United States Patent [19]

Schaub et al.

[11] **3,843,913**

[45] **Oct. 22, 1974**

[54] **SPEED REGULATING ARRANGEMENT FOR DC MOTORS**

[75] Inventors: **Gerhard Schaub,** Nurnberg; **Dietmar Rudolph,** Heilbronn-Sontheim, both of Germany

[73] Assignee: **Gebruder Buhler Nachfolger GmbH,** Nurnberg, Germany

[22] Filed: **May 18, 1971**

[21] Appl. No.: **144,216**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 755,529, Aug. 27, 1968, abandoned.

[30] **Foreign Application Priority Data**

Sept. 13, 1967 Germany 9442921

[52] **U.S. Cl.** **318/308,** 318/328, 318/332

[51] **Int. Cl.** **H02p 5/16**

[58] **Field of Search** 318/308, 332, 326–328

[56] **References Cited**

UNITED STATES PATENTS

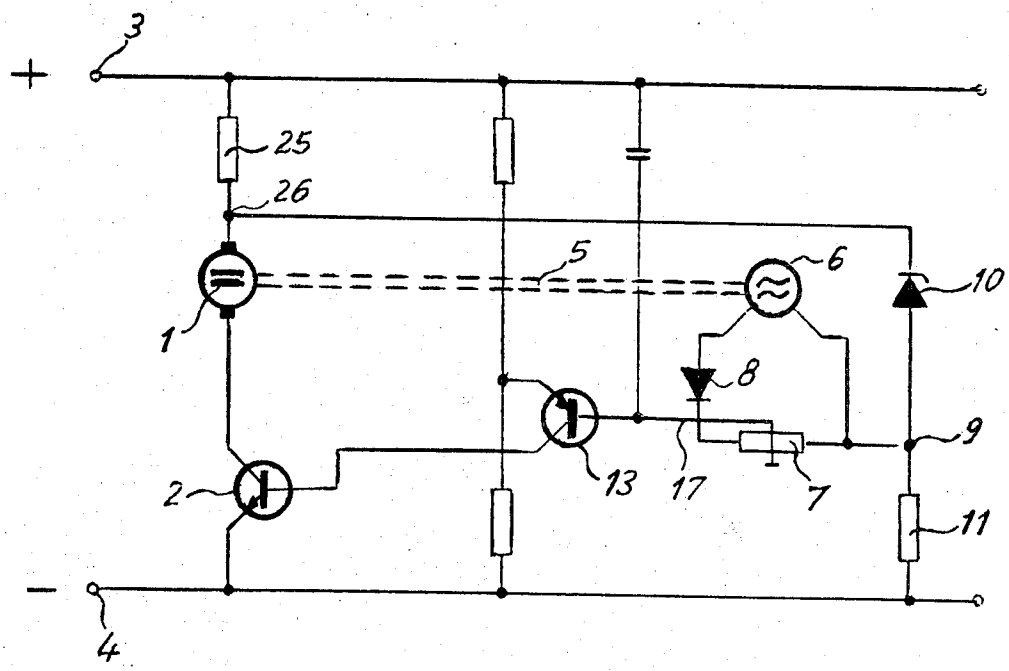
3,284,688	11/1966	Black	318/332
3,360,707	12/1967	Lewis	318/308
3,447,007	5/1969	Deaton	318/328
3,514,686	5/1970	Shano	318/327
3,544,872	12/1970	Rudolph	318/328

Primary Examiner—Bernard A. Gilheany
Assistant Examiner—Thomas Langer
Attorney, Agent, or Firm—Michael S. Striker

[57] **ABSTRACT**

An arrangement for maintaining constant the speed of DC motors. The motor is mechanically coupled to a generator the electrical output of which is added to a reference voltage. A power transistor is connected in series with the motor through its emitter-collector path. The power transistor may be driven by a preamplifying transistor stage. A regulating transistor applies the signal for the power transistor to the preamplifying stage. The power transistor varies the motor current as a result of its conducting state. An auxiliary voltage source connected to the motor provides voltage potential dependent upon the motor load. This potential is applied through the feed-back circuit including the regulating transistor, to the power transistor, in order to vary the conducting state of the latter in accordance with the motor load.

