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[54] **TUNED OSCILLATOR CIRCUIT FOR PROVIDING A ROTATING MAGNETIC FIELD**

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[51] **Int. Cl.** **H03b 3/00**

[58] **Field of Search** .... 331/166, 117, 173, 55, 40; 340/174 TF; 328/223

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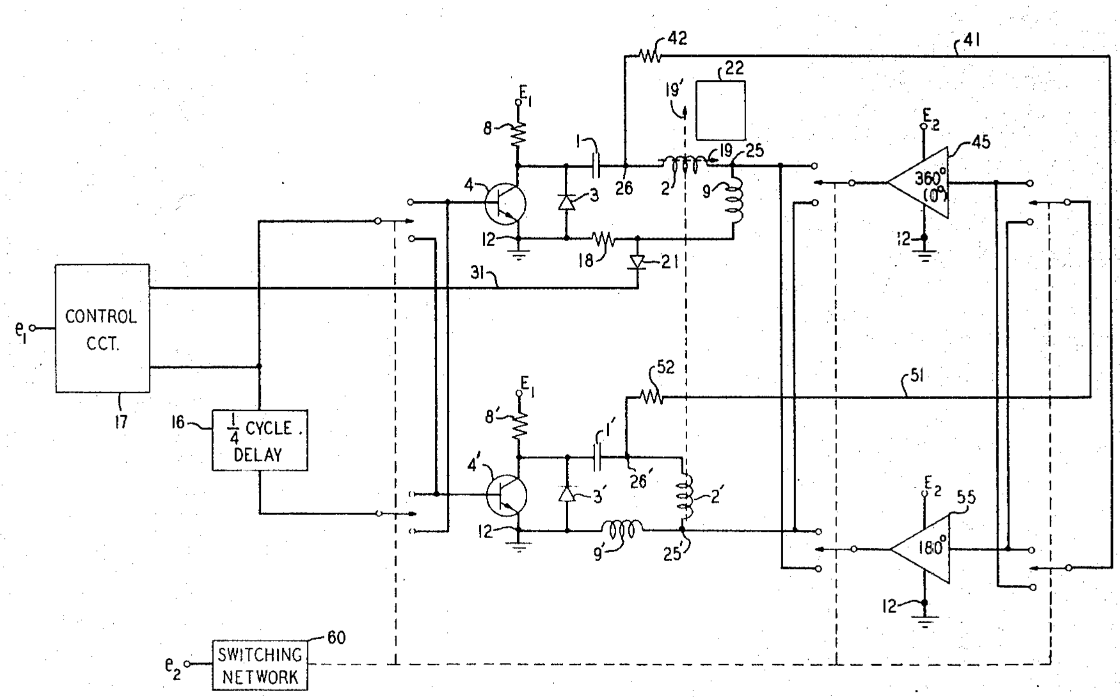
[57] **ABSTRACT**

A tuned field drive circuit for use in magnetic domain apparatus is provided for generating a reversible, rotating, magnetic field in a plane. The circuit is capable of initiating, maintaining and terminating the rotating field with a predetermined phase and with a field strength envelope having a substantially constant amplitude. The basic circuit includes a high-speed transistor switch, a tuned L-C resonant circuit, and a feedback field current amplifier, for compensating for resistive loss in the resonant circuit. Two of the basic circuits are "slaved" together to form the resultant field drive circuit, each basic circuit providing one of two normal magnetic vector components comprising the rotating field.

