April 12, 1949. R. S. CURRY, JR 2,466,690

VARIABLE INDUCTOR

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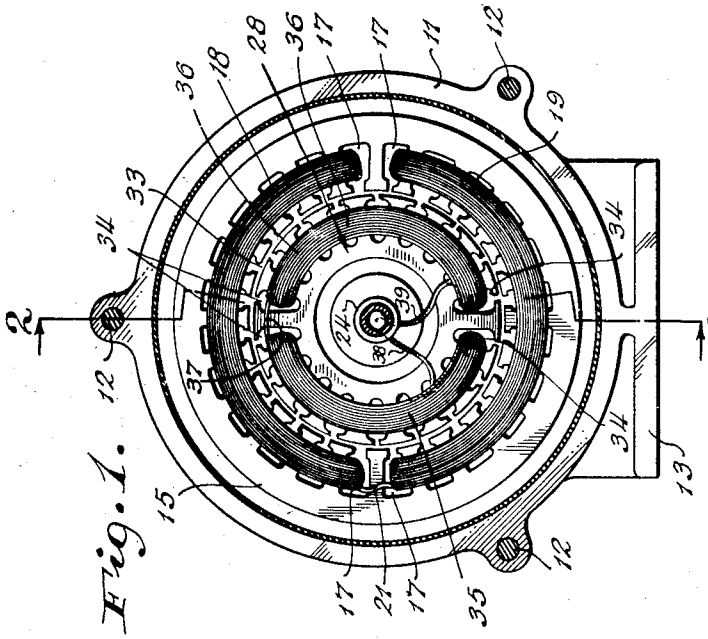


Fig. 1.

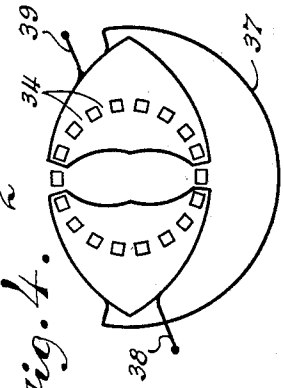


Fig. 4.

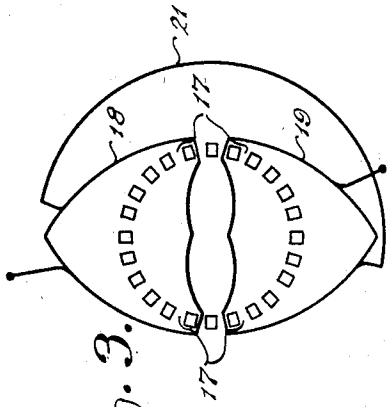


Fig. 3.

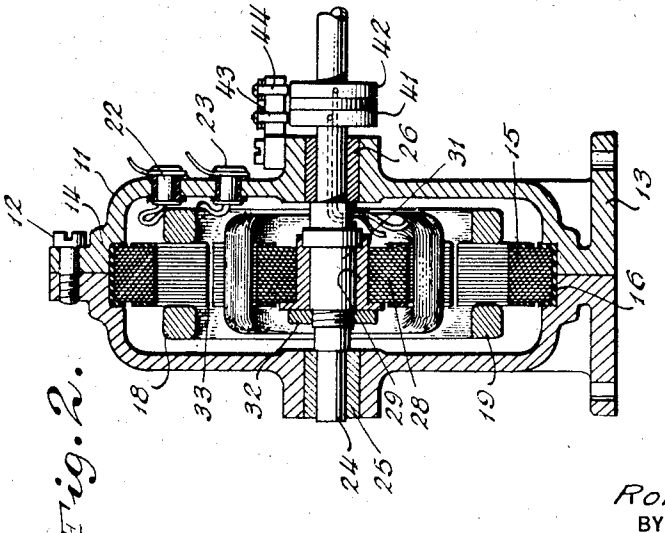


Fig. 2.

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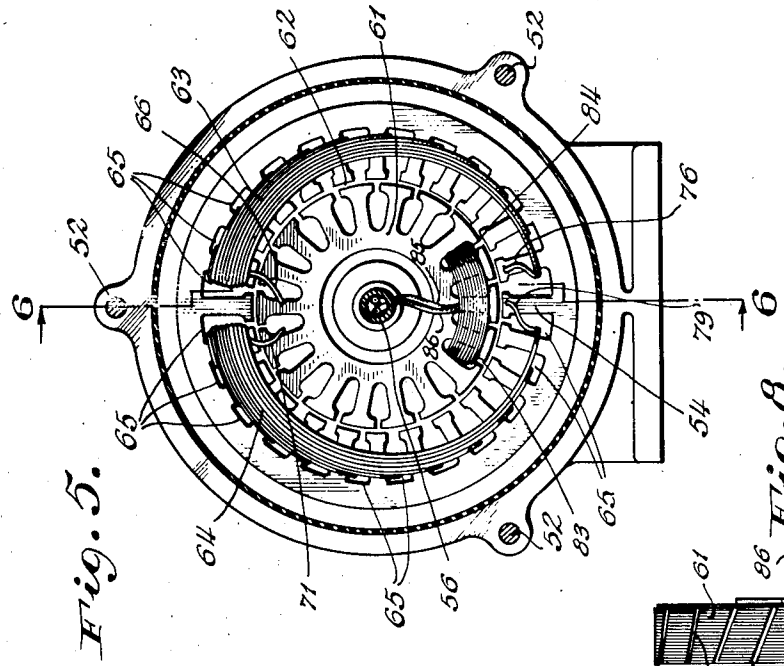


Fig. 5.

