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B. M. CHIN
MAGNETIC OSCILLATOR

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2 Sheets-Sheet 1

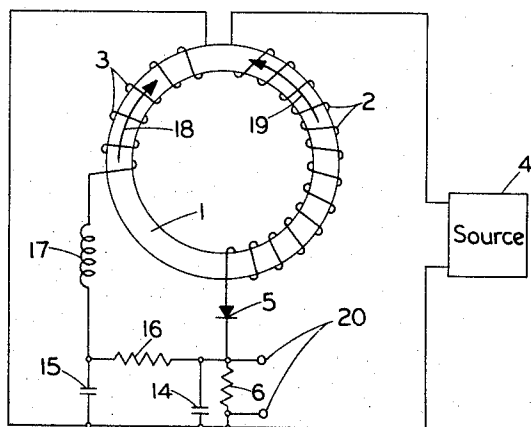


Fig. 1

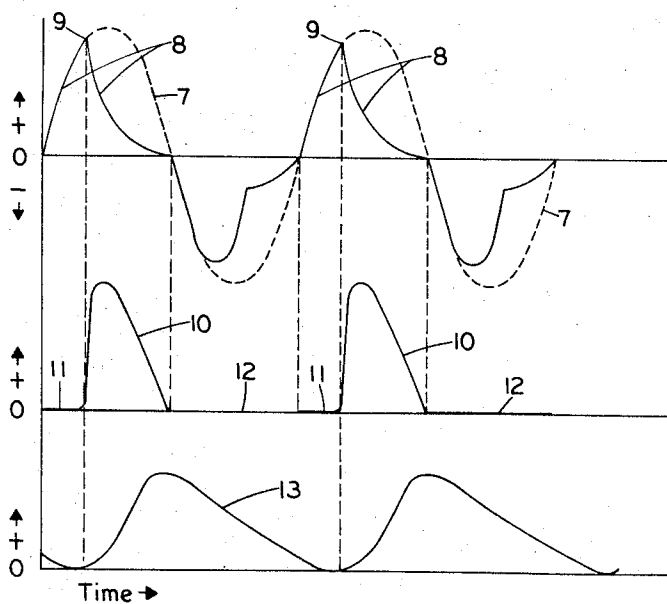


Fig. 2

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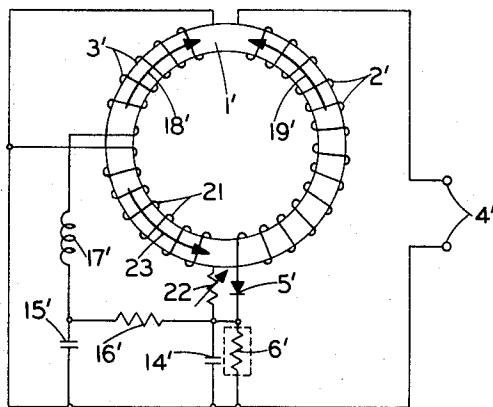
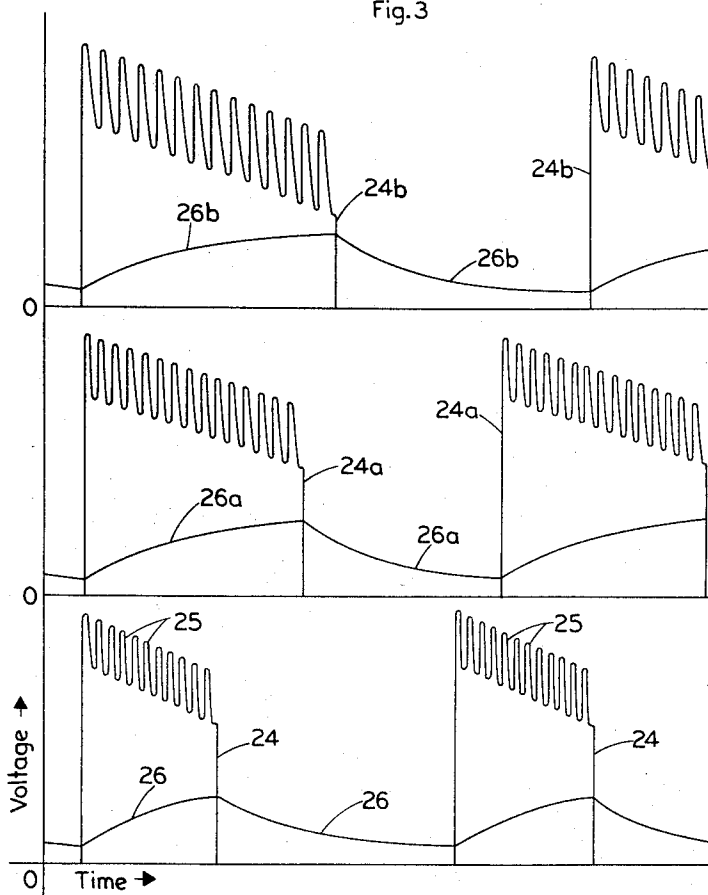
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2 Sheets-Sheet 2



