FIG. 1

INVENTOR
STEPHEN PAULL

BY

[Diagram of a magnetic multivibrator]
VARIABLE FREQUENCY MAGNETIC MULTIVIBRATOR

+ B

+ B_s

+ B_r

- B

\[ \Delta B \neq 2B_s \]

\[ \Delta B \]

FIG. 2

INVENTOR
STEPHEN PAULL

BY

ATTORNEYS
3,150,329

VARIABLE FREQUENCY MAGNETIC MULTIVIBRATOR

Stephen Paull, Falls Church, Va., assignor to the United States of America as represented by the Administrator of National Aeronautics and Space Administration Filed Mar. 11, 1960, Ser. No. 14,488 15 Claims. (Cl. 331—115)

(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 royalties thereon or therefor.

This invention relates generally to magnetic-coupled multivibrator circuits, and more particularly to a variable frequency magnetic-coupled multivibrator. Although variable frequency magnetic-coupled multivibrator arrangements have been heretofore devised and successfully employed, in general, these prior art arrangements have not been found to be entirely satisfactory. For example, in one prior art multivibrator arrangement, frequency variation is obtained by changing the magnitude of the supply voltage. This arrangement results in undesirable variations in amplitude and waveform of the multivibrator signal. In another present day arrangement, frequency change is obtained by short-circuiting windings on one or more serially-connected cores. One significant disadvantage of this arrangement is that the frequency of the multivibrator signal can only be varied is discrete steps. Still another prior art variable frequency multivibrator arrangement provides for the application of a variable reversible current to control windings individually linking each core in a push-pull type of multivibrator circuit. The several limitations of this arrangement are the relatively large magnitude of control current required, non-linearity of the control current-frequency characteristic over a particular frequency band, and waveform distortion.

Accordingly, it is an object of the present invention to provide a new and improved variable frequency magnetic-coupled multivibrator circuit.

Another object of this invention is to provide a novel magnetic-coupled multivibrator in which the frequency of the output signal is continuously variable over a predetermined frequency range.

Still another object of the instant invention is the provision of a novel voltage control variable frequency magnetic core multivibrator.

A further object of this invention is to provide a novel single polarity unidirectional potential controlled variable frequency magnetic-coupled multivibrator.

A still further object of the present invention is to provide a variable frequency magnetic-coupled multivibrator having an output signal of constant amplitude and waveform.

Another still further object of this invention is the provision of linear control means for a variable frequency multivibrator.

Still another further object of the present invention is to provide a new and improved variable frequency magnetic-coupled multivibrator having an output signal free of random variations of period during each half-cycle of operation.