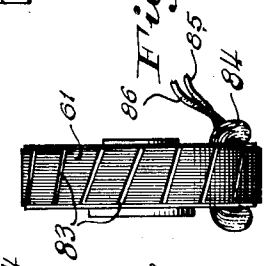


Fig. 8.

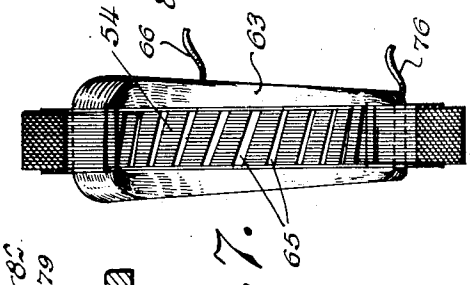


Fig. 7.

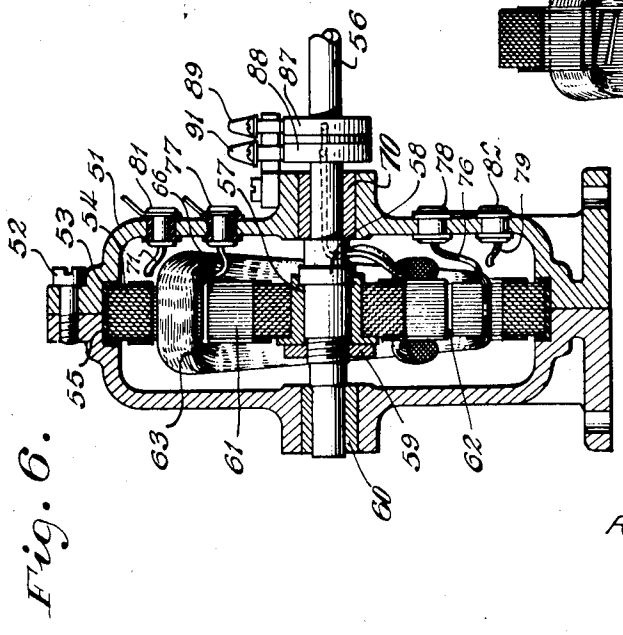


Fig. 6.

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Fig. 9.

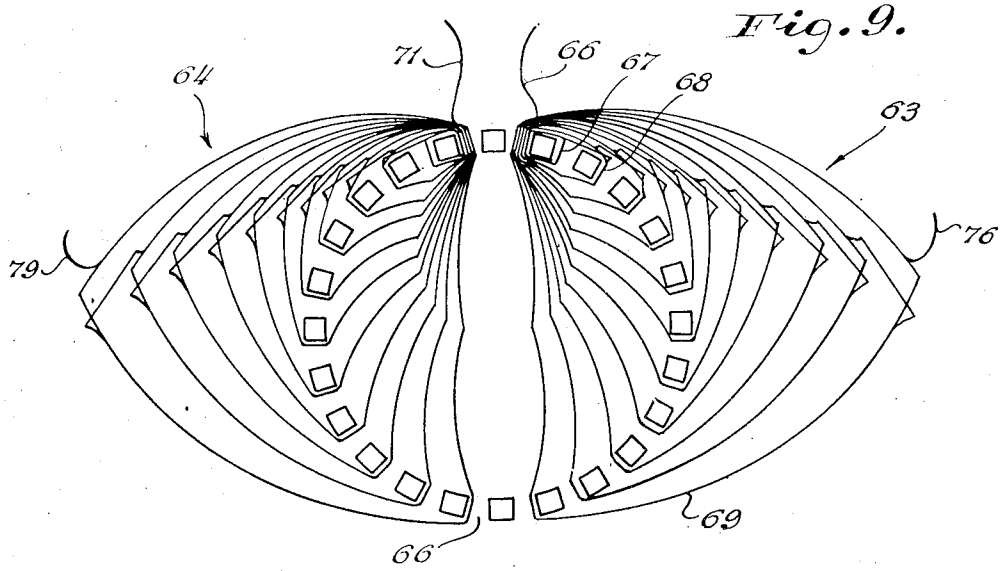
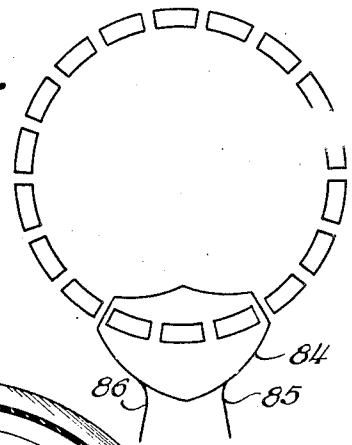


Fig. 10.



