

[54] MONOLITHIC MAD

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[21] Appl. No.: 7,333

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 601,500, Dec. 13, 1966, Pat. No. 3,506,973.

[52] U.S. Cl. 29/604, 29/625, 340/174 MA,
340/174 CT

[51] Int. Cl. H01f 7/06

[58] Field of Search ...340/174 CT, 174 MA; 29/604,
29/602, 625

[56]

References Cited

UNITED STATES PATENTS

3,341,832	9/1967	Nitzan	340/174
3,308,445	3/1967	Rajchman.....	340/174
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Primary Examiner—John F. Campbell

Assistant Examiner—Carl E. Hall

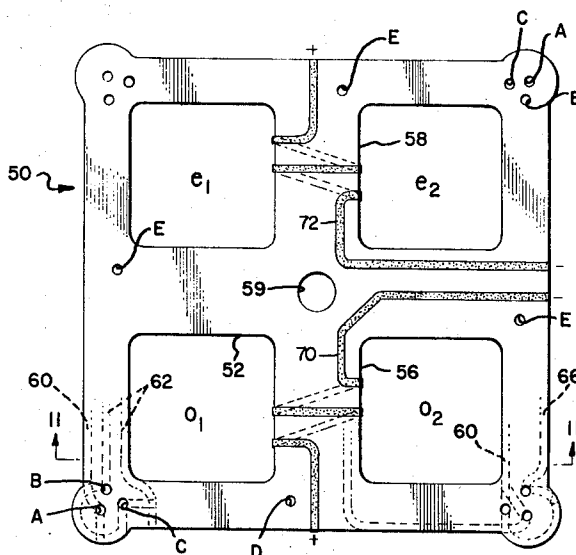
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[57]

ABSTRACT

A method of providing conductive windings on a magnetic core wherein said windings are plated through small apertures in the core and additional windings are plated through a larger aperture.

