ELECTROMAGNETIC TRANSDUCER HEAD ASSEMBLY

Filed April 27, 1948 2 Sheets-Sheet 1

Fig. 1

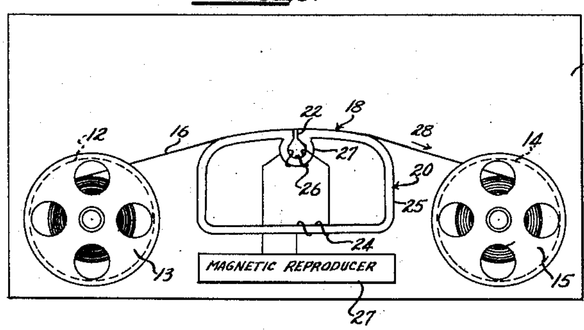


Fig. 2

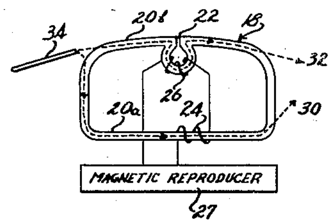


Fig. 3

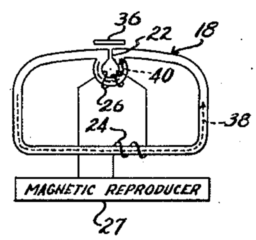


Fig. 4

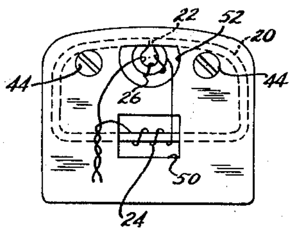


Fig. 5

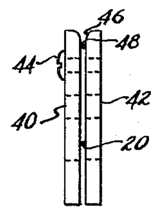


Fig. 6

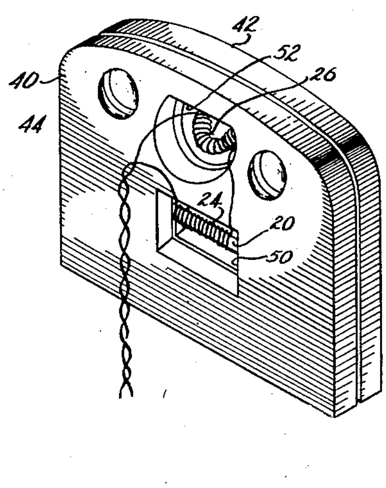
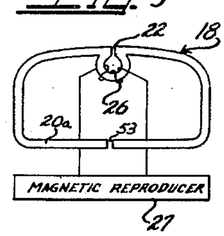


Fig. 9



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Jan. 16, 1951 R. E. ZENNER 2,538,405