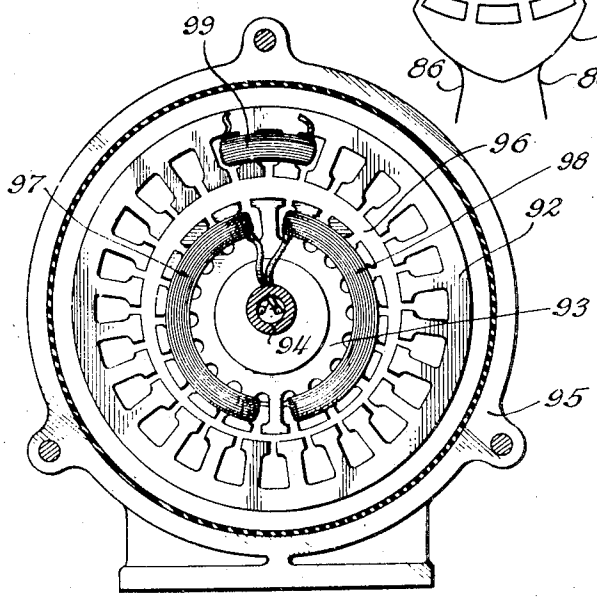


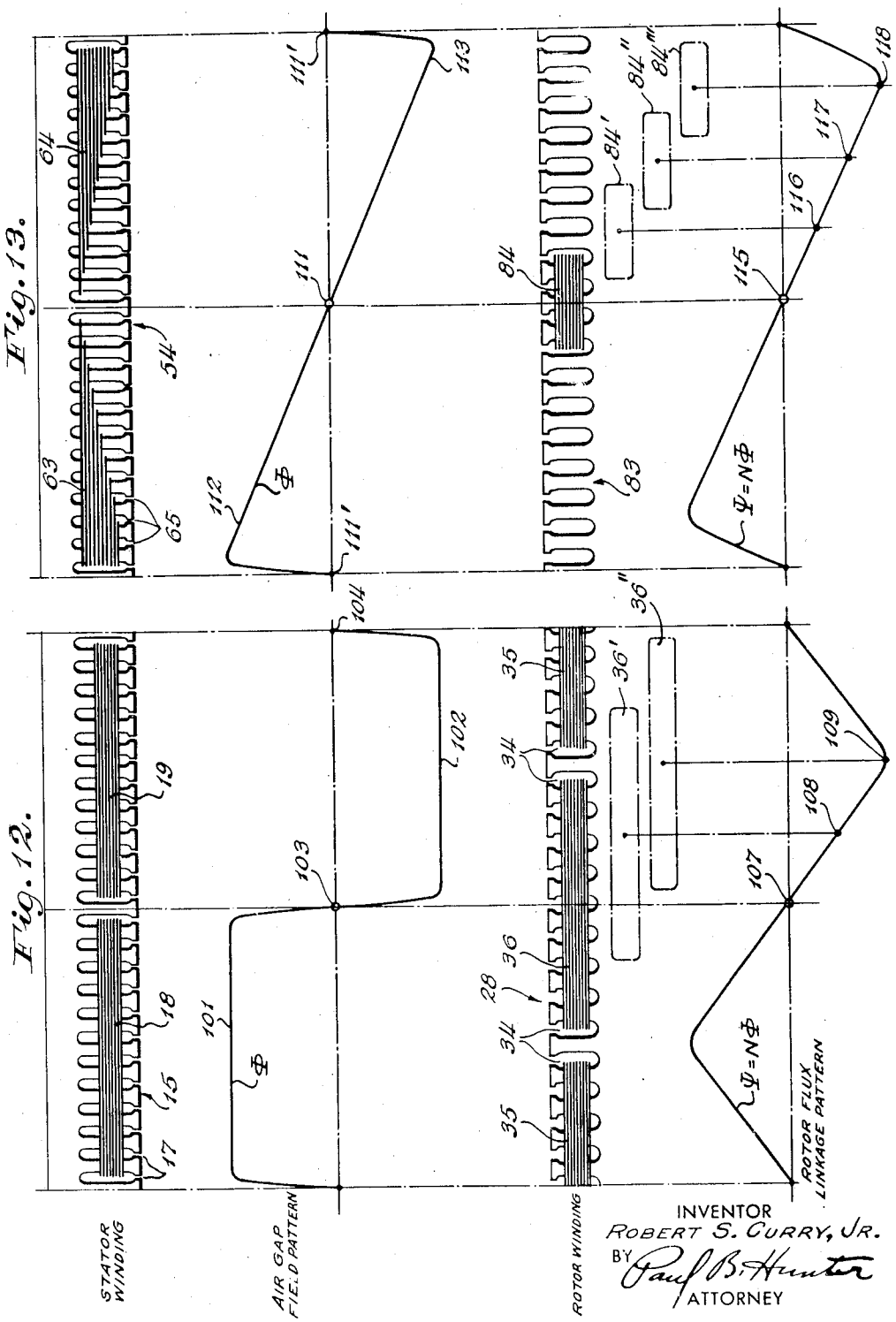
Fig. 11.