11 Claims, 3 Drawing Figures



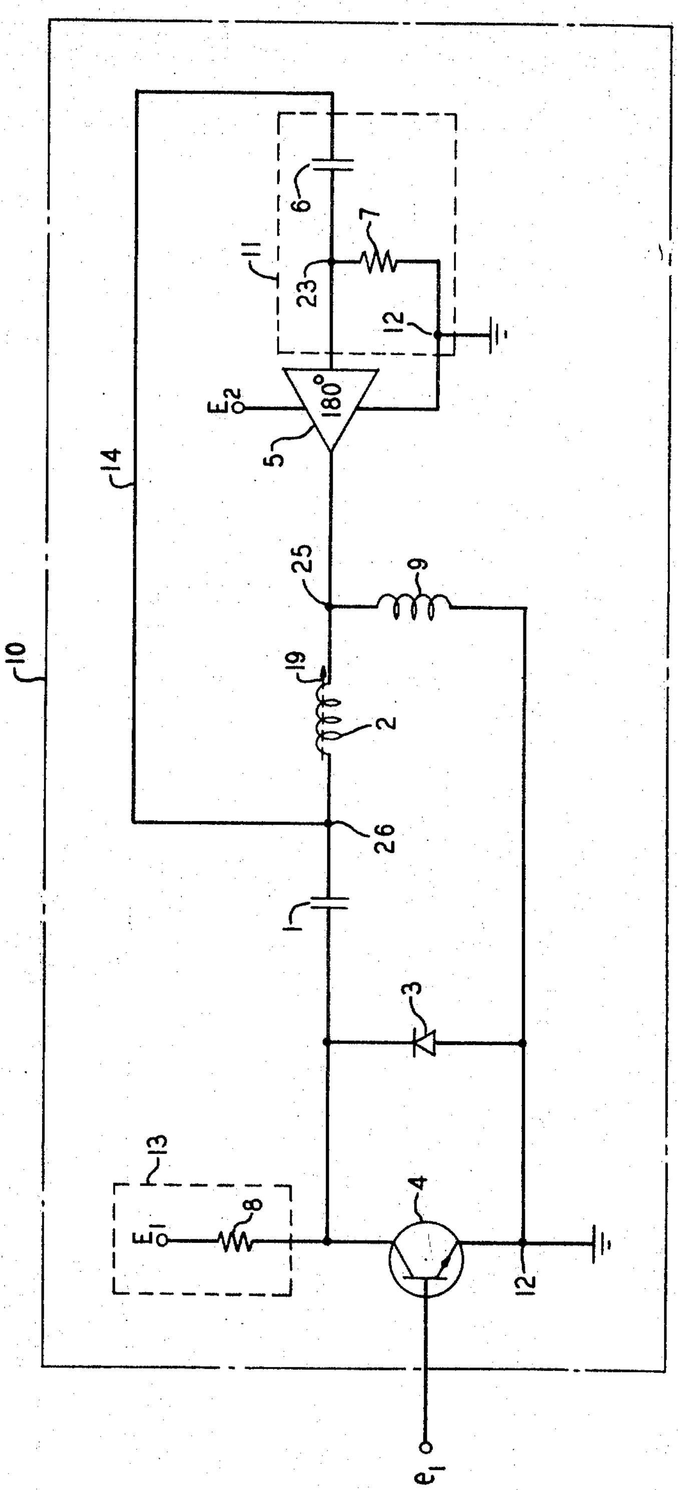


FIG. 1

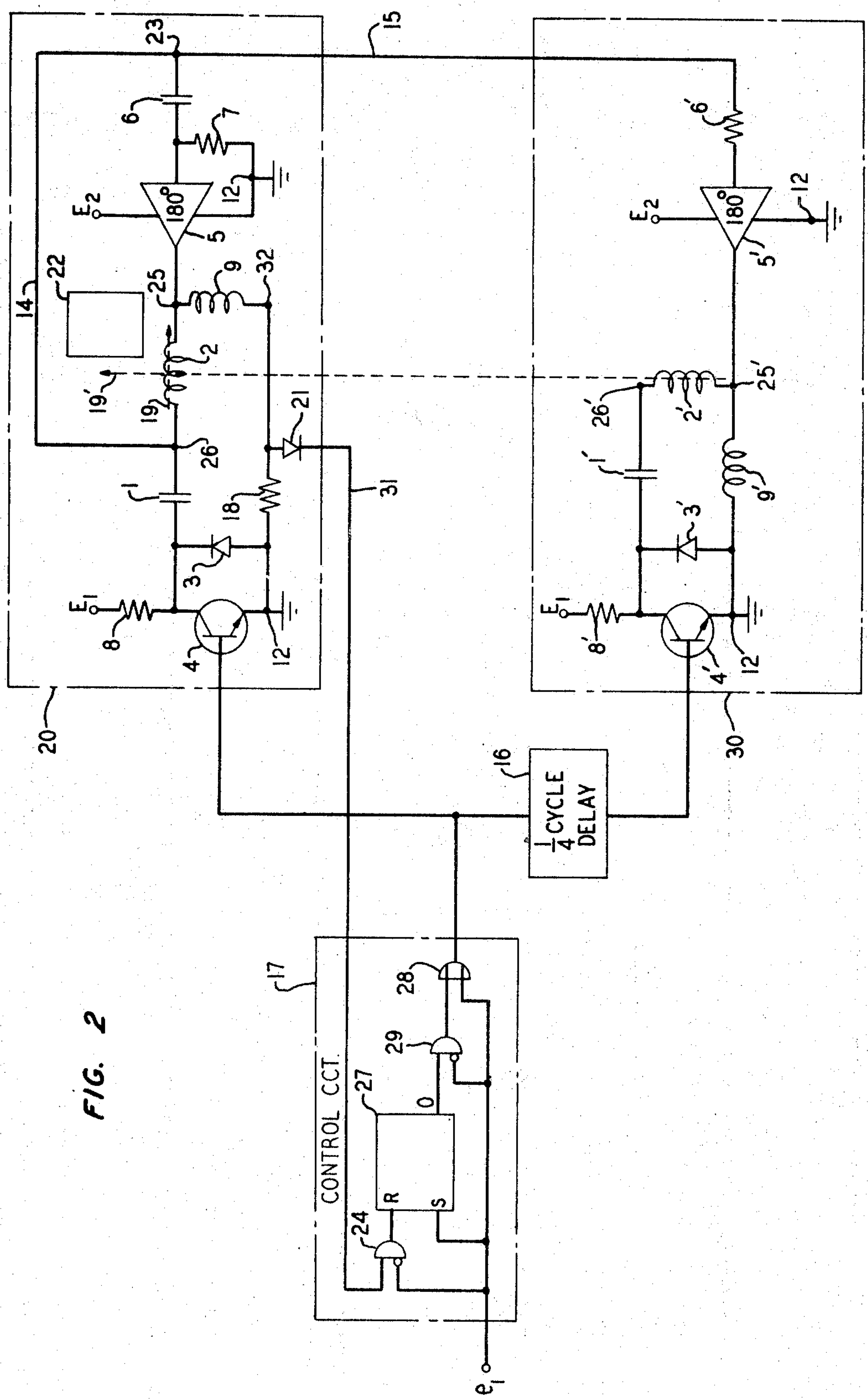


FIG. 2

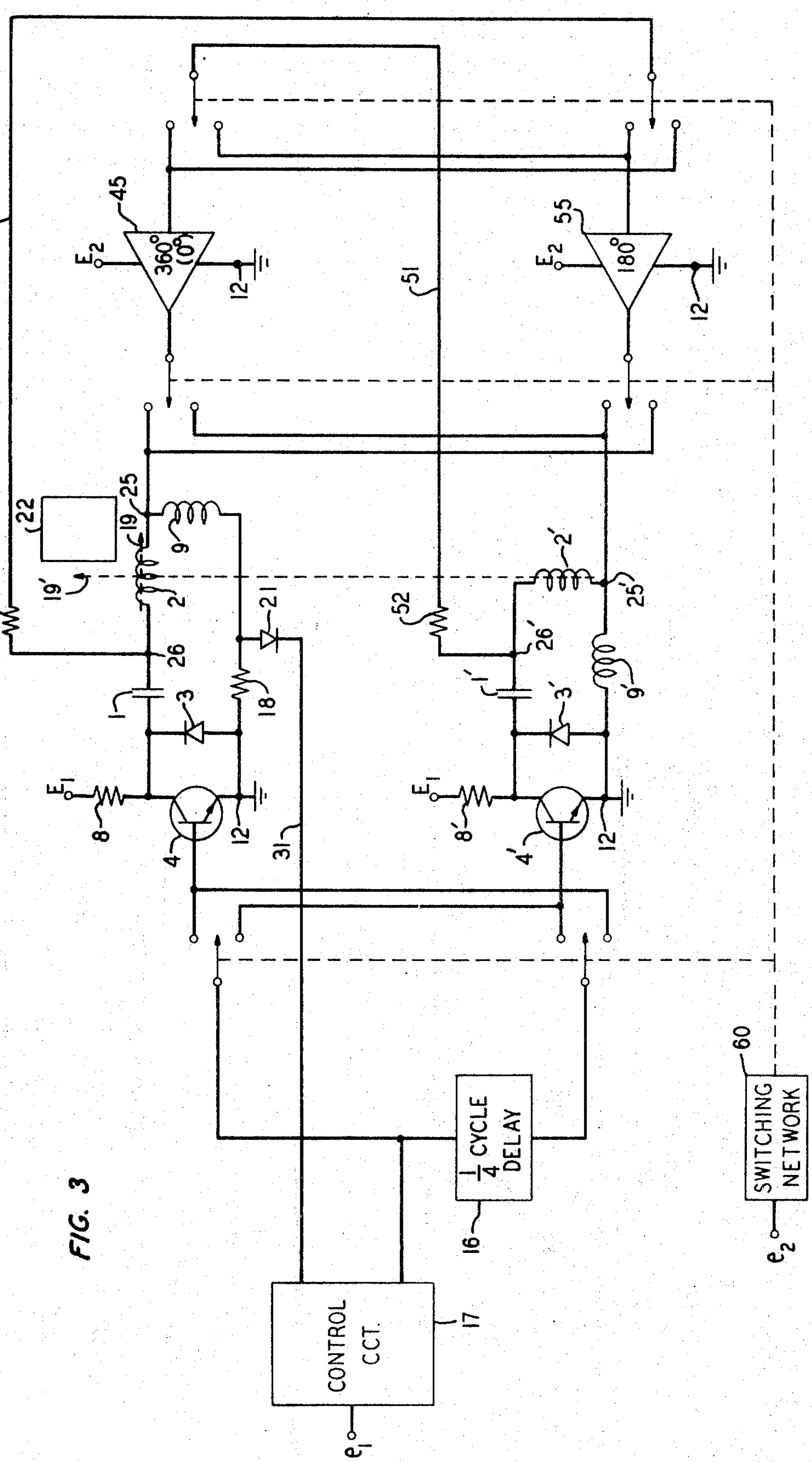


FIG. 3

TUNED OSCILLATOR CIRCUIT FOR PROVIDING A ROTATING MAGNETIC FIELD

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of oscillator circuits, and more particularly to a tuned oscillator circuit for providing a rotating magnetic field.

2. Prior Art

A single wall magnetic domain is a reverse magnetized region in a layer of material. The domain is encompassed by a wall which closes upon itself to form, illustratively, a cylindrical geometry, the diameter of which is a function of the layer of material in which it exists. Inasmuch as the boundary of the domain is stable and does not intersect the edge of the host layer of material, multidimensional selective movement of the domain within the layer can be realized.

The movement of a single wall domain is typically effected by generating a localized attracting magnetic field at a position offset from the position occupied by the domain. The domain moves to the position of the attracting magnetic field in response thereto.

A more complete explanation of single wall domains, various operations employing the movement of single wall domains, and a suitable material in which the domains can be moved is described in the ***Bell System Technical Journal***, Vol. 46, No. 8, October 1967, pages 1,901 et seq., in the article "Properties and Device Applications of Magnetic Domains in Orthoferrites," by A. H. Bobeck.

With this basic concept as a point of departure, a large variety of magnetic domain apparatus has been invented for performing a host of logical, arithmetic, and information storage functions. These apparatus require a simple, dependable method for moving the domains about within the layer of material in response to external control stimuli.

To meet this requirement a variety of magnetic domain propagation circuits have been invented in which domains are moved from predetermined locations to adjacent locations in a layer of material in response to a single cycle of a magnetic field rotating in the plane of the layer. Control of the phase characteristics of the rotating field permits these circuits to avoid the misplacement of domains when the field is initiated and terminated. It is, therefore, important that the phase of each rotation cycle of the rotating field be controlled to the extent that the field can be initiated at a predetermined phase and terminated after any exact number of full rotation cycles. An example of these propagation circuits, a rotating field, and how domains can be moved about in a layer of material in conjunction therewith is shown and described in U.S. Pat. No. 3,534,347 by A. H. Bobeck.

