

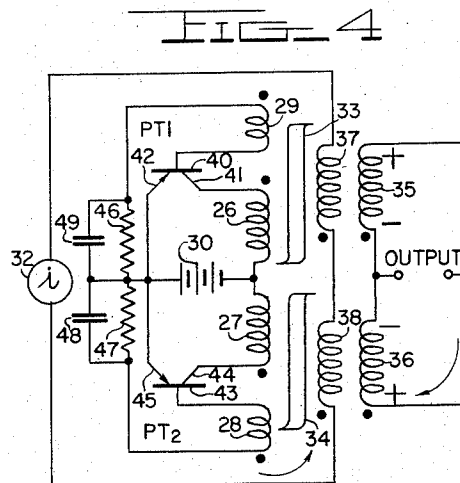
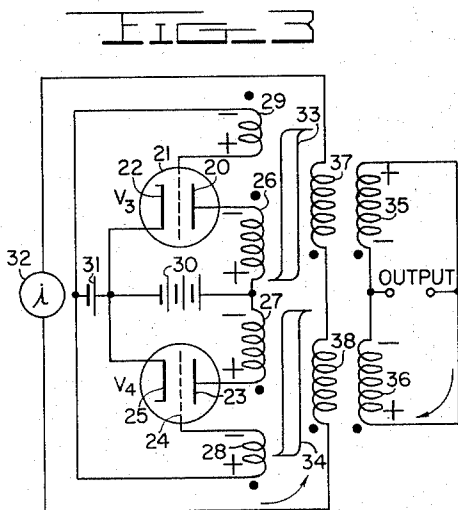
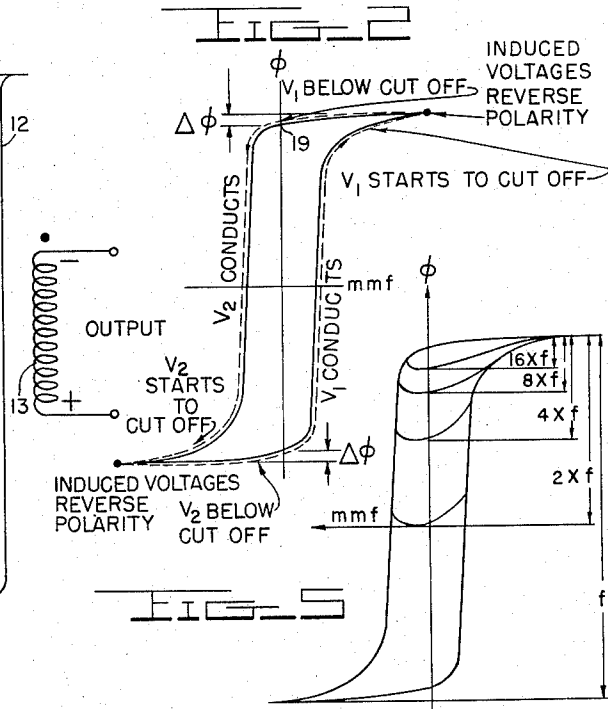
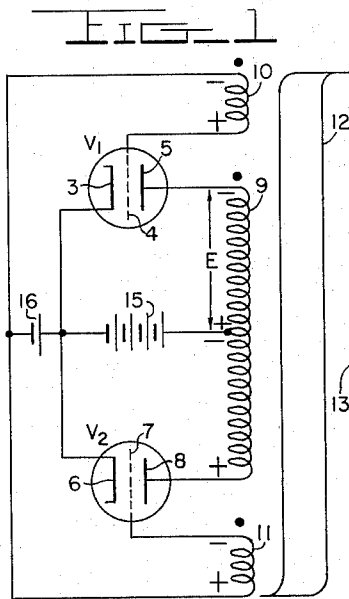
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VARIABLE FREQUENCY TRANSISTOR OSCILLATOR

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VARIABLE FREQUENCY TRANSISTOR OSCILLATOR

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5 Claims. (Cl. 250—36)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates broadly to a variable-frequency magnetic-coupled multivibrator and more particularly to a multivibrator oscillator containing two switching devices with their switching rates controlled in inverse proportion to the state of magnetic flux of their coupling means.