ELECTROMAGNETIC TRANSDUCER HEAD ASSEMBLY

Filed April 27, 1948 2 Sheets-Sheet 2

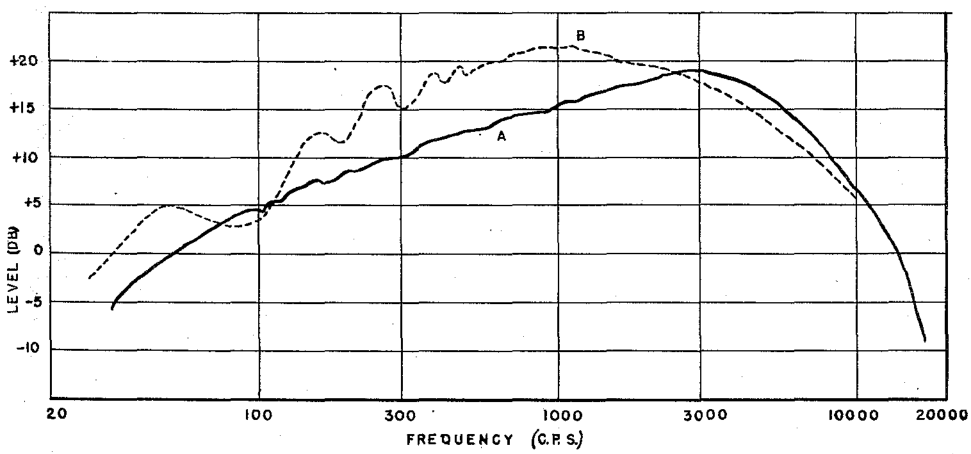

Fig. 7

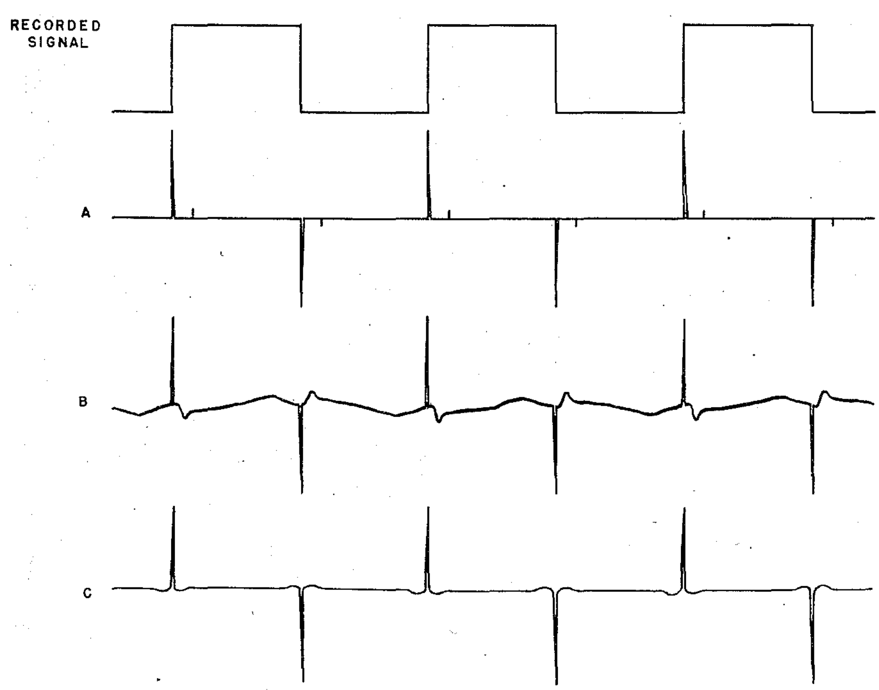

Fig. 8

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UNITED STATES PATENT OFFICE

2,538,405

ELECTROMAGNETIC TRANSDUCER HEAD ASSEMBLY

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Application April 27, 1948, Serial No. 23,507

7 Claims. (Cl. 179—100.2)

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My invention relates to an electromagnetic transducer head assembly and more particularly to an electromagnetic transducer head assembly especially suitable for converting variations in the degree of magnetization along the length of a lengthy magnetized record medium to a time-varying electromotive force.

In one form of recording an intelligence on a lengthy magnetizable record medium, the medium is passed across an electromagnetic transducer head to impart variations in the degree of magnetization along the length thereof in accord with the time variations of the intelligence. This electromagnetic transducer head may include a core member having confronting pole pieces defining a non-magnetic gap and across which the lengthy magnetizable record medium is caused to travel. A coil encircles this core member and current is caused to flow therethrough in accord with the time variations of the intelligence, thus causing a time-varying magnetic field across the air gap. As the medium is drawn across the confronting pole pieces, successive incremental portions thereof are subjected to the flux set up at the air gap at the time of traveling thereover, thereby causing the medium to be magnetized along its length in accord with the time variations of the intelligence.

During the reproducing operation, the magnetized record medium is drawn across the same or a similar electromagnetic transducer head assembly in like fashion. In this case, however, as each incremental portion of the medium passes across the non-magnetic gap, magnetic flux is produced in the core in accord with the degree of magnetization of that incremental portion. Thus, the flux in the core experiences time variations in accord with the passage of the medium thereover and the time variations of the intelligence recorded on the medium. This time-varying flux produces an induced voltage in the coil encircling the core member, which voltage may be amplified and converted by a loudspeaker or similar device to the original intelligence such as, for example, sound waves.

It is well known that for perfect fidelity of operation the various frequency components of the recorded intelligence should be reproduced with like intensity. To achieve this end in a practical manner, it is desirable in magnetic recording and reproducing mechanisms to prevent variations in the intensity of the reproduced intelligence over small changes in frequency. This is a consequence of the fact that while uniform gradual changes over a wide frequency range can

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be overcome by suitable equalizer networks, sudden and abrupt changes are difficult or impossible to compensate.

It is further necessary in electromagnetic transducer head assemblies to provide a mechanism that is relatively insensitive to stray alternating magnetic fields such as those associated with the operation of power transformers, alternating current motors, and the like. Such stray magnetic fields are exceedingly difficult to avoid in magnetic recorders and reproducers and most effective operation demands that their effects on the reproduced intelligence be minimized.