3 Claims, 11 Drawing Figures



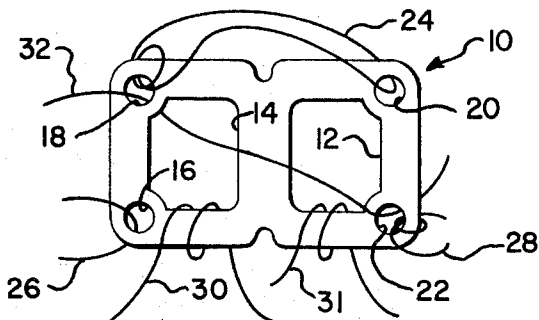


Fig. 1

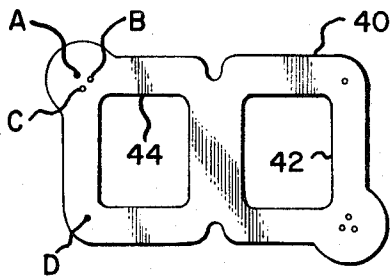


Fig. 2

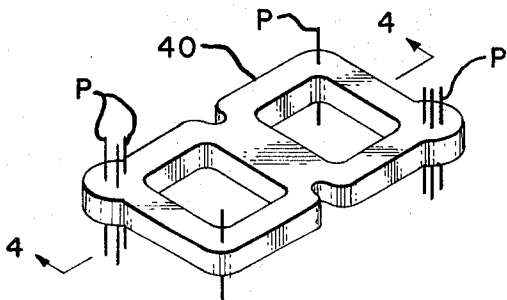


Fig. 3

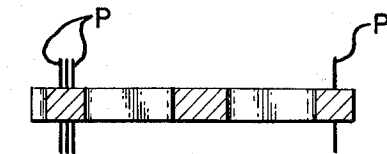


Fig. 4

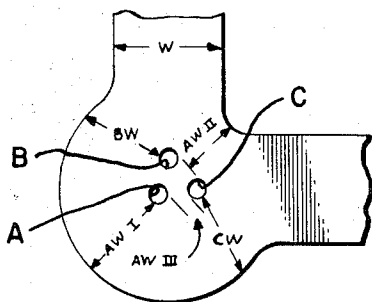


Fig. 5

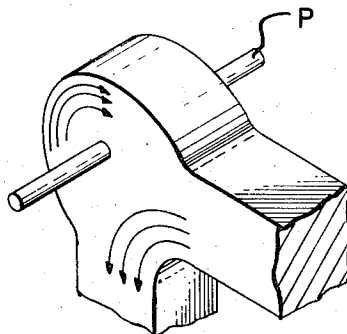


Fig. 6

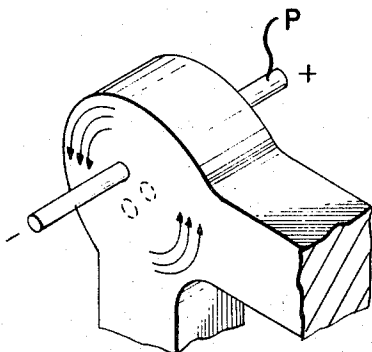


Fig. 7