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VARIABLE INDUCTOR

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Patented Apr. 12, 1949 2,466,690

UNITED STATES PATENT OFFICE

2,466,690

VARIABLE INDUCTOR

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Application July 19, 1944, Serial No. 545,699

11 Claims. (Cl. 171—242)

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This invention relates to variable inductors, and particularly concerns variable inductors of the signal transformer type in which two windings are relatively rotatable to vary the inductive coupling therebetween for modifying the output according to the relative rotation of the windings.

The usual purpose of variable inductors of this type is to produce an output signal from a secondary winding that depends upon the signal applied to the primary winding and is modified according to the relative angular positions of the two windings. Heretofore, relative rotation of the two windings varied the output in more or less sinusoidal fashion.

While a sine function is desirable in some applications of variable inductors, it is frequently preferable to obtain an output signal that is a linear function of the angular displacement. That is, for a constant input signal, the output is substantially proportional to the relative displacements of the primary and secondary windings.

In some cases, linear functions have been approximated by conventional variable inductors wherein only the linear portion of the sine function is used. At best, this provides only a rough approximation of a linear function and is limited to a range of displacement of less than 30 electrical degrees about zero output. Such limitation on the range of operation of the inductor limits its efficiency and usefulness as an instrument.

An important object of the invention is to provide an improved variable inductor in which the output is a linear function of the relative displacement of the two windings of the inductor.

Another important object of the invention is to provide an improved variable inductor in which the flux linkage of the secondary winding is substantially proportional to the relative angular displacement of the primary and secondary windings.

A further object of the invention is to provide an improved variable inductor having a linear characteristic relating input and output signals and which is of simple economical construction and arranged for efficient operation.

Other objects of the invention, particularly with regard to arrangement of parts for convenience, and other special advantages will become apparent in connection with the following description and accompanying drawings illustrated and embodied in the subject of the invention.

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In the drawings,

Fig. 1 is a side elevation of a variable inductor embodying the invention in one form, shown with a portion of the casing removed and some parts in section for purposes of clarity;

Fig. 2 is a vertical section of the variable inductor taken on the line 2—2 of Fig. 1;

Fig. 3 is a schematic winding diagram showing the arrangement of the coils forming the primary winding;

Fig. 4 is a schematic winding diagram showing the arrangement of the coils forming the secondary winding;

Fig. 5 is a side elevation of a variable inductor embodying a modified form of the invention, shown with a portion of the casing removed and some parts in section;

Fig. 6 is a vertical section of the variable inductor taken on the line 6—6 of Fig. 5;

Fig. 7 is a vertical section of the primary winding with the secondary core member removed;

Fig. 8 is an elevation view of the secondary core member;

Fig. 9 is a schematic winding diagram showing the arrangement of the coils forming the primary winding of the modified form of the invention;

Fig. 10 is a schematic winding diagram showing the arrangement of the secondary winding of the modified form of the invention;

Fig. 11 is a side elevation of a further modified form of the invention, shown with a portion of the casing removed and some parts in section;

Fig. 12 shows the relation of the field pattern to the windings of the variable inductor shown in Figs. 1 and 2, and the flux linkage with respect to the secondary or pick-up winding for various relative positions of the two windings; and

Fig. 13 shows the relation of the field pattern to the windings of the variable inductor shown in Figs. 5 and 6, and the flux linkage with respect to the secondary or pick-up winding for various relative positions of the two windings.

In accordance with the invention, a pair of ferromagnetic members are supported for relative rotation and are separated by an air gap. A primary winding is arranged on one of these members to produce, when properly excited, a magnetic field in the air gap between the two members. This winding is preferably so arranged as to produce two opposite poles along the air gap by either reversing connections or direction of winding of the two coils forming the primary winding.

A secondary winding is arranged on the other member adjacent the air gap so the two windings

are inductively coupled by the magnetic field in the air gap. Dependent upon the flux distribution of the magnetic field in the air gap, as determined by the arrangement of the primary winding, the characteristics of the secondary winding are selected so that the flux linkage thereof varies proportionately to the angular displacement of the two windings upon their relative rotation.

By arranging the primary winding to produce uniformly distributed flux in the gap and providing a full pitch secondary winding, the flux linkage of the secondary winding is substantially proportional to the relative displacement of the two windings over a range of 60 electrical degrees or more in either direction from a neutral or zero position between the two poles.

An even greater range may be obtained by producing an unevenly distributed flux in the air gap so the flux density varies at a uniform rate over each pole face. This may be accomplished by starting with a number of turns at one end of one pole face and progressively increasing the number of turns toward the other end or by providing a variable air gap and uniform windings thereabout. Thus, the flux density in the gap is substantially proportional to the distance along the pole face. Preferably, two of these windings are arranged so opposite pole faces extend in different directions along the gap both with their flux densities increasing according to the displacement from the neutral point between the two poles. By arranging a fractional pitch, e. g. one-quarter pole pitch, lumped secondary winding adjacent the air gap, the flux linkage of the secondary winding varies linearly over a range of 150 electrical degrees or more on either side of the neutral point providing a total operation range of greater than 300 electrical degrees.