Still another desirable feature of an electromagnetic transducer head is that the reluctance of the iron be relatively small as compared with the non-magnetic gap while at the same time the non-magnetic gap is of small size for good resolution. Moreover, auxiliary non-magnetic gaps should be avoided as these reduce the output voltage of the head, thereby increasing the noise level of the reproduced intelligence and requiring an increased degree of amplification.

It is therefore a general object of the present invention to provide an improved electromagnetic transducer head assembly.

Further, it is an object of the present invention to provide an improved electromagnetic transducer head assembly wherein the output voltage varies in a uniform manner with frequency.

Yet another object of the present invention is to provide an improved electromagnetic transducer head assembly that is inherently insensitive to stray magnetic fields.

An additional object of the present invention is to provide an improved electromagnetic transducer head assembly having the foregoing advantages and which, in addition, requires only a single non-magnetic gap and in which the reluctance of the iron is relatively small as compared with the non-magnetic gap.

My invention further resides in features of construction, combination and arrangement whereby a new and improved electromagnetic transducer head assembly that is simple in construction and reliable in operation is provided to the end that a unit of maximum utility is achieved.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic top plan view of a complete magnetic recorder incorporating an electromagnetic transducer head assembly of the type contemplated by the present invention;

Figure 2 is a diagrammatic view illustrating how the electromagnetic transducer head assembly of the present invention is insensitive to magnetic variations along the lengthy magnetizable medium as they approach the head;

Figure 3 is a diagrammatic view illustrating how the electromagnetic transducer head assembly of the present invention is sensitive to magnetic variations along the record medium extending over the non-magnetic gap portions thereof;

Figures 4 and 5 are side and end views respectively of a complete electromagnetic transducer head assembly constructed in accordance with the principles of the present invention;

Figure 6 is an isometric view of the head shown in Figures 4 and 5;

Figures 7 and 8 are charts illustrating actual performance achieved with an electromagnetic transducer head like that shown in Figures 4, 5 and 6; and

Figure 9 is a view of an alternative embodiment of the present invention.

In Figure 1 there is shown a top plan view of a complete magnetic recorder incorporating an electromagnetic transducer head constructed in accordance with the principles of the present invention. As shown in this view, the assembly includes a top panel 10 upon which a pair of spaced disks 12 and 14 are rotatably mounted in spaced position relative to each other with their axes parallel. Mounted on the disks 12 and 14 are a pair of spools 13 and 15 upon which is wound lengthy magnetizable medium such as a wire 16. The wire 16 extends between spools 13 and 15 and is transferable therebetween by rotations thereof.

An electromagnetic transducer head assembly 18 is disposed between the spools 13 and 15 to engage the medium 16 in the region that it travels therebetween. This head includes a magnetic core 20 defining the non-magnetic gap 22 across which medium 16 travels and a pair of magnetic circuits including this gap as a portion thereof. One of these circuits is formed by the U-shaped portion 25 of the core 20 and is linked by the bucking winding 24. The other circuit is formed by the O-shaped portion 27 of the core 20 and is linked by the signal winding 26. Windings 24 and 26 are connected in series relationship across the magnetic reproducer unit 27.

During operation of the mechanism of Figure 1, the disk 14 is rotated by suitable mechanical drive elements (not shown) to rotate spool 15 and cause travel of medium 16 in the direction of arrow 28. The disk 12 is retarded in its rotation by a suitable brake, thus retarding spool 13 to maintain the medium 16 taut in the region between the spools and across the head 18. As the medium 16 travels across the head 18, the quantities of magnetic flux linked by the coils 26 and 24 are changed relative to each other, thereby causing a net induced voltage across the series connected coils which is applied to the reproducer 27. The reproducer 27 includes an amplifier to increase the power level of the induced voltage across the coils 24 and 26, together with a suitable converting device such as, for example, a loud speaker. Thus, as the induced voltage in coils 24 and 26 varies with time in accordance with variations in the degree of magnetization of medium 16 along its length, the resultant voltage is amplified and converted to the original intelligence, namely, sound.

In a practical head constructed as shown in Figure 1, the signal coil 26 might have 40 turns and the bucking coil 24 might have 26 turns. The core 20 might comprise a single lamination about 0.015 inch thick and the various portions of the core might be about 0.031 inch wide, giving about 0.0005 square inch cross-sectional area. The O-shaped core portion 26 might have an outer radius of about 0.125 inch and the U-shaped portion 25 might define a rectangle about 0.5 inch by 0.75 inch with the edge adjacent non-magnetic gap 22 tapered off along a radius of about 1½ inches. The coil 24 is wound in bucking relationship with coil 26 so that increasing flux in like direction through these coils induces opposing voltages.

In Figure 2 there is shown a portion of a lengthy bar magnet 34 defining a magnet pole positioned adjacent the corner of the head 18. This magnet is representative of the situation existing when a magnetic variation in the medium 16 approaches the head 18 from one side. As indicated by the dashed lines and the arrows 30 and 32, this magnet pole tends to cause flux passage through the bottom portion 20*a* and the top portion 20*b* of the core 20 in like direction, so that as the pole 34 approaches the head 18 the flux increase in like direction linking coils 24 and 26 takes place. Consequently, opposing voltages are induced in these coils and the voltage applied to the reproducer 27 is much less than if either coil 24 or coil 26 alone is used.

It will be observed that with the representative magnet 34 in the position shown, the length of the flux path followed by flux threading coil 24 is comparable in length to the flux path followed by flux threading coil 26. While it is difficult to predict exactly all the paths followed by the various flux elements and the quantity of flux in each path, it will be evident that a proportioning of the numbers of turns in windings 24 and 26 will give no net voltage at reproducer 27 for one position of the representative magnet 34.

In Figure 3 there is shown the head 18 with a representative bar magnet 36 positioned directly across the air gap 22. This magnet represents the effect of the portion of the medium 16 (Figure 1) located directly over the air gap 22. As will be evident from Figure 3, flux from the representative magnet follows two paths, one path linking the coil 24 as indicated by the arrow 38 and the other path linking the coil 26 as indicated by the arrow 40. Thus, the magnet acts to cause magnetic flux linking coils 24 and 26 in the same direction as does the magnet 34 (Figure 2).

It will be noted, however, that the length of the flux path followed by the flux encircling the coil 24, as indicated by the arrow 38 (Figure 3), is very much greater in length than the path followed by the flux indicated by the arrow 40 and linking the coil 26. Since these two flux paths are effectively in parallel insofar as the magnet 36 is concerned, it will be evident that the quantity of the flux following the path of arrow 40 is greatly in excess of the quantity of flux following the path of arrow 38. Consequently, if the relative numbers of turns on coils 24 and 26 are proportioned to give a small or no resultant induced voltage in the case of the representative magnet of Figure 2, there will be a substantial induced voltage in the case of the magnet 36 of Figure 3.

From the foregoing it will be evident that as a magnet pole in the medium 16 traverses the head 18, the value of the flux encircled by coil 24 is varied relative to the value of the flux encircled by the coil 26. Hence, the induced voltages in these coils are determined by the time rate of change of these separate fluxes, and the net voltage appearing across the reproducer 27 is correspondingly varied. When the magnet pole approaches and recedes from the head, these induced voltages are nearly in balance and little or no net voltage is produced. However, when the magnet pole is over the non-magnetic gap 22, these voltages are out of balance and a substantial net induced voltage is produced.

Stray alternating magnetic fields such as those associated with transformers, alternating current motors, and the like, cause magnetic fields of force of substantially constant direction over the effective dimensions of the electromagnetic transducer head 18. Consequently, these fields tend to produce magnetic flux linking the windings 24 and 26 in like direction and thus act much as the flux from the bar magnet 34 (Figure 2) in producing opposed electromotive forces giving no net voltage for application to reproducer 27.

Figures 4 and 5 are side elevational and end elevational views respectively of a complete electromagnetic transducer head assembly constructed in accordance with the principles of the present invention and intended for use in connection with a lengthy magnetizable medium such as wire. This assembly includes a core portion 20 having U-shaped lower section with its bottom leg encircled by the coil 24 and an O-shaped section encircled by the coil 26. These two sections combine to define a common air gap 22. The core portion 20 is positioned between two spaced non-magnetic members 40 and 42 which are urged against each other by the screws 44. At their upper portions these non-magnetic members define a V-shaped notch 46 to receive the lengthy magnetizable record medium. The core 20 is provided with a slot 48 in aligned relationship with the V-notch 46 to receive the medium 16. The V-notch 46 acts to retain the medium 16 when a knot or other obstruction in the same causes the latter to ride out of the groove 48.

The blocks 40 and 42 are provided with windows 50 and 52 to receive the windings 24 and 26, respectively.

Figure 6 is an isometric view of the complete electromagnetic transducer head shown in Figures 4 and 5.

