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3,312,831

SWITCH CIRCUIT

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Fig. 1.

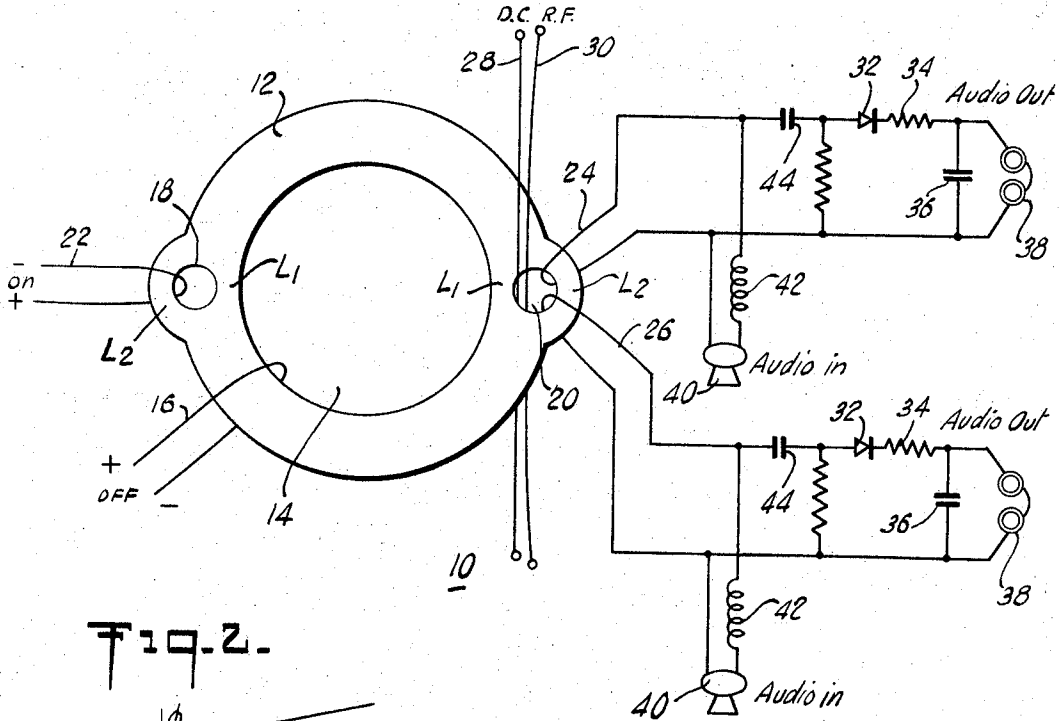


Fig. 2.

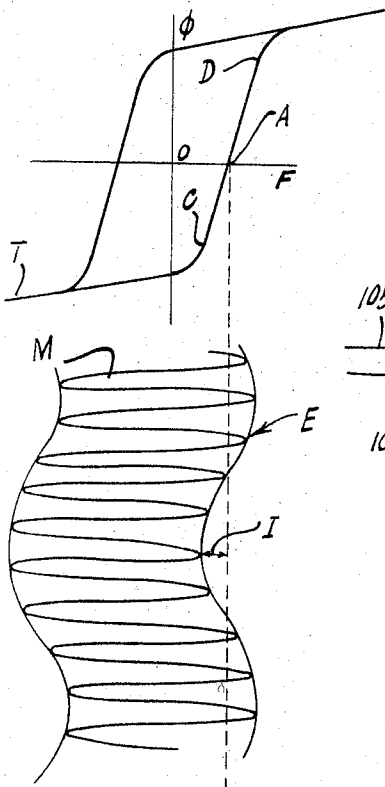
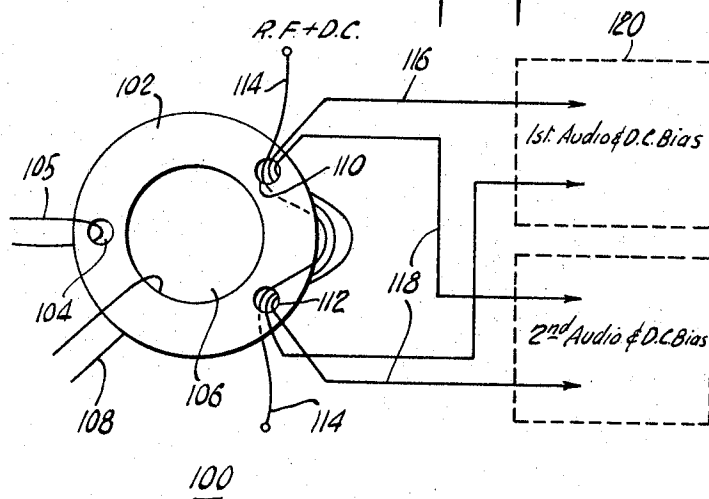