Referring now to Fig. 1, there is shown a variable inductor having a two-part casing **11**, the parts of which may be secured as by bolts **12**, **12** and having a flanged base portion **13** for mounting the inductor on a suitable support. The casing **11** is formed with a groove **14** (Fig. 2) extending circumferentially around its inner wall to carry a pile of ring shaped ferromagnetic laminations insulated from the casing **11** by a suitable lining **16** and formed with slots **17**, **17** adapted to receive coils **18** and **19** connected together as at **21** to form a primary winding, the leads from which may be connected to suitable terminals **22** and **23** mounted in but insulated from the casing **11**.

A shaft **24** is rotatably supported as by bushings **25** and **26** in the casing **11**. A number of ferromagnetic lamination discs **28** arranged to form a core are supported on a sleeve **29** held on the shaft **24** by bolt **31** and nut **32**. The core laminations **28** are so arranged that when supported on the shaft **24** they are separated from the shell laminations **15** by a small air gap **33** extending entirely around the core.

The core laminations **28** are also formed with suitable slots **34**, **34** adapted to receive coils **35** and **36** having their ends connected as at **37** to form a secondary winding with leads **38** and **39** extending through shaft **24** to slip rings **41** and **42**, respectively. Brushes **43** and **44** may be mounted on the casing **11** to contact slip rings **41** and **42**, thereby providing output terminals from the secondary winding.

As shown most clearly in Fig. 3, the coils of the primary winding are lumped windings and extend along approximately one-half of the air gap. The coils as shown in the drawings are oppositely connected so they provide two pole faces of opposite polarity extending along the air gap. Since each of these coils surrounds a portion of the shell formed by the ferromagnetic laminations **15** around the air gap, the flux density in the air gap along the two pole faces is substantially uniform.

In Fig. 12, coils **18** and **19** of the stator winding are shown diagrammatically as developed in a straight line along the air gap with the slots **17** in laminations **15** also developed in a straight line. Directly below these windings is a curve representing the air gap flux (ϕ) produced by the windings **18** and **19** at any selected instant. As may be seen in Fig. 12, the air gap flux (ϕ) is substantially uniform at points **101** and **102** along the pole faces surrounded by coils **18** and **19**. Variations in the uniform flux occur only at points **103** and **104** between the poles. Thus, for a given excitation of the terminals **22** and **23**, coil **18** produces a uniform flux of a selected polarity along substantially one-half of the air gap, whereas coil **19** produces a similar uniformly distributed magnetic field of opposite polarity along the other half of the air gap. Since coils **18** and **19** are electrically connected in series-aiding and have equal turns, the two fields are of equal magnitudes.

With this arrangement of the primary windings for producing a uniformly distributed flux in the air gap and a full pole pitch lumped secondary winding adjacent the air gap, the flux linkage of the secondary winding varies proportionately to the relative angular displacement of the two windings.

Referring again to Fig. 12, the secondary windings **35** and **36** as well as rotor laminations **28** are shown as being developed along a straight air gap of the same length as the stator laminations **15**.

Since the two windings are supported for relative movement, as by turning the shaft **24**, the flux linkage of the secondary coil may be adjusted by turning the shaft. In the positions of the windings shown in Figs. 1 and 12, the secondary coil **36** is linked equally with the flux produced by the primary coil **18** and that produced by the primary coil **19**. Since the flux produced by these two primary coils is of opposite polarity, the resultant effective linkage (ψ) is zero, as indicated at **107** on the flux linkage curve corresponding to the position of the center line of the coil. However, for displacement in either direction, the flux linkage with flux from one of the coils is reduced, whereas that from the other is increased.

For example, the coil **36** may be moved to a position designated **36'** (Fig. 12) where it envelops more flux from coil **19** and less from coil **18**; the resultant flux linkage (ψ), has an indicated negative value as represented by point **108** on the flux linkage curve. When the coil **36** is in position designated **36''**, it envelops substantially all of the flux produced by coil **19**, so the flux linkage (ψ) reaches a maximum as represented by point **109** on the flux linkage curve. If the coil **36** is moved in the opposite direction, the resultant flux linkage increases in a positive direction toward a maximum point where the coil **36** envelops all of the flux produced by primary coil **18**.

Since the flux density in the air gap is uniform, this increase and decrease in flux linkage of the secondary coil **36** is proportional to the angular

displacement of the shaft **24**. It will be apparent from an examination of Fig. 12 that the direction of the change in flux linkage will reverse after the shaft **24** has been turned through an angle of 90 degrees in either direction. It is not practical to produce perfectly uniform flux in the air gap, so the change in the flux linkage may deviate from a linear function for angular displacement of the shaft **24** exceeding 70 or 80 degrees. As shown in Fig. 12, the peaks of the flux linkage curve are rounded due to the variations **103** and **104** in the flux.

