July 8, 1969 E. H. DINGER 3,454,867
SATURABLE TRANSFORMER WITH INHERENT VOLTAGE
REFERENCE LEVEL DUE TO CORE DESIGN
Original Filed Aug. 8, 1963 Sheet 1 of 2

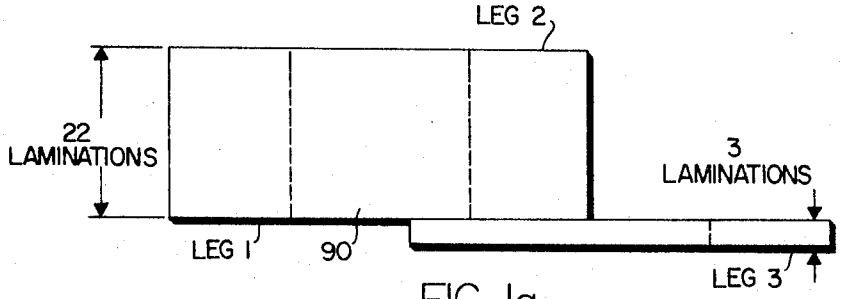


FIG. 1a

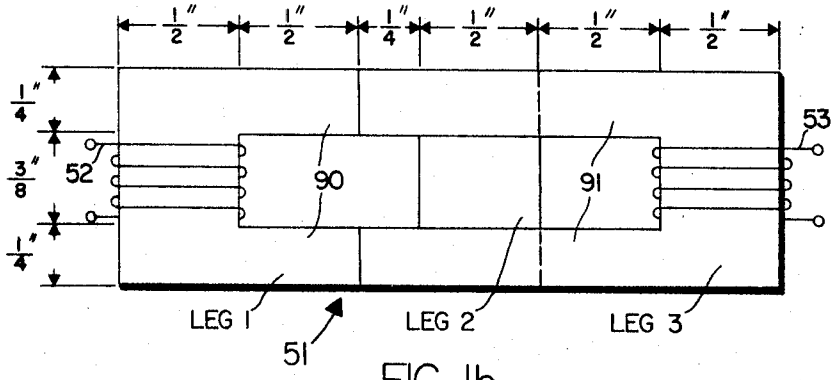


FIG. 1b

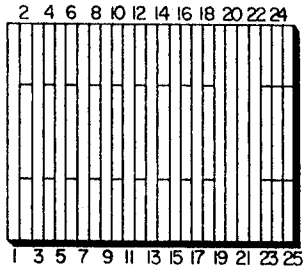


FIG. 1c

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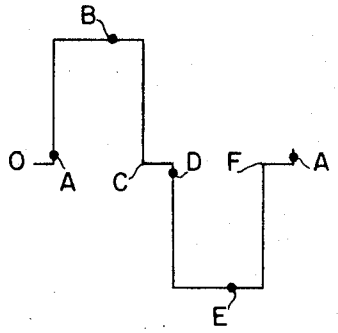