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MAGNETIC OSCILLATOR

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6 Claims. (Cl. 307—88)

The present invention relates to circuitry involving saturable magnetic elements and, more particularly, to oscillatory magnetic circuits.

Saturable core reactance devices of the type including saturable magnetic material associated with one or more windings have experienced widespread use in supplementing or replacing electronic or electromechanical equipment in many applications. The magnetic apparatus is particularly advantageous in that it is commonly of relatively light weight, small size, great sturdiness, and possesses a long life expectancy. The wholly static operation and adaptability to good impedance matching of such apparatus offer further attractions. These characteristics are found in the circuitry of my present teachings relating to magnetic oscillators. Although it has been known heretofore to achieve modulation and generation of electric waves through operation of saturable core devices, such circuitry may involve multiple or complex-shaped cores, D.C.-excited control windings and control signal circuits, relatively low gain, and output frequencies largely variable with the load impedances.

Accordingly, it is one of the objects of the present invention to provide improved and simplified magnetic apparatus for the generation of periodically-varying electric waves wherein a single saturable core member is utilized and wherein D.C. control windings are absent.

A further object is to provide an improved high-gain magnetic circuit of uncomplicated construction in which a generated pulse output repetition rate is largely independent of load impedances.

By way of a summary account of this invention in one of its aspects, an annular core of high-permeability magnetic material carries a pair of toroidal windings, one of which is excited by a source of high-frequency excitation serially through a resistive load and a half-wave rectifier. Alternate half-cycles of the excitation signals are passed by the rectifier, although these rectified currents are significant only when the core is saturated. Saturation occurs very rapidly when excitation is applied, because the rectifier prevents flux resetting in the core. The remaining core winding is disposed in the discharge path of a storage capacitor which is charged by the aforesaid signals passing through the load and developing unidirectional voltages across a filter capacitor. Discharge current through this winding occasions core flux which is in a direction to drive the core below saturation. The core thus becomes saturated and unsaturated periodically, with corresponding periodic variations in the current flowing through the load, and the oscillatory operation is self-sustaining.

Although the features of this invention which are believed to be novel are expressed in the appended claims, fuller details of this invention and the further objects and advantages thereof may be most readily comprehended through reference to the following description taken in connection with the accompanying drawings, wherein:

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Figure 1 is a schematic circuit diagram of a magnetic oscillator;

Figure 2 presents plots of wave-forms appearing in portions of the circuitry of Figure 1;

Figure 3 depicts schematically a high-gain oscillator embodying the present teachings; and

Figure 4 exhibits output and storage capacitor wave-forms for the apparatus of Figure 3.

