March 1, 1960 N. S. PRYWES 2,927,260

STATIC FREQUENCY-CHANGING SYSTEMS

Filed Dec. 28, 1955 2 Sheets-Sheet 1

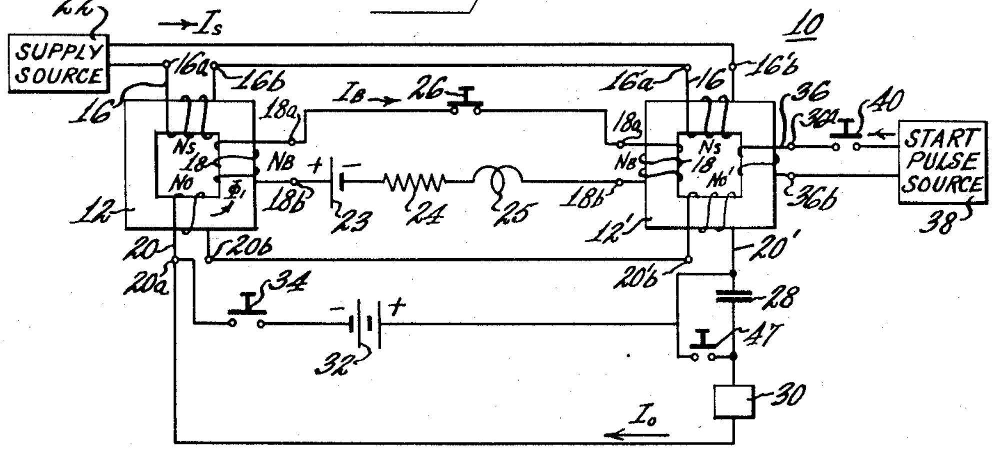

Fig. 1.

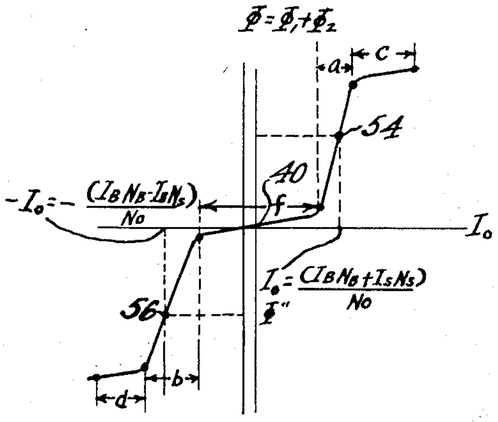

Fig. 2.

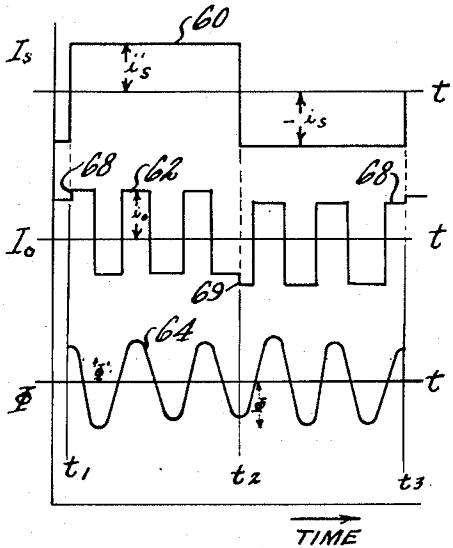

Fig. 4.

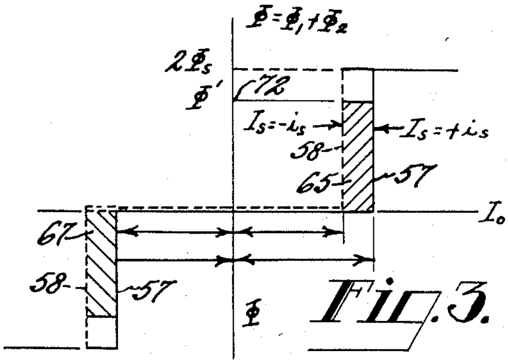

Fig. 3.