It will be observed from the views of the figures that the core member 20 defines two magnetic circuits having the common non-magnetic gap 22. Moreover, the confluences or points of connection of these two circuits are near the common gap 22. One of these circuits, namely, the U-shaped circuit including the portions 20*a* and 20*b* (Figure 2) and the side portions is of relatively great length and, in addition, it defines portions adacent the air gap 22 to receive the medium 16. The other of these circuits is of relatively short length and is relatively remote from the medium 16 throughout its length.

Figure 7, curve A, shows an output characteristic of an electromagnetic transducer head such as that shown in Figures 4 to 6. This characteristic was obtained by measuring the electromotive force applied to the reproducer 27 as the medium 16 was drawn at uniform velocity across the head. The medium 16 actually used for this purpose had variations in magnetization imparted along its length corresponding to a range of frequencies, the constant current imparted in the case of each frequency being held constant.

It will be observed that the output voltage of the head 18 (curve A), as measured on the decibel scale in Figure 7, forms a substantially straight line in the region from 40 to 3000 cycles, and that there are no substantial sudden rises or falls in this line. This line corresponds to the theoretical response curve corresponding to low frequencies, and in a practical reproducer 27 the voltage may be made effectively constant by utilizing a suitable integrating or equalizing network. Above 3000 cycles it will be observed that the output voltage drops off in a substantially even and uniform fashion. In this region it is likewise possible to provide a suitable equalizing network to overcome the variations in the output level of the head.

Curve B (Figure 7) shows the response characteristics obtained with a typical electromagnetic transducer head assembly of the prior art, namely, an assembly having a core portion defining a single non-magnetic gap across which the medium rides and a coil surrounding that core portion. As will be evident from Figure 7, the response of the head rises and falls in the region from 20 to almost 1000 cycles. This characteristic results from the effect of magnetized portions of the wire approaching the edge of the head and alternately bucking or boosting the flux associated with movement of the medium across the non-magnetic gap. It is extremely difficult if not impossible to compensate for these rises and falls by equalizing networks in the magnetic reproducing equipment. For this reason magnetic recorders using such heads have not provided uniform frequency response.

Figure 8 is a diagram showing the results of a further test indicative of the performance of the head of the subject invention. In this test, a 20 cycle per second saturating square wave was recorded on a wire traveling at 4 feet per second. Signals were picked up with various heads, amplified, and applied to the vertical deflection plates of an oscilloscope. A saw-tooth sweep was applied to the horizontal plates, thus producing an apparently stationary picture of the induced voltage in the winding of the head.

The curve A (Figure 8) shows the nature of the voltage induced in the winding of a "closed type" electromagnetic transducer head having a coil encircling the non-magnetic gap itself when the medium described above travels over the non-magnetic gap thereof. In a head of this type the flux associated with approach of the medium to the head tends to encircle the portions of the core other than those portions encircled by the coil and hence tends to produce no voltage. As will be evident from curve A, the reproduced signal corresponds almost exactly to the time rate of variation of the recorded signal, the only departure from this characteristic being the small pips following each major pip and which are due to crossing of the magnetic reversals from erase head laminations to the record-pickup head laminations. The latter effects can be eliminated if desired.

It is, of course, well recognized that a closed type head such as that for which curve A (Figure 8) was obtained has very substantial disadvantages in practical magnetic recorders because of the difficulty of threading the medium through the head.

Curve B (Figure 8) is a curve taken under the same conditions as curve A but with the head for which the curve B (Figure 7) was obtained. It will be evident from this figure that the reproduced voltage departs substantially from the time rate of variation of the recorded signal and contains many spurious dips and bumps. These correspond to the uneven response of this head to various frequencies since if a uniform response were achieved the curve B would correspond identically with the time rate of variation of the recorded signal.

Curve C (Figure 8) shows the induced voltage in the head of the present invention under the same conditions as curves A and B. As will be evident from this curve, the departures from the perfect response curve are very greatly reduced and the resultant voltage corresponds very nearly with the perfect response. This is due to the fact that the initial and final contacts of magnetic reversals of the wire with the head create flux changes threading both coils 24 and 26 to produce no resultant voltage. When a reversal is moving in the region between an initial and final contact with the head, the proportion of the flux through each coil changes, thus producing the slow rises and falls of voltage between the desired pips.