As a result of the development of these propagation circuits a collateral requirement has arisen for a field drive circuit for producing a rotating magnetic field meeting these criteria. Prior attempts to provide such a field drive circuit have resulted in various combinations of rather well-known oscillator circuits with Helmholtz coil structures to generate the rotating field. However, these circuits typically are characterized by high power consumption at high frequencies and poor rotational phase control characteristics which tend to cause domain misplacement.

The high power consumption problem in the prior art field drive circuits has been primarily due to their common feature that the Helmholtz drive coils have been driven as untuned loads. As a result, the oscillator circuits regenerate and dissipate the rotating magnetic field energy twice during each rotation period. At high rotation frequencies the power dissipated in these oscillator circuits becomes large due to the large inductance required for the drive coils.

The poor rotational phase characteristics in the prior art field drive circuits have been largely due to difficulties encountered in developing adequate switching means for terminating the rotating field at the initial phase point after an integral number of field rotation cycles. These difficulties have arisen as a result of transient ringing effects which are produced in the field drive circuits when the field is quickly terminated.

Another disadvantage of the prior art field drive circuits, which ensues from their poor phase control characteristics, is an inability to quickly reverse the direction of field rotation in response to a binary control signal without misplacing domains. The incorporation of a reversing feature into a field drive circuit would enable the addition of another dimension of flexibility to the design of domain propagation circuits in magnetic domain apparatus.

Accordingly, it is an object of this invention to provide a simple, dependable, low-power, rotating magnetic field drive circuit which incorporates the field drive coils into the oscillator circuitry as a tuned load.

It is another object to provide a rotating field drive circuit which is capable of terminating the rotating field without producing transient ringing effects in the oscillator circuitry.

It is still another object to terminate the rotating field at the end of any rotation cycle in response to a change of state of a binary control signal occurring at any time during the second half of the rotation cycle.

It is yet another object to reverse the direction of the rotating field in response to a second binary control signal.

BRIEF SUMMARY OF THE INVENTION

One aspect of the invention is a basic tuned oscillator circuit for providing any integral number of cycles of a sinusoidal magnetic field component having a predetermined frequency and phase. The oscillator circuit comprises a pre-energized, tuned inductance-capacitance (L-C) circuit including a field drive coil for providing the magnetic field component, switching means serially connected in the tuned circuit for initiating and terminating an oscillatory field drive current in the tuned circuit at a predetermined phase point, and a field current amplifier connected in a feedback path for maintaining the amplitude envelope and phase of the field current during a period of oscillation.

Another aspect of the invention is a method for synchronously interconnecting a pair of the tuned oscillator circuits to provide a pair of normal magnetic field components which interact in a plane to form a magnetic field rotating at the resonant frequency of the tuned circuits.

A feature of this invention is the embodiment of a field drive coil into a pre-energized tuned circuit to provide a low-power magnetic field generation circuit.

Another feature of the invention is a combination of a switching arrangement with the tuned circuit for initiating and terminating a field drive current at a predetermined phase point. The switching arrangement enables the field drive current to be terminated at the end of any full oscillation cycle, in response to a change of state of a binary control signal coupled to the switch at any time during the second half of that oscillation cycle.

Still another feature of this invention is an automatic control circuit for allowing the oscillatory field drive current to terminate only at a phase point in an oscillation cycle when all of the oscillatory energy associated with the tuned circuit is stored in a capacitor in the tuned circuit. This feature enables the termination of the field drive current at the end of any oscillation cycle without producing undesirable transient ringing effects.

Yet another feature of this invention is a method for interconnecting the tuned circuits of a pair of the oscillator circuits through at least one synchronization signal path, for maintaining an oscillatory field drive current in one oscillator circuit which is 90° out of phase with respect to an oscillatory field drive current in the other oscillator circuit and providing a resultant magnetic field which rotates in a plane.

A still further feature of this invention is another switching arrangement for effectively interchanging the respective ones of a pair of synchronously interconnected oscillator circuits, for reversing the direction of rotation of the resultant magnetic field. More particularly, this feature is provided by reversing the order in which the oscillator circuits are respectively triggered and by providing different synchronizing signals for reversing the relative phase difference between the respective field drive currents of the oscillator circuits.

These and other features of the invention will appear more clearly upon reading the following detailed description and claims considered in connection with the drawings to which they relate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an abbreviated circuit schematic of the basic tuned feedback oscillator circuit;

FIG. 2 depicts a basic circuit schematic of a pair of the tuned oscillator circuits embodied in a master-slave configuration providing a rotating magnetic field drive circuit; and

FIG. 3 illustrates a basic circuit schematic of a pair of the tuned oscillator circuits embodied in a cross-coupled configuration providing a reversible rotating magnetic field drive circuit.

DETAILED DESCRIPTION OF THE INVENTION

One aspect of the invention is the basic tuned oscillator circuit **10** depicted in FIG. **1**.

For illustrative purposes, oscillator circuit **10** comprises a tuned L-C (inductance-capacitance) circuit in combination with a switching circuit for providing a controlled oscillatory field drive current. A field current regeneration network is also included in oscillator circuit **10** for maintaining the envelope of the field drive current at a full amplitude by offsetting inevitable ohmic losses in the tuned circuit.

The tuned L-C circuit includes capacitor **1**, field drive coil **2**, and coil **9** connected in a serial conduction path between current source **13** and point **12** of reference potential. Current source **13** may consist of a voltage source E_1 and a large resistor **8**.