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STATIC FREQUENCY-CHANGING SYSTEMS

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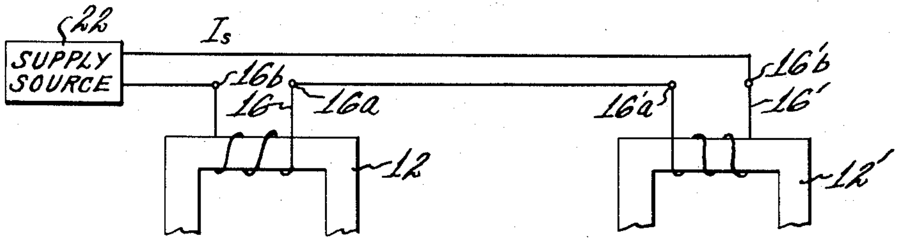

Fig. 5.

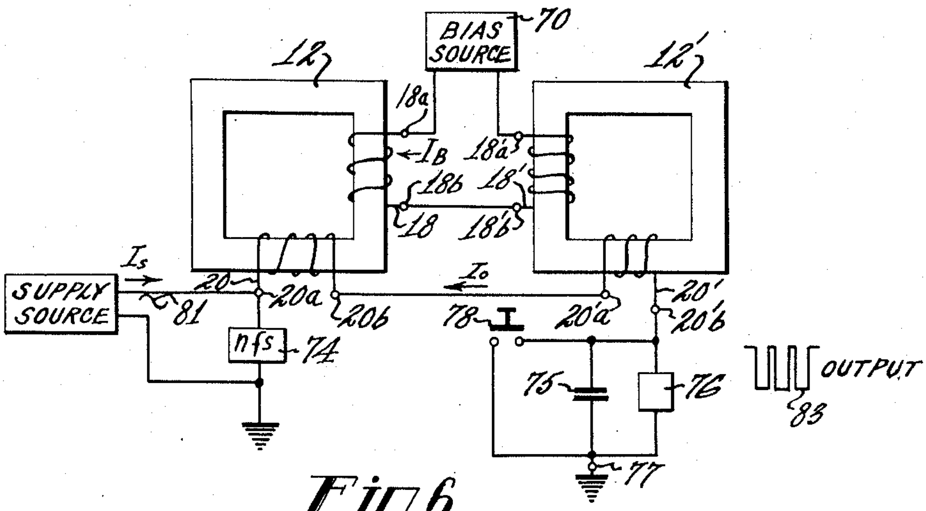

Fig. 6.

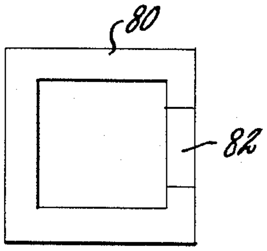

Fig. 7.

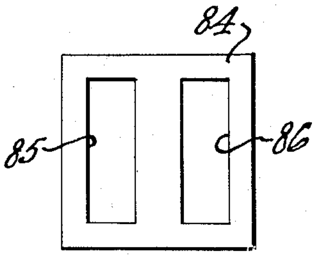

Fig. 8.

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Patented Mar. 1, 1960

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STATIC FREQUENCY-CHANGING SYSTEMS

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Application December 28, 1955, Serial No. 555,809

20 Claims. (Cl. 321—68)

This invention relates to static frequency-changing systems, and particularly to systems using magnetic elements for obtaining frequencies that are multiples of a supply frequency.

In certain of the prior-art frequency-changing systems saturable magnetic elements are used. Harmonics of a supply frequency are obtained by periodically saturating the magnetic elements. A tuned circuit or filter circuit may be used for separating a desired harmonic from the many other harmonics produced in the output circuit. Such systems are relatively inefficient when compared with conventional transformers because (1) a relatively large proportion of the supply power is used in saturating the elements, and (2) much of the supply power appears as undesired harmonics in the output circuits. The efficiency of such systems also falls off rapidly when harmonics of a high order are desired because the output power decreases while the losses increase. Thus, in such systems, for a given amount of output power, relatively large amounts of magnetic material are required to be used.

It is an object of the present invention to provide a novel static frequency-changer which is arranged to provide desired multiples of a supply frequency wherein the supply currents need produce only very small flux changes in the linear regions of the magnetization characteristic of the magnetic elements.

Another object of the present invention is to provide an improved static frequency-changing system which provides multiples of a supply frequency wherein the amplitude in ampere-turns of the desired frequency is greater than that of supply frequency.

Still another object of the present invention is to provide a novel static frequency-changer which has two distinct modes of operation without changing the supply—in one mode, furnishing output power at a desired multiple of the supply frequency and, in the other mode having substantially no output, and which can be triggered from one to the other of the two modes by a suitable triggering excitation.

A further object of the present invention is to provide an improved static frequency-changing system having advantages from the standpoint of reduced size, weight and cost, increased efficiency, and increased output power.

