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[54] **CAPACITOR TRANSDUCER**

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[21] Appl. No.: **227,156**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 7,187, Jan. 30, 1970, abandoned.

[52] **U.S. Cl.** .... **323/93,** 317/249 R, 340/200

[51] **Int. Cl.** **H01g 5/06,** H01g 5/12, H01g 5/14

[58] **Field of Search** .... 318/662; 324/61 P; 340/200; 323/93; 317/246, 249 R

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[57] **ABSTRACT**

A capacitive transducer in which a pair of exciter electrodes connected to an AC source are disposed in common planes to present a gap. A pick-off electrode is disposed in another plane and extends on either side of the gap. A conductive screen is interposed between the exciter electrodes and the pick-off electrode and is connected to ground potential so as to block capacitive coupling between the exciter electrodes and the pick-off electrode except as between discrete areas of the exciter electrodes and an opposite area of the pick-off electrode exposed or coupled through an aperture in the screen.

19 Claims, 11 Drawing Figures

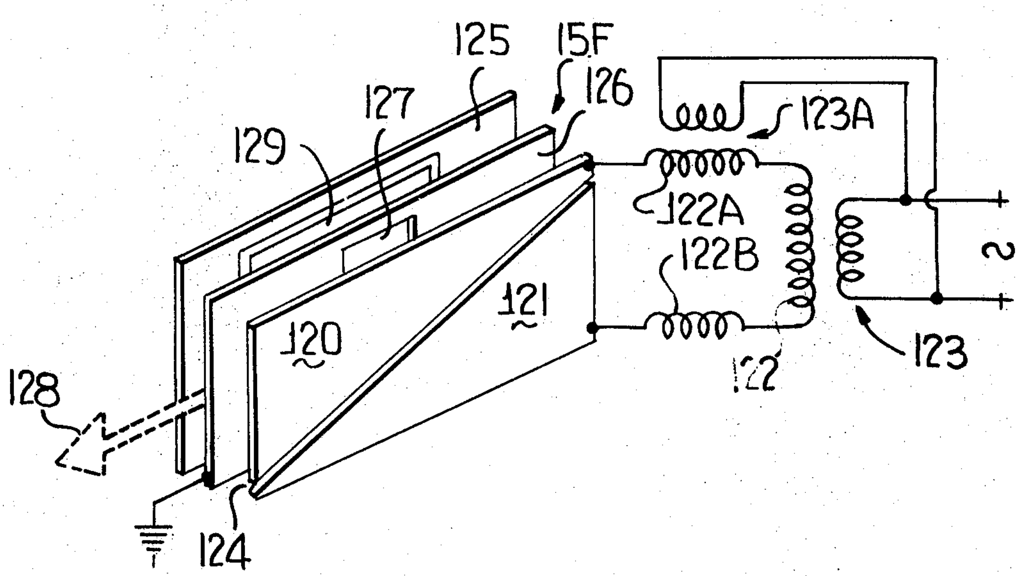


FIG. 1

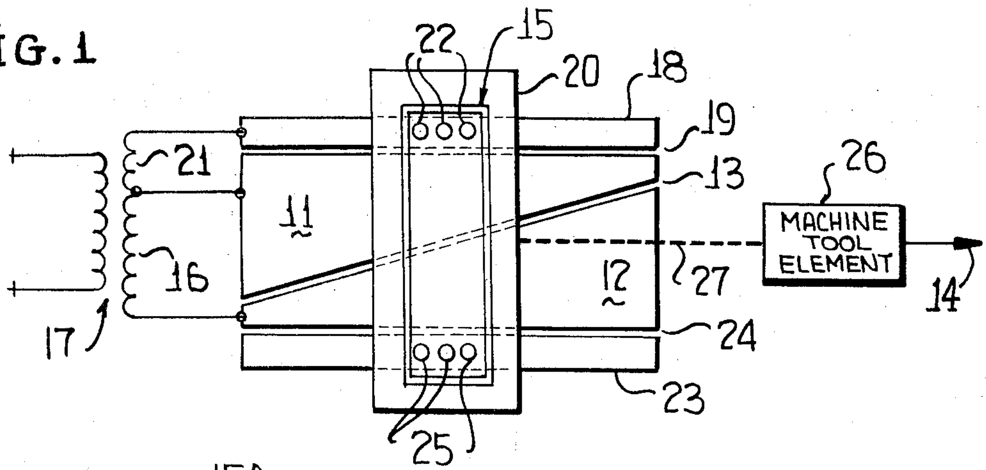


FIG. 2

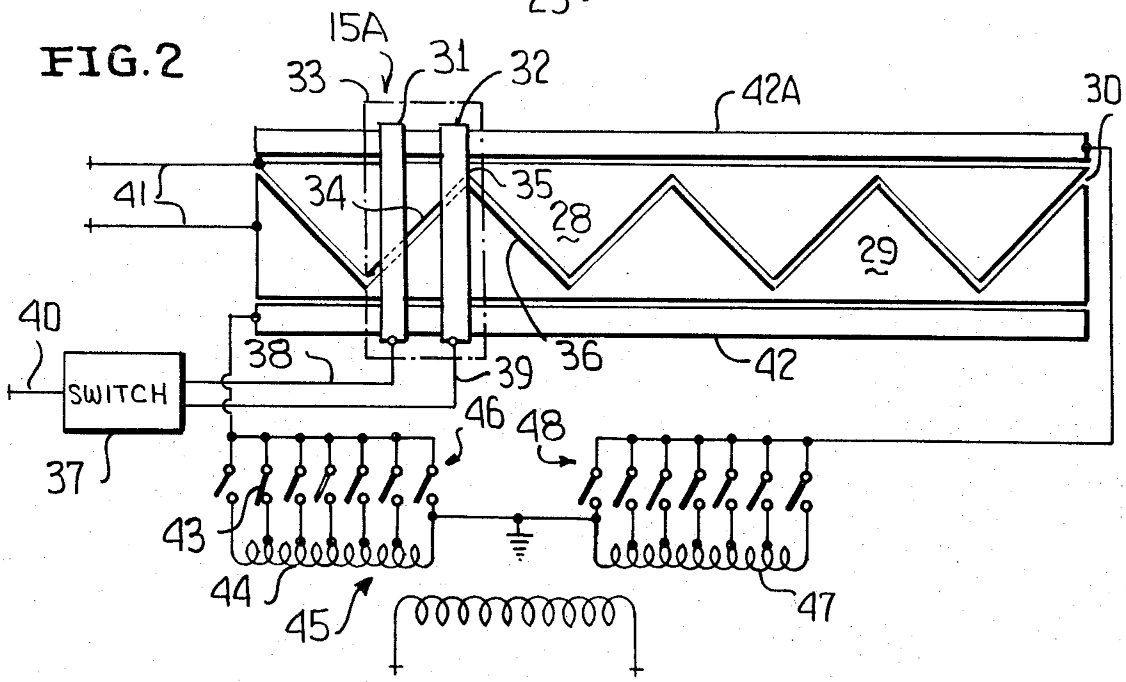
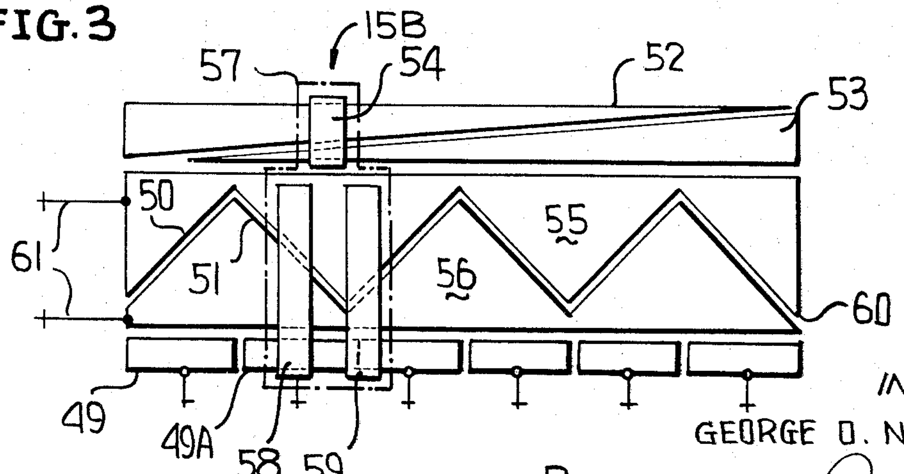


FIG. 3



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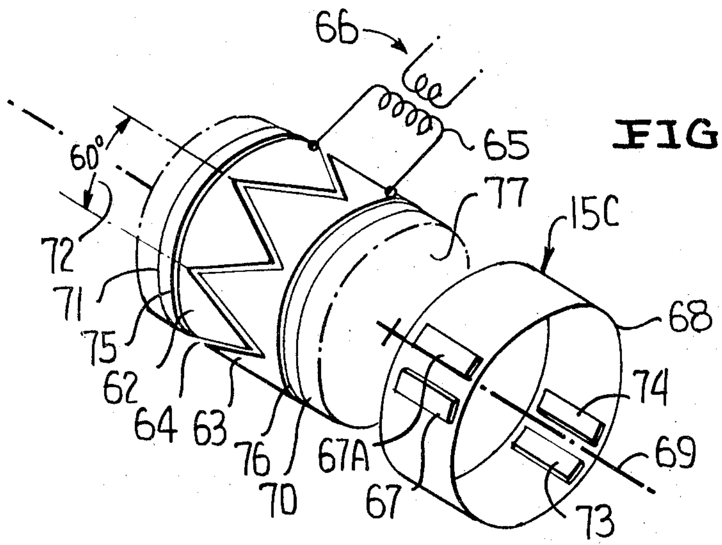