Fig. 3.



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SWITCH CIRCUIT

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Continuation of application Ser. No. 144,790, Oct. 12, 1961. This application Oct. 9, 1964, Ser. No. 405,011 11 Claims. (Cl. 307—88)

This application is a continuation of U.S. application S.N. 144,790, filed Oct. 12, 1961, and now abandoned.

This invention relates to an electronically controlled switch circuit using magnetic cores.

An object of this invention is to provide a simple, yet easily controlled and highly effective magnetic core device for switching either on or off an electrical circuit, such as a voice communication line.

Another object is to provide a switch arrangement using a magnetic core to "remember" indefinitely whether it has been actuated on or off.

These and other objects will in part be understood from and in part pointed out in the following description.

One definition of an ideal electric switch is a device which has no moving parts to wear out, and which when turned on or off will stay so indefinitely without the need for external power to hold it on or off. In addition the switch should be small in size and easy to actuate; for many applications it must also be controlled by an electrical signal, such as a momentary voltage. The present invention provides an improved answer to these needs.

In accordance with the present invention, a multi-aperture magnetic core is arranged as a switch to connect or disconnect two or more external circuits. For the sake of illustration, the invention will be described in connection with audio circuits, such as found in telephone exchanges and the like.

A multi-aperture (MAD) core as used in the invention has a major aperture and one or more minor apertures. In one specific embodiment of the invention, the coupling of one audio circuit to another through such a core is accomplished by applying an RF signal to a minor aperture of the core. When the core is "on," determined by a particular setting of flux in the core, this RF signal rapidly switches flux locally around the minor aperture, and by proper D.C. biasing essentially distortion-free coupling between two or more audio circuits coupled to the minor aperture is achieved. When the core is "off," determined by a different flux setting, no flux can be switched locally around the aperture linked by the audio circuits, and hence they are in effect completely disconnected from each other. A momentary set or clear signal applied to another winding on the core serves to turn it on or off. Thus it is easily actuated.

A better understanding of the invention together with a fuller appreciation of its many advantages will best be gained from the following description given in connection with the accompanying drawings wherein:

FIGURE 1 is a circuit diagram of one embodiment of the invention;

FIGURE 2 shows waveforms illustrating the operation of the circuit; and

FIGURE 3 is a circuit diagram of another embodiment of the invention.

The switching circuit 10 shown in FIGURE 1 includes a multi-aperture core 12, which here for the sake of illustration is shown greatly enlarged and out of proportion to the remaining elements of the circuit. This core is made of magnetic ferrite material and has a hysteresis characteristic as shown in FIGURE 2.

Core 12 has a central or major aperture 14. Encircling the core through this aperture is a winding 16, which when energized with a pulse of current of sufficient ampli-

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tude in the polarity indicated, drives the core to its "off" condition in which all of the remanent flux in the core is in the clockwise direction.