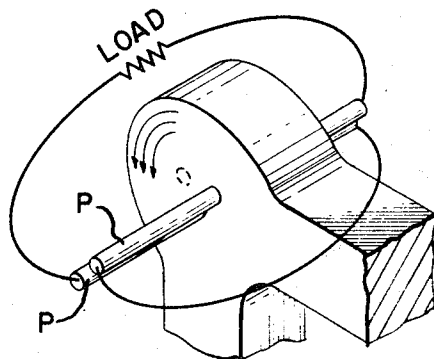
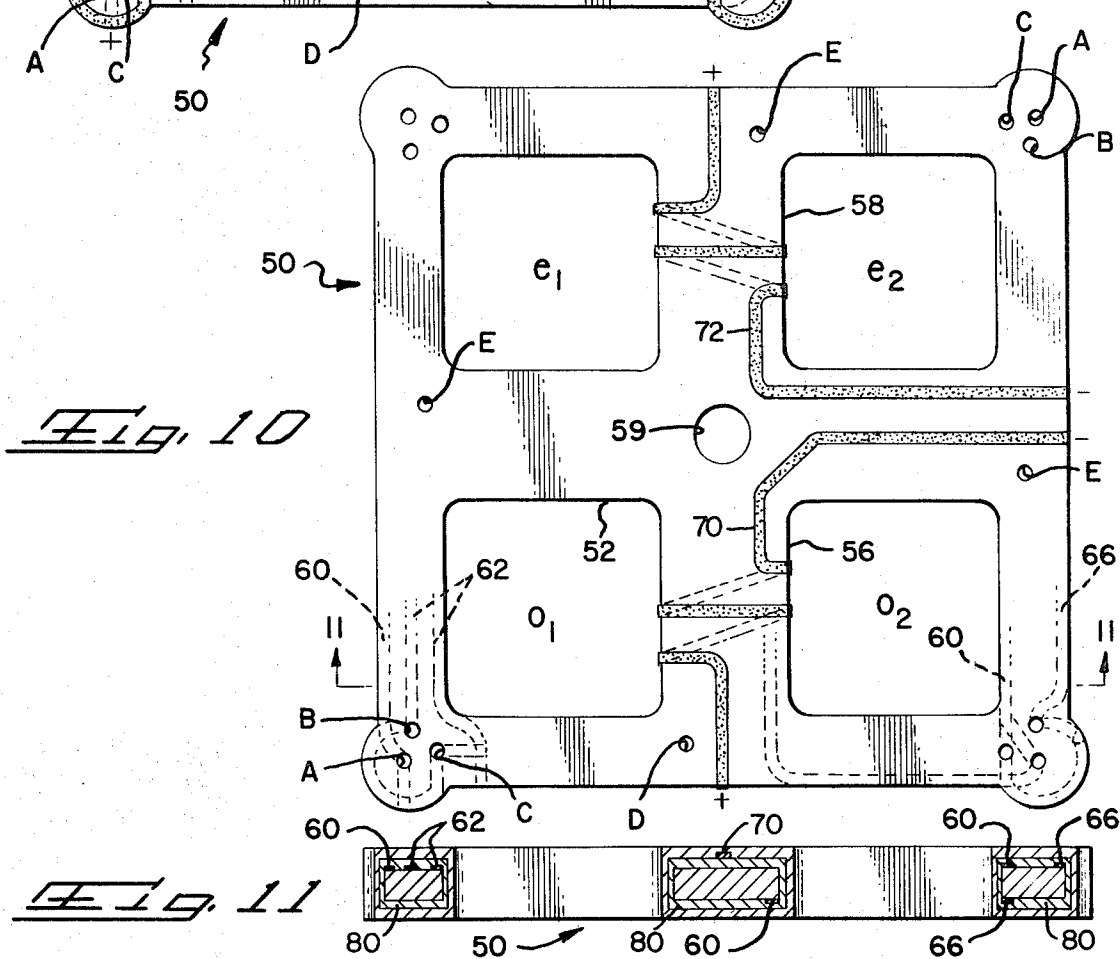
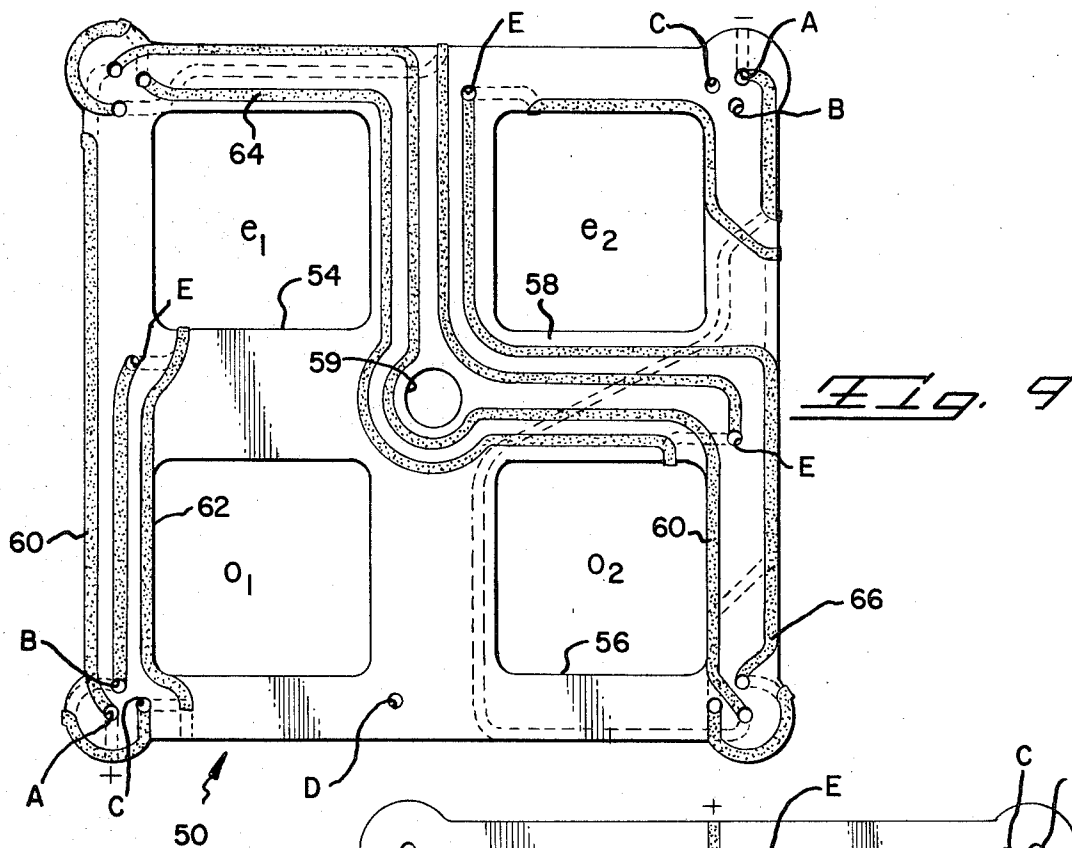


Fig. 8



MONOLITHIC MAD

This application is a division of Ser. No. 601,500, filed Dec. 13, 1966, now U.S. Pat. No. 3,506,973.

This invention relates to magnetic core structures of the type utilized in memory and logic devices and to methods for making such structures.