The magnetic coupled multivibrator resembles the conventional free-running multivibrator both in the waveform produced and the theory of operation. However, in the present invention instead of using the parameters resistance and capacitance to couple and control the frequency of the switching devices, magnetic circuits with high remanence core materials are used. The state of knowledge prior to the present invention relative to the use of magnetic coupling with high remanence cores is aptly set forth in A. I. E. E. transactions paper 55-73, entitled "Switching Transistor D. C. to A. C. Converters," by G. H. Royer and is set out in general terms in the detailed specification below. Royer utilized only one high remanence core and depended on varying of the supply voltage to change the frequency output of his multivibrator. However, and as will be pointed out in greater detail below, such an arrangement possesses several serious disadvantages, one being a limited range of possible output frequencies. To overcome these disadvantages the present invention utilizes two high remanence cores and a separate control voltage is applied to control windings to vary the frequency output from a magnetic coupled multivibrator.

It is therefore one object of the present invention to provide a wide frequency range in the output of a magnetic coupled multivibrator.

It is a further object of the present invention to provide a magnetic coupled multivibrator which has a constant output voltage for a wide frequency range.

Another object of the present invention is to provide a wide frequency range in the output of a magnetic coupled multivibrator utilizing more than one high remanence core and separate frequency control windings.

An additional object of the present invention is to provide a magnetic coupled multivibrator which has a constant output voltage for a wide frequency range utilizing more than one high remanence core and separate frequency control means.

The magnetic-coupled multivibrator of the present invention consists of two switching devices and two high remanence cores which are coupled by electrical circuitry such that the switching devices are switched alternately. Each core carries a primary, a secondary, a feedback and a control winding. Each primary winding connects the corresponding switching device to the same constant supply voltage and serves to saturate the corresponding core a certain time after completion of the circuit through that switching device. The function of the feedback wind-

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ing is to open the corresponding switching device on saturation of its core. The secondary windings, each on separate cores, are electrically connected in series such that they function to reset the core associated with the other switching device. The amount of reset in each case can be controlled by the magnitude and direction of a direct current applied to the control windings on each core and which are connected in series. A square wave output may be taken from across the two common terminals of the two secondary windings. The frequency of the square wave output is changed by modifying the magnitude of the control current. When the two cores switch alternately, the switching operation does not depend upon knee-to-knee saturation to complete the cycle.

Instead, each core need only saturate at one knee and only reset part way on alternate cycles. For each half-cycle, only one core proceeds to saturation, permitting the other core to be reset a predetermined amount which is for the most part dependent on the magnitude of the current through the control windings. When the reset is sufficient for operation of the cores from knee-to-knee the lowest frequency square wave is produced in the output. When the reset of the cores is only part way, the frequency of the square wave output is increased and in a generally proportional manner to the amount of reset.

The nature of the present invention and the manner in which the same operates will be readily understood from the following detailed description read in connection with the drawings in which:

Fig. 1 shows for illustration purposes a magnetic coupled multivibrator utilizing only one core;

Fig. 2 is used to illustrate knee-to-knee operation about the hysteresis loop of a high remanence core;

Fig. 3 shows a variable frequency magnetic-coupled multivibrator of the present invention using vacuum tubes;

Fig. 4 shows a variable frequency magnetic-coupled multivibrator of the present invention using transistors; and

Fig. 5 is used to illustrate the operation of a core resulting from partial reset.

Figure 1 sets forth the essential details of the magnetic coupled multivibrator of Royer, identified above, which will be helpful for a full understanding of the present invention. Two vacuum tubes are used for the switching devices. Tube V_1 has a cathode 3, a grid 4 and a plate 5. Tube V_2 has a cathode 6, a grid 7 and a plate 8. High remanence core 12 has a primary winding 9, secondary winding 13 and two feedback windings 10 and 11. Cathode 3 is connected to cathode 6 and plate 5 is connected to plate 8 through primary winding 9. Supply voltage 15 is connected between the midpoint of primary winding 9 and the connection between cathodes 3 and 6. Grid 4 of tube V_1 is connected to grid 7 of tube V_2 through feedback winding 10 and feedback winding 11 respectively. Bias supply voltage 16 is connected between the common terminals of the feedback windings and the common connection of the cathodes 3 and 6. The windings on the core 12 are wound in the sense as indicated by the heavy dots. Bias voltage 16 is set near cut-off. The output is taken from the terminals of the secondary winding 13.