The above and further objects of the present invention are carried out by arranging a plurality of magnetic circuits to provide a resultant magnetization characteristic having two substantially straight vertical sides parallel to the flux axis and located one on either side of the current axis, and a substantially flat, horizontal portion parallel to the current axis and joining the two vertical sides. An output circuit, including a capacitance element, is linked to the magnetic circuits. A magnetic device so arranged has at least two different modes of operation. In one mode, a suitable supply current, applied to input windings linking the magnetic circuits, produces changes only along the flat horizontal portion of the characteristic, and substantially no output is induced in the output circuit. In a second mode, produced by applying a suitable triggering excitation, the same supply current maintains relatively large amplitude oscillations between two points, one on each of the two vertical portions of the characteristic. Substantial output at a desired multiple of the supply frequency is obtained in the second mode. Another suitable triggering excitation can be used to change the operation back to the one mode. Odd multiples of the supply frequency can be obtained by linking the supply and output windings in series-aiding and the bias winding in series-opposition to the magnetic circuits; or fractional, even, and submultiples of the supply frequency can be obtained by linking the supply windings and bias windings in series-opposition and the output windings in series-aiding to the magnetic circuits. By "series-aiding" is meant that a current flow in the thus connected windings applies magnetizing forces of like polarity to both magnetic circuits. By "series-opposition" is meant that a current flow in the thus connected windings applies a magnetizing force of one polarity to one magnetic circuit and applies a magnetizing force of the opposite polarity to the other magnetic circuit.

The novel features and advantages of the present invention will be described in detail in connection with the accompanying drawing wherein:

Fig. 1 is a schematic diagram of a static frequency changer, according to the invention, for obtaining odd integral multiples of a supply frequency;

Fig. 2 is a graph, somewhat idealized, of the flux versus current characteristic of a system according to the present invention;

Fig. 3 shows two idealized graphs of the magnetization characteristic of a system according to the invention, one graph being taken for positive values of supply current, and the other graph being taken for negative values of supply current;

Fig. 4 is a graph of waveforms, all on the same time scale, of supply current I_s, output current I_0, and flux Φ, useful in explaining the operation of the circuit of Fig. 1;

Fig. 5 is a schematic diagram of an embodiment of the invention showing the connection of the supply windings for obtaining even or submultiples of a supply frequency;

Fig. 6 is a schematic diagram of another embodiment of the invention similar to that of Fig. 1 but modified in that it has the supply source connected across the output windings;

Fig. 7 is a schematic diagram of a magnetic element, including a permanent magnet in the magnetic circuit thereof and which may be used in a frequency-changer system according to the invention, and

Fig. 8 is a schematic diagram of a three-legged magnetic element which provides a pair of magnetic circuits and which may be used in a frequency-changing system according to the invention.

Referring to Fig. 1, a frequency-changing system **10** includes two separate magnetic circuits, for example the two separate magnetic cores **12** and **12'**. The cores **12** and **12'** may have substantially similar dimensions, though not necessarily so, and may be made from conventional saturable magnetic material. A preferred magnetic material is characterized by having a relatively low coercive force and having a relatively sharp saturation characteristic such as molybdenum-permalloy. Other magnetic materials, such as deltamax, ferrite material, and conventional transformer materials also may be used.

Each of the cores **12** and **12'** is linked respectively by a supply winding **16** and **16'**, a bias winding **18** and **18'**, and an output winding **20** and **20'**. In addition to the last-mentioned three windings, one of the cores **12** and **12'**, for example the core **12'**, also may be linked by a start winding **36**. The supply windings **16** and **16'** are connected in series-aiding by connecting the terminal **16*b*** of the winding **16** to the terminal **16'*a*** of the winding **16'**. The remaining two terminals **16*a*** and **16'*b*** of the supply windings **16** and **16'** are connected to a supply source **22**. The supply source **22** may be any suitable constant-current source. The bias windings **18** and **18'** are connected in series-opposition in a bias circuit respectively including in series a direct-current source, illustrated by the battery **23**, a current-limiting element such as a resistor **24**, a choke such as the inductance element **25**, and a normally-closed, double-pole, single-throw switch **26**. The terminal **18*b*** of the bias winding **18** is connected to one terminal, the positive terminal, of the battery **24**; and the terminal **18'*b*** of the bias winding **18'** is connected to the other, the negative terminal of the battery **24**. The other terminals **18*a*** and **18'*a*** are respectively connected to the two fixed terminals of the switch **26**. The output windings **20** and **20'** are connected in series-aiding by connecting the terminal **20*b*** of the winding **20** to the terminal **20'*b*** of the winding **20'**. A capacitor **28** and a load are connected across the other terminals **20*a*** and **20'*a*** of the windings **20** and **20'**.