A considerable effort has been made to utilize the storage and logic capabilities of square loop magnetic material and much of the electronic data processing apparatus in use today is made up of core structures in the form of toroids, sheets, strips and other core structures made of such material. The advantages of intelligence storage without continuous drive power through a device which has an infinite life have no doubt sponsored this. One of the main limitations on core use has been the difficulty encountered in wiring; applying necessary input, output and drive windings. Drive power requirements and to a certain extent frequency response and overall efficiency is related to the amount of magnetic material employed to define a given core and generally speaking, the smaller the core the better. The smallness has aggravated the wiring problem which is directly related to physical size. Even so, the largest usage of magnetic cores has been in memory planes made up of small toroids. It is thought that this usage is due to the fact that memory plane circuits generally require only a single winding turn through a core body for input, output and drive signals. The much lesser usage in the larger multiaperture magnetic cores employed for logic purposes and for providing relatively complex circuit functions is believed to be due to the fact that these cores have circuits which include a number of turns through the core apertures; making production uneconomical. To illustrate the foregoing a comparison may be made between a typical toroid memory device as is shown in U.S. Pat. No. 3,012,231 and a typical multiaperture logic device, as is shown in U.S. Pat. No. 2,810,901.

Even with single turn circuits there has been a problem with winding installation. That the problem is one which has existed for some time is demonstrated in a number of patents: including U.S. Pat. No. 2,911,627 which provides cores slotted to receive windings and then faced over with magnetic material to close the air gap of the slot; U.S. Pat. No. 2,910,675 which shows cores having conductive pins fitted therethrough and terminated to printed circuits for the purpose of adaptation of core devices to automatic production; U.S. Pat. No. 3,127,590 which features a core geometry to facilitate straight through windings; and U.S. Pat. No. 3,129,494 which shows a method for automatically winding cores including multiaperture cores with a plurality of turns. Still other patents of interest to show the problem and an attempt at a solution are U.S. Pat. No. 3,085,899 which discloses the concept of molding up cores and windings in laminations with core material and conductive material being placed between different steps of firing; U.S. Pat. No. 2,882,519 which deals with obtaining desired winding patterns on plate type structures; and U.S. Pat. No. 3,184,719 which deals with cores made through molded and printed circuit techniques.

Some of the foregoing approaches are simple, but many of them are complex. None of them, however, solve the problem of providing multiple turns in a magnetic core structure without the need for insertion of

separate conductors through the same aperture. None of them deal with the problem of placing turns having different functions in a multiaperture core structure without having to insulate between turns. In general, none of the prior art teaches how to obtain a wired multiaperture core structure capable of complex functions in a device which can be readily mass produced.

It is an object of the invention to provide a means and method for obtaining multiple winding turns through a core structure wherein winding placement and insulation between turns having multiple turns therethrough is inherently accommodated.

It is a further object of the invention to provide a simple and inexpensive method and means for achieving multiple turn windings in magnetic core structures for input, output or drive purposes.

It is still a further object to provide a wired multiaperture core device whereon windings may be formed through plating procedures.

It is still another object of the invention to provide a core structure for memory and logic applications which can be more easily produced and which assures the proper placement of windings by permitting an automated installation of windings on a core structure.

It is yet another object to provide a core structure and circuit which is more reliable than devices heretofore available.

The foregoing problems are overcome and the foregoing objectives are attained by the invention through a magnetic core structure wherein separate circuit windings turns are placed on a given core through a series of small holes insulated each from the other only by core material with a spacing which makes the various winding turns link the same flux paths for certain purposes and different flux paths for other purposes. Thus, when a given core geometry and drive circuit calls for several turns which would be normally threaded through a single common aperture to achieve a given function, the invention contemplates a core structure having separate small holes fitted with conductive pins or plated through to be connected externally in a fashion to provide the desired turns. In one aspect the invention contemplates molding and firing a body of magnetic material with extremely small holes therein grouped in a pattern sufficiently close together so as to simulate a much larger aperture wound with multiple turns. In this version the holes may be filled with solid conductive pins inserted therethrough or by standard plating techniques which deposit conductive material through such holes. Suitable linking conductive material to complete the windings may be deposited directly on the core material by plating techniques. Connector means joined in any suitable fashion to the individual conductive paths may be utilized to complete a connection to and from the circuit to provide the desired input, output or transfer functions. In another aspect of the invention it is contemplated that conductive wires or pins may be placed in holes in a pressed or molded core structure to remain therein as the core is fired; such pins then being interconnected in a suitable fashion thereafter to provide desired winding turns for use in a circuit.