Figure 2 shows knee-to-knee operation of a core about a hysteresis loop of a high remanence core and is useful in explaining the operation of Figure 1. Assume the core is initially unsaturated and only V_1 is conducting. The induced voltage in all the windings will have the polarity indicated in Figure 1. Assuming constant load, all induced voltages will remain essentially constant until the core is driven to flux saturation. At core saturation the rate of change of flux, which up until that time had been relatively constant, will suddenly be reduced causing a reduction in all the induced voltages. The decreased in-

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duced voltage in feedback winding 10 allows the grid 4 of tube V_1 to return to cut-off which in turn causes the current of plate 1 to terminate and start a flux reversal toward the residual level 19 (Figure 2) of the core. This small reverse change in flux, $\Delta\phi$ (Figure 2), is the key to the multivibrator action of this circuit. Because of this small inductive "kick" the polarity of all induced voltages in the windings will be reversed instantaneously causing V_1 to be driven well into cut-off and at the same time the reversed voltage on feedback winding 11 will raise the grid 7 of V_2 to the conduction point. With V_2 conducting the current in primary winding 9 reverses and the core flux changes towards the lower knee at a rate determined by the supply voltage 15. At the lower knee the induced voltage in the feedback winding decreases, the voltage of grid 7 goes toward cut-off and the current of plate 3 flowing through primary winding 9 terminates and the inductive "kick" reverses the induced voltage in the windings such that feedback winding 11 cuts V_2 off and feedback winding 10 cuts V_1 on. Thus the flux level of the core then goes toward the upper knee. In this way voltage induced in the secondary winding 13 reverses periodically forming a square wave voltage output at its terminals at a frequency which can be changed by changing the value of the supply voltage 15. As already pointed out the circuit of Figure 1 as a variable frequency device has a number of limitations. One, is that the output voltage will vary with frequency because the input voltage has to be changed to produce a change in frequency. A further limitation is the maximum operating frequency which may be obtained practically because flux changes from knee to knee are required. Core losses will be a predominant factor in limiting a practical upper frequency limit. While the circuit of the present invention does not necessarily operate from knee-to-knee; in fact the flux change is smaller with increased frequency. Hence the upper frequency limits have been extended considerably.

The present invention exploits the frequency-modulation characteristics of the above circuit but without many of its shortcomings. Figure 3 sets forth an embodiment of the present invention utilizing vacuum tubes as switching devices. Included in the circuit are tubes V_3 and V_4 and two high remanence cores 33 and 34. Wound on core 33 is primary winding 26, feedback winding 29, secondary winding 35, and control winding 37. While wound on core 34 is primary winding 27, feedback winding 28, secondary winding 36 and control winding 38. Plate 20 and plate 23 are connected together through primary windings 26 and 27 respectively. Cathodes 22 and 25 are connected together. Grid 21 and grid 24 are connected together through feedback windings 29 and 28. Plate voltage supply 30 is connected between the common terminals of primary windings 26 and 27 and the common connection of cathodes 22 and 25. Bias voltage supply 31 is connected between the common terminals of feedback windings 29 and 28 and the common connection of cathodes 22 and 25. Control windings 37 and 38 are connected in series and together with control current source 32 form a loop circuit. Secondary windings 35 and 36 are connected in series with each other and form a loop circuit. The sense of the windings on cores 33 and 34 are indicated by heavy dots. The output from the multivibrator circuit may be taken from the common terminals of the secondaries.