The switching circuit includes transistor switch **4** arranged with its collector and emitter terminals respectively connected between current source **13** and point **12** of reference potential. The switching circuit also includes diode **3** connecting in a shunt path between the collector and emitter terminals of transistor switch **4** in a manner so as to be poled oppositely with respect to the base-emitter junction of transistor **4**, relative to point **12** of reference potential.

The field current regeneration network includes phase shifter **11**, illustratively comprising capacitor **6** and resistor **7**, and field current amplifier **5** serially connected in feedback loop **14**, which connects between the terminals of field drive coil **2**.

The value of capacitor **1** is chosen in conjunction with the inductive value of field drive coil **2**, and to a lesser extent the inductive value of coil **9**, to provide a tuned L-C combination with a resonant frequency equal to the desired field rotation frequency. Coil **9** is included in the tuned circuit to provide a relatively lossless driving point with a proper impedance match for field current amplifier **5**. Due to the normally large inductance of field drive coil **2**, the necessary inductive value of coil **9** is usually small relative to that of coil **2** and does not substantially contribute to the total inductance of the tuned circuit. In some circumstances a small resistor could be substituted for coil **9**. However, coil **9** is preferable in the sense that it does not dissipate any appreciable power.

Transistor switch **4** is biased to be in a normally nonconducting state. This results in capacitor **1** charging through current source **13** to a potential difference of E_1 when transistor switch **4** is in its normally off state.

Phase shifter **11** is any circuit capable of shifting the phase by 90° of a signal flowing therethrough which has a frequency in the range of the resonant frequency determined by capacitor **1** and field drive coil **2**. One method of providing this function is to use the high-pass filter network shown in FIG. **1** comprising capacitor **6** and resistor **7**, with the values of elements **6** and **7** chosen to shift signals in the range of the resonant frequency by 90°. Field current amplifier **5** may be any prior art current amplifier which is capable of providing an additional 180° of phase shift and which is designed to have what is commonly known in the art as class C operating characteristics.

Briefly, oscillator circuit **10** functions as follows: Oscillation may be initiated in the tuned circuit at any time after capacitor **1** has fully charged through current source **13** to a potential difference of E_1, which is selected to correspond with the desired peak amplitude of the oscillatory field current waveform. The oscillations are started by applying a control signal e_1 of a proper polarity to the base of transistor switch **4**, thereby turning on transistor **4** and effectively grounding the switch side of capacitor **1**. This provides a series L-C resonant loop comprising capacitor **1** and coils **2** and **9** for as long as transistor switch **4** remains in a conducting state. Immediately upon the grounding of the switch side of capacitor **1** an oscillatory field drive current begins to flow toward capacitor 1 from coils 2 and 9. Since the inductance of field drive coil 2 is usually much larger than that of impedance matching coil 9, the electrical field energy initially stored in capacitor 1 is transferred during the first quarter cycle of oscillation into magnetic field energy primarily associated with field drive coil 2. The energy then oscillates between capacitor 1 and coil 2 according to the well-known sinusoidal waveform of an L-C resonant circuit with the oscillating field drive current alternately flowing through transistor switch 4 and diode 3 during the first and second half cycles, respectively, of each oscillation cycle. As a result, a corresponding magnetic field component associated with field drive coil 2 is produced that is proportional to the oscillating field drive current and has a direction determined by magnetic axis 19 of coil 2.

As mentioned before, the field current regeneration network comprising phase shifter 11 and field current amplifier 5 is included to compensate for inevitable ohmic losses in the resonant loop during oscillation. The regeneration network also restores into the resonant loop any energy which may be coupled to magnetic domains by moving them about in a layer of material in response to the magnetic field associated with coil 2.

Current amplifier 5 is triggered by a signal sampled from the oscillatory waveform at junction point 26, located between capacitor 1 and coil 2, and passed through phase shifter 11. The amplifier is biased through voltage source E_2 to provide class C operation. In addition, the internal bias circuitry of the amplifier is adjusted so that the triggering threshold occurs near a predetermined peak in the oscillatory waveform of the sampled signal. The precise level of the threshold is adjusted so that the amplifier remains on for a sufficient interval during each cycle of the field current waveform to maintain the amplitude envelope of the field current at a constant level.

The regenerative network takes particular advantage of the fact that the voltage induced at junction point 26 by the field current flowing through coil 2 leads the field current at junction point 25, located between coils 2 and 9, by 90°. Further advantage is taken of the fact that the current at junction point 23, located between capacitor 6 and resistor 7, leads the voltage at junction point 26 by 90°. Thus, when the signal sampled at point 26 is coupled to amplifier 5, a regenerative current increment is produced which is in phase with respect to the field current at point 25 where the regenerative current increment is coupled into the resonant loop.

When transistor switch 4 is turned off, all of the energy oscillating between capacitor 1 and field drive coil 2 transfers back to capacitor 1 before the oscillations terminate. The only condition which must be met to obtain this result is that transistor switch 4 can be turned off only during the last half of an oscillation cycle when the field current is flowing through diode 3. If this condition is met, the field current continues to flow through diode 3 during the remainder of a half cycle in which switch 4 is turned off. At the end of the cycle all of the oscillatory energy is stored back in its initial state in capacitor 1 and the field current terminates at precisely the initial phase point. At this point oscillator circuit 10 is ready to be triggered into another series of oscillations. It should now be apparent that with the proper control signaling the inclusion of shunting diode 3 automatically ensures that the oscillatory field current is both initiated and terminated at the same phase point in the oscillatory waveform.