In the drawings:

FIG. 1 is a schematic view of a core wound in accordance with an accepted wiring scheme for input,

transfer and output from a core device (enlarged approximately five times actual size);

FIG. 2 is a plan view of a core having the same function as that shown in FIG. 1, but made in accordance with the invention in one aspect thereof;

FIG. 3 is a perspective of the core of FIG. 2;

FIG. 4 is a section taken along lines 4—4 of FIG. 3;

FIG. 5 is a plan view of a corner of the core of FIGS. 2—4 (enlarged even further) showing the details of the positions for turn placement;

FIGS. 6—8 are perspectives of a corner of the core of FIGS. 2—5 showing various turns and an associated flux distribution to explain the invention;

FIGS. 9 and 10 are plan views showing another core structure having windings and turns plated thereon to provide a completed two bit register; and

FIG. 11 is a section through lines 11—11 of FIG. 10.

Turning now to FIG. 1, there is shown a core structure which has been used in a number of commercial applications. The structure is wound in what is now a standard manner in accordance with a circuit which is believed to offer perhaps the best range of operation for multiaperture devices. This type of circuit is termed MAD-R for Multi-Aperture Device - Resistance, and is disclosed in detail in U.S. Pat. No. 3,125,747 to D. R. Bennion, granted Mar. 17, 1964, and in U.S. Pat. No. 2,995,731 to J. P. Sweeney, granted Aug. 8, 1961. The exact core structure and circuit is described in detail in U.S. application Ser. No. 305,780, in the name of Nitzan et al.

Cores of the type used in such circuits are typically made of a square loop ferrite material which is first pressed into the desired geometry and then fired at relatively high temperature. Most of the materials have insulating qualities. Prior to firing it is a standard practice to utilize a binder which is burned out during firing to leave the ferrite material having square loop characteristics. Considerable shrinkage (20 or 30 percent) occurs during firing and cooling of the formed core geometry. The significance of these factors will be made apparent hereinafter.

The core shown as 10 includes a pair of major apertures 12 and 14, each placed in the body of magnetic material to define separate bit positions. In each half surrounding a major aperture there is a minor aperture such as 16, shown in the left half, which may be employed as an input aperture. Also in the left half is a slightly larger minor aperture shown as 18, which may be used as an output aperture. The minor apertures 20 and 22 in the right half of the core structure 10 have similar functions. The minor apertures of the core define legs of magnetic material which permit multiaperture magnetic core operation including diodeless transfer and nondestructive readout, generally, and MAD-R operation, specifically. The core 10 is shown wound by windings including a coupling loop 24 linking the left core half to the right core half to transfer information stored in the left core half to the right core half. The coupling loop 24 is made to link the transmitter aperture 18 by two turns and the aperture 20 by one turn. This difference in turns is to achieve a sufficient gain to overcome the losses inherent in the device. Further included is an input winding 26 linking the input aperture 16 and an output winding linking the transmitter aperture 22. The input winding 26 has one

turn and the output winding 28 again has two turns for the reasons mentioned. Also threading the core are drive windings including an advance winding 30 which is made to link the major aperture of the left hand portion of the core by several turns and an advance winding 31 made to link the major aperture 12 by several turns. The clearing windings serve to cause an advance of intelligence stored in the core and are pulsed at separate times in an advance cycle. A further drive winding 32 is provided to prime the core through one turn made to link both transmitter apertures 18 and 22 and operable to prime the material about such apertures prior to transfer initiated by the advance pulse of the transfer cycle.

In an actual core like 10 the apertures 18 and 22 have diameters which were approximately 0.030 of an inch. In order to provide windings it is necessary to insert insulated wires on the order of a few mills in diameter through these apertures. Where there is more than a single turn around the legs as in loop 24 it is necessary to carry the wire back through the apertures again in the manner indicated in FIG. 1. Aside from the difficulty of inserting small wires through small apertures, other problems are encountered including the possibility of scraping insulation off of the wires by engagement with the hard and abrasive ferrite material employed for cores. As will be appreciated by those skilled in the art, the wiring procedure for devices like shown in FIG. 1 is almost altogether manual and, notwithstanding a considerable skill developed to do this task, variations in skill and approach from worker to worker tend to result in undesirable variations in windings from core to core.

Techniques which might permit an automated manufacture such as plating of conductive paths or jig mounting of conductors have proven to be extremely difficult with core structures like that of 10, which is representative of a typical core winding scheme. Those skilled in the art will appreciate that many applications call for considerably more turns placed through an aperture than those shown.