11 Claims, 9 Drawing Figures



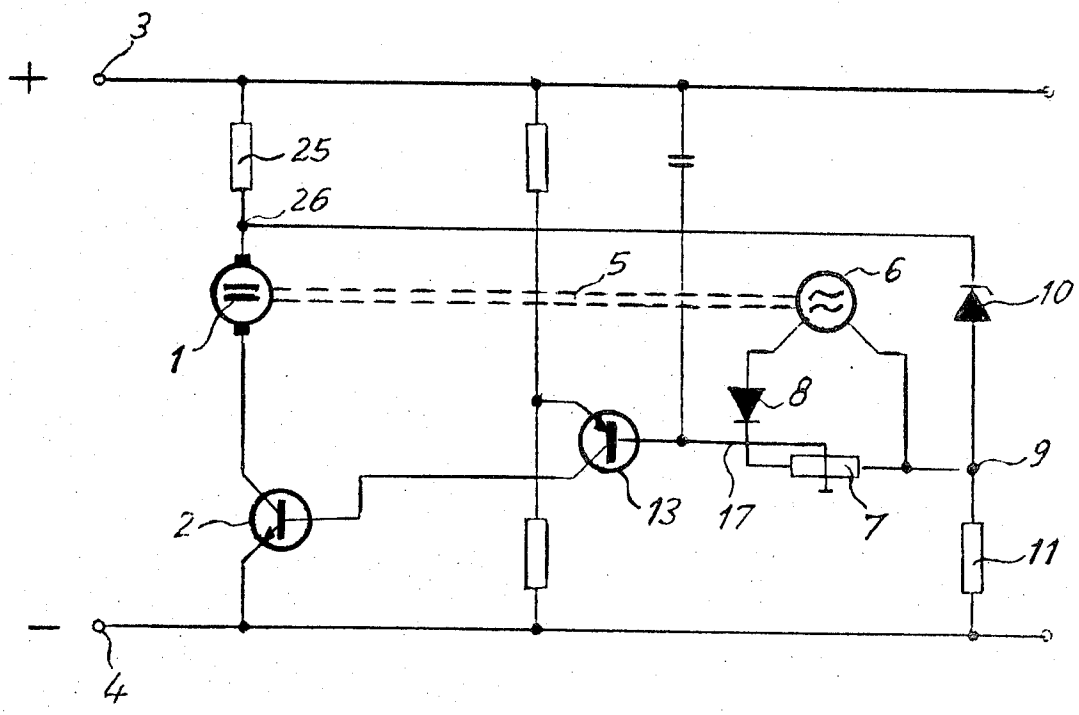


Fig. 1

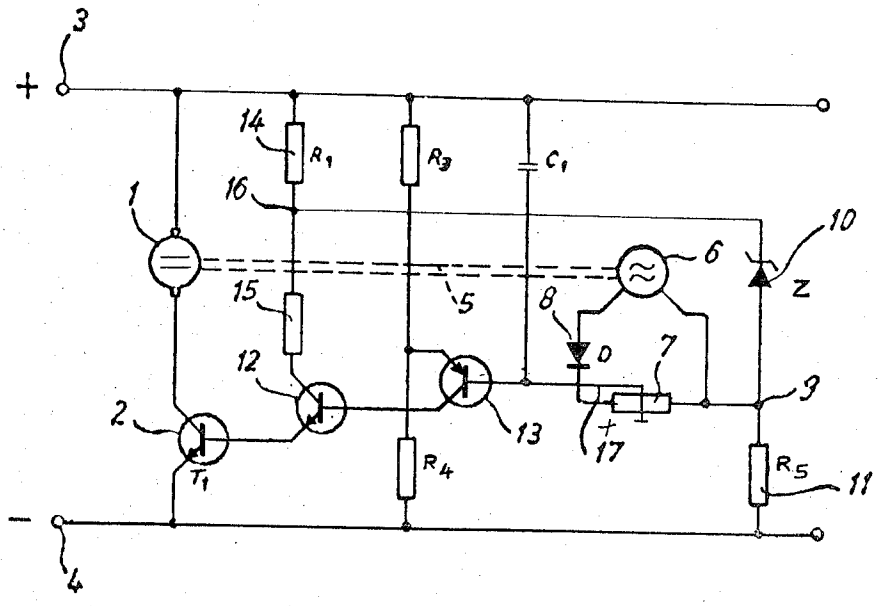
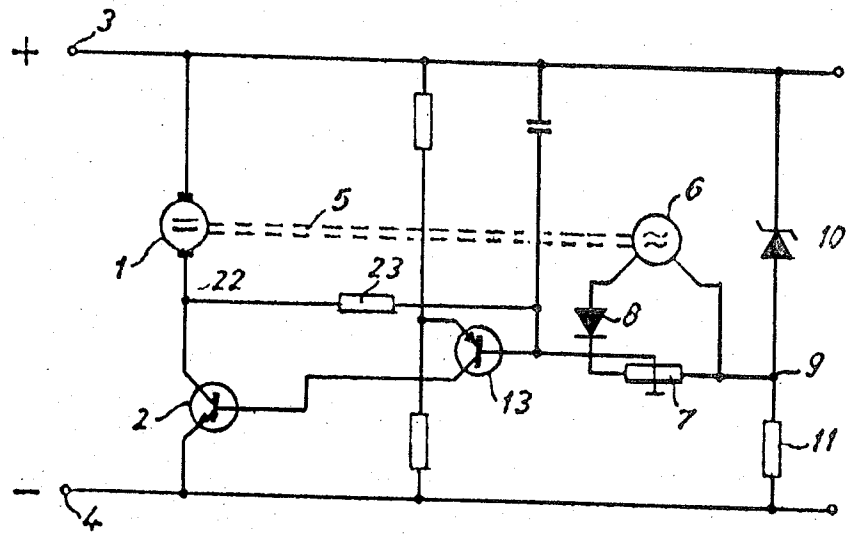