FIG. 2

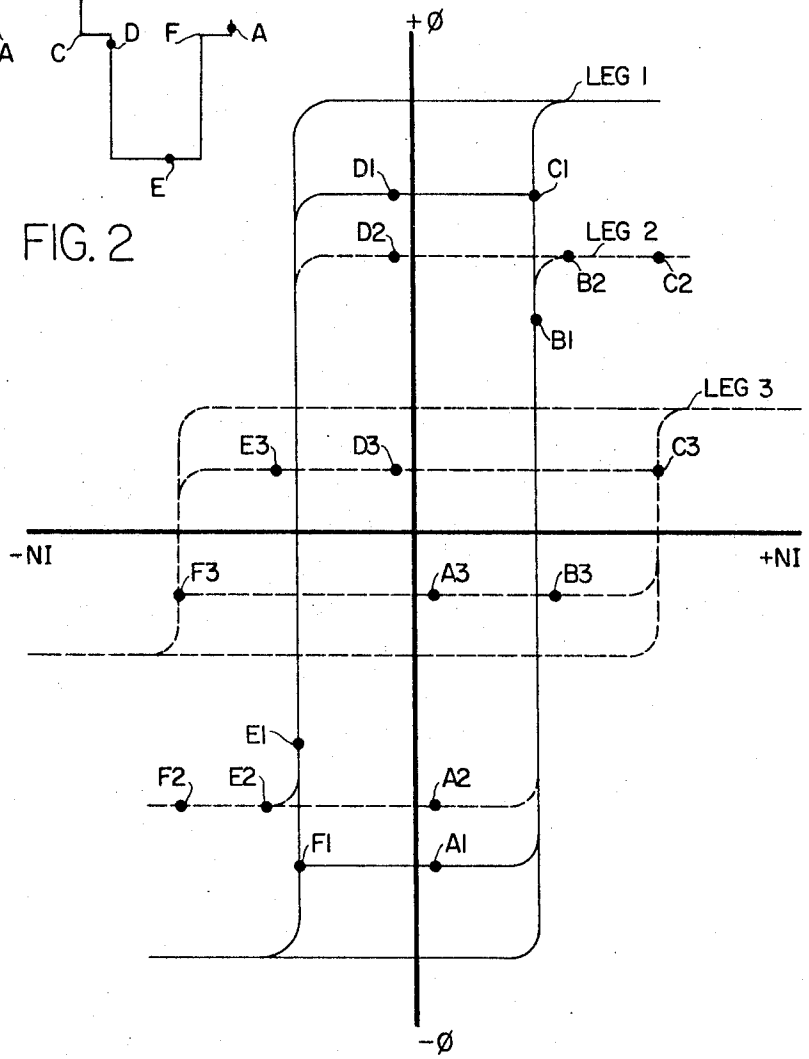


FIG. 3

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United States Patent Office

3,454,867

Patented July 8, 1969

3,454,867

SATURABLE TRANSFORMER WITH INHERENT VOLTAGE REFERENCE LEVEL DUE TO CORE DESIGN

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Original application Aug. 8, 1963, Ser. No. 300,876, now Patent No. 3,346,798, dated Oct. 10, 1967. Divided and this application June 7, 1967, Ser. No. 650,151

Int. Cl. H02p *13/04;* H02m *5/12*

U.S. Cl. 323—44

6 Claims

ABSTRACT OF THE DISCLOSURE

A saturable transformer having a builtin reference is provided. The transformer has two cores in magnetic shunt, the input core being a shorter magnetic path than the output core. By selecting the saturation level of the input core, the point at which an output is obtained is ascertained. The output from the transformer is the difference between the reference level and the input level.

Background of the invention

This is a division of application Ser. No. 300,876, filed Aug. 8, 1963, now U.S. Patent No. 3,346,798.

The invention relates to a feedback device for a regulator circuit. The invention relates particularly to a saturable reactor with a built-in reference which can be used in the feedback circuit of a voltage regulator such as disclosed in the aforementioned copending application. Regulator circuits of various types depend upon an indication of the deviation of the signal being controlled from a reference level. Often isolation is required between the regulator circuit and the circuit being regulated. The saturable reactor reference circuit disclosed herein is a single device capable of providing both isolation and a reference level so that the output is the difference between the monitored signal level and the reference level.

An object of the invention is to provide an improved static device of the magnetic type.

Another object is to provide a static feedback device for a regulator circuit which isolates the signal being regulated from the regulator and contains a reference level indicator.

Another object is to provide a saturable reactor in which the saturation level can be utilized as a signal reference level.

Summary of the invention

Briefly, these and other objects of the invention are achieved with a saturable transformer which has both a primary and secondary core. The primary or input core has a shorter magnetic path than the secondary or output core. The saturation level of the input core is controlled by adjusting the amount of laminations in the core. The output core is in magnetic shunt with the input core such that the voltage which appears on the secondary winding is the input voltage which exceeds the voltage necessary to cause saturation of the input core (the reference voltage level).

Brief description of the drawings

Other objects and advantages of the invention may be better understood from the following description given in connection with the accompanying drawing, in which:

FIGURES 1*a*, 1*b*, and 1*c* show the arrangement and construction of a magnetic element in accordance with the invention; and

FIGURES 2 and 3 show waveforms for explaining the

operation of the magnetic element of FIGURES 1*a*, 1*b*, and 1*c*.