Piercing the body of the core is a first minor aperture 18, and a second minor aperture 20. Adjacent each of these apertures the outer rim of the core is enlarged so that the cross-sectional areas of the inner leg portion L_1 and of the outer leg portion L_2 of the core are equal, and together are substantially equal in area to the area of the unpierced body of the core. However, as will appear, aperture 20 here advantageously is enlarged slightly so that the sum of the areas of its legs L_1 and L_2 is slightly less than that of the main body of the core. This enlarging of aperture 20 insures that its legs L_1 and L_2 will both be completely saturated with flux in the clockwise direction when the core is turned off.

Encircling the outer leg of minor aperture 18 is an "on" winding 22. When a momentary current in the polarity indicated, and of sufficiently large amplitude is applied to this winding, the flux in this outer leg will be set in the counter-clockwise direction. This simultaneously causes the counter-clockwise setting of flux in the inner leg L_1 of aperture 20. In this condition, the "on" state of the core, and assuming the flux in outer leg L_2 is clockwise, there is in effect flux locally circulating around aperture 20. As is known, to switch this local flux back and forth requires an M.M.F. much smaller in amplitude than that which will switch flux around the major aperture of the core.

Coupling the outer leg L_2 of the core at aperture 20 are a first audio winding 24 and a second audio winding 26. Also threading aperture 20 are a first conductor 28 and a second conductor 30. The first of these is adapted to be energized with direct current and the second, with a radio frequency current, the frequency of which should be at least several times higher than the top frequency carried by the audio circuits.

FIGURE 2 illustrates the ϕ -F loop characteristic of core 12 with respect to flux switching locally around aperture 20. In the circuit of FIGURE 1 an RF current is applied to winding 30 and a biasing direct current to winding 28. The amplitudes of these currents are such that approximately one-half of the available flux around aperture 20 is switched by each RF cycle. The ϕ -F loop is traversed each cycle from point A, down toward negative saturation, point T, and back up to point A. When an audio frequency current is applied to winding 24, for example, its M.M.F. will be superimposed and will alternately aid and oppose to M.M.F. due to the RF current and bias. This gives an envelope E shown in FIGURE 2, the amplitude I of this envelope with respect to the zero audio operating point, A, being proportional to the audio current applied to winding 24. This audio current will then cause more or less flux to be switched around the minor aperture during each RF cycle. The amount of flux switched will be linearly related to the audio current so long as the envelope E does not exceed the linear portion of the ϕ -F loop as indicated by points C and D.

Since this changing flux at aperture 20 also links audio winding 26, a voltage is induced in winding 26. This induced voltage is a radio frequency wave (actually, a considerably distorted sine wave) whose fundamental component is the frequency of the carrier applied to winding 30. The induced voltage on winding 26 is modulated (i.e. multiplied) by the audio frequency wave applied to winding 24. Therefore, by feeding this modulated RF voltage to a suitable audio frequency detector, the audio itself substantially without distortion is obtained. This audio detector as seen in FIGURE 1, comprises a half-wave rectifier 32, a small resistor 34 and a filter capacitor 36. The operation of these elements as a detector for an amplitude modulated RF signal is conventional. The audio voltage itself is developed across capacitor 36 and

is fed to a pair of earphones 38, or any other suitable receiver.

To apply an audio signal to winding 26 so that a like audio signal can be applied (in modulated RF form) to winding 24, there is connected to winding 26 in parallel with the detector a microphone 40, which is in series with a radio frequency blocking choke 42. To prevent audio frequencies from reaching the detector, a small capacitor 44 is connected in series with rectifier 32. It will now be appreciated that when core 12 is on, a signal can be transmitted from one audio winding to the other, and vice versa. When the core is off, and assuming that each leg L_1 and L_2 at aperture 20 is fully saturated with flux in the same direction (i.e. clockwise) no flux can be switched locally around the aperture by the applied RF current, so long as the RF current is not of sufficient amplitude to switch flux around the major aperture. Hence, there is no coupling between the audio windings and no transmission of signal from one to the other. By enlarging aperture 20 so that the sum of the cross-sectional areas of legs L_1 and L_2 is slightly less than the cross-sectional area of the main body of the core, discrimination of the order of 10,000 to 1 for detected audio signals between the on and off conditions of the core is achieved. Where the legs are approximately equal to or greater than the main body of the core, this ratio drops drastically.

