United States Patent [19]

Hafner

[11] **3,745,420**

[45] **July 10, 1973**

[54] **CIRCUIT ARRANGEMENT FOR THE ACCURATE ADJUSTMENT OF ELECTROMAGNETIC ADJUSTING ELEMENTS AS A FUNCTION OF A D.C. VOLTAGE**

[75] Inventor: **Günther Häfner**, Stuttgart, Germany

[73] Assignee: **Daimler-Benz Aktiengesellschaft**, Stuttgart, Germany

[22] Filed: **Apr. 25, 1972**

[21] Appl. No.: **247,334**

[30] **Foreign Application Priority Data**

Apr. 26, 1971 Germany ..... P 21 20 458.0

[52] **U.S. Cl.** ..... **317/146**, 307/261, 307/271, 317/DIG. 1, 317/DIG. 4, 317/DIG. 6, 318/599, 331/177 R

[51] **Int. Cl.** **H01h 47/32**

[58] **Field of Search** ..... 317/123, 148.5, 146, 317/DIG. 1, DIG. 4, DIG. 6; 318/596, 599, 606, 696, 678, 681; 331/177 R; 307/230, 261, 264, 271

[56] **References Cited**

UNITED STATES PATENTS

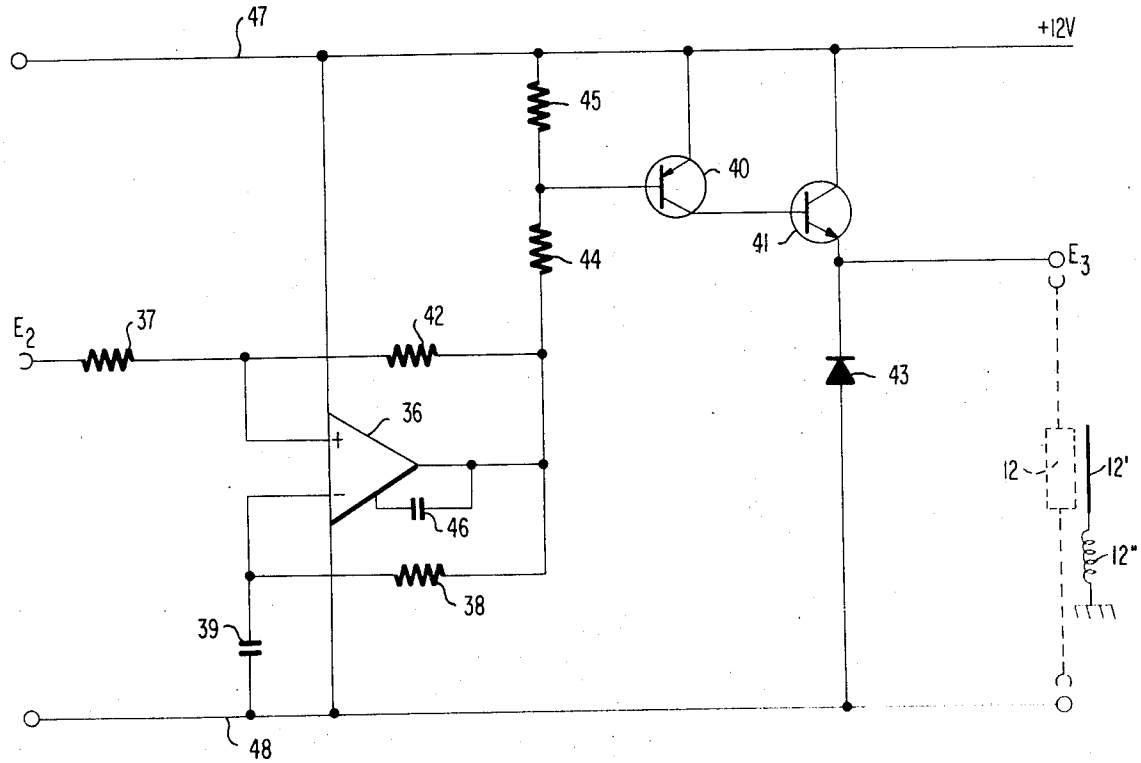
3,671,814	4/1971	Dick	317/123
3,656,066	5/1970	Reynal	331/177 R

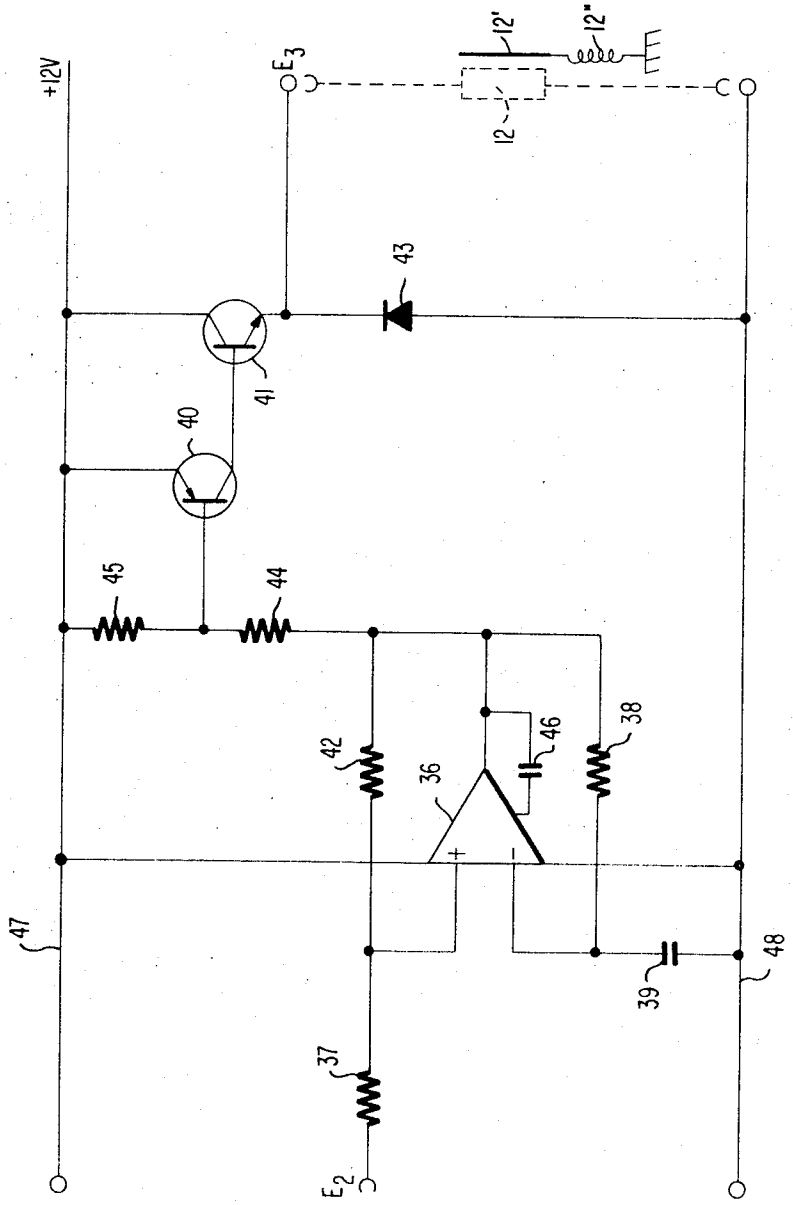
Primary Examiner—J. D. Miller
Assistant Examiner—Harry E. Moose, Jr.
Attorney—Paul M. Craig, Jr. et al.

[57] **ABSTRACT**

A circuit arrangement for accurately positioning and adjusting an electromagnetic actuating member as a function of a d.c. voltage, in which the d.c. voltage is chopped into a rectangular pulse voltage with constant amplitude as well as with variable pulse spacing and variable pulse width such that the average value of the pulse voltage is equal to the d.c. voltage; the pulse voltage thus obtained acts on an adjusting member opposite a prestress engaging at this adjusting member.

15 Claims, 1 Drawing Figure




+12V
E3
12'
12"
12
43
41
40
45
44
42
36
46
38
47
48
39
37
E2

CIRCUIT ARRANGEMENT FOR THE ACCURATE ADJUSTMENT OF ELECTROMAGNETIC ADJUSTING ELEMENTS AS A FUNCTION OF A D.C. VOLTAGE

The present invention relates to a circuit arrangement for the accurate adjustment of electromagnetic actuating or correcting members as a function of a direct current voltage.

Such circuit arrangements are required, for example, in order to actuate by way of an actuating magnet the control rack of a Diesel injection pump in dependence on the engine rotational speed.

A problem with such types of circuit arrangements resides in that the correcting or adjusting members cannot follow immediately slight changes of the d.c. control voltage, for example, by reason of mechanical friction.

Accordingly, the aim of the present invention resides in providing a circuit arrangement of the aforementioned type by means of which the adjusting members are realiably readjusted also in case of only slight changes of the d.c. control voltage.

As solution to the underlying problems, the present invention proposes that the d.c. voltage is chopped into a rectangular pulse voltage with constant amplitude as well as with a varying pulse spacing and varying pulse width in such a manner that the average value of the pulse voltage is equal to the d.c. voltage, and that the pulse voltage acts against a prestress engaging at the adjusting member. In this manner, the adjusting member carries out slight vibrational movements under the influence of the pulse voltage which assures that also with slight changes of the d.c. control voltage, the static friction is reliably overcome and an accurate readjustment of the adjusting member takes place.

In one preferred embodiment, provision is made that the d.c. voltage is applied by way of a series-resistance to the non-inverting input of an operational amplifier, to the inverting input of which is connected a condenser charged by way of a resistance from the output of the amplifier, and in that the output of the operational amplifier controls a transistor amplifier, in the output circuit of which is connected the adjusting member. With this type of construction, the additional advantage exists that the transistors of the transistor amplifier are operated only in the fully opened and fully closed condition, i.e., in the fully conductive and in the fully non-conductive condition so that an undesired ohmic heating up is advantageously avoided.

The use of an operational amplifier assures a conversion of the direct current voltage into a rectangular voltage pulse which can be carried out both in a simple and economic manner.

The output of the operational amplifier is preferably connected with the non-inverting input by way of a positive feedback resistance. The values of the positive feedback resistance and of the series-connected resistance are thereby preferably at a ratio of approximately 10 : 1. The condenser has preferably a capacity of the order of magnitude of one-tenth microfarads.

Advantageously, the output of the operational amplifier controls an output or final transistor by way of a Darlington-circuit including a transistor. The two transistors are preferably of opposite conductivity type.

In order to protect the final or output transistor against peaks as occur when turning off, a diode which is poled oppositely to the base emitter circuit of the output transistor, is preferably connected in parallel with the adjusting member.

For purposes of avoiding switching uncertainties and unreliabilities, the output compensation of the operational amplifier preferably includes a condenser having a low capacity.

The adjusting or correcting member is preferably prestressed by a spring against the effect of the pulse voltage. It consists advantageously of an actuating or adjusting magnet.

Accordingly, it is an object of the present invention to provide a circuit arrangement for the accurate adjustment of electromagnetic correcting members as a function of a d.c. voltage which avoids by simple means the aforementioned shortcomings and drawbacks encountered in the prior art.

Another object of the present invention resides in a circuit arrangement which assures reliable and immediate readjustments of the adjusting member even in case of only slight changes in the d.c. control voltage.

A further object of the present invention resides in a circuit arrangement for accurately adjusting electromagnetic actuating members as a function of a d.c. voltage which permits a simple and economic conversion of the d.c. voltage into rectangular pulse voltages while at the same time avoiding undesired ohmic heating of the transistors used in the circuit.

Still another object of the present invention resides in a circuit arrangement of the type described above which effectively protects its components against peak voltages and which is characterized by extraordinary reliability in its switching operations.

These and other objects, features and advantages of the present invention will become more apparent from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, one embodiment in accordance with the present invention, and wherein:

The single FIGURE is a schematic circuit diagram for the control circuit arrangement of a preferred embodiment in accordance with the present invention.

Referring now to the single FIGURE of the drawing, an operational amplifier **36** of any conventional construction is connected between two lines **47, 48** which carry a voltage of, for example, **12** volts, which may stem for instance from a vehicle battery. The non-inverting input (+) of the operational amplifier **36** is connected with the control d.c. voltage E_2 by way of a series resistance **37.** The output of the operational amplifier **36** is connected on the one hand, with the non-inverting input (+) by way of a positive feedback resistance **42** which is approximately 10 times as large as the series resistance **37,** and, on the other, is connected by way of a resistance **38** with a condenser **39** which is connected between the line **48** and the inverting input (−).

Furthermore, the output of the operational amplifier **36** is connected to the line **47** by way of a voltage divider **44, 45.**

A first transistor **40** is connected with its base to the point of connection of the two resistances **44** and **45** whereas its emitter is directly connected with the line **47.** The collector of the transistor **40** is connected to the base of an output or power transistor **41** which is of opposite conductivity type as the transistor **40.** The collector of the transistor **41** is connected with the line

47 whereas its emitter supplies the rectangular pulse voltage E_3 to an adjusting magnet **12** of any conventional construction having a servo element **12'** connected to bias spring **12''**.

A diode **43** is connected in parallel to the adjusting magnet **12**, which is conductive in a direction opposite to the direction of the base emitter circuit of the transistor **41**.

The output compensation of the operational amplifier **36** is equipped with a condenser **46** having a slight capacity.

OPERATION

The operation of the described circuit is as follows:

Upon application of a d.c. control voltage E_2, the operational amplifier output at first becomes positive. Due to the positive feedback by way of the resistance **42**, the voltage at the non-converting input (+) increases additionally.

The output transistor **41** is now blocked, i.e., non-conductive.