The multiple frequency is delivered by the frequency-changing system to the load **30**. The series load connection is the one prepared for a low-impedance load; in case of a high-impedance load, the load is preferably connected in parallel with the capacitor **28**. A battery **32** and a normally open, double-pole, single-throw switch **34** may be connected in series across the output winding terminals **20*a*** and **20'*a***. One terminal, the positive terminal, of the battery **32** may be connected to the terminal **20'*a*** of the winding **20'**; and the other terminal, the negative terminal, of the battery **32** may be connected in series with the switch **34** to the terminal **20*a*** of the winding **20**. The terminals **36*a*** and **36*b*** of the start winding **36** may be connected in series with a normally open, single-throw, double-pole switch **39**, to a start pulse source **38**. The start pulse source **38** may be any source adapted to furnish current pulses to the start winding **36**. A normally open, single-throw, double-pole switch **47** may be connected across the capacitor **28**.

The three double-pole, single-throw switches **26**, **34** and **39** are used to illustrate three different means for initiating oscillations in the output circuit, including the output windings **20**, **20'** and the capacitor **28** of the system. Once initiated, such oscillations are maintained by the energy supplied by the supply source **22**. The output circuit oscillations can be terminated, for example, by momentarily closing the fourth double-pole, single-throw switch **47** connected across the capacitor **28**.

A characteristic magnetizing curve for the system of Fig. 1 is shown in Fig. 2 by the curve **40**. The curve **40** is somewhat idealized in that the small hysteresis effect is neglected. The curve **40** may be obtained in a conventional manner by connecting an alternating power supply in the output circuit and observing the total flux changes Φ and the output current I_o. The illustrated curve **40** is obtained with the bias source **24** connected in the circuit. If the bias source **23** were disconnected, as by opening the switch **26**, the characteristic **40** would be compressed along the I_o axis and would resemble the conventional Z-type characteristic. The characteristic **40** has two regions of substantial "current saturation," shown as the regions *a* and *b* on either side of the output current axis I_o. By "current saturation" is means that large changes of flux Φ in the cores **12** and **12'** produce small changes of output I_o in the output circuits. The regions *c* and *d* of the characteristic **40** represent flux-saturated conditions when both magnetic circuits are substantially saturated with flux, oriented in either the clockwise or counterclockwise senses.

In certain prior-art systems, material having the conventional Z-type characteristic is employed and operation is carried out in the non-linear region of the "knees" of the characteristic. In other prior-art systems, a bias is used; however, the supply ampere-turns are required to be in excess of the bias ampere-turns in order to reach a non-linear region of the characteristic. In the latter systems, a linear inductance and a capacitor are included in the output circuit and are tuned to the desired multiple frequency. In such prior-art systems the efficiency, i.e., output power supply power, is relatively low because of the large supply ampere-turns required. This large supply ampere-turns is required in order to reach the non-linear regions. In the present invention the supply ampere-turns (I_sN_s) are much smaller, say five to ten times, than those of the bias ampere-turns (I_BN_B) as only a parametric change in exclusively linear regions is required. At the same time the output ampere-turns (I_oN_o) are approximately equal to the bias ampere-turns. In addition, a linear inductance element for tuning or filtering is neither required nor desirable in the output circuit. Accordingly, the efficiency of the present invention is appreciably better than that of prior-art systems. Also the efficiency remains substantially constant even when operating at higher frequency multiplication ratios and is of the same order of efficiency as a conventional transformer.

Referring again to Fig. 2, the output at the desired frequency shifts back and forth between the two current-saturated regions *a* and *b*, as described more fully hereinafter. The region *f* between the two current-saturated regions *a* and *b* represents an intermediate condition when the algebraic sum of the flux in the two similar circuits is substantially at a zero value.