According to the present invention, the foregoing and other objects are attained by the provision of a plurality of high remanence cores, an electrical energy source, a pair of conductive loops including windings linking each of the cores and coupled across the energy source, switching means included in each of the loops for rendering them alternately operative, circuit means including windings linking each of the cores for effecting re-
of a frequency control circuit 32. Also included in the control circuit is a signal translating element 33, such as PNP type transistor, and a conventional source 34 of a selectivity variable single polarity direct current signal. Transistor 33 is operated in the common collector configuration with the direct current control signal being applied to the control winding 31 being connected across the emitter and collector electrodes thereof. The control winding 31 is polar so that the voltage induced therein by the flux change in core 11 in response to a negative magnetizing force is in series-opposition to the control signal and will result in producing a net negative base-to-emitter potential on transistor 33. Transistor 33 is therefore turned off during this half-cycle and clamps the induced voltage to the level of the applied control signal thereby limiting the rate of flux change in core 11 to less than that of core 12. During the half-cycle that a positive magnetizing force is applied to core 11, the voltage induced in control winding 31 is in series-aiding with the control signal and transistor 33 is cut-off. This results in the absence of any clamping action during this half-cycle of multivibrator operation. The multivibrator operating frequency is determined by the algebraic sum of the flux changes in cores 11 and 12 during each half-cycle. Since the flux changing windings are wound on cores 11 and 12, each having the same flux changing windings, the flux change during each half-cycle are of equal magnitude. However, during the clamping half-cycle when control transistor 33 is ON, current in the control winding opposes the applied magnetizing force and results in a slower rate of flux change in core 11. Core 12 reaches negative saturation while core 11 flux reversal is still in progress. The flux change in core 11 is zero when the input control voltage is zero, and increases to full flux reversal as the control voltage is increased to its maximum value. This maximum value is determined by the ratio of cross section area of core 11 to core 12, the number of turns of the control and flux changing windings, and the supply voltage. It therefore will be apparent that the multivibrator operating frequency is linearly variable from an upper frequency limit, when the control signal is zero with no flux reversal in core 11 and full flux reversal in core 12, to a lower frequency limit, when the control signal is maximum and complete flux reversal takes place in both cores. It will be appreciated by those skilled in the art that since the multivibrator described herein is a variable frequency multivibrator according to this invention operates under constant switching conditions over the entire frequency range of operation, the generated output signal will exhibit constant amplitude and waveshape characteristics and will be free of random variations from cycle to cycle. It will also be appreciated that temperature effects on the switching transistors, which tend to cause frequency instability will be compensated for by the temperature effects on the clamping, or control, transistor. Having described the circuit elements and arrangement of the variable frequency multivibrator according to this invention, the operation thereof will now be described in relation to FIG. 2. During the beginning of the initial half-cycle of operation it be assumed that the flux density in both cores is at positive remanence, +Br, and that transistors 16, 19 and 33 are off, on, and on, respectively. The current flow in loop 15 produces a negative magnetizing force, H, tending to drive both cores toward negative saturation, -Bs. Since both cores have equal inside diameters and identical flux changing windings, the applied magnetizing force is the same for both cores. However, by reason of the clamping action of control transistor 33 during this half-cycle, an induced current flows through control winding 31 which introduces an opposing magnetizing force thereby limiting the rate of flux change in controlled core 11. The net magnetizing force on core 11 is therefore less than that on uncontrolled core 12 by an amount determined by the magnitude of the control signal provided by source 34. Core 12 reaches negative saturation, -Br, while core 11 is still switching, whereupon voltages on all windings linking core 12 vanish. Since windings 24 and 26 furnish base drive for transistor 19, the moment core 12 saturates, the drive on transistor 19 diminishes thereby turning the transistor off and flip-flop action is initiated. The flux density of core 12 then returns to negative remanence, -Br, while the flux density of core 11 is at some value between negative and positive remanance depending upon the amount of clamping action taking place during the initial half-cycle. At the initiation of the terminal half-cycle of operation, transistors 16, 19 and 33 will be on, off, and off, respectively. Current flows in loop 14 thereby producing a positive magnetizing force, +H, tending to drive both cores toward positive saturation, +Br. However, the residual flux density on core 11 acts as a magnetic bias aiding the applied magnetizing force. Core 11 therefore begins its flux reset ahead of core 12. As core 11 neats positive saturation a small flux change decreases while that in core 12 increases. Since the total amount of flux change involved in this half-cycle is the same as it took place in the initial half-cycle, both cores reach positive saturation, +Br, in a time interval equal to the switching time of the initial half-cycle. When the cores saturate, the voltage across windings 23 and 25 diminishes suddenly thereby turning off transistor 16. Thereupon the above described operation repetitiously continues. In the alternative embodiment of the variable frequency multivibrator illustrated in FIG. 3, switch transistor 19 is provided with only base drive winding 26 on uncontrolled core 12, and in lieu of the common limiting resistor 27 of the embodiment of FIG. 1, transistors 16 and 19 are provided with individual resistors 35 and 36, respectively, in the base circuits thereof. To insure proper switching operation of transistor 19, the serially connected resistor 36 and winding 26 are adjusted to saturate transistor 19 during the initial half-cycle of multivibrator operation. Serially connected resistor 35 and windings 23 and 25 are adjusted to provide for similar operation of transistor 16 during the terminal half-cycle. Obviously numerous modifications and variations of the present invention are possible in the 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 herein. What is claimed is new and desired to be secured by Letters Patent of the United States is:

1. A multivibrator comprising a pair of magnetic cores having a substantially square wave hysteresis characteristic, a pair of circuit means linking said cores for effecting flux changes therein in opposite directions, circuit switching means interposed therein for rendering each of said pair of circuit means alternately operative, circuit means cooperating with said cores for effecting an alternate mode of operation of said circuit switching means, output means responsive to the flux changes in said cores, a control winding on one of said cores, a variable uni-directional electrical energy source, and circuit means connected between said energy source and said control winding for limiting the magnitude of flux change in said one core correlative to the instantaneous value of the unidirectional electrical energy of said source.

