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Reply to Attn of: GP

TO: NHB/Scientific & Technical Information Office

FROM: GP-4/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP-4 and Code NHB, the enclosed NASA-owned U.S. Patent is being forwarded for abstracting and announcment in NASA STAR.

The following information is provided:

U.S. Patent No.	: 3,475,675
Government or Corporate Employee	: United Aircraft Corporation East Hartford, Conn.
Supplementary Corporate Source (if applicable)	:
NASA Patent Case No.	: XGS-09186

NOTE - Is this an invention made by a corporate employee of a NASA contractor? YES [X] NO [ ]

If "YES" is checked, the following is applicable: Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

Elizabeth A. Carter/sn

Enclosure

Oct. 28, 1969 F. L. RAPOSA 3,475,675

TRANSFORMER REGULATED SELF-STABILIZING CHOPPER

Filed Sept. 22, 1967

Fig. 1

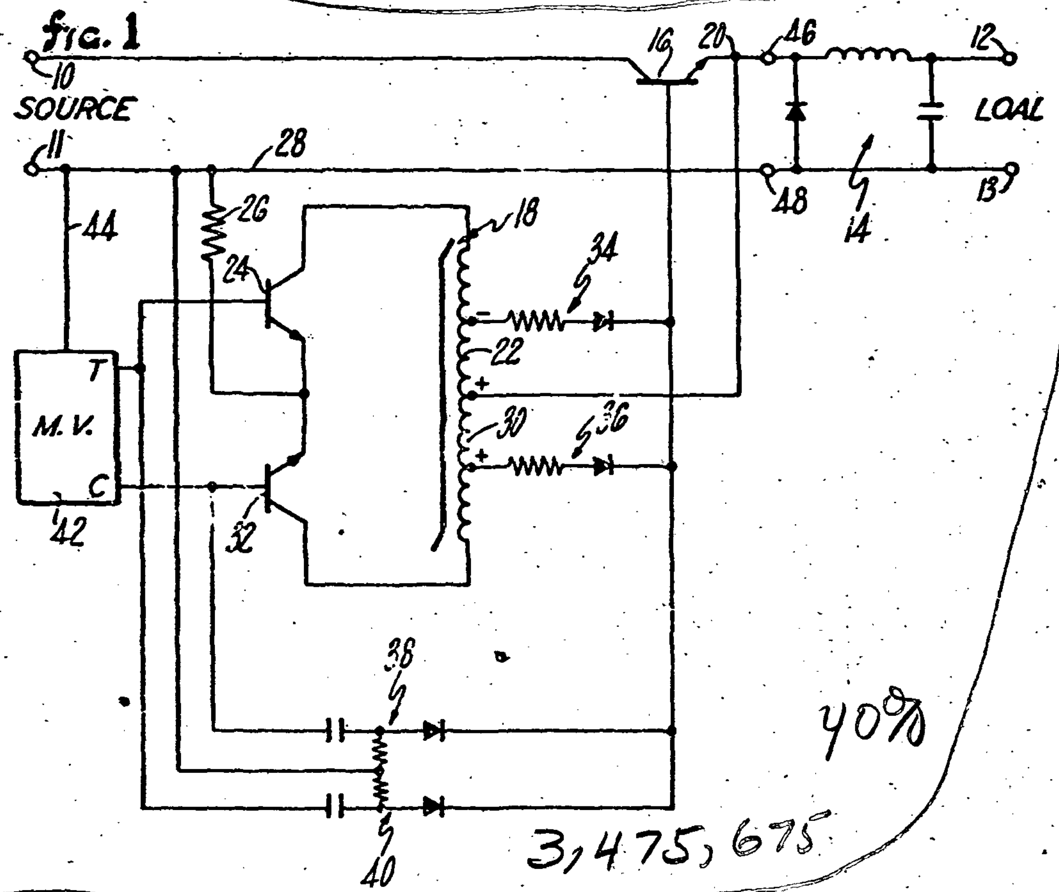
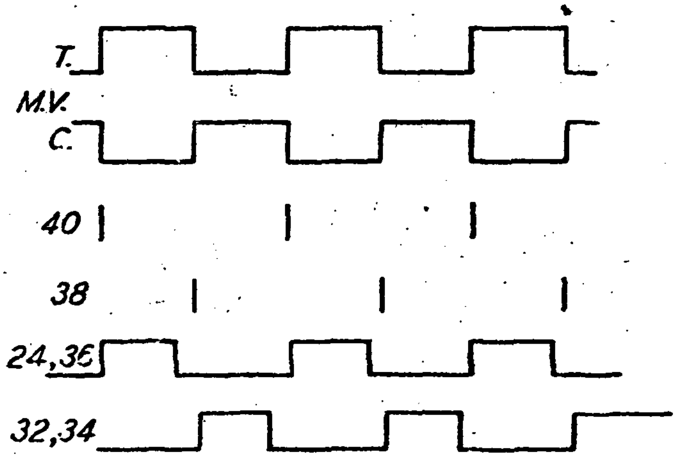