Fig. 2

Fig. 3



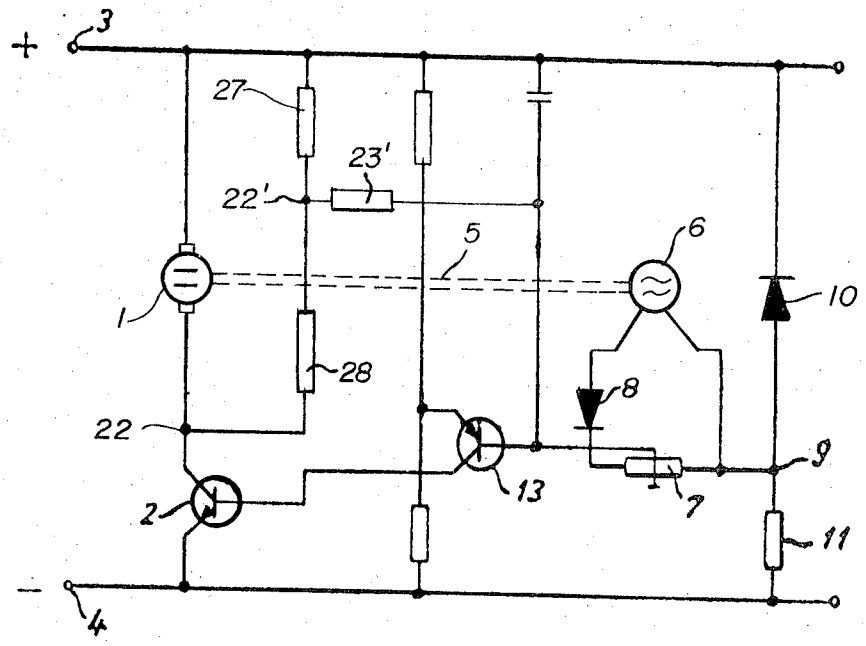


Fig. 3a

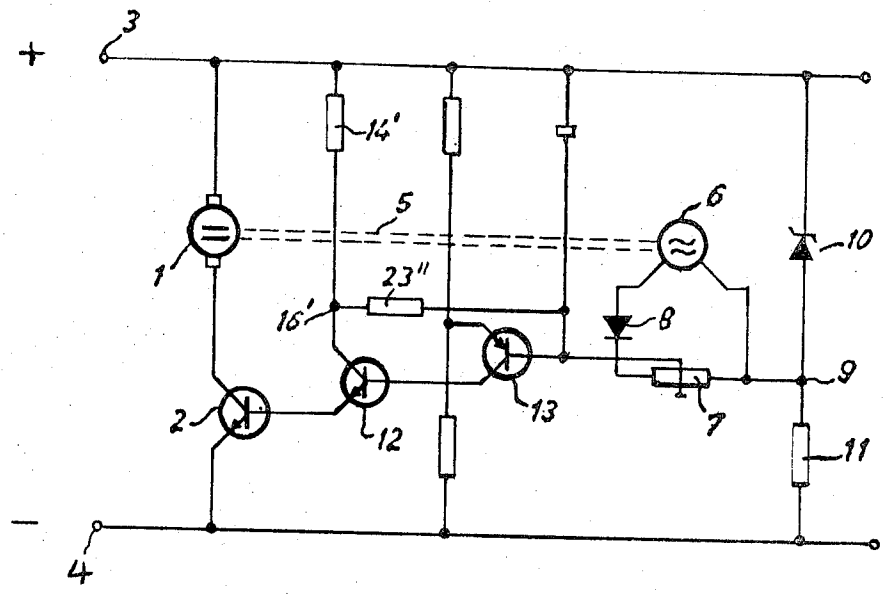


Fig. 4

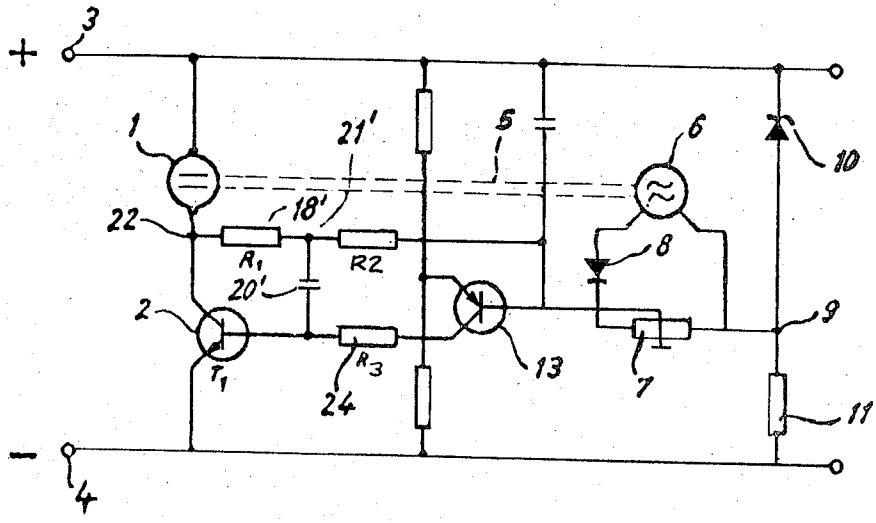


Fig. 5

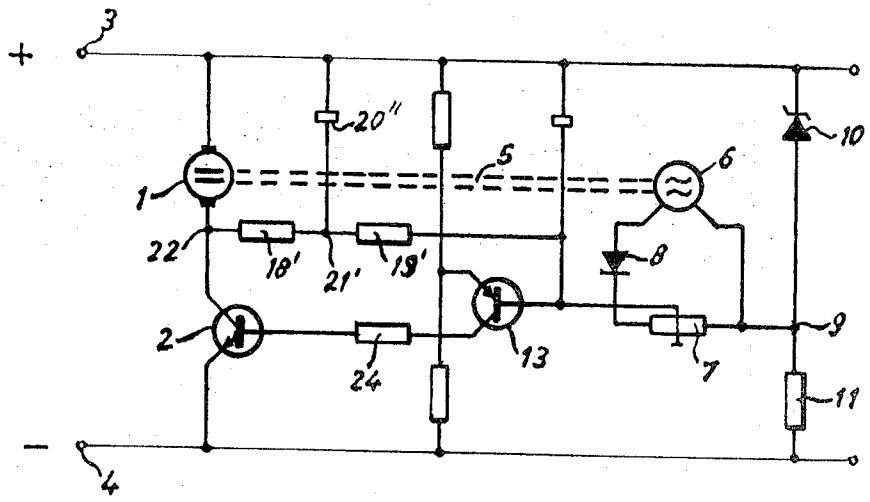


Fig. 6

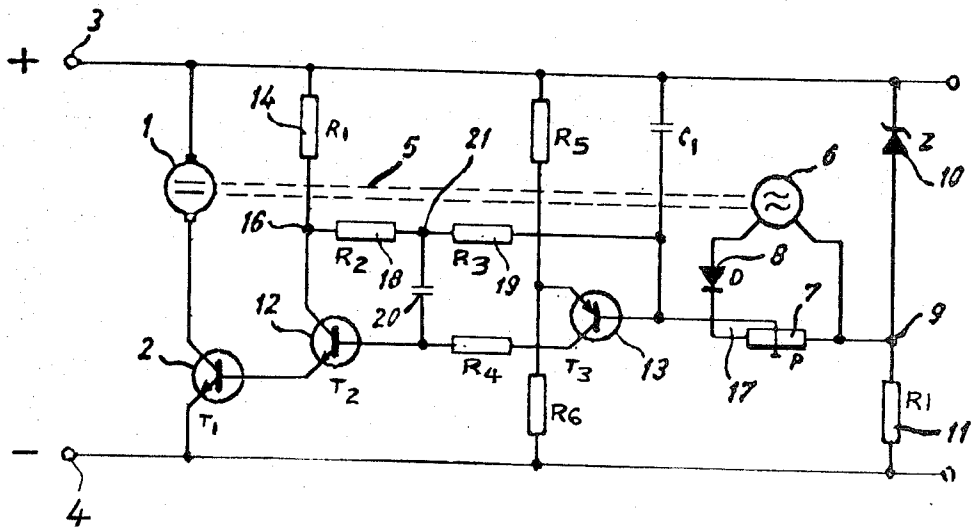

+
3
1
14
R1
5
21
R5
C1
6
Z
10
16
R2
18
R3
19
D
8
7
9
12
20
2
T2
R4
T3
13
P
17
T1
R6
R1
11
−
4

FIG. 7

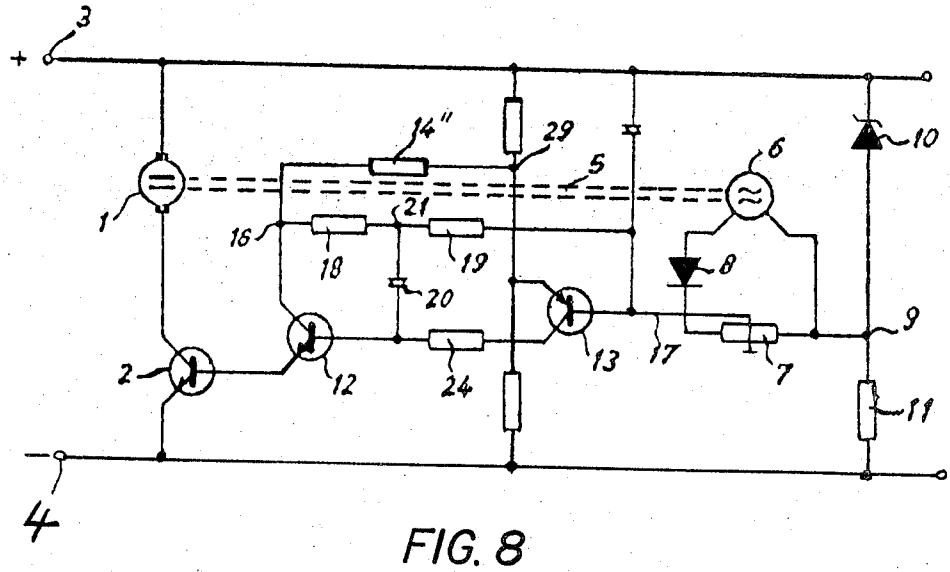


FIG. 8

SPEED REGULATING ARRANGEMENT FOR DC MOTORS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of application Ser. No. 755,529, filed Aug. 27, 1968, now abandoned.

BACKGROUND OF THE INVENTION

The present invention resides in an arrangement for maintaining constant the rotational speed of a DC motor, through the use of a power transistor which controls the current to the motor, and through the use of an auxiliary generator and reference voltage source for varying motor loads.

The regulation of the speed of miniature DC motors through the use of auxiliary generators coupled thereto, is well known in the art. In such known arrangements, as is disclosed in the German Patent No. 1,166,904, a Zener diode serves as a voltage reference source and is connected in series with a resistor and the output of the auxiliary generator. Such regulating arrangements, however, are not satisfactory to motors which are subjected to severe load variations, in the absence