2. A multivibrator comprising a pair of high remanence toroidal cores, first circuit means linking said cores and being operative for effecting a flux change in said cores in one direction, second circuit means linking said cores and being operative for effecting a flux change in said cores in the opposite direction, switching means interposed in said circuit means for rendering first and second circuit means alternately operative, third circuit means linking said cores for rendering said circuit switching means alternately on and off, output means re-
To form a second current conductive loop across said energy source, said second flux changing windings and said first transistor switching means being serially connected to form a second current conductive loop across said energy source, a control transistor, a fifth winding wound on one of said cores and being connected across the emitter and collector electrodes of said control transistor, and a source of a selectively variable unidirectional electrical signal connected across the base and collector electrodes of said control transistor.

A multivibrator according to claim 8 wherein said selectively variable unidirectional electrical signal of said source is of a single polarity.

10. A multivibrator according to claim 8 wherein said high remanence cores are of the same inside diameter, and said first and second flux changing windings are identical.

11. A multivibrator comprising a pair of high remanence cores of a toroidal ring configuration, a unidirectional electrical energy source, first and second flux changing windings wound in opposite rotational sense with respect to each other on each of said cores, first and second transistor switching means, said first flux changing windings and said first transistor switching means being serially connected to form a first current conductive loop across said energy source, said second flux changing windings and said second transistor switching means being serially connected to form a second current conductive loop across said energy source, a resistor having one end thereof connected to one side of said energy source, third and fourth base drive windings wound on each of said cores in one rotational sense with respect to each other on each of said cores, first and second transistor switching means being serially connected to form a third current conductive loop across said energy source, a control transistor, a fifth winding wound on one of said cores and being connected across the emitter and collector electrodes of said control transistor, and a source of a selectively variable unidirectional electrical signal connected across the base and collector electrodes of said control transistor.

12. A multivibrator according to claim 11 wherein said selectively variable unidirectional electrical signal of said source is of a single polarity.

13. A multivibrator according to claim 11 wherein said high remanence cores are of the same inside diameter, and said first and second flux changing windings are identical.

14. A multivibrator comprising a pair of high remanence cores of a toroidal ring configuration, a unidirectional electrical energy supply, first and second flux changing windings wound in opposite rotational sense with respect to each other on each of said cores, first and second transistor switching means, said first flux changing windings and said first transistor switching means being serially connected to form a first current conductive loop across said energy supply, said second flux changing windings and said second transistor switching means being serially connected to form a second current conductive loop across said energy supply, a control transistor, a fifth winding wound on one of said cores and being connected across the emitter and collector electrodes of said control transistor, and a source of a selectively variable unidirectional electrical signal connected across the base and collector electrodes of said control transistor.

15. A multivibrator according to claim 14 wherein said...
16. A multivibrator according to claim 14 wherein said high remanence cores are of the same inside diameter, and said first and second flux changing windings are identical.

17. A multivibrator comprising a plurality of magnetic cores each having a substantially square wave hysteresis characteristic, circuit means linking said cores for effecting flux changes in opposite directions therein, means responsive to the magnetic condition of said cores for controlling said circuit means, output means responsive to the flux changes in said cores and adjustable means associated with all but one of said plurality of magnetic cores for limiting the magnitude of flux change in said associated cores in one direction.

18. A multivibrator comprising a plurality of magnetic cores each having a substantially square wave hysteresis characteristic, a pair of circuit means linking said cores for effecting flux changes therein in opposite directions, switching means included therewith for rendering each of said pair of circuit means alternately operative, means associated with said cores for effecting an alternate mode of operation of said switching means, output means responsive to the flux changes in said cores and adjustable control means associated with all but one of said plurality of magnetic cores for limiting the magnitude of flux change in said associated cores in one direction.

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