FIG. 4

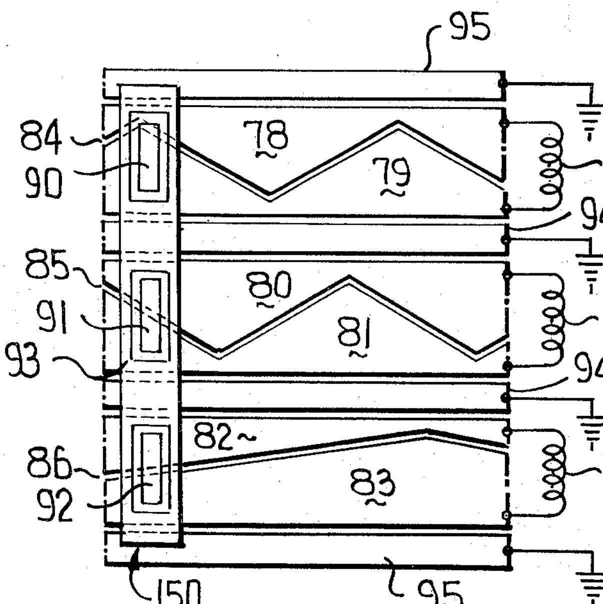

FIG. 5

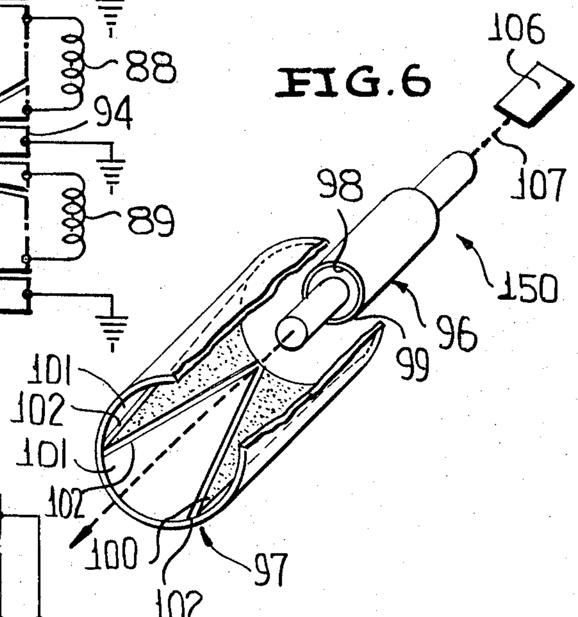

FIG. 6

FIG. 7

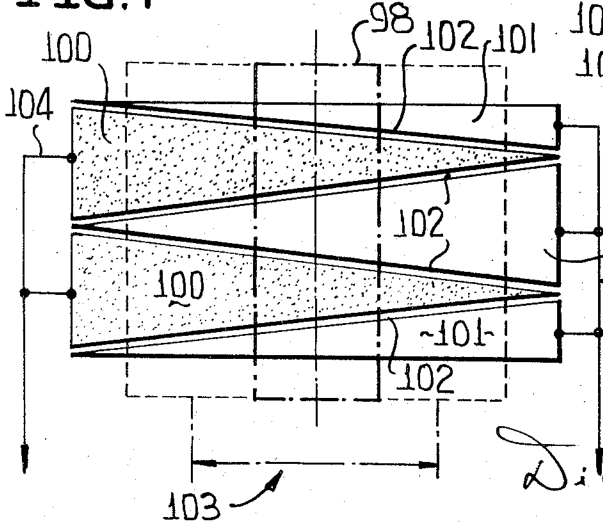

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FIG. 8