A second aspect of the invention is a method for interconnecting a pair of these basic oscillator circuits together to form a field drive circuit for providing a rotating magnetic field in a magnetic domain apparatus. FIG. 2 shows a pair of basic oscillator circuits interconnected in a master-slave configuration wherein master oscillator circuit 20 forces slaved oscillator circuit 30 to oscillate at the same frequency, but 90° out of phase, with respect to the field drive current of master oscillator circuit 20. Magnetic axes 19 and 19' of field drive coils 2 and 2' are physically arranged to be perpendicular in a plane defined by the field coil axes and schematically represented by plane 22 in FIG. 2. The orthogonal magnetic components produced thereby interact to produce a rotating magnetic field in plane 22. This resultant field rotates at the angular frequency of the oscillatory field current components and has a strength depending upon the respective amplitude envelopes of the current components. The direction of the rotating field at any instant depends upon the relative alignment of the perpendicularly directed field coil axes in the plane defined thereby, the maintenance of 90° of phase difference between the two orthogonal oscillatory field current components, and the initial phase of the field current components.

Converting a pair of the basic oscillator circuits shown in FIG. 1 to the rotating field drive circuit shown in FIG. 2 involves several relatively simple modifications. First, the phase shifter in oscillator circuit 30 is replaced by current limiting resistor 6' with a resistance substantially equivalent to that of the reactance of capacitor 6 at the field current oscillation frequency. Secondly, path 15 containing resistor 6' and amplifier 5' is connected from points 23 and 26 in oscillator circuit 20 to point 25' in oscillator circuit 30, rather than from point 26' to point 25' in oscillator circuit 30. Thirdly, the external binary control signal e_1 necessary to operate transistor switch 4 in oscillator circuit 20 is coupled to transistor switch 4' in oscillator circuit 30 through a delay circuit 16 which provides a delay amounting to one-quarter of the oscillatory field current cycle time.

The purpose of delay circuit 16 is to delay binary control signal e_1 by a quarter of a field rotation cycle before coupling the delayed signal to transistor switch 4'. This provides an initial 90° of phase difference between the oscillatory field drive currents in the respective oscillator circuits.

Resistor 6', included into path 15, in lieu of a phase shifter, results in the field current of oscillator circuit 30 being regenerated at point 25' by a current increment which lags by 90° the phase of the field current increment being injected into the corresponding point 25 in the resonant loop of oscillator circuit 20. Thus, the field current of oscillator circuit 30 is synchronized with the field current of oscillator circuit 20 so that it not only initially lags the field current of oscillator circuit 20 by 90°, but is also maintained, or slaved, in this state through path 15. In this configuration path 15, as modified, is actually a synchronizing signal path for forcing the field current in the slaved oscillator circuit **30** to oscillate 90° out of phase with respect to the field current of oscillator circuit **20**.

In addition, control circuit **17** is advantageously used to sense the last half of an oscillation cycle of field current in oscillator circuit **20**. Such a circuit is used to ensure that the switches **4** and **4'** are not turned off during the part of an oscillation cycle when the field current is flowing therethrough. As mentioned before, in order to prevent ringing effects in the tuned circuits, the transistor switches included therein can be turned off only when the field currents are flowing through the diodes shunting the terminals of the switches.

One method of implementing control circuit **17** is to provide a small resistor **18** serially connected between point **32** and point **12** in the resonant loop of oscillator circuit **20**. Also a diode **21** is included in a conduction path **31** connecting between point **32** in the resonant loop of oscillator circuit **20** and AND gate **24** in control circuit **17**. Diode **21** is poled in a manner so as to only conduct current during a half cycle when oscillatory current is flowing through diode **3**. As a result, current flowing through conduction path **31** provides indication to control circuit **17** that oscillator circuit **20** can be turned off without producing ringing effects.

This particular manner of implementing control circuit **17** requires three logic gates and a flip-flop which are of the common type that respond only to signals of a positive polarity with respect to reference point **12**. Flip-flop **27** is required to have only the normal set and reset terminals S and R, respectively, and an output which maintains a high state when the flip-flop is in the set state. AND gates **24** and **29** are each required to have one inverting input and one noninverting input, and OR gate **28** is required to have a pair of noninverting inputs.

AND gates **24** and **29**, OR gate **28** and flip-flop **27** are interconnected in the straightforward manner shown in control circuit **17** in FIG. **2**. It is apparent from the figure that when binary control signal e_1 goes to an off state flip-flop **27** will remain set and maintain oscillator circuit **20** in operation as long as no current flows through path **31**. When current is flowing through path **31** flip-flop **27** is reset and a turn-off signal is coupled via gates **29** and **28** to transistor switch **4** and delay circuit **16**, resulting in oscillator circuits **20** and **30** receiving turn-off signals during the proper half cycles of their respective oscillations.

Hence, control circuit **17** allows a change in state in binary control signal e_1 from an on state to an off state to be coupled to the respective oscillator circuits only during alternate half cycles when the oscillatory field currents are flowing through diodes **3** and **3'**, respectively. Consequently, switches **4** and **4'** are turned off without producing ringing effects in the respective tuned circuits. As mentioned before, the oscillatory field currents continue to flow through diodes **3** and **3'** during the remainder of the respective half cycles in which transistor switches **4** and **4'** are turned off. This enables the particular oscillating cycles to be fully completed and the oscillator circuits to be enabled for another series of oscillations.