In Figure 9, an alternative embodiment of the present invention is shown. As indicated in this figure, the core 20 comprises a U-shaped portion and an O-shaped portion, each defining a common air gap 22. The single coil 26 encircles this air gap and is directly connected to the reproducer 27. This head functions to eliminate most of the effects of stray magnetic fields and the effects due to the lengthy magnetizable medium approaching the air gap 22 since it defines a shunt magnetic path about the coil 26 which has a varying proportion of the total flux passing through it as the position of the magnetic variation in the medium changes. A non-magnetic gap 53 is provided in the lower portion 20*a*. The structure shown in Figure 9 has been found advantageous under certain circumstances, but is not considered to give the outstanding advantages of the structure shown in Figure 2.

In the appended claims I have described the direction of windings 24 and 26 as in such direction as to produce opposing voltages upon change in the flux of the air gap 22. By reference to Figure 3, it will be evident that when the flux traversing the coils 24 and 26 is in the direction of the arrows 38 and 40 (the direction to which the output voltage is in opposition), the flux across the air gap corresponding to the arrows 38 and 40 is of like direction.

In the foregoing specification I have described the structure of the present invention in detail and in addition I have explained what I believe to be its mode of operation. It will, of course, be understood that I do not wish to be limited thereto since many modifications both in the circuit arrangement and the structures disclosed may be made without departing from the spirit and scope of my invention. I, of course, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

I claim as my invention:

1. An electromagnetic transducer head assembly for use with a lengthy magnetizable record medium including a core member defining two magnetic loops having spaced portions as well as a common non-magnetic gap, said loops being integrally joined at portions near said common gap, and a pair of windings each encircling a respective one of said loops said windings being electrically connected in series relationship to produce opposed induced voltages therein upon change in the flux of said gap.

2. An electromagnetic transducer head assembly for use with a lengthy magnetizable record medium including a core member defining two magnetic circuits having spaced portions and a common non-magnetic gap, said circuits being integrally joined at portions near said common gap, one of said circuits having relatively great reluctance when viewed from said gap as compared to the reluctance of the other, a pair of windings each linking a respective one of said circuits, and electrical circuit means connecting said windings in series relationship to produce opposing voltages upon change in flux across said gap.

3. An electromagnetic transducer head assembly for use with a lengthy magnetizable record medium including a magnetic core member defining two magnetic circuits having spaced portions and a common non-magnetic gap, said circuits being integrally joined near said common gap and on each side thereof, one of said circuits having a relatively great reluctance when viewed from said gap as compared to the reluctance of the other, said one circuit including opposed magnetic portions adjacent said gap to guide said medium through said non-magnetic gap, and a winding linking said other circuit.

4. An electromagnetic transducer head assembly for use with a lengthy magnetizable record medium including a core member defining two spaced magnetic circuits having a common non-magnetic gap, said circuits being integrally joined near said common gap, one of said circuits having relatively great reluctance when viewed from said gap as compared to the reluctance of the other, said one circuit including opposed portions adjacent said gap to receive said medium, and a pair of windings each linking a respective one of said circuits, said windings being electrically connected in series and oppositely wound to produce opposing induced voltages therein upon change in the flux of said gap.

5. An electromagnetic transducer head assembly having a core member defining a non-magnetic gap and two individual magnetic circuits therethrough, one of said circuits comprising a relatively short length of magnetizable material shunting said gap and the other a relatively long length of magnetizable material defining portions adjacent said gap to receive said medium as it approaches and leaves said gap and portions of said core member connecting said circuit portions, a winding linking said one magnetic circuit, a winding linking said other magnetic circuit, said windings being connected in series and oppositely wound to produce oposed induced voltages upon change of flux through said gap, said windings being proportioned to produce negligible net voltage when a magnetic change in said medium approaches or leaves said head assembly.

6. An electromagnetic transducer head assem-

bly having a core member defining a non-magnetic gap and two individual magnetic circuits of substantially equal cross-section, said circuits being joined near said gap, one of said circuits comprising a relatively short length of magnetizable material shunting said gap and the other a relatively long length of magnetizable material of greater reluctance than said short length circuit defining opposed portions adjacent said gap to receive said medium as it approaches and leaves said gap and a magnetic circuit connecting said portions, and a winding linking said one circuit.

7. An electromagnetic transducer head assembly for use with a lengthy magnetizable record medium, including a first magnetic core portion defining a non-magnetic gap and having portions adjacent said gap to receive said medium as it approaches and leaves said gap, a second magnetic core portion having greater magnetic reluctance than said first magnetic core portion and shunting said gap, and a winding encircling said second magnetic core portion.

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