The foregoing discussion in connection with coil **36** applies equally to the secondary coil **35** and since the two coils are connected, as shown in Fig. 4, by a jumper **37** to add the voltages induced in the two coils, the resultant output signal of leads **38** and **39** is a voltage proportional to the angular displacement of the shaft **24**. Since the voltage is proportional to the rate of change of flux, it will be apparent that the variable inductor described changes the voltage induced in the secondary winding as a linear function of the relative angular displacement of the two windings. In this manner, the electromotive force induced in the coils **35** and **36** of the secondary winding is substantially proportional to the angular displacement of shaft **24** and the voltage output from the variable inductor that appears at brushes **43** and **44** is a linear function of the angular displacement of the shaft **24**.

As stated above, the linear response characteristic of the variable inductor shown in Fig. 1 drops off for angular displacements between the two windings exceeding 70 or 80 electrical degrees. Therefore, the effective range in which the output is a linear function of angular displacement is limited to a maximum of approximately 150 degrees.

If it is desired to obtain an output signal over a greater range of angular displacement, a variable inductor, such as that shown in Fig. 5, may be used. This modified variable inductor also includes a two-part casing **51** held together by suitable bolts **52**, **52** and formed interiorly with a circumferential groove **53** for supporting shell laminations **54** insulated from the casing **51** by fiber lining **55**.

A shaft **56** is journaled in the casing **51** as by bushings **60** and **70**. The shaft **56** has a bushing **57** mounted thereon as by bolt **58** and nut **59** for carrying core laminations **61** spaced from the shell laminations **54** by an air gap **62**.

In this form of the invention, primary coils **63** and **64** are wound in suitable slots **65**, **65** formed in the shell laminations **54** to produce two opposite poles, each extending approximately one-half way around the air gap. However, the coils **63** and **64** are so arranged that the flux (ϕ) in the air gap varies uniformly along the air gap as shown in Fig. 13. This is accomplished by progressively increasing the number of turns wound in each slot **65** along the respective pole faces, as shown most clearly in Fig. 9. This type of winding is sometimes referred to as a stairstep winding.

It may be seen in Fig. 9 that coil **63** beginning at lead **66** is wound for a certain number of turns as represented at **67** in the first and second slots along the pole face and an equivalent number of turns as represented at **68** is wound in the first and third slots. In this manner, the number of turns effective along the pole face is gradually reduced until an equivalent number of turns as represented at **69** is wound in the first and last slots along the pole face.

It will be apparent from an examination of Fig. 9 that the flux density in the air gap adjacent the last slot is produced solely by the turns **69**, whereas that in the first slot is a maximum, since it is the sum of the flux produced by all of the turns.

The coil **64** is similarly arranged starting from lead **71** and gradually reducing the number of effective turns producing flux in the air gap. With this arrangement, each of the coils **63** and **64** produces a magnetic field in the air gap **62**. The flux density in the air gap is unevenly distributed and varies at a uniform rate along the gap adjacent each of the coils due to the progressively increasing number of turns wound in each slot.

Thus, starting from the lower center portion of the shell laminations **54**, as seen in Fig. 5, the effective flux (ϕ) in the air gap at a point equally spaced between the two coils **63** and **64** is zero as represented by point **111** in Fig. 13. Since the number of turns in each slot progressively increases in both directions from this neutral point, the flux density in the air gap increases at a uniform rate to positive maximum **112** in one direction and a negative maximum **113** in the other direction.

Leads **66** and **76** from the coil **63** are connected to terminals **77** and **78**, whereas leads **71** and **79** from the coil **64** are connected to terminals **81** and **82**, respectively. With this arrangement, the coils may be excited in any desired fashion, but are preferably arranged so the magnetic fields produced in the air gap **62** are of opposite polarity adjacent to pole faces provided by the two coils.

The core laminations **61** are provided with suitable slots **83**, **83** adapted to receive a secondary winding **84**. The slots **83**, **83** are so arranged that the secondary winding **84** is only a fractional portion of a pole pitch. This is preferably approximately one-quarter or one-third of the pole pitch, as shown most clearly in Figs. 10 and 13. Output leads **85** and **86** on the secondary winding **84** are connected through the shaft **56** to slip rings **87** and **88** which engage brushes **89** and **91**, providing outputs from the variable inductor.

In the position of the secondary winding **84**, as shown in Figs. 5 and 13, a minimum flux produced by the windings **63** and **64** links the secondary winding **84**. Since the fluxes from the windings **63** and **64** are of opposite polarity, the effective flux linkage of the secondary winding **84** is zero as represented at point **115** on the flux linkage curve of Fig. 13. Upon a change in the relative angular positions of the primary and secondary windings in either direction, the flux linkage of the secondary winding **84** will increase, the polarity of the increase being dependent upon the direction of rotation. As the angular displacement continues to increase, the flux linkage of the secondary winding **84** continues to increase at a uniform rate, because the flux density in the air gap **62** increases at a uniform rate in either direction.

As illustrated in Fig. 13 for the position of coil **84** as represented by **84'**, the flux linkage (ψ) has a value corresponding to point **116** on the flux linkage curve. Similarly for positions **84''** and **84'''**, the flux linkage (ψ) corresponds to the points **117** and **118**. For corresponding positions in the opposite direction, the flux linkage again varies uniformly, but with opposite sign. Since the induced voltage is proportional to the rate of change of the flux linkage, the uniform variation of the flux linkage of the secondary winding **84** induces a uniform electromotive force there-

in, providing an output potential at brushes 89 and 91 which is substantially proportional to the relative angular positions of the primary and secondary windings corresponding in turn to the angular displacement of shaft 56.