For the operation of the multivibrator of Figure 3 reference should be had to Figure 5 which in addition to the illustration of knee-to-knee operation shown in Figure 2 shows operation about minor hysteresis loops when partial reset is desired. The operation on each of the cores 33 and 34 is the same and the illustration of Figure 5 applies to both. Bias voltage 31 is set near cut-off. For initial conditions, assume zero control current in the control windings and also assume tube V_3 is conducting and tube V_4 is cut-off. Therefore current flows through

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the primary winding 26 such that the flux induces voltages of the relative polarity indicated by the dots in Figure 3 and the upper core 33 proceeds toward saturation at the upper knee (Figure 5). The switching action is identical to that of Figure 1 wherein the upper core reaches the upper knee of the hysteresis loop, saturation occurs, the rate of change of flux decreases, and the induced voltage in feedback winding 29 decreases such that V_3 cuts off. This results in a collapse of the flux in the core 33 and a reversal of the induced voltage in the windings on both cores 33 and 34 and V_4 commences to conduct. In Figure 1, where both primary windings were on the same core, on conduction of the first switching device the core flux would go from the lower knee to the higher knee and on conduction of the second switching device the core flux would go from the higher knee to the lower knee. However, in the present invention there is a separate core 33 and 34 associated with each of the switching devices V_3 and V_4 . While the core associated with the conducting switching device is going toward saturation at the upper knee, the core associated with the non-conducting switching device is going from the upper knee toward the lower knee operating to "reset" that core. This is because the lower core 34 is coupled to the upper core 33 through secondary windings 35 and 36, such that when switching device V_3 conducts the lower core 34 receives a resetting action from the voltage applied across secondary winding 36 by the voltage induced in secondary winding 35. Likewise when switching device V_4 conducts the upper core 33 receives a "resetting" action from the voltage applied across secondary winding 35 and resulting current by the voltage induced in secondary winding 36. Because of the voltage drop around the loop consisting of secondary windings 35 and 36 the resetting core is never reset completely by the firing core. That is the resetting core never has the total amount of flux change required to go from the upper knee all the way to the lower knee. When the particular core doesn't go all the way to the lower knee on the resetting half cycle the time required for it to go to the upper knee on the firing cycle is less and hence the frequency of operation is increased.

Figure 5 illustrates the operation of either of the cores about minor hysteresis loops as a result of partial reset and its relation to frequency. Complete reset of each core provides a minimum frequency of operation of the device of Figure 4. Since the flux level to which the resetting core is driven will determine the flux change to occur when the core fires (when the associated switching device conducts), it follows that a means of control of the flux level of the cores 33 and 34 on reset, will control the frequency output of the magnetic coupled multivibrator while keeping the supply voltage source constant. In Figure 3, current control means 32 provides this control by causing a control current of a particular direction and magnitude to flow through the control windings 37 and 38. For example when core 34 is being reset a clockwise current as indicated in Figure 3 will flow through the secondary circuit and if a counter-clockwise current is caused to flow in the control winding 38, it will aid the reset in core 34 thereby causing that core to operate on a larger hysteresis loop with a resultant lowering of the frequency. For illustration purposes arrows are placed in the control and secondary circuits to show the directions and cooperation of the circuits. When switching device V_4 is conducting instead of V_3 the induced voltages are reversed and the secondary winding 36 acts as source of voltage while the secondary winding 35 acts as a load. However, it should be noted that the circulating current in the secondary loop circuit flows in the same direction. Therefore the counter-clockwise current in the control winding 37 aids in the reset action of core 33. Changes in magnitude of this counter-clockwise control current will modify the amount of reset of both cores the same amount and if made small enough

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the control winding will be ineffective. When the magnitude of this counter-clockwise current is increased such that it aids complete reset of each of the cores 33 and 34 and their operation is around the upper and lower knee further increase of the control current is ineffective. Knee-to-knee operation provides the lower limit of frequency output. If the current in the control windings is reversed in direction and flows in a clockwise sense in the control windings it will act to oppose the effect of the resulting clockwise current in the secondary loop circuit and therefore act to inhibit resetting action. Increased control current in the clockwise sense with its inhibiting action on the resulting core and operation of each core of the multivibrator on minor hysteresis loops similar to those shown in Figure 5. The greater the clockwise control current, the smaller the loop. Figure 5 shows minor hysteresis loops related to knee operation by frequency multiplication factors of 2, 4, 8, 16.