With reference to the Figure 1 illustration, there is displayed an annular core 1 of high permeability magnetic material about which there are disposed two toroidally-wound coils 2 and 3. Source 4, which is of a frequency higher than that of the desired circuit output, energizes coil 2 with A.C. signals through the rectifier 5 and load resistance 6 which are in series with coil 2 across the source. The excitation signals from source 4 are of values which would be insufficient to cause saturation of core 1 by coil 2 were the rectifier 5 absent from such saturation to occur because the unidirectional current flow prevents flux resetting from occurring in the core. Shortly after the excitation is applied, the flux level in core 1 builds up to an extent permitting alternate half cycles of the excitation to saturate the core and drive large currents through the rectifier and load. This effect is observed in the wave-form plots of Figure 2 for the aforesaid simple circuit. Dashed-line plot 7 there represents a 400 cycle excitation signal from source 4, and the solid-line wave-form 8 represents the voltage drop appearing across coil 2. At level 9, core 1 saturates and a large current pulse 10 flows through the rectifier 5 and load resistance 6 during the remainder of the conducting half cycle, although only a relatively minute excitation current 11 flows prior to core saturation during the same half cycle. Half cycles of opposite polarity are blocked by the rectifier, such that the current then is essentially the zero value identified by numerals 12. Current pulses 10 are of a form corresponding to the voltage pulses appearing across the resistive load 6, also. However, for oscillation purposes, it is desired that these voltage pulses be smoothed or filtered to appear in the form designated by wave-form 13, and this result obtains through action of the capacitor 14 which is placed in parallel with the load resistance 6.

Unidirectional voltages from across the paralleled load 6 and capacitor 14 are impressed across a storage capacitor 15 through a resistance 16 which regulates the charging rate. As capacitor 15 charges, it is also caused to discharge through the series combination of inductance 17 and coil 3. The unidirectional discharge current thus caused to flow through coil 3 is of a sense, and the winding of coil 3 is also of a suitable sense, such that the resulting magnetic flux 18 traverses core 1 in a direction opposite to that of the net unidirectional flux 19 occasioned by coil 2. In the course of this discharging process, the magnetomotive force 18 produced by coil 3 will cancel the magnetomotive force 19 generated by coil 2, such that core 1 becomes unsaturated and coil 2 represents a large reactance. Consequently, the load current is reduced, the charging of storage capacitor 15 is likewise reduced, and the magnetomotive force 18 ultimately drops sufficiently to permit re-saturation of core 1 by coil 2 and an automatic repetition of the cyclic operation. Periodicity is largely controlled by the circuit elements 16, 15, and 17. Pulse output signals having this periodicity appear through and across the load resistance 6, as well as across the output terminals 20 for application to a separate load.

High gain and adjustable pulse widths of output are attainable with a circuit arrangement such as that of Figure 3, the circuit elements there corresponding to

those appearing in the circuit of Figure 1 being identified by the same reference characters bearing distinguishing prime accents. This improved circuit includes an auxiliary feedback winding 21 and a series resistance 22, which may be varied, this series combination being paralleled with the load 6'. Resistance 22 is of a value high in relation to the resistive component of coil 21 such that currents through the latter may be adjusted over an appropriately wide range in response to adjustments of resistance 22. Operating effects of this auxiliary feedback loop are best perceived in the following statement of the complete operating sequences experienced in the circuit as a whole. As source terminals 4' apply 400 cycle A.C. signals across the series-connected coil 2', rectifier 5' and resistance 6', the unidirectional magnetomotive force 19' occasions rapid saturation of core 1' and causes coil 2' to pass large unidirectional half-cycles of current. These half-cycles of current flow through resistance 6', and storage by capacitor 14' achieves a filtering which yields a smoothed unidirectional voltage across capacitor 14'. Storage capacitor 15' in turn becomes unidirectionally charged, by this filtered signal, through resistance 16'. However, as capacitor 15 is charged, it also tends to discharge through the series-connected inductance 17' and feedback coil 3'. Inductive reactance of inductance 17' is high enough to provide a needed delay or lag in the discharging of capacitor 15', although the discharge current shortly reaches a value sufficient to generate a feedback magnetomotive force 18' which tends to drive core 1' below saturation. Part of this time lag is responsible for the continued flow of rectified excitation currents through resistance 6', such that an extended pulse formed by these rectified currents is delivered through the load resistance 6' until the aforementioned core desaturation takes place. Because of this same time lag, the discharging current from capacitor 15' continues to flow through coil 3' until, after a predetermined interval, the magnetomotive force it produces is so diminished that core 1' can again become saturated by action of the excitation appearing across coil 2'. Rectified 400 cycle output current flows through load resistance 6' only during those alternate intervals when core 1' is saturated, and drops to a negligible value when the core is unsaturated. With the addition of coil 21 and resistance 22, it becomes possible to enlarge and vary the intervals during which the large load currents flow in relation to the intervals when the core is unsaturated and the load currents are negligible. Coil 2' is preferably of a relatively small number of turns, which permits the desired rapid saturations of core 1', and the added unidirectional flux needed to extend the load current intervals is derived from coil 21 rather than from added turns on coil 2'. As large load current pulses flow, coil 21 receives the unidirectional current, by virtue of its parallel relationship with load 6', and provides a magnetomotive force 23 which is in an aiding relationship to the saturating magnetomotive force 19'. Therefore, the desaturating magnetomotive force 18' must overcome a greater magnetomotive force tending to preserve saturation in core 1', with the result that the saturation intervals and load current pulses are extended. In one arrangement wherein the load current pulses were of about 40% of the repetition period, the pulse lengths were extended to about 60% of the period by operation of the auxiliary coil.

The plots of voltage vs. time appearing in Figure 4 illustrate the effects achieved with variations in the magnitudes of charging resistance 16' and positive feedback resistance 22 in the circuitry of Figure 3. In each instance, the A.C. supply at terminals 4' was of a 400 cycle frequency, capacitors 14' and 15' were both of 9 microfarad values, and the load 6' possessed a 350 ohm resistance. Voltage pulses 24 appearing across load 6' are observed to include components 25 which represent filtered rectified half cycles of the 400 cycle excitation. Pulses 24 are shown related to the voltages 26 appearing

across the storage capacitor 15'. Both of these plotted waveforms were realized with the value of 2,000 ohms for both resistances 22 and 16'. When the storage circuit resistance 16' was increased from 2,000 to 4,000 ohms, with the positive feedback circuit resistance 22 remaining at 2,000 ohms, the voltages 24a and 26a were produced across the load and storage capacitor 15', respectively, it being apparent that the repetition period was lengthened (frequency or pulse rate decreased) and the load voltage pulses 24a were increased in duration in relation to the pulse repetition period. These effects are attributable to the greater time required for capacitor 16 to charge and to discharge currents large enough to achieve desaturation of core 1'. With the resistance 22 reduced to 1,100 ohms, and the storage circuit resistance 16' again fixed at 2,000 ohms, the voltages 24b and 26b were produced across the load resistance 6' and storage capacitor 15', respectively. The load voltage pulses 24b were further increased in duration, as a consequence of increased current through feedback coil 21 and resulting increased mmf. 23 tending to defer desaturation. It is also found that increases in the capacitance value of storage capacitor 15' are accompanied by decreased pulse repetition frequencies, and vice versa. Output signals ranging from 0.086 to 45 cycles per second were obtained with apparatus energized by 400 cycle excitation.

Where an excitation source of periodically varying unidirectional signals is available, the excitation circuit rectifiers 5 and 5' may be dispensed with. Such excitation signals may comprise a train of unidirectional pulses from a multivibrator, for example, and the other operating effects will be like those described in connection with the rectified A.C. excitation. It should also be recognized that certain of the components may be altered. By way of illustration, the charging circuit resistances 16 and 16' may be replaced by components partly or wholly inductive. The same is true of the loads 6 and 6', which may also possess capacitive reactance. It is further found that the filtering capacitor 14' may be omitted while yet permitting oscillations to occur, although it is preferred that the filtering be accomplished.

Accordingly, it should be understood that the specific preferred embodiments selected for description are intended to be illustrative, and that various changes, modifications, and substitutions may be effected by those skilled in the art without departure from the spirit and scope of this invention as set forth in the appended claims.

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

1. Apparatus for producing periodically varying electrical signals comprising a saturable magnetic core, first and second winding means disposed in inductive relationship with said core, a load impedance, means impressing periodically varying signals across the series combination of said first winding means and said impedance to cause unidirectional current conduction therethrough at a first repetition rate, a capacitor, means applying to said capacitor unidirectional voltages developed across said load impedance, an inductance, and means coupling said inductance and said second winding means serially in a discharge path for said capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said capacitor which is opposed to magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said load impedance at a second repetition rate which is less than said first repetition rate.

2. Apparatus for producing periodically varying electrical signals comprising: a saturable magnetic core; first and second winding means disposed in inductive relationship with said core; a load impedance; a rectifier; means applying alternating current excitation across the series combination of said first winding means, said impedance and said rectifier, said excitation being of ampli-

tude sufficient to occasion saturation of said core when said rectifier is in said series combination and being of amplitude insufficient to occasion said saturation without said rectifier in said series combination; a capacitor; means applying to said capacitor unidirectional voltages developed across said load impedance; an inductance; and means coupling said inductance and said second winding means serially in a discharge path for said capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said capacitor which is opposed to magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said load impedance at a repetition rate less than the frequency of said alternating current excitation.

3. Apparatus for producing periodically varying electrical signals comprising a saturable magnetic core, first, second, and third winding means disposed in inductive relationship with said core, a load impedance including resistance, means impressing periodically varying signals across the series combination of said first winding means and said impedance to cause unidirectional current conduction therethrough at a first repetition rate, a capacitor, means applying to said capacitor unidirectional voltages developed across said impedance, an inductance, means coupling said inductance and said second winding means serially in a discharge path for said capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said capacitor which is opposed to magnetomotive force produced by said first winding means, and means energizing said third winding means with currents responsive to said unidirectional current conduction through said first winding means and said impedance, said third winding means being disposed to produce in said core magnetomotive force aiding said magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said load impedance at a second repetition rate less than said first repetition rate.

4. Apparatus for producing periodically varying electrical signals comprising: a high-permeability magnetic core; first, second, and third winding means disposed in inductive relationship with said core; a load impedance including resistance; a rectifier; means applying alternating current excitation across the series combination of said first winding means, said impedance and said rectifier, said excitation being of amplitude sufficient to occasion saturation of said core when said rectifier is in said series combination and being of amplitude insufficient to occasion said saturation without said rectifier in said series combination; a capacitor; means applying to said capacitor unidirectional voltages developed across said load impedance; an inductance; means coupling said inductance and said second winding means serially in a discharge path for said capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said capacitor which is opposed to magnetomotive force produced by said first winding means; and means energizing said third winding

means with currents responsive to unidirectional currents flowing through said series combination, said third winding means being disposed to produce in said core magnetomotive force aiding said magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said series combination at a repetition rate less than the frequency of said alternating current excitation.

5. Apparatus for producing periodically varying electrical signals comprising: a high-permeability magnetic core; first and second winding means disposed in inductive relationship with said core, a load impedance; a rectifier; means applying alternating current excitation across the series combination of said first winding means, said impedance and said rectifier; a first capacitor filtering unidirectional voltages developed across said load impedance; a second capacitor; impedance means applying to said second capacitor voltages filtered by said first capacitor; an inductance; and means coupling said inductance and said second winding means serially in a discharge path for said second capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said second capacitor which is opposed to magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said series combination at a repetition rate which is less than the frequency of said alternating current excitation.

6. Apparatus for producing periodically varying electrical signals comprising: a high permeability magnetic core, first, second, and third winding means disposed in inductive relationship with said core; a load impedance; a rectifier, means applying alternating current excitation across the series combination of said first winding means, said impedance and said rectifier; a first capacitor paralleled with said load impedance; a second capacitor; impedance means applying to said second capacitor voltages filtered by said first capacitor; an inductance; means coupling said inductance and said second winding means serially in a discharge path for said second capacitor, said second winding means being disposed to produce in said core magnetomotive force responsive to discharge current from said second capacitor which is opposed to magnetomotive force produced by said first winding means; a control impedance; and means coupling said third winding across said load impedance and said first capacitor through said control impedance, said third winding means being disposed to produce in said core magnetomotive force aiding said magnetomotive force produced by said first winding means, whereby said core is alternately saturated and unsaturated to control currents through said series combination at a repetition rate less than the frequency of said alternating current excitation.

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