In the arrangement shown in FIGURE 1, RF winding 30 sees an impedance changing with audio signal, thus this winding should be energized from a constant current source. To prevent RF from reaching the direct current source which energized lead 28, a suitable choke coil may be inserted in this lead. In a switch circuit substantially identical to circuit 10 which has been built and successfully operated, a core 12 about the size of a shirt button and made of General Ceramics type 5209 ferrite material was used. About 80 ma. turns of D.C. bias, and 500 ma. turns of 100 kc. sine wave current were found suitable. It is to be understood, of course, that this circuit can be operated satisfactorily with different current and frequency values. Operation at RF frequencies of the order of several megacycles is possible, though at these higher frequencies, the amount of flux switched around aperture 20 each half cycle is determined by the duration of a half cycle of RF drive and not by the amount of flux which could be switched under low frequency or D.C. conditions, as illustrated in FIGURE 2. If desired, audio windings 24 and 26 may be combined into a single winding.

FIGURE 3 shows another circuit 100 embodying the invention. Here a core 102 is coupled through a minor aperture 104 by an "on" winding 105, corresponding to winding 22 of core 12. Core 102 through its major aperture 106 is likewise threaded by an "off" winding 108. In addition to these apertures, the core has two minor apertures 110 and 112, each of which is substantially equal in size to aperture 20 of core 12. These apertures 110 and 112 are threaded by an RF winding 114 which passes through each in the same sense. As will appear, a direct current bias is also applied to this winding. In addition to winding 114, the apertures are threaded by a first audio winding 116 and a second audio winding 118, each of which threads the apertures in opposite sense but in the same relation to each other. Winding 116 connects to an audio circuit 120, which may be the same as the audio circuit connected to winding 24 in FIGURE 1. Here, in addition, audio circuit 120 applies to winding 116 a D.C. bias, the size and function of which will be described shortly. Similarly, winding 118 is connected to an audio circuit 122 which applies to the winding a suitable D.C. bias.

Assuming core 102 has been set "on", then there will be coupling between audio windings 116 and 118 when an RF current and a suitable D.C. bias current is applied to RF winding 114 and one or both of windings 116 and 118. The D.C. bias on winding 114 should be set at a level corresponding to the bias on lead 28 in the circuit of

FIGURE 1. With the bias so set in circuit 100, and with no D.C. bias on either audio winding, no RF voltage will appear on the latter windings. The D.C. bias applied to each of windings 116 and 118 should in total be such that a proper amplitude RF voltage is then induced on these windings.

Since RF current on winding 114 of circuit 100 is substantially independent of modulation this winding presents effectively a constant load, and can be driven from a low impedance source. The modulation signal does not appear across RF winding 114. Hence, even though the source impedance is low, RF winding 114 can thread more than one core. For best operation the cross-sectional areas of material adjacent to minor apertures 110 and 112 should be as nearly equal to each other as possible and slightly less than the cross-sectional area of the main body of the core.

It will be understood from the above explanation that two or more circuits, such as the audio circuits illustrated, can be connected together or disconnected by means of a core switch. The core of the switch circuit may be controlled as one element of an array of cores so that one audio circuit can be connected to any one of a number of other like circuits.

The above description of the invention is intended in illustration and not in limitation of the invention. Various changes or modifications in the embodiments set forth may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention as set forth.

What is claimed is:

1. A self-holding switch circuit comprising a multi-aperture magnetic core having a minor aperture, means to set the flux in said core in either on or off condition, a plurality of energizing means to apply to said minor aperture a rapidly fluctuating M.M.F., a relative steady biasing M.M.F. and a signal M.M.F., and output detection means coupled to said minor aperture.