Another embodiment of the basic field drive circuit is shown in FIG. **3**. This embodiment features a different method of interconnecting the tuned circuits of a pair of the basic oscillator circuits through a pair of synchronizing signal paths **41** and **51** in such a manner as to enable the direction of rotation of the resultant magnetic field produced thereby to be reversed in response to a change in state of a second binary control signal e_2. In addition, synchronizing paths **41** and **51** also serve to force a fixed phase relationship of 90° between the two oscillatory field drive currents.

The embodiment of the field drive circuit shown in FIG. **3** is essentially the same as the circuit shown in FIG. **2** with several exceptions. First, each of the synchronizing signal paths **41** and **51** includes a current amplifier of the general type discussed above. However, in this embodiment one of the amplifiers **45** and **55** must provide 180° of phase shift, or any odd integral multiple thereof; and the other amplifier must provide zero degrees of phase shift, 360° of phase shift, or any integral multiple thereof. Secondly, current limiting resistor **42(52)** is usually required in synchronizing path **41(51)** so as not to overload the input to amplifier **45** **(55)** due to the high signal level at sampling point **26** **(26')** between capacitor **1(1')** and coil **2(2')**. Thirdly, a switching network **60** enabled by the second control signal e_2 is included to provide the field reversal effect. Switching network **60** can be any well-known switching arrangement which operates in response to a binary control signal and which provides the three pairs of two-position switches shown in FIG. **3**. As is apparent from FIG. **3**, switching network **60** in response to a change in state in binary control signal e_2 interchanges current amplifiers **45** and **55** between synchronization paths **41** and **51**, and also interchanges the transistor switches to which the delayed and undelayed versions of control signal e_1 are respectively coupled.

In short, the oscillatory field currents are effectively interchanged between the oscillator circuits when e_2 changes states, so that the oscillator circuit with the leading field drive current, with respect to the field drive current in the other oscillator circuit, becomes the oscillator circuit with the lagging field drive current, and vice versa. Since the magnetic axes **19** and **19'** of the respective field drive coils **2** and **2'** remain fixed during the switching process, the net effect of the switching is to reverse the direction of rotation of the resultant magnetic field in plane **22** defined by the field coil axes.

Other embodiments of the field drive circuit similar to that shown in FIG. **3** are readily obtainable without departing from the spirit and scope of the invention. For example, the relative position and direction of amplifier **45(55)** within path **41(51)** could be reversed to provide a high-impedance output driving point for amplifier **45(55)** at point **26(26')** and a low-impedance input sampling point at point **25(25')**. This would obviate the need for the large attenuating resistor **42(52)**. In addition coil **9(9')** could readily be replaced with a small resistor for developing thereacross a small sampling signal to drive amplifier **45(55)**. Also many other embodiments of control circuit **17** which would result in the elimination of the need for resistor **18**, diode **21** and path **31** could readily be implemented into the field drive circuit.

What is claimed is:

1. A field drive circuit for providing a magnetic field rotating in a plane including:

first and second tuned circuits, each of which provides a different one of two orthogonal magnetic field components comprising said rotating field;

means for initiating and terminating said rotating field at a predetermined point in each field rotation cycle;

means responsive to a first state of a binary control signal for starting first and second oscillatory field drive currents having a like frequency and a predetermined phase difference in said first and second tuned circuits, respectively;

means for maintaining the amplitude envelopes of said first and second currents at a predetermined level; and

means responsive to a second state of said binary control signal occurring during the last half of said cycle for terminating each of said currents at the end of an oscillation cycle without producing substantial ringing effects in said tuned circuits.

2. An oscillator circuit including:

a series tuned circuit comprising a capacitor and at least one coil;

means, connected to said series circuit, for precharging said capacitor in response to a first state of a first binary control signal;

means, having first and second terminals connected across said series circuit, for switching said series circuit into a closed resonant loop and initiating an oscillatory current therein by shorting said terminals in response to the application of a second state of said binary signal to said switching means;

means, connected across first and second points in said series circuit, for maintaining the envelope of said oscillatory current at full amplitude; and

means, connected across said first and second terminals of said switching means, for terminating said oscillatory current at the end of any oscillation cycle without producing ringing effects in said loop in response to the application of said first state of said binary signal to said switching means at any time during the final half of such a cycle.

3. The oscillator circuit in accordance with claim **2** in which

said maintaining means comprises a feedback network connected across said coil between said first and second points in said series circuit, said feedback network including means for sampling a signal representative of said oscillatory current at said first point and in response thereto coupling a proportional amount of regenerating current into said loop at said second point.

4. A field drive circuit including:

first and second oscillator circuits, each of said oscillator circuits comprising,

a series tuned circuit comprising a capacitor and at least one coil,

means, connected to said series circuit, for precharging said capacitor in response to a first state of a first binary control signal,

means, having first and second terminals connected across said series circuit, for switching said series circuit into a closed resonant loop and initiating an oscillatory current therein by shorting said terminals in response to the application of a second state of said binary signal to said switching means,

means for maintaining the envelope of said oscillatory current at a predetermined amplitude, and

means, connected across said first and second terminals of said switching means, for terminating said oscillatory current at the end of any oscillation cycle without producing ringing effects in said loop in response to the application of said first state of said binary signal to said switching means at any time during the final half of such a cycle;

means for coupling said binary control signal to said switching means of said first oscillator circuit and for delaying said signal by a predetermined amount and thereafter coupling the delayed signal to said switching means of said second oscillator circuit, for controlling the respective oscillations of the oscillatory currents in response thereto;

a feedback network in said maintaining means of said first oscillator circuit, said network connecting between first and second circuit points in said series circuit of said first oscillator circuit; and

a synchronization path in said maintaining means of said second oscillator circuit, said path connecting between said first circuit point in said series circuit of said first oscillator circuit and a third circuit point in said series circuit of said second oscillator circuit, for maintaining the envelope of said oscillatory current therein at full amplitude.