The point **54** in the current-saturated region *a* of the characteristic **40** represents the case when one core is saturated and the other has substantially zero flux. In such case the output circuit has an output current I_o'. The point **56** in the current-saturated region *b* represents another value of flux where the other core is saturated and the one has substantially zero flux. In such case the output circuit has an output current $-I_o'$. The values of output current I_o' and $-I_o'$ are approximately equal to:

$$(1) \qquad I_o' = \frac{(I_BN_B + I_SN_S)}{N_o}$$

and

$$(2) \qquad -I_o' = -\frac{(I_BN_B - I_SN_S)}{N_o}$$

where I_B, I_S are respectively the bias and supply-current amplitudes, and N_b, N_s, and N_o are respectively the number of turns of the bias, the supply and the output windings linked to the magnetic circuits.

If conventional transformer material is employed, the bias ampere-turns is made sufficiently large to obtain the desired non-linearity between the zero flux and the current-saturated regions.

The operation of the system of Fig. 1 may best be explained in connection with the idealized graphs of the magnetizing characteristics of Fig. 3 and the waveforms of Fig. 4. The characteristics **57** and **58** of Fig. 3 represent two idealized graphs of the magnetizing characteristics for the system of Fig. 2. The solid graph **57** represents the magnetizing characteristic during the interval when the supply current I_S is at its maximum positive value $+i_S$ and the dotted characteristic **58** represents the magnetizing characteristic when the supply current I_S is at its maximum negative value $I_S = -i_S$.

For convenience of drawing and explanation, each of the regions of the characteristics **57** and **58** is shown by a straight line. Oscillograms of the supply current I_s, the output current I_o and the flux Φ, all on the same time scale, are shown in Fig. 4. One cycle of the supply current I_s is shown by the waveform **60**. The supply current I_s has a positive value of $+i_s$ and a negative value of $-i_s$, and has a frequency f_s. Five cycles of output current I_o are shown by the waveform **62** of Fig. 4. The output current is square wave and has a maximum positive value of $+i_o$ and a maximum negative value of $-i_o$, and has a frequency of 5 f_s. The waveform **64** shows five cycles of flux Φ in the circuit corresponding to the five cycles of output ciurrent I_o of the waveform **62**.

During operation, oscillations in the output circuit are started by applying a momentary triggering excitation to the magnetic circuits. Prior to the initiation of oscillations, the supply current I_s produces changes only in the zero flux region of the characteristic, for example, the region *f* of the characteristic **40** of Fig. 2. The zero flux condition is a stable condition and represents one mode of operation of the system. Thus, in this condition substantially no output is delivered to the load device **30** of Fig. 1.

The triggering excitation can operate as a pedestal to which the supply is added, bringing the operation from the zero flux region to one of the current-saturated regions. For example, the triggering excitation can be applied during the positive phase of the supply current I_s, thereby moving the operation point to the upper current-saturated region of the solid characteristic **57**. The triggering excitation can then be removed and the output current I_o thereafter oscillates between the current-saturated regions of the characteristics **57** and **58**. The pedestal type of triggering can be applied in the system of Fig. 1 either by momentarily closing and then opening the single-throw switch **34** in the output circuit, or by closing the start switch **39** and activating the start pulse source **38** to apply positive, constant-current start pulses, in the direction of the arrow, to the start winding **36**.

The trigger excitation also can operate to compress the zero flux region along the I_o axis of the characteristic. In such case the supply current I_s will then have sufficient amplitude to change the operating point from the zero flux region to a current-saturated region. Upon removal of the latter triggering excitation, the characteristic expands to its initial width and the output current I_o oscillates between the two current-saturated regions of the characteristics **57** and **58**. The latter type triggering excitation may be applied in the system of Fig. 1, for example, by momentarily opening and then closing the switch **26** connected in the bias circuit.

In general, the magnitude of the triggering excitation is made sufficiently great either to charge the capacitor **28** in excess of a maximum amplitude V_c, as described hereinafter, or, in the case of the start pulses to supply a saturation flux Φ_s as described hereinafter.

The second mode of operation of the system, with large oscillations at the multiple frequency in the output circuit, is also stable, and output power at the desired multiple frequency is delivered across the output circuit of Fig. 1. The supply source **22** supplies the power absorbed in the output circuit and the system losses, mainly resistive losses, at the lower supply frequency f_s. Substantially no power is required from the bias source **23**.