Turning now to FIG. 2 there is shown a core 40 having the same overall function as the core 10 shown in FIG. 1. The core 40 includes major apertures 42 and 44 and the leg widths of the various legs of magnetic material are substantially the same or the equivalent to those in core 10 in FIG. 1. In lieu of simple minor apertures having multiple apertures at input, output and drive positions in these legs, the invention contemplates a series of turn positions placed in a closely spaced pattern to simulate multiple turns through a single aperture with the material itself serving to insulate between turns. These positions are labeled A, B, C and D, for the left half of the core, the right half having a similar array. The positions A, B, C or D may be defined by either holes or by conductive material, wires or pins. In accordance with one embodiment of the invention and contemplated thereby, a core like 40 may be molded, cast or pressed out of suitably prepared magnetic material to have the small holes therein in the pattern shown. The holes are made just large enough to accommodate a conductive pin or wire which is placed therein with the core then being fired with the wires in place. If this procedure is followed the wire utilized is, of course, uninsulated and must be of a material to

withstand the considerable firing temperatures employed. With ferrite material systems having firing temperatures up to 2,600° F. conductors such as platinum are recommended. It has been found that molding or casting is preferable when the holes are as small as is contemplated by the embodiments herein described, although pressing is fully contemplated.

Alternatively, and as another embodiment, the cores may be molded, cast or pressed in the geometry shown with small holes therein; the core fired and then, after firing, conductive material placed in the holes in the form of either precut pieces of uninsulated wire or plating material deposited therein.

As far as the invention is concerned the choice of one of the above procedures will depend to an extent upon the particular material used, the amount of usage contemplated for a given core geometry, and overall, the extent to which expected production will permit savings to be made. It is fully contemplated by the invention that the techniques may also be used to advantage with materials which do not require firing to the temperatures of the magnesium, copper or cobalt ferrite systems presently in use.

FIG. 3 shows the core of FIG. 2 with conductive wire or pin members P located at the input and output positions in the core. FIG. 4 shows the core of FIG. 3 in section with certain of the members P shown therein. In FIG. 5 a corner of the core 40 is shown enlarged with A, B and C, as positioned in a leg of the core. As a basic aspect of the invention A, B and C are positioned relative to each other with a certain spacing relative to the amount of material which will be linked when the conductive members P are joined to windings. Consider first the prime winding shown in FIG. 1 as lead 32 linking aperture 18 to prime flux set in the inner leg around into the outer leg of material surrounding 18. Referring to FIG. 6, a portion of the core is shown with the position A emphasized and the positions B and C, for the moment, de-emphasized and with flux set in the core as it would be when the left hand of the core contains a binary 1 or is in a set state. If a current is applied to P in the polarity shown in FIG. 7 an MMF will result which will switch the flux in the material about the pin, not under the coupling loop turns, into an orientation as indicated in FIG. 7. This is known as priming and the core half is driven into a primed set state preparatory to a transfer of the state stored in the core. As can be appreciated from FIG. 5, the amount of flux which can be transferred via the coupling loop is dependent upon the amount of flux set into the outer leg when the core is primed. The placement of position A with respect to the cross-section through the core material determines this amount of flux and, with the invention, the amount of flux which can be switched can be easily controlled.

In FIG. 5 there is shown a third cross-sectional area AWIII between A and a tangent touching both B and C. Generally, this area should be made as small as possible. For best efficiency on transfer of a binary 1 the areas should be made so that AWI is equal to or greater than $AWII + AWIII$. For minimum binary 0 output the areas should be made so that $AWI + AWII - AWIII$ is equal to or less than the area represented by W.

FIG. 8 shows a portion of the corner of the core with conductive member P placed through the positions B and C and with leads attached thereto for the purposes

of illustration to form a coupling loop linking the outer leg of core material by two turns equivalent to the windings shown in FIG. 1 or loop 24. The loop load is as represented. Current cause to flow in a coupling loop is dependent upon the voltage induced in these turns by flux switched thereunder. This flux is controlled by the amount of material in the cross-sectional areas BW or CW, shown in FIG. 5; the lesser area controlling if the areas are different. The total current caused to flow in the coupling loop is then the net current resulting from voltage induced in the windings responsive to flux switched through cross-sectional areas in BW and CW. It may be desirable to place points B and C relative to the core geometry to define a net cross-sectional area of material in which the flux switched is approximately equal to that switched in AWI so that the amount of flux switched during transfer under clear drive is substantially the same as the amount of flux primed under the coupling loops by the priming MMF applied to the conductor through position A. Again, the invention technique permits a variation in the amount of flux switched under the coupling loops by varying the positions B and C relative to the position A.