2. The circuit in claim 1 wherein said plurality of means includes a winding threading said minor aperture and to which an RF current is applied, and further includes D.C. current bias means and A.C. signal input means, said output detection means including a second winding threading said minor aperture.

3. A switching circuit of the character described comprising a multi-aperture magnetic core having a major aperture and at least one minor aperture, means to set the flux in said core in either on or off condition, energizing means coupling said minor aperture to apply thereto a bias current, a signal current and a radio frequency current, and detector means coupled to said minor aperture, whereby when said core is on an audio signal and the like applied to said energizing means can produce at said detector means a similar audio signal, and when said core is off no signal will appear at said detector means.

4. The circuit in claim 3 wherein said energizing means includes first and second signal windings, threading said minor aperture and detector means connected to said windings, respectively.

5. The circuit in claim 4 wherein said core has two minor apertures, said signal windings threading said minor apertures in opposite sense to the remainder of said energizing means.

6. The circuit in claim 3 wherein said core at said minor aperture has a cross-sectional area less than elsewhere in order to insure saturation with flux of the legs of the core adjacent said aperture when said core is off.

7. A linear switching circuit comprising a multi-aperture magnetic core having a minor aperture, signal means coupled to said aperture, energizing means coupled to said aperture to apply thereto signal, bias and rapidly reversing drive currents, and means to set said core in on and off conditions.

8. A balanced switch circuit comprising a first multi-aperture magnetic core portion and a second multi-

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aperture magnetic core portion surrounding first and second minor apertures respectively, means including a winding wound through said apertures in the same sense to apply high frequency drive and bias magnetomotive forces to said core portions, means to set and to clear said core portions, and signal means including a pair of windings threading said apertures in opposite sense to apply signal magnetomotive forces to said portions, whereby said signal means are coupled together when said core portions are set and are de-coupled when said portions are cleared.

9. A linear switching circuit comprising a magnetic core of saturable magnetic material, said core having a first aperture about which flux can be switched locally at low M.M.F., and having a second aperture about which flux can be switched at substantially higher M.M.F. to prevent local switching around said first aperture, means coupled to said first aperture to bias the core into a linear region of its hysteresis loop characteristic, high frequency means coupled to said first aperture to apply thereto a rapidly switching M.M.F., signal frequency means coupled to said first aperture to apply thereto an M.M.F. which alternately adds to and subtracts from the rapidly switching M.M.F. in the linear region of the hysteresis loop characteristic, detector means coupled to said core to extract a signal proportional to the signal applied to said signal frequency means, and on-off means to switch flux around said second aperture.

10. A core of magnetic material having a generally square hysteretic characteristic having a central aperture with at least two minor apertures, the core at one of said minor apertures having an increased dimension to provide a radial cross-sectional area of material on the axis of said one minor aperture, approximately equal to that of typical radial cross-sections of the remainder of the body of the core between said minor apertures and having at another of said minor apertures an increased dimension

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to provide radial cross-sectional areas of material slightly less than that herein above defined whereby the material at said last named minor aperture will be completely saturated as said core is driven into a clear state of magnetization to thus reduce the noise transmitted by an output loop linking said other minor aperture.

11. A core of magnetic material having a generally hysteretic characteristic and a body including a major and at least two minor apertures positioned in said body to define inner and outer legs of material at each minor aperture, the sum of cross-sectional areas of material of said inner and outer legs at one of said minor apertures being less than the sum of cross-sectional areas, respectively, of material of the inner and outer legs at each of the other said minor apertures, the said cross-sectional area of said inner and outer legs of material at the radii common to the major and said other minor apertures along said other minor apertures being approximately equal to the cross-sectional area of the square-loop material surrounding said major aperture at points apart from said minor apertures, the said one minor aperture having the least cross-sectional area of material being the transmitter aperture for said core.

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