Description of the invention

The voltage regulator described in the above-mentioned copending application utilizes a feedback saturable reactor **51**, as shown in FIGURE 1 therein, to provide a feedback or error voltage. This feedback voltage is provided by a comparison of an inherent reference voltage within the reactor **51** with a portion of the output voltage at the tap **50** on the voltage level potentiometer **49**. The inherent reference voltage is provided by the volt-second characteristics of the reactor **51**. The inverter output voltage is applied to the primary winding **52** of the reactor **51**. The feedback voltage appears across the secondary winding **53** of the reactor **51**. The voltage across the secondary winding **53** is rectified by the voltage feedback bridge **54** and supplied as a direct current signal to the base electrode of the voltage regulator transistor **59** to control the exciting current for the voltage regulator saturable reactor **64**. FIGURES 1*a*, 1*b*, and 1*c* show details of the construction and arragenment of the saturable reactor **51**. FIGURE 1*a* shows a top view of the saturable reactor **51**, FIGURE 1*b* shows a front view of the reactor **51**, and FIGURE 1*c* shows a view of the left end of the saturable reactor **51**. As shown in FIGURES 1*a* and 1*c*, the reactor **51** preferably comprises **25** similar laminations of suitable saturable magnetic material such as Orthonol, a product trade name of Nagnetics, Inc. Butler, Pa. These laminations are generally U-shaped, and have a thickness of 0.01 inch (which is greatly exaggerated in FIGURES 1*a* and 1*c*), a length 1¾ inches, and a width of ⅞ inch. These and other dimensions are shown in FIGURE 1*b*. The laminations are numbered in FIGURE 1*c*. An input core or magnetic path comprising leg **1**, leg **2**, and two portions **90** is formed of 22 laminations. Eighteen of these laminations are stacked together in alternate fashion as indicated in FIGURE 1*c*. That is, those **18** laminations are stacked with the odd number laminations having the base (of their U shape) positioned on the left, as viewed in FIGURE 1*b*, and with the even number laminations having the base (of their U shape) positioned on the right, as viewed in FIGURE 1*b*. The next four laminations are stacked the same way relative to each other with the base (of their U shape) positioned on the left, as viewed in FIGURE 1*b*. Leg **1** and the portions **90** (between leg **1** and leg **2**) have substantially equal amounts of magnetic material (and hence substantially equal magnetic reluctance) because half of leg **1** has air space, the portions **90** are all magnetic material and the cross-sectional area of leg **1** is twice the cross-sectional area of each of the portions **90**. Because the last four laminations of the **22** laminations are stacked the same way with the base (of their U shape) on the left, leg **2** has the smallest amount of magnetic material (and hence the greatest magnetic reluctance). An output core or magnetic path comprising leg **3** and portions **91** is formed of three laminations having the base (of their U shape) positioned on the right. These three laminations are placed alongside or against the **22** laminations of the input core with the ends (of their U shape) across or in magnetic shunt with leg **2**. The air gap or air space (with no magnetic material) between the ends of the U shape of the output core causes the output core to have a magnetic path of greater magnetic reluctance than the magnetic reluctance of leg **2**. The input or primary winding **52** for the reactor **51** is wound on leg **1** (or may be more conveniently wound on a portion **90**), and in the embodiment described includes approximately 7,320 turns of No. 38 wire. The output or secondary winding **53** is wound on leg **3** (or more conveniently on a portion **91**), and includes approximately 2,085 turns of No. 38 wire. The entire

structure of the laminations and windings is suitably enclosed or set in a potting material.