As can be appreciated, and as an important aspect of the invention, the winding difficulties which accompany the prior art approach, as indicated in FIG. 1, are reduced. Even in applications wherein it is desirable to place fixed pins through small apertures it has been found to be easier relative to the prior art to place fixed length, fixed size pins through fixed size apertures and then to connect such pins through printed circuits, soldering tabs or the like; easier from both a production control standpoint and labor involved. More importantly, the devices which result from the invention technique have a more consistent performance and, therefore, the overall reliability of a system is improved.

FIGS. 9, 10 and 11 relate to another embodiment of the invention, including a larger two bit position core structure having windings plated thereon to form a circuit like that of FIG. 1. The core shown as 50 includes four major apertures 52, 54, 56 and 58, defining four major paths of flux closure labeled O_1 , E_1 , O_2 , E_2 to represent odd and even bit positions. At the four outside corners are positions A, B, C for prime and coupling loop turns. The position D is for an input to the core and, particularly, to the bit position O_1 . A further position E is provided for a coupling loop input from a bit position such as O_1 to a bit position such as E_1 . The center aperture 59 is provided to eliminate nonsaturable material.

In accordance with the invention, the core 50 is molded with small holes at A, B, C, D and E. The core is then fired, cooled and the entire core is plated with plating material being deposited through the holes at A, B, C, D and E. Next, through standard photo-etch procedures, the windings shown in FIG. 7 are formed on the core structure. These windings include a prime winding 60 which extends through each position A to prime each bit position. The polarity shown indicates the desired circuit for serial transfer from O_1 to E_1 , E_1 to O_2 , O_2 to E_2 and out of the core. The coupling loops are formed as at 62, linking O_1 to E_1 ; at 64, linking E_1 to O_2 ; and at 66, linking O_2 to E_2 .

The linking conductive paths forming these windings are positioned so as not to contact each other, but to join with the positions A, B, C and D to complete the circuit.

Next, the entire assembly is insulated by a standard coating process and a second winding pattern forming the advance turns is deposited as shown in FIG. 10. FIG. 11 shows the insulation as 80. Winding 70 represents advance O drive and 72 represents the advance E drive. With suitable input and output connection made to the positions for advance and prime drive and for intelligence input and output, the structure may then be used as a two bit shift register.

It is contemplated that a variety of circuit devices having any of the additional standard functions such as logic or nondestructive readout may be made utilizing the invention technique.

In a core like 50 for shift register use the dimension in inches were as follows:

W = 0.063

AWI = 0.044

AWII = 0.028

AWIII = 0.012

Having now disclosed and described the invention in terms intended to enable its practice in a preferred mode, we define it through the appended claims.

What is claimed is:

1. A method of manufacturing wired core devices comprising the steps of: forming a multiaperture magnetic core body as by molding or casting of substantially unfired insulating magnetic material to define a geometry including a major aperture and a plurality of closely spaced minor apertures, firing said core body to provide permanent square loop characteristics to the material thereof, plating said body with a first layer of conductive material, minor apertures to define conductive paths extending through said body insulated each from the other only by material therebetween, selectively removing portions of said first layer of conductive material to define a first plurality of turns, covering said body and said first plurality of turns with a layer of insulating material, plating said layer of insulating material with a second layer of conductive material, and selectively removing portions of said second layer of conductive material to form a second plurality of turns.

2. The method of claim 1 including the additional step of selectively removing conductive material to define a drive circuit for said device.

3. The device of claim 2 including as a further step connecting said various turns to an input, output and drive circuit for operating said device in controlled states of magnetization.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,683,494 Dated August 15, 1972

Inventor(s) WILLIAM BAIRD FRITZ ET AL

It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

Claim 1, column 8, line 9, after "material," insert
- - - plating the walls of said - - - .

Signed and sealed this 2nd day of January 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents