Oct. 12, 1965 J. F. DUNDOVIC ETAL 3,211,843

MULTI-CHANNEL ELECTROMAGNETIC HEAD STRUCTURES

Filed March 29, 1962 2 Sheets-Sheet 1

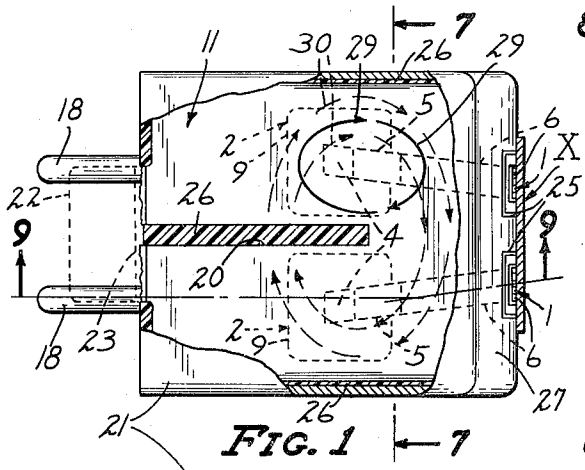


FIG. 1

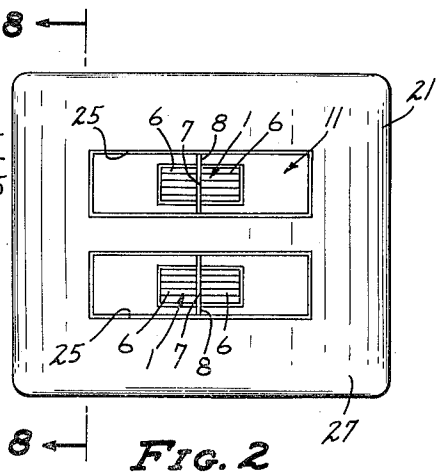


FIG. 2

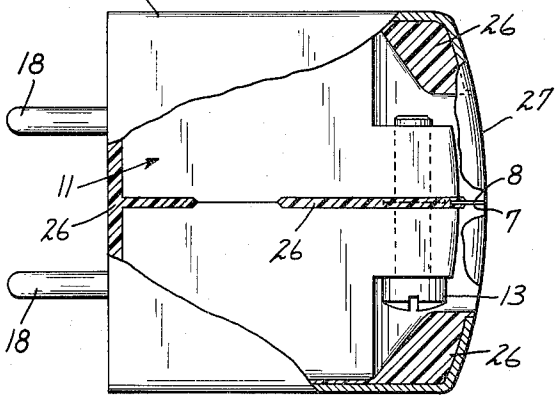


FIG. 3

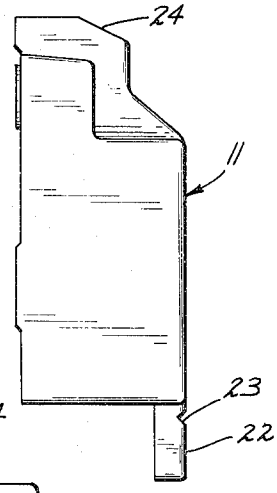


FIG. 4

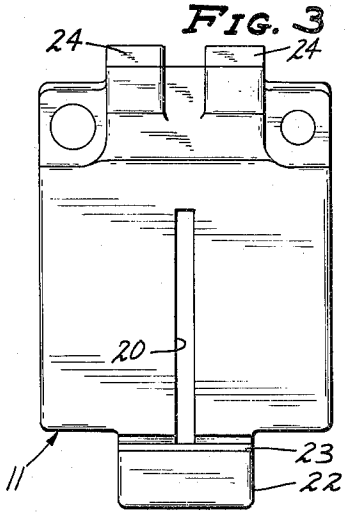


FIG. 5

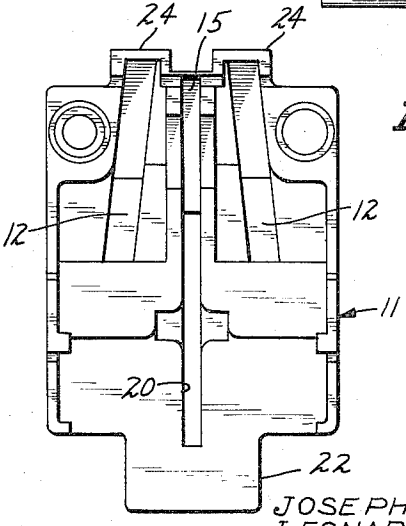


FIG. 6

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MULTI-CHANNEL ELECTROMAGNETIC HEAD STRUCTURES

Filed March 29, 1962 2 Sheets-Sheet 2

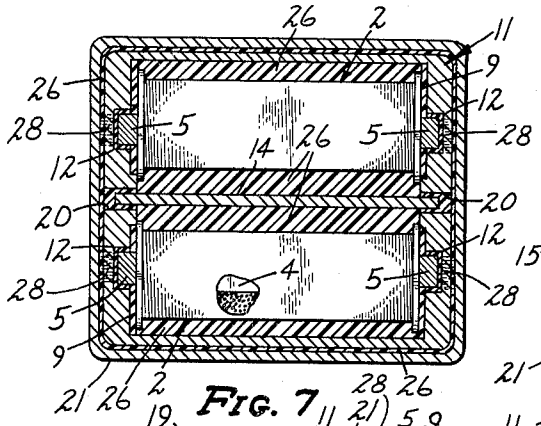


FIG. 7

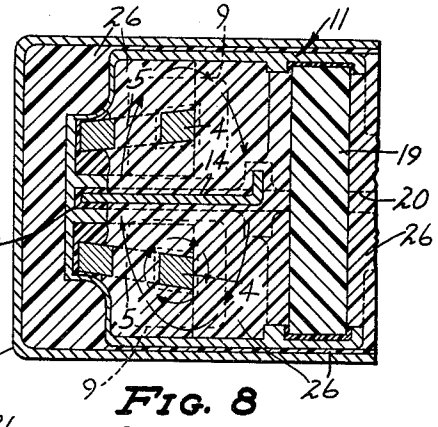


FIG. 8

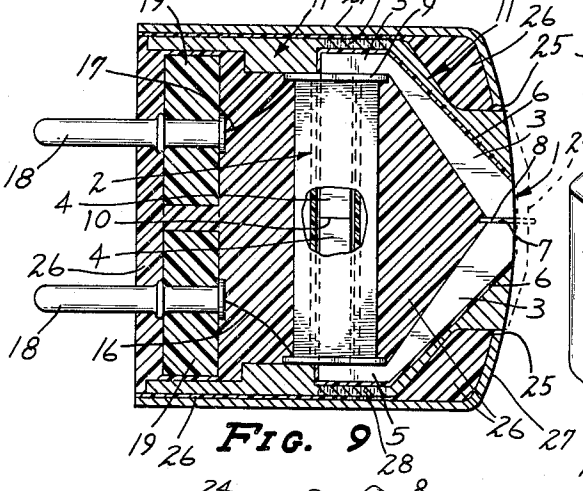


FIG. 9

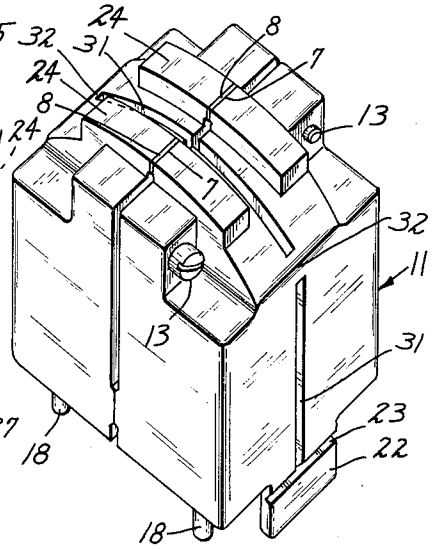


FIG. 10

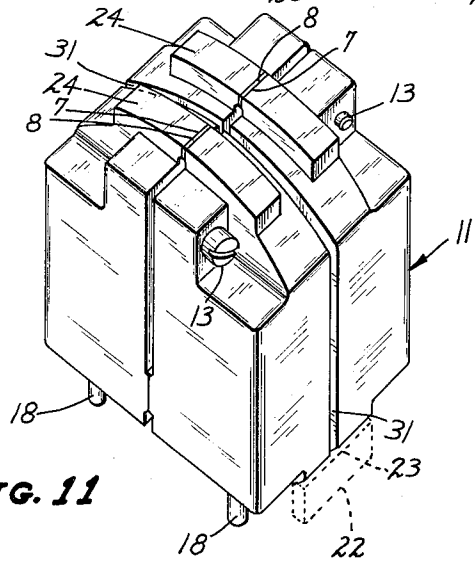


FIG. 11

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MULTI-CHANNEL ELECTROMAGNETIC HEAD STRUCTURES

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Filed Mar. 29, 1962, Ser. No. 183,647
8 Claims. (Cl. 179—100.2)

Generally stated, our present invention relates to improvements in multi-channel electromagnetic head structures used to record on and/or play-back from a cooperating magnetic record member, such as the conventional magnetic tape, a plurality of signal tracks each representing a different signal channel.

More specifically stated, our present invention may be said to relate to and to have as a major objective, the reduction of inter-channel cross-talk or coupling, due to circulating eddy currents, between any two electromagnetic transducers of a common multi-channel electromagnetic head. Still more particularly, the instant invention pertains to multi-channel transducer heads of the kind wherein a plurality of electromagnetic transducers are encased and held in a close fitting, electrically conductive, non-magnetic, inner shell of metal such as zinc, for example, which is then placed and secured in a close fitting, electrically conductive, magnetic outer shell or case of metal such as "Mu-Metal," for example.

Multi-channel head structures of the general character last above described have recently come to replace otherwise similar multi-channel head structures wherein the non-magnetic inner shell, which directly contains the plurality of transducers, was of a plastic material such as "Nylon" that is not electrically conductive and for that reason did not present the inter-channel cross-talk or coupling problem solved by the instant invention. In fact, inter-channel coupling or cross-talk between adjacent transducers of a common head structure, due to circulating eddy currents, did not arise until the said inner shells were made of an electrically conductive non-magnetic metal such as zinc, which has come to be preferred primarily due to the fact it presents a more desirable bearing surface for frictional contact with the magnetic record material at areas immediately adjacent the gap-defining portions of the cores of the individual transducers.

It appears that the reason for the presence of bothersome inter-channel coupling or cross-talk between different transducers of a common head structure wherein the inner shell directly containing the plurality of transducers is of electrically conductive non-magnetic metal, as distinguished from earlier structures wherein the said inner shell was of a plastic material that was not electrically conductive, is best explained as follows:

In multi-channel head structures of the kind described wherein the said inner shells are of electrically conductive non-magnetic metal, as well as in structures of the same general kind wherein the inner shells are not electrically conductive, laterally opposite portions of the core structures of the transducers that become oppositely polarized at any instant of activity are disposed in very close relationship to opposite side wall portions of the magnetic outer shell from which said oppositely polarized portions of the core structures are separated primarily by intervening wall portions of the non-magnetic inner shell. Hence, leakage flux flows between the said opposite polarized portions of the core structures of active transducers and the outer shell through the intervening wall portions of the non-magnetic inner shell; this flux leakage being most predominant in very compact or miniaturized structures wherein the spacing between elements is held to a minimum. The outer shell or shield may be considered to be

at zero, ground or neutral magnetic potential and to serve as a magnetic sink.

When the inner shell is electrically conductive the leakage flux passing therethrough produces or induces circulating eddy currents in the adjacent electrically conductive wall areas of the inner shell, some of which would, in the absence of this invention, encompass and link the core structure of an adjacent transducer; the circulating eddy currents thus produced by leakage flux from an active transducer tending to induce undesired magnetic flux signals in an adjacent transducer or transducers.

In accordance with the instant invention, the solution to this problem of inter-channel coupling or cross-talk caused by circulating eddy currents comprises the provision of elongated isolation slots in side wall portions of the electrically conductive non-magnetic inner shells separating adjacent areas of the shell walls which would, in the absence of suitable isolation slot means, jointly provide a field of circulation for inter-channel coupling eddy currents. This slotting technique has proven very successful and will hereinafter be described in greater detail.

In the accompanying drawing, like characters identify like parts throughout the several views.

Referring to the drawings:

FIGS. 1–11 are all on the same greatly enlarged scale with respect to head sizes considered generally acceptable for most commercial applications.

FIG. 1 is a view in side elevation with some portions of the magnetic metal outer shell and immediately underlying portions of the potting compound broken away in order to expose adjacent side surface areas of the non-magnetic metal inner shell of a two-channel transducer head embodying the invention;

FIG. 2 is a view in elevation of the record traversing end of the multi-channel head structure of FIG. 1, as viewed from right toward left with respect to FIG. 1;

FIG. 3 is a view in side elevation of the head of FIGS. 1 and 2 but showing the same rotated 90° about a horizontal axis with respect to FIG. 1 and having some parts of the electrically and magnetically conductive outer shell and potting compound broken away to expose adjacent side wall portions of the non-magnetic metal inner shell;

FIG. 4 is a view in side elevation of one of the two mating sections comprising the non-magnetic metal inner shell;

FIG. 5 is a view in elevation of a closed side of the non-magnetic metal inner shell section of FIG. 4 as it would appear viewed from right toward left with respect to FIG. 4;

FIG. 6 is a view of the open side of the non-magnetic metal inner shell section of FIGS. 4 and 5 as viewed from left toward right with respect to FIG. 4;

FIG. 7 is a transverse sectional view taken on the line 7—7 of FIG. 1;

FIG. 8 is a sectional view taken approximately on the line 8—8 of FIG. 2;

FIG. 9 is a sectional view taken on the somewhat irregular line 9—9 of FIG. 1;

FIG. 10 is an end and side perspective view of a completely assembled, dual-section, non-magnetic metallic inner shell, incorporating a somewhat modified embodiment of the invention with respect to the extent of the channel isolation slot means, and showing the inner shell as it appears after assembling and potting of a pair of transducers therein but prior to breaking off of the temporary connecting tabs and prior to the step of cutting out corner portions of the inner shell to connect closely associated isolation slot sections; and

FIG. 11 is a perspective view generally corresponding to FIG. 10 but illustrating the inner shell after breaking off of the temporary tabs which connect the side wall

areas of the inner shell otherwise divided by isolation slots and after connection of the isolation slot sections by sawing or the like to thereby provide one continuous isolation slot.

The multi-channel head illustrated comprises two identical electromagnetic transducers and each such transducer comprises a laminated core structure **1** and a multi-turn coil **2**. It will be understood that each of the laminated core structures is adapted to define, in combination with a suitable magnetic record member, a magnetic flux-conducting loop. As will be seen by reference to FIG. 9, each laminated core structure **1** comprises laterally opposed arms **3** that are connected at their rear or inner ends by a transverse connecting arm **4**. The laterally opposed arms **3** of each core structure comprise generally parallel inner portions **5** and forwardly or outwardly converging portions **6**. The outer ends of the converging portions **6** of the core arms **3** of the core structures **1** define between them a magnetic gap **7** the length of which is determined by a very thin shim **8** of non-magnetic material such as gold foil, for example. A spool **9** having wound thereon a suitable multi-turn coil **2** is telescopically mounted on the connecting arm **4** of each core structure **1**. Particularly by reference to FIG. 9 it will be seen that each laminated core structure **1** comprises a pair of identical core sections lying on opposite sides of a central plane passing through the centers of the magnetic gaps **7** and the longitudinal centers **10** of the connecting arms **4** of the two transducers.

As previously indicated, the plurality of transducers of the multi-channel head structures built in accordance with the instant invention are directly mounted in an inner shell or casing of electrically conductive non-magnetic metal such as zinc. Such an inner shell is indicated as an entirety in all figures hereof by the numeral **11**. In the preferred construction illustrated, this electrically conductive non-magnetic inner shell **11** is formed of two identical shell sections that are joined at a plane extending through the centers of the magnetic gaps **7** of the core structures **1** and the centers **10** of the coil receiving inner arms **4** of the core structures **1**. Also, in the preferred structure illustrated the laterally opposed sections of the core structures **1** of the two transducers are mounted in receiving grooves or channels **12** (see particularly FIGS. 6–9) of opposite sections of the said inner shell or casing **11**, which sections are primarily held together by suitable headed screws **13** that pass freely through one shell section and are screw threaded in the other shell section. Preferably, the core structures of adjacent transducers converge toward one another from their rear or inner coil receiving ends toward their outer or front gap-defining ends; this feature being best illustrated by dotted lines in FIG. 1 and by the core section receiving channels **12** of FIG. 6.

In preferred practice the half section of each laminated core structure **1** is seated in and adhesively secured in a channel **12** of its respective half section of the inner shell prior to the assembly of the two sections of the inner shell. With this accomplished, the open ends of the two inner shell sections, that are ultimately to be joined together with the ends of the sections of core structures **1** contained therein, are ground or otherwise finished to a common plane. Before joining the two sections of the inner shell **11** each now containing and mounting one half of each of the two core structures **1**, the spools **9** containing the multi-turn coils **2** are mounted each on a half section of an arm **4** of a different core structure **1** mounted in the same half section of the inner case or shell **11**. Following this the two shell sections are assembled together with a suitable gap-defining shim **8** between the ends of the opposite converging arm portions **6** of each transducer. After the two sections of the inner shell **11** have been duly secured and clamped together by the screws **13** the thin gap-defining shims **8** will be firmly clamped in place and a tight butt joint will be defined at **10** between opposite half sections of the coil receiving inner arms **4** of the core structures **1**.

In accordance with usual practice in multi-channel transducer construction, a shield **14** of suitable magnetic material such as "Mu-Metal" is disposed in the inner shell **11** and located in a plane passing between the two transducers, each of which transducers comprise a core structure **1** and a coil **2**. As will be seen by reference to FIG. 8, for example, the opposite sections of the inner shell **11** are formed with grooves or channels **15** in which the lower portions of the shields **14** are mounted and secured by means of a suitable non-conductive adhesive such as an epoxy resin.

By further reference to the drawings (see particularly FIG. 9) it will be seen that the coils **2** each terminate in leads **16** and **17** and that each lead of each coil goes to a different one of a pair of plug-in type contact prongs **18** that are fixedly mounted in a centrally perforated mounting panel **19**, of suitable insulating material, that is mounted in and largely closes the otherwise open rear end of the inner shell **11** and is held firmly in place by a suitable potting compound which is subsequently applied. As will be seen, this potting compound quite completely fills all otherwise void spaces within the inner shell and is preferably in the nature of a suitable epoxy resin that is applied in a liquid state through the perforations in the panel **19** and sets to a solid state providing a high degree of electrical insulation and having the characteristic of tightly bounding together all elements in contact therewith.

In the form of the invention shown in FIGS. 1–9 each half of the inner shell **11** is provided with an isolation slot **20**, each of which spans adjacent areas of a common wall of the electrically conductive non-magnetic inner shell **11** transversed by leakage flux between the core structures **1** and the magnetic outer case or shell **21**. The inner ends of these isolation slots **20** of FIGS. 1–9 extend beyond the inner ends of the shell sections **11** and are originally closed at their inner or rear ends by means of break off tabs **22** which serve to strengthen the structure until final assembly is completed and are thereafter broken off along weakening channels or score lines **23**. Obviously, after the tabs **22** are broken off the isolation slots **20** are open at their rear ends.

The front end of the inner shell **11** is provided with arcuate projecting portions **24** which receive and originally enclose the gap-defining outer or front end portions of the core structures **1** but which, as will hereinafter be seen, are subsequently ground off to expose the gap-defining ends of the core structures **1**.

The usual next step in the assembly of the multi-channel head structure of FIGS. 1–9 comprises the inserting of the inner case or shell **11**, together with its contained core and coil structures **1**, **2** and mounting panel **19**, into the outer case or shell **21** which is shown as being and preferably is a single unit structure of electrically conductive magnetic material such as "Mu-Metal." The side walls of this outer shell or casing **21** completely surround and overlie the sides of the inner shell **11** with very little space therebetween. The rear end of the outer shell **21** is completely open, whereas the outer or front end of the outer shell **21** is arcuate and closed except for apertures **25** which receive the arcuate projections **24** of the inner shell **11**.

The inner and outer shells **11** and **21** respectively, are adhesively bonded together by a suitable adhesive which can be and preferably is the same epoxy resin potting compound employed to fill all void spaces within the inner shell **11** and which, epoxy resin potting compound, is indicated in the drawings by **26**. Generally the break off tabs **22** of the inner shell **11** will not be broken off until the void spaces in the inner shell **11** and the outer shell **21** have been completely filled with adhesive potting compound **26** or the like.

Initially, the arcuate projections **24** of the inner shell

11 and the gap forming end portions of the core structures 1 will project somewhat beyond the arcuate surface of the outer shell, as shown best by dotted lines in FIG. 9. As a final step in finishing a multi-channel head structure of the kind described, those portions of the inner shell projections 24 and core tips projecting beyond the arcuate outer surface of the outer shell 21 will be ground and honed to expose the gap-defining end portions of the core structures and providing a uniform arcuate surface comprising the outer or front end wall 27 of the outer shell 21, the now outer end portions of the projections 24 of the inner shell 11, and the now exposed outer end portions of the core structures 1 defining the magnetic gaps 7. In FIG. 9, dotted lines show the projecting outer end portions of the core structures 1 and and the inner shell projections 24 as they appear before finishing, as described above, and by full lines when finished by grinding and honing, for example.

OPERATION OF FIGS. 1–9

When either of the transducers comprising a core structure 1 and coil structure 2 is rendered active, as by application of an electrical signal to its coil 2 for the purpose of recording on a suitable magnetic record, such as a conventional magnetic tape record illustrated by X in FIG. 1, or by recovery of play-back of a signal previously recorded on the tape record X, the opposite portions 5 of that active transducer core structure 1 will become opposely polarized at any given instant and flux will leak therebetween and the outer shell 21, as indicated by dotted flow lines 28 of FIGS. 7 and 9. As previously indicated, this flux leakage between the laterally opposite portions 5 of the core structures 1 and the outer casing 21 passes through the non-magnetic electrically conductive inner shell 11. As also previously indicated, this flux leakage through the electrically conductive inner shell produces circulating eddy currents in the adjacent inner shell wall portions, some of which circulating eddy currents tend to and will, if preventive measures are not taken, cover a field that encompasses and links the core structures 1 of an adjacent transducer and induce in the latter inter-channel coupling magnetic flux signals corresponding to the magnetic flux signals in the active transducers from which the circulating eddy currents originated. The flux leakage through the inner shell is indicated by dotted flow lines 28 in FIGS. 7 and 9 and the resulting circulating eddy currents are shown by flow arrows in FIGS. 1 and 8. Referring particularly to FIG. 1, localized and unharmful circulating eddy currents in a wall of the inner shell 11 are shown by full line flow arrows 29 and eddy currents that would cover a much larger field sufficient to produce cross inter-channel coupling between adjacent transducers in the absence of the instant invention are shown by dotted flow arrows 30 in said FIG. 1. However, by reference to the drawings and particularly to FIG. 1 it will be seen that the field of inter-channel coupling eddy currents, as indicated by dotted arrows 30, has been interrupted by the isolation slots 20 which effectively interrupt electrical continuity between adjacent side wall portions of the inner shell separating adjacent areas thereof which would, in the absence of isolation slots, provide a very efficient field of circulation for inter-channel coupling eddy currents.

While isolation slots 20 of the extent shown in FIGS. 1–9 will generally provide satisfactory protection against inter-channel coupling due to eddy currents caused by flux leakage through the electrical conductive inner shell, it will, nevertheless, sometimes prove advantageous to increase the length or lengths of the isolation slot means and that is precisely the purpose of the modification shown in FIGS. 10 and 11. Referring to FIGS. 10 and 11, it will be seen that the inner shell, as shown in its finished form shown in FIG. 11, is provided with an isolation slot 31 that extends completely through diametrically opposite side walls of the inner shell 11 and completely through the front end wall thereof, so that after the break off tabs 22 have been removed the inner shell will actually be divided into two halves spaced apart by the width of a continuous slot 31. In carrying out this form of the invention it will generally be preferred, in the interest of structural rigidity during the assembling process, to leave adjacent portions of the isolation slot 31 adjacent the junctions of the inner shell front end wall and side walls unconnected or bridged as shown at 32 in FIG. 10. These connecting portions 32 can then be readily cut away with a saw after the various components have been duly assembled and adhesively secured together with the inner shell.

Our invention has been thoroughly tested and found to be completely satisfactory for the accomplishment of the objectives set forth; and, while we have shown and described a preferred embodiment of our invention, and a single modification thereof, it will be understood that the same is capable of further modification without departure from the spirit and scope of the invention, as defined in the claims.

What we claim is:

1. In a multi-channel electromagnetic head for use with a relatively movable magnetic record medium:

(a) a plurality of closely associated laterally spaced electromagnetic transducers each adapted to serve a different channel;

(b) said transducers each comprising a core structure and a coil structure;

(c) said core structures each defining a magnetic flux conducting loop having a flux gap therein adapted to be disposed adjacent the surface of a cooperating magnetic record medium;

(d) said loop defining core structures each having a front portion wherein said gap is located, a rear portion generally opposite the said front portion, and laterally spaced side portions connected by said rear portion;

(e) each of said core structures and an associated portion of a magnetic recording medium being adapted to define a magnetic flux circuit;

(f) the coil structure of each of said transducers comprising a coil mounted on the rear portion of its respective cooperating core structure;

(g) an electrically conductive non-magnetic inner shell structure in which said transducers are mounted in close laterally spaced relationship;

(h) said electrically conductive non-magnetic inner shell structure having side wall portions substantially surrounding said transducers and portions of which are in very close proximity to the opposite side portions of said core structures;

(i) a magnetically conductive outer casing having side walls surrounding the side walls of the electrically conductive non-magnetic inner shell and being in such close proximity to a side wall portion of the inner shell structure and the side portions of the core structures of adjacent transducers that magnetic flux flowing in the core structure of an active one of said transducers will leak through said electrically conductive non-magnetic inner shell to the magnetically conductive outer casing;

(j) the leakage flux from the core structure of one transducer, upon passing through the non-magnetic electrically conductive inner shell, inducing in the adjacent wall portion of said inner shell circulating electrical eddy currents some of which would, in the absence of the hereinafter described improvement, encompass and link the core structure of an adjacent transducer and thereby induce in the latter undesired magnetic flux signals; the improvement comprising:

(1) said electrically conductive non-magnetic inner shell defining an elongated isolation slot in

a side wall portion of the inner shell separating adjacent areas of said shell wall portion which would, in the absence of said isolation slot, provide the field of circulation for interchannel coupling eddy currents;

(2) said isolation slot extending unidirectionally with respect to and being closely associated with a plane passing between adjacent transducers.

2. The structure defined in claim 1 wherein opposite side wall portions of said electrically conductive non-magnetic inner shell defines an elongated isolation slot.

3. The structure defined in claim 1 in which said slot is open at one of its ends and closed at the other of its ends.

4. The structure defined in claim 1 wherein the said isolation slot is closed at its front end but open at its rear end.

5. The structure defined in claim 2 wherein the said opposite side walls of the inner shell define different isolation slots each of which is open at one of its ends and closed at the other of its ends.

6. The structure defined in claim 2 wherein the said opposite side walls of the inner shell define different isolation slots each of which is open at its rear end and is closed at its front end.

7. In a multi-channel electromagnetic head for use with a relatively movable magnetic record medium:

(a) a plurality of closely associated laterally spaced electromagnetic transducers each adapted to serve a different channel;

(b) said transducers each comprising a core structure and a coil structure;

(c) said core structures each defining a magnetic flux conducting loop having a flux gap therein adapted to be disposed adjacent the surface of a cooperating magnetic record medium;

(d) said loop defining core structures each having a front portion wherein said gap is located, a rear portion generally opposite the said front portion, and laterally spaced side portions connected by said rear portion;

(e) each of said core structures and an associated portion of a magnetic recording medium being adapted to define a magnetic flux circuit;

(f) the coil structure of each of said transducers comprising a coil mounted on the rear portion of its respective cooperating core structure;

(g) an electrically conductive non-magnetic inner shell structure in which said transducers are mounted in close laterally spaced relationship;

(h) said electrically conductive non-magnetic inner shell structure having side wall portions substantially surrounding said transducers and portions of which

are in very close proximity to the opposite side portions of said core structures;

(i) a magnetically conductive outer casing having side walls surrounding the side walls of the electrically conductive non-magnetic inner shell and being in such close proximity to a side wall portion of the inner shell structure and the side portions of the core structures of adjacent transducers that magnetic flux flowing in the core structure of an active one of said transducers will leak through said electrically conductive non-magnetic inner shell to the magnetically conductive outer casing;

(j) the leakage flux from the core structure of one transducer, upon passing through the non-magnetic electrically conductive inner shell, inducing in the adjacent wall portion of said inner shell circulating electrical eddy currents some of which would, in the absence of the hereinafter described improvement, encompass and link the core structure of an adjacent transducer and thereby induce in the latter undesired magnetic flux signals; the improvement comprising:

said electrically conductive non-magnetic inner shell defining an elongated isolation slot dividing the inner shell into electrically isolated adjacent shell sections, said slot being closely associated with and extending unidirectional with respect to a plane passing between adjacent transducers.

8. A multi-channel electromagnetic head for use with a relatively movable magnetic record medium comprising:

(a) a plurality of closely associated laterally spaced electromagnetic transducers each adapted to serve a different channel;

(b) an electrically conductive nonmagnetic inner shell structure having side wall portions substantially surrounding said transducers, said electrically conductive nonmagnetic inner shell defining an elongated isolation slot in a side wall portion of the inner shell;

(c) and a magnetically conductive outer casing having side walls surrounding the side walls of the electrically conductive nonmagnetic inner shell.

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