of stable operating DC voltages realized through auxiliary circuit components. In the application of motors, there are cases when it is desired to maintain the motor speed constant with substantially high tolerances, while the motor load varies severely. Such an application may, for example, be found in the driving or operation of instrumentation associated with information storage.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an electrical arrangement for regulating the speed of motors such that the regulating sensitivity is increased as a function of the load variations of the motor. The arrangement is such that stiffening of the desired speed is realized. The object of the present invention is achieved by providing an auxiliary voltage source in the regulating circuit. The auxiliary voltage source is a function of the motor load and hence of the motor current. The potential of this auxiliary voltage source is transmitted through a feed-back branch directly or indirectly to the power transistor controlling the motor current. A simple arrangement for taking into account motor speed as a function of load variation is realized in accordance with the present invention, by providing an auxiliary resistor in series with the motor. A current and hence load dependent voltage is derived from this resistor and is used for the purpose of controlling the motor speed. This auxiliary resistor can also, in accordance with the present invention, be inserted into a branch of the regulating circuit in which the current is proportional to the motor current, or a corresponding voltage. In the arrangement of this auxiliary resistor, an auxiliary voltage may be derived as a function of the motor current, in an indirect manner, and the auxiliary voltage may be applied to the base of the power transistor controlling the motor. At the same time, the auxiliary voltage may also be applied to a preamplifying driving transistor that may be used to preamplify the signal applied to the power transistor. It is also possible to use directly the internal resistance of the motor for the auxiliary voltage source. In this arrangement, a voltage is derived in dependence of the motor current, and is applied to the regulating circuit by means of a feed-back branch.

In the regulating circuit of the present invention, the current variations resulting from corresponding load variations are directly applied as auxiliary or additional regulating parameters in the regulating circuitry. The regulating parameters are not applied in a round-about way as a function of the speed variations resulting from the load variations. Through this arrangement, a stiffening of the desired speed value is essentially realized in relation to the load variations of the motor.

The arrangement in accordance with the present invention can be designed in different ways. For example, the auxiliary voltage source as reflected by a resistor can be connected in series with a Zener diode and a further resistor applied to the operating DC power supply. The resistor associated with the auxiliary voltage force is connected in series with the emitter-collector path of the power transistor or a preamplifying driving transistor connected to the power transistor. In this design, a resistor provides an auxiliary voltage source proportional to the current of the power transistor or of the preamplifying transistor. This auxiliary voltage is added to the Zener voltage. This auxiliary voltage can also be applied together with a stabilized reference voltage to the base of the power transistor or the preamplifying transistor, by way of a regulating transistor preceding these two transistors. In this configuration, the reference voltage is stabilized with respect to the desired value of the rotational speed. In this design, furthermore, the base of the regulating transistor can be linked or connected with the resistor serving as the auxiliary voltage source, by way of a resistor or a chain of resistors. A coupling circuit through means of a capacitor can also be provided between the base of the power transistor or the driving transistor and a tap of the resistor chain. In a variation of this design, the capacitor can be connected between the tap of the resistor chain and a terminal of the battery supplying the power. In this arrangement, the capacitor functions as a filtering circuit in conjunction with a resistor of the resistor chain.

Briefly the regulating circuit of the invention consist of first transistor means connected in series with the motor to conduct the operating current thereof, an alternating current generator mechanically coupled to the motor so as to provide an output voltage of which the value is proportional to the motor r.p.m., second transistor means connected to the base of the first transistor means for varying the conductivity of the first transistor means and therefore the amount of operating current fed to the motor in dependence on the conductivity of the second transistor means, means connecting the output of the generator to the second transistor means so as to vary the conductivity of the latter in dependence on the conductivity of the generator, a first resistor in circuit for providing a voltage drop that is proportional to the motor operating current and therefore to the motor load, a positive feedback circuit connected between the first resistor and the second transistor means for controlling the conductivity of the latter in dependence on the voltage drop and thereby respectively increasing or decreasing, in dependence on the operating current, the conductivity of the first transistor means when the motor load increases or decreases, and reference voltage means connected to the output of the generator.

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.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an electrical schematic diagram of a first embodiment of a speed regulating arrangement, in accordance with the present invention;

FIG. 2 is an electrical schematic diagram and shows an embodiment similar to that of FIG. 1 with the addition of a driving stage;

FIG. 3 is an electrical schematic diagram in which the internal resistance of the motor serves directly as an auxiliary voltage source depending upon the motor load;

FIG. 3*a* is an electrical schematic diagram corresponding to the embodiment of FIG. 3 in which the auxiliary voltage source is realized through a voltage divider connected in parallel with the motor;

FIG. 4 is an electrical schematic diagram of an embodiment in accordance with FIG. 3 in which an auxiliary voltage is derived from a collector resistor of a driving transistor;

FIG. 5 is an electrical schematic diagram of an embodiment of the present invention including a resistor chain and coupling capacitor in the regulating circuitry;

FIG. 6 is an electrical schematic diagram of an embodiment of the present invention including a resistor chain and a filter capacitor;

FIG. 7 is an electrical schematic diagram similar to the embodiment of FIG. 5, in which a preamplifying driving stage is included; and

FIG. 8 is an electrical schematic diagram of a variation of the embodiment shown in FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, a DC motor 1 is connected in series with the emitter-collector path of a power transistor 2 constituting first controllable electronic impedance means which, in turn, leads to a DC power supply. The latter is in the form of, for example, a battery having a negative terminal 4 and a positive terminal 3. The motor 1 is mechanically coupled to an auxiliary generator 6 by means of a shaft denoted in the drawing by the dashed lines 5. The auxiliary generator 6 serving as a speed-monitoring means is designed in the form of, for example, a plurality of permanent magnets mounted upon the shaft 5 and a stationary or fixed stator winding. The stator winding provides an AC voltage which is induced and depends upon the speed of the shaft 5 and hence of the motor 1. The output circuit for the auxiliary generator 6 consists of the series combination of a potentiometer winding 7 and a rectifying diode 8. One terminal of the generator 6 is connected to one end of the winding of potentiometer 7 and this junction is denoted by the reference numeral 9. Connected also to this junction 9 is a Zener diode 10 and a resistor 11. As a result of its breakdown voltage, the Zener diode serves in the commonly-known manner as a reference source. The Zener diode can operate in conjunction with the resistor 11, as in FIG. 3, so that stabilization of the battery with terminals 3 and 4 is applied to its output voltage and thus to the regulating circuit.

The base of the power transistor 2 is connected to the emitter of a preamplifying driving transistor 12, in the conventional manner, as shown in the embodiment of FIGS. 2, 4, 7 and 8. A regulating transistor 13 precedes the power transistor 2 and the driving transistor 12 which latter constitutes second controllable electronic impedance means.

In accordance with the embodiment of FIG. 1, a resistor 25 is connected in series with the motor 1 and the collector-emitter path of the power transistor 2 which controls the motor current. The resistor 25 serves as auxiliary voltage source. Between the junction 26 and the positive terminal 3 of the battery, a voltage is realized which is proportional to the motor current. This voltage is added to the reference voltage of the Zener diode 10, and the resulting sum of voltages is applied to the base of the regulating transistor 13, by way of the path including the path of the junction 9 and the potentiometer winding 7.

In the embodiment of FIG. 2, a resistor 14 is connected in series with a second resistor 15 and this latter combination is in turn connected to the emitter-collector path of the driving transistor 12. The resistor 14 serves both as an impedance-monitoring means and as an auxiliary or additional source of voltage. The emitter of the driving transistor 12 is connected, in the conventional manner, to the base of the power transistor 2 which has its emitter-collector path connected in series with the motor 1. A voltage potential at the junction 16 between the resistors 14 and 15 is proportional to the emitter-collector current of the driving transistor 12. Thus, the voltage drop across the resistor 14 is an indication of the magnitude of the emitter-collector current of the transistor 12. Since the emitter-collector current depends upon the operating current of the motor 1 which, in turn, depends upon the load of the motor, the voltage drop across the resistor 14 is also dependent upon the motor load.

The junction 16 is connected to the Zener diode 10. As a result, the voltage drop appearing across the resistor 14 is added to the Zener voltage as determined by the Zener diode 10. The summation of the two voltages appears at the junction 9, and is transmitted to the base of the regulating transistor 13, by means of the sliding contact 17 of the potentiometer 17. With the summation of the two voltages thus applied to the base of the transistor 13, the power transistor 2 is also influenced.

With the circuitry, in accordance with the present invention, stiffening of the speed of the motor 1 is essentially achieved. As soon as an increase in the operating current of the motor appears as a result of added load, the reference potential at the junction 9 is correspondingly increased. This increase in the potential at the junction 9 results from the added voltage source through the regulating circuit including resistor 14 or resistor 25. As a result of this increased potential at the junction 9 the power transistor 2 is made further conductive as a result of the transistorized path of the circuit. The regulation is increased or improved by taking directly into account the motor load in relation to a pure speed dependent control, through means of the auxiliary generator 6. It will be clear from the above de-

scription that components **10, 7, 17, 13,** R3 and R4 constitute negative-feedback means operative for applying to the base of transistor **12** negative feedback signals derived from the generator **6** and the monitoring impedance **14.**

In the embodiment of FIG. **3,** the internal resistance or the copper resistance of the DC motor itself is used as the auxiliary or additional voltage source, in place of the resistor **14** or **25.** The voltage at the junction **22,** in FIG. **3,** is a function of the load, in the respect that the magnitude of the voltage or potential at this junction is dependent on the magnitude of the motor current. This potential at the junction **22** is applied, by way of the resistor **23,** to the base of the transistor **13.** As a result, of this circuit design, improved regulation of the arrangement is realized.

FIG. **3***a* shows a variation of the embodiment of FIG. **3.** In the design shown in FIG. **3***a*, the voltage potential at the junction **22** is applied to a voltage divider consisting of resistors **27** and **28.** The potential appearing at the junction **22'** between the resistor **27** and the resistor **28,** is applied to the base of the resistor **23,** by way of the resistor **23'.** The voltage divider of resistors **27** and **28** serves to adapt the potential at the junction **22',** to the base potential of the regulating transistor **13.**

In the embodiment of FIG. **4,** the resistor **14'** is connected in series with the emitter-collector path of the transistor **12.** The collector potential of the transistor **12** appearing at the junction **16'** is applied, by way of the resistor **23''**, to the base of the regulating transistor **13.**

In FIGS. **5** to **8,** a resistor chain or combination of resistors **18** and **19** or **18'** and **19',** is used to interconnect the junction **22** or **16** with the base of the regulating transistor **13.** A capacitor **20'** is connected, in FIG. **5,** between the base of the power transistor **2** and the junction of the resistors **18'** and **19'.** The purpose of this capacitor is to improve the dynamic regulating characteristics of the arrangement. The capacitor **20'** serves as electrical damping means for reducing the stabilizing action of the negative-feedback circuit in response to sudden and short lasting changes in motor speed. In FIG. **6** a similar such capacitor (capacitor **20''**), serving the same purpose, is connected between the positive terminal **3** of the battery and the junction of the resistors **18'** and **19'.** In FIGS. **7** and **8,** on the other hand, this capacitor (capacitor **20**) for improving the dynamic regulating characteristics of the arrangement, is connected between the base of the preamplifying transistor **12** and the junction **21** of the resistors **18** and **19.** In the embodiment shown in FIG. **7,** the capacitor **20** can also be connected between junction, or tap, **21** and the base of transistor **2.**

FIG. **8** shows an extended design of the circuit embodiment of FIG. **7.** The additional auxiliary voltage source **14'** is, in this case, not connected to the positive terminal **3** of the battery. Instead, the resistor is connected to the emitter terminal **29** of the regulating transistor **13.** The resulting DC coupling circuitry produces an improvement in the regulating characteristics of the arrangement.