After the operational amplifier output becomes positive, the condenser **39** begins to charge by way of the resistance **38**. As soon as the voltage at the condenser **39** reaches the value at the non-inverting input (+), the operational amplifier **36** operating as comparator flips over. Its output now becomes negative and the output transistor **41** becomes conductive. Simultaneously, the voltage at the condenser **39** again decreases, and the voltage at the non-inverting input (+) jumps down by the value of the positive feedback. The operational amplifier **36** now flips back again into its original condition only when the voltage at the condenser **39** drops below the value at the non-inverting input. Up to that point of time, the output transistor **41** remains conductive.

The condenser **46** serves for avoiding switching uncertainties. The average voltage at the non-inverting input corresponds to the control voltage and to the average charging voltage at the condenser **39**.

The output voltage of the operational amplifier **36** therefore assumes only two end values so that the keying ratio of the output voltage is fixedly coordinated to the d.c. control voltage E_2. Thus, the duration of energization of the adjusting magnet **12** is proportional to the d.c. control voltage E_2.

If the d.c. control voltage changes within a shifting period by more than the width of the positive feedback hysteresis, then an excessively long pulse will appear during a control voltage rise at the output. The pulse lasts for such length of time until the condenser voltage has reached the new hysteresis band.

During a rapid drop of the control voltage, the operation is correspondingly reverse.

From an over-all point of view, a rate action is produced by the described effect which improves the adjusting velocity of the adjusting magnet **12** in an advantageous manner. The final stage operates nearly loss-free.

By an appropriate selection of the pulse frequency, a slight co-vibration or sympathetic vibration of the adjusting member **12** is achieved according to the present invention whereby the mechanical friction hysteresis is decisively lessened. The pulse frequency therefore has to be matched to the inertia of the adjusting magnet.

Typical values for the individual parameters of a circuit of a preferred embodiment in accordance with the present invention are as follows:

Resistor **37** = 18 K
Resistor **38** =270 K
Condenser **39** = 0.15 μF
Resistor **42** = 180 K
Resistor **44** = 2.7 K
Resistor **45** = 1 K
Condenser **46** = 22 p

While I have shown and described only one embodiment in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to those skilled in the art. For example, the values of the component elements may be changed to suit a particular need and appropriate changes may also be made in the circuits of the operational amplifier and/or other transistors as known to those skilled in the art. Hence, I do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

What I claim is:

1. A circuit arrangement for the accurate adjustment of an adjusting member as a function of a d.c. control voltage, characterized by means for chopping the d.c. control voltage into a substantially rectangular pulse voltage with substantially constant amplitude as well as with varying pulse spacing and varying pulse width in such a manner that the average value of the pulse voltage is substantially equal to the d.c. control voltage, and connecting means operable to cause the pulse voltage to act against a prestress engaging at the adjusting member, characterized in that the chopper means includes an operational amplifier means having a non-inverting input and an inverting input as well as an output, the d.c. control voltage being applied by way of a series-connected resistor to the non-inverting input, condenser means charged from the output of the operational amplifier means by way of a charging resistor and connected to the inverting input, the output of the operational amplifier means controlling a transistor amplifier means, and said transistor amplifier means having an output circuit to which the adjusting member is operatively connected.

2. A circuit arrangement according to claim **1**, characterized in that the adjusting member is an electromagnetic adjusting member.

3. A circuit arrangement according to claim **1**, characterized in that the output of the operational amplifier means is operatively connected with the non-inverting input thereof by way of a positive feedback circuit.

4. A circuit arrangement according to claim **3**, characterized in that the positive feedback circuit includes a feedback resistor.

5. A circuit arrangement according to claim **5**, characterized in that the values of the feedback resistor and of the series-connected resistor are at a ratio of approximately 10 : 1.

6. A circuit arrangement according to claim **5**, characterized in that the condenser means has a capacitance of the order of magnitude of one-tenth of one microfarad.

7. A circuit arrangement according to claim **6**, characterized in that the output of the operational amplifier

means controls an output transistor by way of Darlington circuit including a transistor.

8. A circuit arrangement according to claim 7, characterized in that the two last-mentioned transistors are of opposite conductivity type.

9. A circuit arrangement according to claim 8, characterized in that a diode is connected in parallel to the adjusting member which has a polarity opposite to the base emitter circuit of the output transistor.

10. A circuit arrangement according to claim 9, characterized by output compensation means for the operational amplifier means which includes a condenser with slight capacity.

11. A circuit arrangement according to claim 10, characterized in that the adjusting member is prestressed by a spring against the effect of the pulse voltage.

12. A circuit arrangement according to claim 11, characterized in that the adjusting member is an adjusting magnet.

13. A circuit arrangement according to claim 11, characterized in that the adjusting member is an electromagnetic adjusting member.

14. A circuit arrangement according to claim 1, characterized in that the condenser means has a capacitance of the order of magnitude of one-tenth of one microfarad.

15. A circuit arrangement according to claim 1, characterized in that the adjusting member is prestressed by a spring against the effect of the pulse voltage.

* * * * *