitance of capacitor 68, that the potential of the base of transistor 62 is lowered to the value of the positive line 41 only after the elapse of a period of time $b=0.012$ sec.=12 milliseconds. Only after this period of time is the transistor 62 returned to its

5

6

quiescent, conductive state, thereby terminating the working current pulse 36.

As can be seen from the diagram in the middle of FIGURE 4, when the rotational speed $n_2=1500$ r.p.m., the rectangular pulses 53 follow each other so rapidly that there are pauses of only 8 milliseconds remaining between the individual working current pulses 36 which arrive at the magnetic winding 30. When the speed is 2500 r.p.m., a new working pulse 36 follows a preceding working pulse 36 directly, without any hiatus therebetween, as in this case a new charge from capacitor 65 is fed to capacitor 68 at the same instant at which it is discharged to a value at which the transistor 62 could become conductive. At engine speeds above 2500 r.p.m., for example at the speed assumed for the third diagram of FIGURE 4, wherein $n_3=3000$ r.p.m., the rectangular pulses 53 follow one another so quickly that the base of transistor 62 is constantly kept at a positive value so that the transistor 60 can feed the magnetic winding 30 with an uninterrupted exciter current which, in FIGURE 4, is indicated by line 70 which runs level at the same distance above the time axis t . This continuously flowing direct current can be set, by selecting the number of windings and the thickness of the wire of the magnetic winding such that for maximum engine output to be transmitted by the clutch, the electrical losses in the clutch will be at a minimum. The maximum torque transmittable by the clutch then remains constant at speeds above 2500 r.p.m., as can be seen from FIGURE 5, and decreases to 80% of maximum torque at 2000 r.p.m., and to 40% at 1000 r.p.m.

The particular advantage of the circuit arrangement according to the present invention comprising the capacitor 65, the rectifiers 66 and 69, as well as the resistors 63 and 67 and the capacitor 68, in connection with the pre-transistor 62 operating in phase opposition, consists in that the working current pulses which follow one another, with pauses, at low speeds, change over, without an abrupt jump, into an uninterrupted direct current at speeds above 2500 r.p.m. In contradistinction to the known control devices, this result is achieved without requiring any additional switching systems.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of control circuits differing from the types described above.

While the invention has been illustrated and described as embodied in a clutch control system incorporating a magnetic powder clutch, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of the prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A circuit arrangement for operating an electromagnetically engageable and disengageable clutch having a magnetic winding, wherein working current pulses of at least approximately uniform duration are fed to the magnetic winding from a source of direct current and at a pulse repetition frequency which is in synchronism with a control value, said current pulses being fed via a power transistor operating in on-off operation which is controlled by an input transistor operating in phase opposition, ahead of which input transistor there is connected a control transistor which changes between conductive and blocked states in synchronism with the beat

of the control value, the improvement which comprises, in combination:

(a) resistor means connected between the collector of said control transistor and one terminal of said source of direct current;

(b) a series-circuit incorporating

(1) a first capacitor having one terminal connected to said collector of said control transistor,

(2) a first rectifier having one terminal connected to the other terminal of said first capacitor, and

(3) a first resistor having one terminal connected to the other terminal of said first rectifier, the other terminal of said first resistor being connected to the base of said input transistor;

(c) a second resistor connected between the base of said input transistor and said one terminal of said source of direct current;

(d) a second capacitor connected between said base of said input transistor and the opposite terminal of said source of direct current; and

(e) a second rectifier connected between said opposite terminal of said source of direct current and the juncture of said other terminal of said first capacitor and said one terminal of said first rectifier, said first and second rectifiers having dissimilar electrodes connected to each other so that both rectifiers pass current in the same direction.

2. A circuit arrangement for operating an electromagnetically engageable and disengageable clutch having a magnetic winding, wherein working current pulses of at least approximately uniform duration are fed to the magnetic winding from a source of direct current and at a pulse repetition frequency which is in synchronism with a control value, said current pulses being fed via a power transistor operating in on-off operation which is controlled by an input transistor operating in phase opposition, ahead of which input transistor there is connected a control transistor which changes between conductive and blocked states in synchronism with the beat of the control value, the improvement which comprises, in combination:

(a) resistor means connected between the collector of said control transistor and one terminal of said source of direct current;

(b) a series-circuit incorporating

(1) a first capacitor having one terminal connected to said collector of said control transistor,

(2) a first rectifier having one terminal connected to the other terminal of said first capacitor, and

(3) a first resistor having one terminal connected to the other terminal of said first rectifier, the other terminal of said first resistor being connected to the base of said input transistor;

(c) a second resistor connected between the base of said input transistor and said one terminal of said source of direct current;

(d) a second capacitor connected between said base of said input transistor and the opposite terminal of said source of direct current;

(e) a second rectifier connected between said opposite terminal of said source of direct current and the juncture of said other terminal of said first capacitor and said one terminal of said first rectifier, said first and second rectifiers having dissimilar electrodes connected to each other so that both rectifiers pass current in the same direction; and

(f) a further transistor connected to said control transistor for changing the state of conductivity thereof between conductive and blocked states in synchronism with the beat of the control value, said further transistor and said control transistor together forming a monostable flip-flop circuit whose unstable position results in rectangular pulses for

7

effecting a transfer of charge from said first capacitor to said second capacitor.

3. A circuit arrangement for operating an electromagnetically engageable and disengageable clutch having a magnetic winding, wherein working current pulses of at least approximately uniform duration are fed to the magnetic winding from a source of direct current and at a pulse repetition frequency which is in synchronism with a control value, said current pulses being fed via a power transistor operating in on-off operation which is controlled by an input transistor operating in phase opposition, ahead of which input transistor there is connected a control transistor which changes between conductive and blocked states in synchronism with the beat of the control value, the improvement which comprises, in combination:

- (a) resistor means connected between the collector of said control transistor and one terminal of said source of direct current;
- (b) a series-circuit incorporating
 - (1) a first capacitor having one terminal connected to said collector of said control transistor,
 - (2) a first rectifier having one terminal connected to the other terminal of said first capacitor, and
 - (3) a first resistor having one terminal connected to the other terminal of said first rectifier, the other terminal of said first resistor being connected to the base of said input transistor;
- (c) a second resistor connected between the base of said input transistor and said one terminal of said source of direct current;
- (d) a second capacitor connected between said base of said input transistor and the opposite terminal of said source of direct current;
- (e) a second rectifier connected between said opposite terminal of said source of direct current and the juncture of said other terminal of said first capacitor

8

and said one terminal of said first rectifier, said first and second rectifiers having dissimilar electrodes connected to each other, so that both rectifiers pass current in the same direction; and

(f) a further transistor connected to said control transistor for changing the state of conductivity thereof between conductive and blocked states in synchronism with the beat of the control value, said further transistor and said control transistor together forming a monostable flip-flop circuit whose unstable position results in rectangular pulses for effecting a transfer of charge from said first capacitor to said second capacitor, said rectangular pulses having a duration which is shorter than the minimum time interval between successive pulses of said control value.

4. A circuit arrangement as defined in claim 3 wherein said control value pulses are supplied from an internal combustion engine pertaining to a vehicle with which said clutch is used, and wherein the minimum time interval between successive control value pulses occurs at the maximum rotational speed of said engine.

5. The combination defined in claim 4 wherein said engine incorporates an ignition system which operates in synchronism with the rotational speed of the engine and wherein said control value pulses are derived from said ignition system.

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