In accordance with the invention, in the embodiment shown in FIG. **8,** a capacitor (not shown) can be connected between the junction, or tap, **21** and the positive or negative terminal **3** or **4,** respectively.

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 constructions differing from the types described above.

While the invention has been illustrated and described as embodied in speed controls for DC motors, 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 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 protected by Letters Patent is set forth in the appended claims.

We claim:

1. An arrangement for stabilizing the speed of a D.C. motor, comprising, in combination, first controllable electronic impedance means connected in the current path of the motor and having first control input means; second controllable electronic impedance means including output means connected to said first control input means and operative for controlling the impedance of said first impedance means in dependence upon the impedance of said second impedance means to thereby influence the speed of said motor, said second controllable electronic impedance means having respective second control input means, and said second impedance means further including impedance-monitoring means for generating a monitoring signal varying in dependence upon changes in the impedance of said second impedance means; speed-monitoring means coupled to the motor and operative for generating a speed signal varying in dependence upon motor speed, said speed-monitoring means including means coupled to the motor for producing a variable alternating voltage proportional in amplitude to the speed of said motor, a rectifier, a capacitor, a source of fixed direct reference voltage, a voltage divider having an adjustable tap, said voltage divider and said rectifier being connected in series with the means for producing alternating voltage and said capacitor being connected between said tap and one terminal of said source of fixed direct reference voltage, to provide across said voltage divider a direct feedback voltage variable in proportion to said motor speed; negative-feedback means connecting said tap to said control input means for applying to the latter a speed-dependent negative-feedback signal to vary the impedance of said second impedance means in response to changes in motor speed and accordingly vary the impedance of said first impedance means and cause changes in said monitoring signal indirectly indicative of changes in motor current, and also connecting said impedance-monitoring means to said second control input means for influencing said negative-feedback signal in indirect dependence upon changes in motor current, said negative-feedback means including electrical damping means operative for reducing the negative-feedback stabilizing action of said negative-feedback means in response to sudden and short-lasting changes in motor speed.

2. An arrangement as defined in claim **1,** wherein said first controllable electronic impedance means

comprises a first transistor having an emitter-collector path connected in series in the motor current path and having a base constituting said first control input means, and wherein said second controllable electronic impedance means comprises a second transistor having an emitter-collector path and having a base constituting said second control input means, and wherein said impedance monitoring means comprises a monitoring resistor connected is series with the emitter-collector path of said second transistor, and wherein said second transistor has one output electrode connected to the base of said first transistor for controlling the conductivity of said first transistor in dependance upon the voltage at the base of said second transistor.

3. An arrangement as defined in claim **2,** wherein said second transistor has another output electrode connected to one terminal of said monitoring resistor and wherein said monitoring resistor has another terminal, and wherein said negative-feedback means further includes a third transistor having a base connected to said tap, one output electrode connected to the base of said second transistor for controlling the latter and having another output electrode connected to said other terminal of said monitoring resistor.

4. An arrangement as defined in claim **2,** and further including a voltage source having two terminals, said monitoring resistor having one terminal connected to one terminal of said source and having another terminal, and wherein said source of reference voltage comprises a Zener diode connected between said other terminal of said monitoring resistor and said base of said second transistor.

5. An arrangement as defined in claim **4,** wherein said negative-feedback means further includes a third transistor having a base connected to said tap and having an output electrode connected to the base of said second transistor.

6. An arrangement as defined in claim **4,** wherein the electrode of said Zener diode not connected to said monitoring resistor is connected to one terminal of a further resistor, with the other terminal of said further resistor being connected directly to the other terminal of said voltage source.

7. An arrangement as defined in claim **6,** wherein said second impedance means further includes an additional resistor also connected in the emitter-collector path of said first transistor and forming a junction with said other terminal of said monitoring resistor.

8. An arrangement as defined in claim **2,** and further including a voltage source having two terminals, said monitoring resistor having one terminal connected to one terminal of said source and having another terminal, and wherein said negative-feedback means comprises a third transistor having an output electrode connected to the base of said second transistor for controlling said second transistor, and said third transistor also having a base connected to said tap, and resistor means connecting said other terminal of said monitoring resistor to said base of said third transistor for transmitting variations in the voltage across said monitoring resistor to said base of said third transistor.

9. An arrangement as defined in claim **8,** wherein said resistor means consists of a plurality of discrete resistor elements.

10. An arrangement as defined in claim **9,** wherein said plurality of discrete resistor elements comprises two resistor elements defining a junction, and wherein said damping means further includes a capacitor connected between said just-mentioned junction and said base of said second transistor.

11. An arrangement as defined in claim **8,** wherein said resistor means consists of a single resistor element.

* * * * *