5. A field drive circuit comprising first and second oscillator circuits, each of said oscillator circuits comprising,

a series tuned circuit compriring a capacitor and at least one coil,

means, connected to said series circuit, for precharging said capacitor in response to a first state of a first binary control signal,

means, having first and second terminals connected across said series circuit, for switching said series circuit into a closed resonant loop and initiating an oscillatory current therein by shorting said terminals in response to the application of a second state of said binary signal to said switching means,

means for maintaining the envelope of said oscillatory current at full amplitude, and

means, connected across said first and second terminals of said switching means, for terminating said oscillatory current at the end of any oscillation cycle without producing ringing effects in said loop in response to the application of said first state of said binary signal to said switching means at any time during the final half of such a cycle;

first and second synchronization paths in the maintaining means of said first and second oscillator circuits, respectively, each of said synchronization paths interconnecting said oscillator circuits between different circuit points in said series circuits of said oscillator circuits;

said first synchronization path including means for sampling a first signal representative of said oscillatory current in said first oscillator circuit and in response thereto cross-coupling a proportional amount of regenerating current into said second oscillator circuit;

said second synchronization path including means for sampling a second signal representative of said oscillatory current in said second oscillator circuit and in response thereto cross-coupling a proportional amount of regenerating current into said first oscillator circuit; and

means for coupling said first binary control signal to said switching means of said first oscillator circuit and for delaying said signal by a predetermined amount and thereafter coupling the delayed signal to said switching means of said second oscillator circuit, for controlling the respective oscillations of said field currents in response thereto.

6. The field drive circuit in accordance with claim 5 including:

means for coupling said first control signal to said switching means of said first oscillator circuit and for coupling said delayed first control signal to said switching means of said second oscillator circuit, in response to a first state of a second binary control signal;

means for coupling said first control signal to said switching means of said second oscillator circuit and for coupling said delayed first control signal to said switching means of said first oscillator circuit, in response to a second state of said second control signal; and

means responsive to a change in state of said second control signal for interchanging said circuit points between which said first and second synchronization paths interconnect.

7. An oscillator circuit including:

a first serial conduction path comprising a current source, first and second terminals of an electronic switch which operates in response to a first binary control signal, and a point of reference potential serially connected in that order therein;

a second conduction path including a diode shunting said terminals of said switch;

a third conduction path connecting between said point of reference potential and said first terminal, including at least one coil and a capacitor connected therein in a tuned inductive-capacitive circuit; and

a regenerative feedback path, connecting between the terminals of said coil in a path exclusive of said capacitor, for maintaining the amplitude envelope of an oscillatory current flowing therethrough at a predetermined level.

8. The oscillator circuit in accordance with claim 7 in which

said regenerative feedback path comprises a current amplifier and a phase shifter serially connected therein.

9. The oscillator circuit in accordance with claim 8 in which

said phase shifter includes means for shifting the phase of a signal flowing therethrough by 90°; and

said current amplifier includes means for shifting the phase of a signal flowing therethrough by 180°.

10. A field drive circuit for providing a magnetic field rotating in a plane including:

first and second oscillator circuits, each of said oscillator circuits including

a first serial conduction path comprising a current source, first and second terminals of an electronic switch which operates in response to a first binary control signal, and a point of reference potential serially connected in that order therein,

a second conduction path including a diode shunting said terminals of said switch, and

a third conduction path connecting between said point of reference potential and said first terminal, including at least one coil and a capacitor connected therein in an inductive-capacitive circuit;

the magnetic axis of said coil in said first oscillator circuit intersecting at a substantially right angle with the magnetic axis of said coil in said second oscillator circuit, thereby defining said plane;

control means for coupling said first control signal to said switch in said first oscillator circuit and for delaying said first control signal by a predetermined amount and thereafter coupling the delayed first signal to said switch of said second oscillator circuit;

a first synchronizing path connecting between a first point in said third conduction path of said first oscillator circuit and a second point in said third conduction path of said second oscillator circuit, said first path including means for maintaining an oscillatory current in said third conduction path of said second oscillator circuit which has a substantially constant amplitude envelope level and a predetermined phase difference with respect to an oscillatory current flowing in said third conduction path of said first oscillator circuit.

11. The field drive circuit in accordance with claim 10 including means for reversing the direction of rotation of said field in said plane, said reversing means comprising:

a second synchronizing path connecting between a third point in said third conduction path of said first oscillator circuit and a fourth point in said third conduction path of said second oscillator circuit;

said second path including means for maintaining said oscillatory current in said third conduction path of said first oscillator circuit with a substantially constant amplitude envelope level and at a predetermined phase difference with respect to said oscillatory current in said third conduction path of said second oscillator circuit;

means for coupling said first signal to said switch in said first oscillator circuit and for coupling said delayed first signal to said switch of said second oscillator circuit, in response to a first state of a second binary control signal;

means for coupling said first signal to said switch in said second oscillator circuit and for coupling said delayed first signal to said switch of said first oscillator circuit, in response to a second state of said second control signal;

a switching network including means for connecting said first synchronizing path between said third point and said fourth point and connecting said second synchronizing path between said first point and said second point, in response to said first state of said second control signal; and

said switching network also including means for connecting said first synchronizing path between said first point and said second point and connecting said second synchronizing path between said third point and said fourth point in response to said second state of said second control signal.

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