The saturable reactor **51** described in connection with FIGURES 1*a*, 1*b*, and 1*c* provides a feedback device with a built-in reference voltage or signal which is provided by the magnetic characteristics of the reactor, and specifically leg **1**. These characteristics are such that when a voltage is applied to the primary winding **52**, no voltage appears at the secondary winding **53** until the input core including leg **1** and leg **2** becomes saturated. As mentioned above, the cross-sectional area of leg **2** has the least amount of magnetic material in it. Therefore, the cross-sectional area or magnetic reluctance of leg **2** is the determining factor as to when the input core of the reactor becomes saturated. When this input core, and specifically leg **2**, does become saturated, then magnetic flux may travel around the path of the output core including leg **3**. When magnetic flux does travel around the path of the output core including leg **3**, the secondary winding **53** produces a signal. Thus, the saturable reactor **51** provides an output signal at the secondary winding **53** after the input core leg **2** becomes saturated. Thus, leg **2** provides a volt-second reference level. When this level is exceeded by the volt-second characteristics of the input signal applied to the primary winding **52**, the secondary winding **53** produces an output signal. Thus the saturable reactor **51** has an interent or included reference, namely the volt-second saturation characteristics of leg **2**. Although the saturable reactor **51** has been described in terms of a specific embodiment, it will be appreciated that different core configurations, different materials, and different constructions can be used. The arrangement shown and described in connection with FIGURES 1*a*, 1*b*, and 1*c* is by way of example only.

The operation of the saturable reactor of FIGURES 1*a*, 1*b*, and 1*c* is described in connection with FIGURES 2 and 3 which represent a steady-state condition. FIGURE 2 shows a waveform of the output voltage which might be applied to the primary winding **52** of the saturable reactor **51**. FIGURE 3 shows hysteresis loops for leg **1**, leg **2**, and leg **3** of the saturable reactor **51**. Leg **1** is shown by the solid line hysteresis loop, leg **2** is shown by the dashed line hysteresis loop, and leg **3** is shown by the dashed and dotted line hysteresis loop. Points in time on the output voltage waveform are indicated by the letters A, B, C, D, E, and F. Corresponding points on the hysteresis loops are indicated by the same letters with a suffix numeral indicating the particular leg. At the point A in FIGURE 2, the voltage has risen only slightly above zero in a positive direction, so that the three hysteresis loops are still at a negative flux level as indicated by the points A1, A2, and A3. In FIGURE 2, point B is the point at which leg **2** is assumed to become saturated. The positive flux level saturation of leg **2** is indicated by the point B2. Leg **1** has a positive flux level indicated by the point B1, the point B1 being below the point B2 by an amount equal to the negative flux level in leg **3** as indicated by the point B3. During the interval from the point D to the point C (zero) in FIGURE 2, the secondary winding **53** of the saturable reactor **51** produces a voltage. At the point C, leg **1** has a positive flux level indicated by the point C1 (which is less than its flux saturation level), and leg **2** still has its positive saturation flux level indicated by the point C2. Leg **3** now has a positive flux level indicated b ythe point C3. Again, it will be noted that the sum of the flux levels of legs **2** and **3**, as indicated by the points C2 and C3, equals the flux level of leg **1**, as indicated by the point C1. Nothing further happens in the saturable reactor while the voltage on the primary winding **52** remains at the zero level of point C. However, at point D, the current in the primary winding **52** has just reversed and is slightly negative. This is indicated by the point D1 for leg **1**, the point D2 for leg **2**, and the point D3 for leg **3**. In the interval between the points D and E in FIGURE 4, no output is produced by the secondary winding **53** of the saturable reactor **51**. However, when leg **2** becomes saturated at the point E, the secondary winding **53** can and does produce an output signal. The negative saturation flux level of leg **2** is indicated by the point E2. At this time, leg **1** has a flux level indicated by the point E1, and leg **3** has a flux level indicated by the point E3. Again, it will be seen that the sum of the positive flux level of leg **3** and the negative flux level of leg **2** equals the flux level of leg **1**. From the time between points E and F the secondary winding **53** produces an output signal. At the point F, the voltage shown in FIGURE 2 returns to zero. At this point, leg **1** has a flux level indicated by the point F1, leg **2** still has its negative saturation flux level indicated by the point F2, and leg **3** now has a negative flux level indicated by the point F3. Nothing further happens as long as the voltage level remains zero. However, when the voltage becomes positive again, the cycle or excursion on the hysteresis loops is repeated as described beginning at the points A1, A2, and A3. It will thus be seen that leg **1** and leg **3** never become fully saturated in the particular operation shown. This is the preferred operation. Leg **2** however does become saturated, and when it does, the secondary winding **53** produces an output signal. Thus, the saturable reactor **51** incluudes an inherent reference, this reference being determined by the volt-second characteristics of leg **2**. Other configurations can also be utilized and still provide the operation described.