The flux density in the air gap increases at a uniform rate until the end of the respective pole faces is reached, so the linear output of the variable inductor is faithful over a range exceeding 150 degrees in either direction. It will be apparent, therefore, that this latter embodiment of the invention provides a variable inductor having a linear characteristic that is effective over a total range exceeding 300 degrees.

Fig. 11 shows a modified form of variable inductor embodying the invention in which the magnetic reluctance of the air gap is varied to provide a uniformly varying flux which in turn produces a change in the flux linkage of the secondary winding which is substantially proportional to the relative angular displacement of the primary and secondary windings. A ferromagnetic shell formed of circular laminations 92 is arranged to receive a rotor formed of circular laminations 93 mounted eccentrically on shaft 94 that is supported concentrically within casing 95 surrounding the shell laminations 92. Since the rotor laminations 93 are eccentric on the shaft 94 that coincides with the center of the circular laminations 92, the rotor laminations 93 are eccentric with respect to shell laminations 92, thereby producing a variable width air gap 96 between the two ferromagnetic members.

Primary coils 97 and 98 are wound on the rotor laminations 93, each extending substantially half way around the rotor and arranged adjacent the air gap. A secondary or pickup coil 99 is wound on stator laminations 92 in the form of a fractional pitch lumped winding with respect to primary windings 97 and 98.

Since the width of the air gap 96 varies around the circumference of the core laminations 93, the reluctance of the magnetic circuit from one of the primary coils through the air gap, the stator laminations, back through the air gap to the other coil, varies around the circumference of the core. This has the effect of producing a variable flux density in the air gap, the maximum flux density occurring at the narrowest point of the air gap and the minimum flux density at the widest point thereof. With this arrangement it will be apparent that the flux pattern in the air gap will correspond to the flux diagram of Fig. 13, in which the zero point 111 corresponds to the widest portion in the air gap and point 111' corresponds to the narrowest point in the gap. The wide and narrow portions are arranged intermediate the two primary windings 97 and 98, so the flux in the air gap increases around the circumference of the rotor in each direction from the zero points. The increase is gradual in both directions from the wider portion of the air gap but more rapid adjacent the narrower portion thereof.

In the position shown in Fig. 11, the pickup winding 99 envelops equal portions of the flux produced by the coils 97 and 98, so the resultant flux linkage in the pickup winding 99 is zero. As the shaft 94 is turned, the eccentric rotor laminations 93 and primary windings 97 and 98 are turned relative to the secondary winding 99. This turning movement also moves the wide point of the air gap with respect to the secondary winding 99, so the resultant flux linkage gradually increases in proportion to the relative angular displacement of the primary and secondary windings until a maximum position is reached at a point adjacent the narrowest portion of the air gap.

As previously described in connection with the other forms of the invention, the voltage induced in the secondary winding is proportional to the rate of change of the flux linkage of the secondary winding, therefore the voltage induced in secondary winding 99 is proportional to relative angular displacement of the primary and secondary windings as determined by the position of shaft 94.

In the variable inductors shown in Figs. 5 and 11, the flux distribution varies around the air gap in a more or less linear fashion. Since the pickup coil is a lumped fractional pitch winding, the voltage induced therein depends upon the relative flux linkage at the particular position of the secondary winding with respect to the flux in the air gap. In both cases, the electromotive force induced in the secondary winding is substantially proportional to the angular displacement of the shaft supporting the rotor over a range exceeding 150 degrees in either direction from the zero point.

In both embodiments of the invention the primary and secondary windings are so related that the flux linkage of the secondary winding is substantially a linear function of the relative angular displacement of the two windings. It is contemplated that this important feature of the invention may be accomplished by other specific arrangements of variable inductors without departing from the intended scope of the invention, as defined by the appended claims.

What is claimed is:

1. A variable inductor comprising two relatively rotatable ferromagnetic members spaced from each other to form a gap, a primary winding on one of said members adapted to be connected to a source of electromotive force for producing a magnetic field in said gap and arranged in a manner such that the flux density in said gap varies substantially directly proportionately to the distance from a predetermined reference point, and a concentrated secondary winding on the other of said members arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

2. A variable inductor comprising two relatively rotatable ferromagnetic members spaced from each other to form a gap, a pair of coils on one of said members connected together to form a primary winding adapted to be connected to a source of electromotive force for producing a pair of opposite magnetic poles adjacent said gap and arranged in such a manner such that the flux density in said gap varies substantially directly proportionately to the distance from a predetermined reference point between said poles, and a concentrated secondary winding on the other of said members arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

3. A variable inductor comprising a ferromagnetic shell member, a ferromagnetic core member within said shell member, said members being supported for relative rotation and spaced from

each other to form a gap, a primary winding on one of said members adapted to be connected to a source of electromotive force for producing a magnetic field in said gap and arranged on one said member in a manner such that the flux density in said gap varies substantially directly proportionately to the distance from a predetermined reference point, and a concentrated secondary winding on the other of said members arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