Fig. 2



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TRANSFORMER REGULATED SELF-STABILIZING CHOPPER

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Int. Cl. H02m 3/10, 5/22; H02p 13/16
U.S. Cl. 323—18 3 Claims

ABSTRACT OF THE DISCLOSURE

D.C. voltage regulation employing a series transistor rendered conductive during various portions of a cycle is controlled by saturation of an autotransformer. The constant volt-second capacity of the transformer provides conduction time inverse to the input voltage, whereby average output voltage is maintained constant. Conduction commensed in response to short gate signals; resistor feedback for degenerative turn-off of the transistor after transformer saturation; and a standard output filter are included.

The invention described herein was made in the performance of work under an NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (77 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

Field of invention

This invention relates to voltage regulation, or D.C. to D.C. voltage converters, and more particularly to voltage regulation under the control of a saturating transformer.

Description of the prior art

The art is replete with D.C. voltage regulators in which power conversion circuits possess capability to automatically compensate for variations in input line voltage. Recently, such devices have used the constant volt-second capacity of a saturating transformer as a main control therefor. However, such devices have heretofore required standard reference sources or reference diodes, etc., to contol the transformer. In order to simplify and to provide self-stabilization of D.C. voltage regulators, the elimination of comparative standards, such as voltage limiting active or passive devices, is desirable.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved self-stabilizing voltage regulator.

According to the present invention, the duty cycle of a series switch is under the complete control of a saturating transformer. In accordance with further aspects of the present invention, the series switch is momentarily turned on by gating signals, and the conduction thereof is thereafter controlled solely by the volt-second capacity of the transformer.

The foregoing and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of one embodiment of the present invention; and

FIG. 2 is a simplified timing diagram illustrating operation of the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a pair of terminals 10, 11 are connected to a source of D.C. potential, variations in the voltage of which are to be regulated by the circuitry of FIG. 1. A pair of terminals 12, 13 connect to the load apparatus, at which the voltage is to be maintained constant with respect to variations in the source voltage. An output filter 14, including a diode, a series inductor, and a parallel capacitor, is connected across a load 12, 13 so as to filter the power applied to the load, in a well-known manner. The nature and extent of the output filter 14 forms no part of the present invention, any suitable filtering means for smoothing out the current and voltage applied to the load 12, 13 may be utilized in accordance with any one of a plethora of expedients known to the art.

Control over the average voltage applied to the output filter 14, and therefore voltage at the load terminals 12, 13 is maintained by regulating the duty cycle of a series transistor switch 16. The series transistor switch 16 is controlled to conduct on a duty cycle basis, so that its conduction takes place in a series of cycles of substantially the same duration, the portion of each cycle in which the transistor 16 conducts being inversely proportional to the voltage applied at the source terminals 10, 11. Thus, as voltage at the source terminals 10, 11 increases, the transistor 16 will be conducting during a lesser portion of each cycle; on the other hand, if the voltage applied at the source terminals 10, 11 decreases, then the transistor 16 will conduct for a greater portion of each cycle. The net result is that the average voltage applied to the load terminals 12, 13 through the filter 14 will remain essentially constant.

The length of time during which the transistor 16 will conduct is directly controlled by the volt-second capacity of a saturating transformer 18 which will support voltage for a given length of time only, and will thereafter represent essentially a short circuit, or negligible impedance, to current passing therethrough. The saturating transformer 18 is connected from a point 20 at the output side of the transistor 16, through a first winding 22 thereof and a transistor 24 and a resistor 26 to the ground side 28 of the D.C. power line. It is also connected from the point 20 through a second winding 30 and another transistor 32 through the resistor 26 to the ground line 28.

Assuming momentarily that the transistor 16 is turned on, then line voltage appears between the point 20 and the ground line 28 and this voltage will be impressed across both windings 22, 30 of the transformer 18 in series with the resistor 26 and supplies collector voltage to both of the transistors 24, 32. If either of these transistors are forwardly biased by the application of a positive potential to a respective base, then current will flow through a related one of the windings of the transformer 18. With current flowing through one of the windings of transformer 18, and a potential drop being developed across that winding as a result of a rate of change of flux with respect to time, this potential may be picked off by either one of two resistor diode combinations 34, 36 by autotransformer action so as to supply base potential to the transistor 16. Thus if transistor 24 conducts there will be a plus to minus drop from point 20 to the transistor 24; by autotransformer action, this will cause a plus to minus drop from network 36, through coil 30 to point 20. This base potential causes the transistor 16 to be forwardly biased insuring that the transistor 16 will be maintained in the ON condition and that the point 20 will be at line voltage with respect to the ground line 28. However, as current flows through one of the windings 22, 30, eventually the winding becomes saturated so that there is no longer a potential drop across the winding, all of the potential drop appearing across the resistor 26 except for a small drop across a respective transistor 24, 32. With no potential drop across one of the windings 22, 30 then there is no potential between the point 20 which is connected to the emitter of the transistor 16 and the base of the transistor 16. Therefore, the transistor will then turn off and disconnect the load terminal 12 as well as the point 20 from the source terminal 10. This provides a period with no power out of the load terminals 12, 13, which, when averaged with the period of time in which potential at source voltage is applied across the load terminals 12, 13, will supply as average D.C. voltage at the load terminals which mitigates the variations in source voltage.

In order to initially achieve conduction in the transistor 16, so that the foregoing discussion will hold true, a pair of capacitor-diode-resistor connections 38, 40 are used to couple a short pulse of positive voltage to the base of the transistor 16 at the start of each cycle. Each of the networks 38, 40 is a differentiator with diode isolation. These will turn the transistor 16 ON momentarily, and once ON, conduction from the point 20 through the transformer 18 and one of the transistors 24, 32, together with the concurrent potential drop across one of the windings 22, 30 will maintain the transistor 16 ON until the transformer 18 saturates.

The timing control of the embodiment of FIG. 1 is supplied by a source of complementary, substantially square-wave signals, having a period which is appropriate for the duty cycle control of the transistor 16 in any given utilization of the present invention. This may take the form of a multivibrator 42 which has complementary output signals, designated in FIG. 1 for convenience as T (True) and C (Complementary), the multivibrator 42 being referenced with respect to the ground line 28 through a suitable connection 44. Referring to FIG. 2 along with FIG. 1, at the start of any given cycle, such as just before the True terminal of the multivibrator 42 goes positive, the transistor 16 will have previously been turned off, and there is no connection to the transformer 18 from the source terminal 10. However, with the positive swing of the voltage at the True terminal of the multivibrator 42, a positive pulse will pass through the capacitor-diode-resistor network 40 thus applying a positive signal to the base of transistor 16. This will cause the transistor 16 to momentarily conduct, so that line voltage appears at the terminal 20. At the same moment, the positive voltage is provided from the True terminal of the multivibrator 42 to the base of the transistor 24. Thus, the transistor 24 is in a condition to conduct as soon as collector voltage is applied thereto. As soon as the transistor 16 is turned on by the pulse from the capacitor-diode-resistor network 40, then potential is applied to the collector of the transistor 24 through the winding 22 of the transformer 18. With the build-up of current in winding 22, there is a potential drop developed between the point 20 and the resistor diode network 34 as a result of the build-up of flux within the coil 22. This potential is coupled by the resistor diode network 34 to the base of the transistor 16 so that the potential is applied between the emitter and base of the transistor 16. As a result of this, the transistor 16 can now stay in a conducting condition as long as the potential drop maintains itself across the coil 22. Current flow at this time is from the point 20, through the coil 22, through the transistor 24 and resistor 26 back to the ground line 28. As a result of current flowing through the coil 22, eventually the transformer 18 becomes saturated, and by choosing a transformer having a substantially square hysteresis loop, this saturation can take place rather quickly. As a result of the saturation, the voltage between point 20 and ground line 28 will be almost all dropped across the resistor 26, the transfer of voltage from coil 22 to resistor 26 being rather rapid in dependence upon how square the hysteresis loop of the transformer 18 is. At some point, the voltage coupled to the base of the transistor 16 by the resistor-diode network 34 is insufficient to maintain the transistor in a conducting condition, and the transistor will cease to conduct. This puts the circuitry back into a quiescent state where it will remain until such time as the Complementary (C) output of the multivibrator 42 becomes positive. At this time the capacitor-diode-resistor network 38 will cause a short pulse of positive potential to be applied to the base 16 of the transistor 16, so that the transistor 16 will be forwardly biased and commence conduction. At the same time, the Complementary output of the multivibrator 42 supplies a positive signal to the base of transistor 32, so that current will then flow from the point 20, through coil 30, transistor 32 and resistor 26 to the ground line. As a result of this current build-up in the coil 30, a potential is developed between the point 20 and the base of transistor 16 which is coupled through the resistor diode network 36. Thus, transistor 16 will be maintained in a conducting condition for an additional half cycle until such time as the transformer 18 is saturated so that no voltage is developed across the coil 30; at this time, the transistor 16 will again cease conduction.

The choice of resistor 26 can be made in conjunction with the square-loop characteristic of the transformer 18, so that the turn-off of the transistor 16 can be very rapid and closely controlled.

The multivibrator 42 may comprise any one of a number of well-known circuits available in the art, and its particular characteristics are not germane to the present invention. In fact, any suitable source of timing control which will provide a starting pulse to the transistor 16 and alternate control of conduction of the transistors 24, 32 may be utilized. Additionally, the capacitor-diode-resistor networks 38, 40 are exemplary merely of ways in which short starting pulses may be applied to the base of the transistor 16: other suitable means may be provided in accordance with the skill of the art.

The embodiment of the invention shown in FIG. 1 includes push-pull control: that is, the transformer 18 is center-tapped so as to provide two coils 22, 30 together with the use of two transistors 24, 32 and two sets of networks 34, 38 and 36, 40. However, it should be understood by those skilled in the art that use of but a single set of transistor, resistor-diode network and capacitor-diode-resistor network, together with a suitable wave shape in the controlling voltage will work equally well. For instance, any source of positive potential which momentarily disappears and then reappears may be utilized with, for instance, the capacitor-diode-resistor network 40, the transistor 24, coil 22, and resistor-diode network 34, so as to cause the turning on of the transistor 16 during each cycle with the same apparatus. The choice of such an embodiment is left to the design skill of the artisan to suit the needs of any given implementation of the present invention.

It is to be particularly noted that all power to the load is supplied directly from the source terminals 10, 11 through the transistor 16 and the filter network 14 to the load terminals 12, 13. No power is transferred by transformer action. All of the circuitry which is located in FIG. 1 below the ground line 28 comprises merely the controls for the duty cycle of the series transistor switch 16. It is to be noted that the sole control herein is the saturation characteristic, that is the volt-second capacity, of the transformer 18. Even the particular frequency for the multivibrator 42 is not critical, although a smoother and more satisfactory output voltage will be achieved provided the multivibrator period is chosen so that the transistor 16 is conducting almost all of the time at the lowest possible source voltage 10, 11 and conducting over a substantial portion of the cycle even when the voltage applied to the source terminals

10, 11 is the maximum possible. This applies the smoothest possible output to the load terminals 12, 13. Choice of the parameters used in a circuit embodying the present invention is left to the skill of the art.

The output filter 14 may be eliminated in any case where filtering is provided in the load itself, or in a case where filtering is not critical to the load (such as a dynamoelectric machine). The filter itself is therefore not germane to the present invention; it provides the filtering function when needed, and is capable of being eliminated when not needed. Therefore, as far as the invention is concerned, the output terminals are really terminals 46, 48 rather than terminals 12, 13.

Although the invention has been shown and described with respect to preferred embodiments thereof, it should be understood by those skilled in the art that the foregoing and other changes and omissions in the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

Having thus described typical embodiments of the invention, that which I claim as new and desire to secure by Letters Patent of the United States is:

1. A D.C. voltage regulator adapted for connection between a pair of D.C. voltage source terminals and a pair of D.C. voltage output terminals comprising:

a first electronic switch having its current conducting elements connected between a first one of said source terminals and a first one of said output terminals, and having a control element;

a second electronic switch having one of its current conducting elements connected to the second one of said source terminals;

a saturating transformer coil;

means connecting said coil between a second conducting element of said second switch and said first one of said output terminals;

means connecting a portion of the potential across said saturating transformer coil to said control element of said first switch;

a source of control potential having a duty cycle, said source impressing a control potential to a control element of said second switch;

and gate means synchronized with said source of control potential for supplying a potential to the control element of said first switch momentarily, whereby said switch is turned on by said last named means, and is maintained in the on condition by the potential developed across said saturating transformer coil until said coil becomes saturated, at which time said first switch turns off.

2. The D.C. voltage regulator according to claim 1 additionally comprising at least one additional saturating transformer coil connected through at least one additional second electronic switch to said second input terminal, and wherein said source of control potential and said gate means provide a plurality of respective potentials arranged in a sequence so that said first switch is selectively controlled by a repetitive sequence of different ones of said second switches.

3. The D.C. voltage regulator according to claim 1 including an additional second electronic switch, and an additional connection means, and wherein said saturating transformer coil is connected between conducting electrodes of each of said second switches, with a center tap to said first output terminal, and with said connection means connecting the control electrode of said first switch from respective points in between the center tap and the ends of said saturating transformer coil.

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U.S. Cl. X.R.

321—18, 21, 25