The shaded areas **65** and **67** between the two characteristic curves **57** and **58** of Fig. 3 represent, respectively, the energy supplied to the output circuit when the supply current changes from $-i_s$ to $+i_s$, and vice versa. The fluxes Φ' and Φ'' represent the magnetic flux in the circuit at the time when the supply current changes. The output current I_o changes abruptly in step fashion when the supply current I_s switches from $+i_s$ to $-i_s$, and from $-i_s$ to $+i_s$. The steps **68** of the output current I_o waveform **62** indicate the abrupt increase in the positive phase of output current I_o when the supply current changes from $-i_s$ to $+i_s$, and the step **69** represents the abrupt change in the output current I_o when the supply current I_s changes from $+i_s$ to $-i_s$. The amount of output current change represented by the steps **68** and **69** is approximately equal to a value

$$2i_o\frac{N_B}{N_S}$$

Thus, each time the supply current I_s changes phase, a parametric change from one to the other of the characteristics **57** and **58** is produced and energy is added to the output circuit. It is these added increments of energy which enable stable oscillation and enable output energy to be delivered to the load device.

The waveform **64** of the flux Φ' indicates that positive fluxes are produced when the supply current I_s changes from negative to positive, and negative fluxes Φ'' are produced when the supply current changes from positive to negative. The flux Φ waveform **64** shows a dampening effect during each half cycle of supply current, with the flux Φ being repeatedly restored to its initial amount each time the supply current changes phase.

The magnetic energy of the circuit is stored in the capacitor **28** of Fig. 1 when the magnetic flux Φ is changing. Thus, the output circuit operates in a manner somewhat analogous to a LCR tank circuit, with the stored energy being switched back and forth between the magnetic circuits and the capacitive element at the desired multiple frequency.

In order to maintain the proper relations between the supply-current (I_s) changes and the circuit flux (Φ) changes, the output current I_o is required to oscillate at an odd integral multiple of the supply frequency f_s.

The following equations are approximate, but are sufficiently accurate for use in designing a frequency-changing system as described in Fig. 1:

$$P=8N_s i_s \Phi_s f_s \tag{1}$$

where P is the maximum output power in watts available at the desired output frequency nf_s; f_s is the supply frequency in cycles/sec.; N_s is the number of turns of the supply windings **16** and **16'**; i_s is the amplitude, in amperes, of the supply current, and Φ_s is the saturation flux in volt-seconds of the cores **12** and **12'**.

$$C=\frac{i_o}{64N_o\phi_s(nf_s)^2} \tag{2}$$

where C is equal to the value of the capacitor **28** in farads; N_o is the number of turns of the output windings **20** and **20'**.

$$V_c\max=N_o\Phi_s(nf_s) \tag{3}$$

where V_c max is the maximum voltage, in volts, developed across the capacitor **28**, and

$$nf_s=\frac{I_o}{4(V_c\max)C} \tag{4}$$

where I_o is the average value of the output current i_o.

The circuit of Fig. 1 can be arranged to supply desired even integrals, fractional and sub-integrals of the supply frequency by changing the connection of the supply windings **16**, **16'** thereof from series-aiding to series-opposition relation. Fig. 5 shows the series-opposition connection of the supply windings with the terminals **16*a***, **16'*a*** connected to each other, and the terminals **16*b***, **16'*b*** connected to the supply source **22**. The remaining winding connections to the cores **12** and **12'** may be the same as those of Fig. 1. In the case of the series-opposition connection of the supply windings, the flux changes in the cores **12** and **12'** are in phase with the changes of the supply current i_s. Accordingly, stable operation is produced when the output frequency nf_s is an even integral, a fractional integral, or a sub-integral of the supply frequency f_s.

In the embodiment of Fig. 6, a supply source is connected across the output windings **20** and **20'** of the cores **12** and **12'**. One output terminal of the supply source is connected to the one terminal **20*a*** of the output winding **20**, and the other output terminal of the supply source is connected to a source of reference potential, indicated in the drawing by the conventional ground symbol. The terminal **20'*b*** of the output winding **20'** is connected in series with the parallel circuit comprising a capacitor **75** and a load **76** to a terminal **77** connected to the common ground. The bias windings **18** and **18'** are connected in series-opposition relation to a direct-current bias source **70**.

The supply source may be, for example, any suitable one arranged to furnish a sinusoidal waveform **81** at a frequency f_s. The output waveform is then substantially square wave, as indicated by the waveform **83**, at the desired multiple n of the supply frequency f_s. A bypass filter **74** is connected across the terminals **20*a*** and ground to bypass the multiple frequency (nf_s) currents of the output circuit from the supply source. In practice, the filter **74** may consist of a cage in the rotor of the supply generator.

Oscillations may be initiated in the output circuit by momentarily interrupting the bias current I_B, or by charging the capacitor **75**, or by a separate start winding, as described for the system of Fig. 1. The system can be switched to the non-oscillating, for example, by interrupting the supply current I_s, or by momentarily short-circuiting the capacitor **75**, as by momentarily closing the double-pole, single-throw switch **78** connected across the capacitor **75**.

The cores **12** and **12'** of the systems of Figs. 1 and 6 each may be replaced, if desired, by a composite core **80** of Fig. 7. The core **80** has a permanent magnet portion **82** for supplying the bias flux. By using a composite magnetic core, the bias source and the bias windings may be dispensed with. The permanent magnet portion **82** is bonded to the remaining portions of the core **80** so as to minimize the air-gaps. A composite core, such as the core **80**, is known in the art. The volume of the permanent magnet portion **80** is made sufficiently large to produce a biasing flux equal to the bias magnetizing force N_BI_B of Figs. 1 and 6.

The two magnetic cores **12** and **12'** of the systems of Figs. 1 and 6 may be combined into a single three-legged magnetic core **84**, as shown in Fig. 7. The core **84** has two separate magnetic circuits each about one of the apertures **85** and **86**. The respective supply and output windings may be linked to the outside legs of the core **84** and a single bias winding may be linked to the center leg. Also, if desired, a permanent magnet portion may be included in the center leg of the core **84**.

There has been described herein an improved frequency-changing system which provides advantages by way of efficiency, size and cost. Odd, even, fractional, or submultiples of a supply frequency may be obtained. The output frequency consists essentially of the desired frequency, and additional filtering or tuning elements are not required. The circuit is stable in either of two modes. A supply either does or does not produce output frequency depending upon the mode selected. In one mode a substantial output is obtained and, in the other mode, substantially no output is obtained. The system can be triggered back and forth between the two modes by applying suitable triggering excitations. A relatively large output can be delivered to a load in an efficient manner.

What is claimed is:

1. A static frequency-changing system comprising a pair of magnetic circuits, means for biasing said circuits in opposite directions of magnetization, a supply circuit for applying alternating magnetizing forces simultaneously to said circuits, an output circuit including energy-storing means connected to said magnetic circuits for storing energy supplied to said circuits by said supply circuit, said biasing magnetization being substantially greater in magnitude than the magnetizations produced by said alternating magnetizing forces, and triggering means connected to said system for applying an electrical pulse to initiate electrical oscillations in said output circuit.

2. A frequency-changing system comprising a pair of magnetic circuits, a pair of supply windings respectively linked to said circuits for receiving an alternating input of one frequency, an output circuit including in series a pair of output windings respectively linked to said circuits and a capacitor, means for applying a bias magnetizing force simultaneously to said magnetic circuits, and triggering means connected to said system for applying an electrical signal to said circuits, said signal operating to induce an alternating output of a frequency different from said one frequency in said output circuit, and a load device connected in said output circuit.

3. A frequency-changing system comprising a pair of magnetic circuits, a supply, a bias, and an output winding for each magnetic circuit, means for applying an alternating supply current of one frequency to said supply windings, means for applying a bias current to said bias windings, an output circuit including in series said output windings and a capacitor, and triggering means connected to said system for applying an electrical pulse to said magnetic circuits, said electrical pulse operating to initiate alternating currents in said output circuit at a frequency different from said supply frequency.

4. A static frequency-changing system comprising a pair of magnetic cores, a pair of supply windings respectively linked to said cores for receiving alternating supply currents of one frequency, a pair of bias windings respectively linked to said cores for receiving a bias current, the magnetizing forces applied to said cores by said bias current and bias windings being substantially greater in magnitude than the magnetizing forces applied to said cores by said alternating supply signal and said supply windings, an output circuit including a pair of output windings respectively linked to said cores and a capacitor connected in series with said pair of output windings, winding means coupled to at least one of said cores, and means for applying an electrical pulse to said winding means for inducing an alternating signal in said output circuit, the frequency of said output signal being different from the frequency of said supply signal.

5. A static frequency-changer for changing the frequency of alternating-supply currents to a desired odd integral of said supply frequency, comprising a pair of magnetic circuits each having supply and output windings, corresponding ones of said supply and output windings being respectively connected in series-aiding, means for biasing said circuits to produce a magnetization characteristic having current-saturated regions respectively located on either side of the flux axis of said characteristic, an output circuit including said output windings and a capacitor, triggering means connected to said circuits for a first electrical pulse to said circuits to initiate alternating currents at said desired frequency in said output circuit, whereby said output-circuit currents are maintained by energy derived from said supply currents and second triggering means connected to said circuits for applying another electrical pulse to said circuits to stop said output circuit oscillating currents.

6. A static frequency-changer as described in claim 5, wherein said pair of magnetic circuits are included in a three-legged magnetic core.

7. A static frequency-changer as described in claim 5, wherein said pair of magnetic circuits consists of a pair of magnetic cores.

8. A static frequency-changer as described in claim 5, wherein said biasing means includes a separate bias winding for each of said magnetic circuits, and said bias windings being connected in series-opposition.

9. A static frequency-changer as described in claim 5, wherein said biasing means includes a permanent magnet in each of said pair of magnetic circuits.

10. A static frequency-changer for changing an alter-

nating supply frequency to a desired one of an even multiple, a fractional multiple, or a sub-multiple of said supply frequency comprising a pair of magnetic circuits each having a supply and an output winding, said supply windings being connected in series-opposition relation and said output windings being connected in series-aiding relation, means for biasing said circuits to produce a resultant magnetization characteristic having current-saturated regions respectively located on either side of the flux axis of said characteristic, an output circuit including said output windings and a capacitor connected across said output windings, triggering means connected to said circuits for applying an electrical pulse to said triggering means to initiate alternating currents at said desired frequency in said output circuit, whereby said initiated alternating currents are maintained in said output circuit by energy derived from said supply currents.

11. A static frequency-changer as described in claim 10, including a load device connected to said capacitor.

12. A static frequency-changer as described in claim 10, wherein said pair of magnetic circuits consist of a pair of magnetic cores.

13. A static frequency-changer as described in claim 10, wherein said pair of magnetic circuits are included in a three-legged magnetic core.

14. A static frequency-changer comprising a pair of magnetic circuits, a pair of supply windings respectively linked to said circuits in the same one sense for receiving supply currents of one frequency, an output circuit including a pair of output windings respectively linked to said circuits in said one sense and a capacitor, a pair of bias windings respectively linked in the one sense and the sense opposite the one sense to said magnetic circuits, said pair of bias windings being arranged for receiving a unidirectional bias current, said supply currents and said supply windings and said bias current and said bias windings being so proportioned that the supply ampere-turns of magnetizing force applied to said circuits are appreciably less than the bias ampere-turns of magnetizing force, triggering means connected to said circuits for selectively initiating oscillations at a desired frequency in said output circuit whereby said oscillations are maintained by energy derived from said supply currents at said one frequency, and second triggering means connected to said circuits for selectively stopping said oscillations in said output circuit.

15. A frequency-changing system comprising a pair of magnetic circuits, a supply, a bias, and an output winding for each magnetic circuit, means for applying an alternating supply current of one frequency to said supply windings, means for applying a bias current to said bias windings, an output circuit including in series said output windings and a capacitor, triggering means connected to said system for applying a first electrical pulse to at least one of said magnetic circuits, said first electrical pulse operating to initiate in said output circuit alternating currents of a frequency different from said one frequency, said alternating currents being maintained in said output circuit by energy derived from said supply currents, and second triggering means connected to said system for applying a second electrical pulse to said at least one of said magnetic circuits, said second electrical pulse operating to stop any alternating currents of said desired frequency in said output circuit.

16. A frequency-changing system as described in claim 15, wherein corresponding ones of said supply and output windings are connected in series-aiding relation, and said bias windings are connected in series-opposition relation.

17. A frequency-changing system as described in claim 15, wherein corresponding ones of said supply and bias windings are connected in series-opposition relation, and said output windings are connected in series-aiding relation.

18. A frequency-changing system comprising a pair of magnetic circuits, means for supplying alternating magnetizing forces of one frequency simultaneously to said circuits, means for applying a unidirectional biasing magnetizing force simultaneously to said circuits, said biasing magnetizing force being appreciably greater in magnitude than said alternating magnetizing forces, means including winding means linked to said circuits and a capacitor for deriving alternating currents at a frequency different from said one frequency from said circuits, triggering means connected to said system, and means for applying an electrical pulse to said triggering means for initiating said alternating currents.

19. A frequency-changing system as described in claim 18, wherein said means for supplying said alternating currents includes said winding means, and a filter connected across said winding means for bypassing said alternating currents of said different frequency.

20. A frequency-changing system as described in claim 18, wherein said means for supplying said alternating magnetizing forces includes a pair of supply windings respectively linked to said circuits.

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