Figure 4 illustrates the present invention utilizing transistors instead of vacuum tubes which in principle operates the same as Figure 3 described above. The main difference lies in the fact that no bias voltage is necessary and the efficiency is higher. Like numbers are given to corresponding circuit components in both Figures 4 and 3. However it should be noted that supply voltage 30 is reversed in polarity. No detailed description of the similar circuitry and its operation is thought to be necessary in view of the description of Figure 3 above. T_1 and T_2 which are substituted for V_3 and V_4 are PNP-junction transistors. T_1 has a base 40, a collector 41 and an emitter 42 while T_2 has a base 43, a collector 44 and an emitter 45. When a PNP transistor is substituted for a vacuum tube in switching circuitry like that of Figure 4 the base functions in a manner similar to that of the grid, the emitter has functions similar to that of a cathode and the collector has functions similar to that of an anode. In Figure 4, emitters 42 and 45 are connected together with their common connection being connected to the positive side of the supply voltage 30. Collectors 41 and 42 are connected in the circuit like the anodes of Figure 3. Bases 40 and 43 are connected together through biasing resistors 46 and 47 respectively. The common connection of the resistors is also connected to the positive side of the supply voltage. Capacitances 48 and 49 may be each placed in parallel with resistances 46 and 47 respectively with the result of reducing the switching time of the overall circuit. During the operation of Figure 4 the transistors T_1 and T_2 are switched alternately from nearly zero collector resistance to high collector resistance, thus permitting an efficient transfer of the supply voltage to the secondary output terminals. The core corresponding to the transistor at nearly zero collector resistance (conducting transistor) proceeds to saturation and the other core resets in the manner described in Figure 3. At saturation of the conducting core the base voltage of the conducting transistor changes to nearly zero and the collector resistance rises sharply (similar to non-conduction of the vacuum tube), resulting in a reversal of the induced voltages of system. Switching of the other transistor to the low collector resistance or conduction condition takes place in a manner similar to the switching in Figure 3. The efficiency and desirability of the transistor magnetic coupled multivibrators of Figure 4 results from the fact that the collector resistance drops to nearly zero on conduction of that transistor, that transistors dissipate very little energy internally and that collector conduction current is permitted many times over the normal rated value as long as a maximum collector dissipation is not exceeded.

Several refinements of the present invention as set out in Figures 3 and 4 have been found to be desirable in certain applications of the circuit. One is the inclusion of a rectifier in series with each secondary winding, both providing low resistance to the counter-clockwise resetting current and yet functioning to decouple the resetting

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core from the load resistance appearing across the output terminals. Another refinement might be to combine the functions of the control windings and the secondary windings for each case by using an autotransformer for each core connected in series with a source of control current with their common connection and respective taps forming the terminals for the secondary circuit described in Figures 3 and 4.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. A variable frequency magnetic multivibrator operative in accordance with a variable input comprising first and second pluralities of windings wound on first and second cores, respectively; each of said first and second pluralities including at least first and second windings wound in opposite rotational sense; each of said first and second cores having a substantially rectangular hysteresis loop characteristic; a first energy source; first and second on-off switching means coupled to said first winding in said first and second pluralities, respectively, and to said first energy source; said first and second switching means being adapted to drive their respective cores to saturation in continuous alternate order; means intercoupling said second winding in each of said first and second pluralities such that a portion of the energy operative to bring one core to saturation is simultaneously operative to reset the other core; current limiting means for controlling the amount of current flow in said second windings in accordance with a variable input; and output means responsive to the frequency of operation of said switching means.