4. A variable inductor comprising a ferromagnetic shell member, a ferromagnetic core member within said shell member, said members being supported for relative rotation and spaced from each other to form a gap, a pair of coils on one of said members connected together to form a primary winding adapted to be connected to a source of electromotive force for producing a pair of opposite magnetic poles adjacent said gap and arranged on said one member in a manner such that the flux density in said gap varies substantially directly proportionately to the distance from a predetermined reference point between said poles, and a concentrated secondary winding on the other of said members arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

5. A variable inductor comprising a ferromagnetic shell member, a ferromagnetic core member, said members being supported for relative rotation and spaced from each other to form a gap, a pair of coils wound on said shell member along separate portions of said gap and connected together to form a primary winding adapted to be connected to a source of electromotive force for producing a pair of opposite magnetic poles adjacent said gap and arranged in a manner such that the flux density in said gap varies substantially directly proportionately to the distance from a predetermined reference point between said poles, and a concentrated secondary winding upon said core member arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

6. A variable inductor comprising two relatively rotatable ferromagnetic members spaced from each other to form a gap, a primary winding in the form of a conductor wound with a minimum number of turns at a predetermined reference point and a progressively greater number of turns at successive equally spaced points extending in one direction along said gap adapted to be connected to a source of electromotive force for producing a non-uniform magnetic field in said gap wherein the flux density increases linearly from said reference point, and a concentrated secondary winding on the other of said members arranged adjacent said gap, said secondary winding having a pitch which is a fraction of the pitch of said primary winding, and means for relatively moving said windings with respect to each other whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

7. A variable inductor comprising two relatively rotatable ferromagnetic members spaced from each other to form a gap, a conductor wound on one of said members with a minimum number of turns adjacent a reference point and a progressively greater number of turns at successive equally spaced points extending in one direction, a second conductor wound on said member with a minimum number of turns adjacent said reference point and a progressively greater number of turns at successive equally spaced points extending in the opposite direction, said conductors being connected together and having their terminals adapted to be connected to a source of electromotive force to produce a non-uniform magnetic field in said gap wherein the flux density increases linearly in either direction from said reference point, and a secondary winding on the other of said members whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

8. A variable inductor comprising a ferromagnetic shell member and a ferromagnetic core member within said shell member, said members being supported for relative rotation and spaced from each other to form a gap, a conductor wound on said shell member adjacent said gap with a minimum number of turns adjacent a predetermined reference point and a progressively greater number of turns at successive equally spaced points extending in one direction from said point to form a primary winding adapted to be connected to a source of electromotive force for producing a non-uniform magnetic field in said gap wherein the flux density increases linearly in one direction from said reference point, and a concentrated fractional pitch secondary winding on said core member, and means for obtaining relative movement between said windings, whereby the flux linkage of said secondary winding varies linearly upon relative rotation of said members.

9. In a variable inductor comprising a ferromagnetic shell member and a ferromagnetic core member, said members being supported for relative rotation and spaced from each other to form a gap, a conductor wound on said shell member adjacent one portion of said gap with a minimum number of turns adjacent a reference point and a progressively greater number of turns at successive equally spaced points extending in one direction along said gap, a second conductor wound with a minimum number of turns adjacent said reference point and a progressively greater number of turns at successive equally spaced points extending in the opposite direction along said gap, said conductors being connected together to form a primary winding adapted to be connected to a source of electromotive force for producing a non-uniform magnetic field in said gap wherein the flux density increases linearly in either direction from said reference point, and a fractional pitch secondary winding on said core member adjacent said gap whereby the flux linkage of said secondary winding varies substantially directly proportionately to the relative angular positions of said members.

10. In a variable inductor, a winding for producing a non-uniform magnetic field in which the flux density increases linearly in both directions from a selected reference point of minimum flux comprising a first conductor wound with a minimum number of turns adjacent said reference

point and a progressively greater number of turns at successive equally spaced points extending in one direction from said reference point, and a second conductor wound with a minimum number of turns adjacent said reference point and a progressively greater number of turns at successive equally spaced points extending in the opposite direction from said reference point, said conductors being adapted to be connected to a source of electromotive force whereby the flux density produced by said conductors at any point in either direction is substantially directly proportional to the distance of said point from said reference point.

11. In a variable inductor having a pair of relatively rotatable ferromagnetic members spaced from each other to form a gap wherein one of said members has uniformly spaced raised portions projecting toward said gap to form slots extending transversely of and adjacent to said gap, a winding for producing a non-uniform magnetic field in said gap comprising a first conductor wound with a certain number of turns in one of said slots and progressively fewer turns in successively adjacent slots extending in one direction along said gap, and a second conductor wound with a certain number of turns in a slot in the opposite direction from said one slot and progressively fewer turns in successively adjacent slots extending in said opposite direction along said gap, said conductors being connected together and having their terminals adapted to be connected to a source of electromotive force.

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