The invention provides an improved feedback and reference comparison arrangement in the form of a saturable reactor. While the inevntion has been described in a particular form and embodiment, other arrangements can be used. For example, other core configurations and winding arrangements can also be used. Further, some degree of adjustment can be provided for the saturation point of leg **2**. However, these and other modifications will be apparent to persons skilled in the art.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A device for indicating the volt-second characteristics of a signal comprising an input magnetic core having a flux path, said path including a portion having a magnetic reluctance that is greater than any other part of said path, an input circuit coupled to said core for applying said signal thereto, an output magnetic core having a first portion of relatively high magnetic reluctance and a second portion of relatively low magnetic reluctance, said output core being positioned with said first portion of relatively high magnetic reluctance in magnetic shunt relation to said portion of said input core, and an output circuit coupled to said output core for deriving a signal therefrom.

2. A device for indicating the volt-second characteristics of a signal comprising an input core of magnetic material having a substantially rectangular flux path, said path including a leg having a magnetic reluctance that is greater than the magnetic reluctance of the other portions of said input core, means coupled to said input core for applying said signal thereto, a substantially U-shaped output core of magnetic material having a flux path including said magnetic material and the air between the ends of said U-shaped core, said output core being positioned adjacent said input core with said ends of said U-shaped core being on each side of said leg with respect to said flux path of said input core, and means coupled to said output core for deriving a signal therefrom.

3. A device for indicating the volt-second characteristics of an alternating current signal comprising an input saturable magnetic core having a flux path, said path including a portion having a magnetic reluctance that is greater than the remainder of said path, an input winding coupled to said core for applying said alternating current signal thereto, an output magnetic core having at least a portion of high magnetic reluctance, said output core being positioned with said portion of high magnetic reluctance in

magnetic shunt relation to said greater magnetic reluctance portion of said input core, and an output winding coupled to said output core for deriving a signal therefrom, said derived signal having a characteristic indicative of the volt-second characteristics of said alternating current signal.

4. A device for indicating the volt-second characteristics of an alternating current signal comprising an input core of saturable magnetic material having a substantially rectangular closed magnetic flux path, said path including a leg having a magnetic reluctance that is greater than the magnetic reluctance of other portions of said input core, an input winding coupled to said input core for applying said alternating current signal thereto, a substantially U-shaped output core of magnetic material having a magnetic flux path including said magnetic material and the air between the ends of said U-shaped output core, said output core being positioned adjacent and in contact with said input core with said ends of said U-shaped output core being on each side of said leg which is in said magnetic path of said input core, and an output winding coupled to said output core for deriving a signal therefrom at a time determined by the volt-second characteristics of said alternating current signal and the volt-second characteristics of said leg of said input core.

5. A device for indicating the volt-second characteristics of an alternating current signal comprising an input saturable magnetic core having a closed flux path of magnetic material, said path including a portion having a magnetic reluctance that is greater than any other part of said path, an input winding coupled to said core for applying said alternating current signal thereto, an output magnetic core having a first portion of relatively high magnetic reluctance and a second portion of relatively low magnetic reluctance, said magnetic reluctance of said second portion of said output core being greater than said magnetic reluctance of said portion of said input

core, said output magnetic core being positioned with said first portion in magnetic shunt relation to said portion of said input core, and an output winding coupled to said output core for deriving a signal therefrom at a time determined by the volt-second characteristics of said alternating current signal and the volt-second characteristics of said portion of said input core.

6. A device for indicating the volt-second characteristics of an alternating current sginal comprising an input core of saturable magnetic material having a substantially rectangular magnetic flux path, said path including a first leg, a second leg, and portions joining said legs, said first leg and said portions having substantially equal magnetic reluctances, and said second leg having a magnetic reluctance that is greater than said equal magnetic reluctances, an input winding coupled to said input core for applying said alternating current signal thereto, an output core of magnetic material having a magnetic flux path partially through said material and partially through air, said output core being positioned adjacent said input core so that said flux path through air provides a magnetic shunt flux path for said second leg, and an output winding coupled to said output core for deriving a signal therefrom that is determined by the volt-second characteristics of said alternating current signal and the volt-second characteristics of said second leg.

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U.S. Cl. X.R.

323—82; 336—115, 234