2. A variable frequency magnetic multivibrator operative in accordance with a variable input comprising first and second pluralities of windings wound on first and second cores, respectively; each of said first and second pluralities including at least first and second windings wound in opposite rotational sense; each of said first and second cores having a substantially rectangular hysteresis loop characteristic; a first energy source; first and second transistor switching means coupled to said first winding in said first and second pluralities, respectively, and to said first energy source; said first and second switching means being adapted to drive their respective cores to saturation in continuous alternate order; means intercoupling said second winding in each of said first and second pluralities such that a portion of the energy operative to bring one core to saturation is simultaneously operative to reset the other core; current limiting means for controlling the amount of current flow in said second windings in accordance with a variable input; and output means responsive to the frequency of operation of said switching means.

3. A variable frequency magnetic multivibrator operative in accordance with a variable input comprising first and second pluralities of windings wound on first and second cores, respectively; each of said first and second pluralities including at least first and second windings wound in opposite rotational sense; each of said first and second cores having a substantially rectangular hysteresis loop characteristic; a first energy source; first and second on-off switching means coupled to said first winding in said first and second pluralities, respectively, and to said first energy source; said first and second switching means being adapted to drive their respective cores to saturation in alternate order; means intercoupling said second winding in each of said first and second pluralities such that a portion of the energy operative to bring one core to saturation is simultaneously operative to reset the other core; current limiting means, including a second energy source, for controlling the amount of current flow in said second windings in accordance with a variable input;

and output means responsive to the frequency of operation of said switching means.

4. A variable frequency magnetic multivibrator comprising first and second pluralities of windings wound on first and second cores, respectively; each of said pluralities of windings including at least a primary, a secondary, a control and a feedback winding; each of said first and second cores having a substantially rectangular hysteresis loop characteristic; a first energy source; a first transistor having a first emitter, a first base, and a first collector, a second transistor having a second emitter, a second base, and a second collector; means electrically connecting said first and second emitter in common; means electrically connecting said first and second collector to a primary winding in said first and second pluralities, respectively; said first energy source being electrically connected between said emitters connection and said first and second collectors via the primary windings in said first and second pluralities, respectively; means electrically connecting said first and second bases to a feedback winding in said first and second pluralities, respectively; first and second impedance means electrically connected between said emitters connection and said first and second bases, respectively, via said first and second feedback windings, respectively; said first and second transistors being adapted to conduct current and to drive their respective cores to saturation in alternate order; a control winding in each of said first and second pluralities electrically connected together in series; a current control means connected to said series connection of said control windings to control current flow therein; said control means being adapted to simultaneously reset one of said cores as the other of said cores is brought to saturation; and output means coupled to an output winding in said first plurality and to an output winding in said second plurality such that an alternating output is obtainable therefrom.

5. A variable frequency magnetic multivibrator comprising first and second pluralities of windings wound on first and second cores, respectively; each of said pluralities of windings including at least a primary, a secondary,

a control and a feedback winding; each of said first and second cores having a substantially rectangular hysteresis loop characteristic; a first energy source; a first vacuum tube having at least a first cathode, a first control grid, and a first plate; a second vacuum tube having at least a second cathode, a second control grid, and a second plate; means electrically connecting said first and second cathodes in common; means electrically connecting said first and second plates to a primary winding in said first and second pluralities, respectively; said first energy source being electrically connected between said cathode connection and said first and second plates via the primary windings in said first and second pluralities, respectively; means electrically connecting said first and second control grids to a feedback winding in said first and second pluralities, respectively; biasing means electrically connected between said cathode connection and said first and second control grids via said first and second feedback windings, respectively; said first and second vacuum tubes being adapted to conduct current and to drive their respective cores to saturation in alternate order; a control winding in each of said first and second pluralities electrically connected together in series; a current control means connected to said series connection of said control windings to control current flow therein; said control means being adapted to simultaneously reset one of said cores as the other of said cores is brought to saturation; and output means coupled to an output winding in said first plurality and to an output winding in said second plurality such that an alternating output is obtainable therefrom.

References Cited in the file of this patent

UNITED STATES PATENTS

1,788,533	Morrison	Jan. 13, 1931
2,482,150	Bocciarelli	Sept. 20, 1949
2,605,404	Valley	July 29, 1952
2,708,241	Bess	May 10, 1955
2,740,086	Evans et al.	Mar. 27, 1956
2,748,274	Pearlman	May 29, 1956