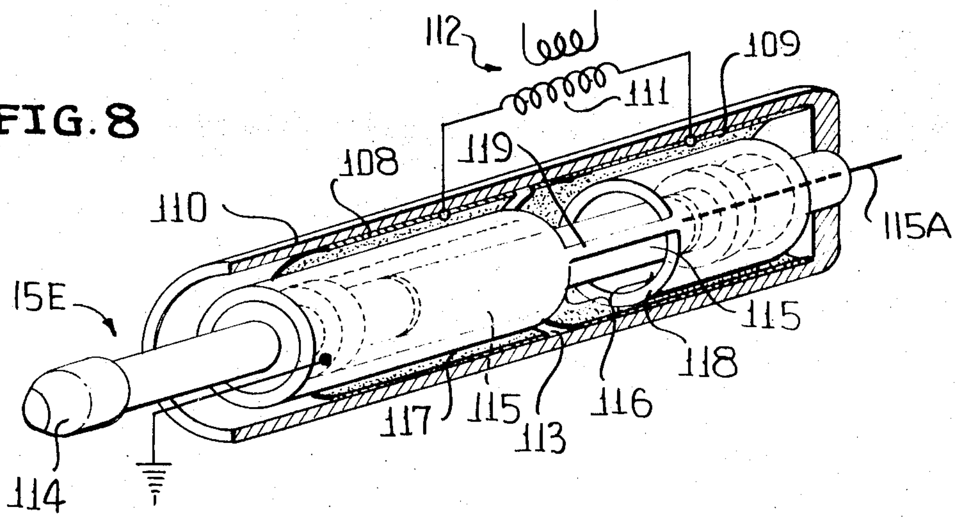

FIG. 9

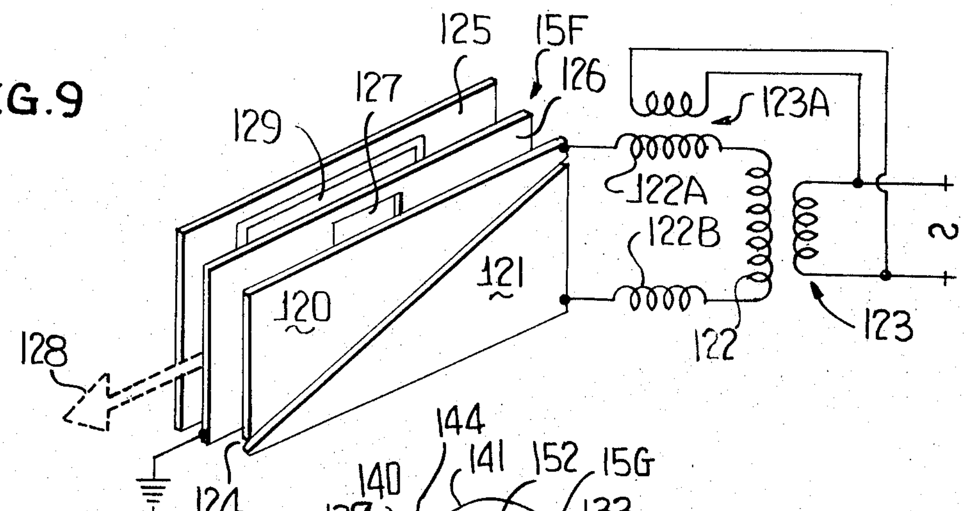

FIG. 10

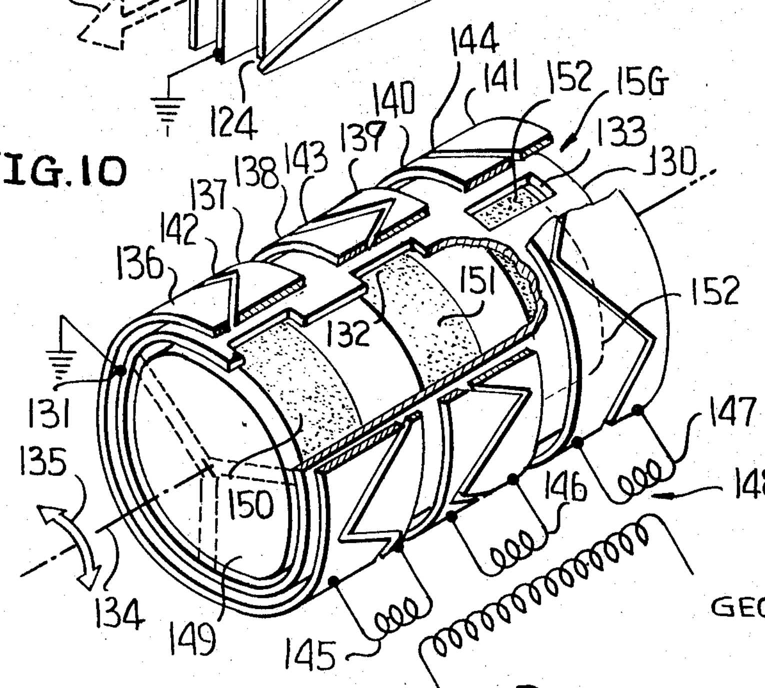

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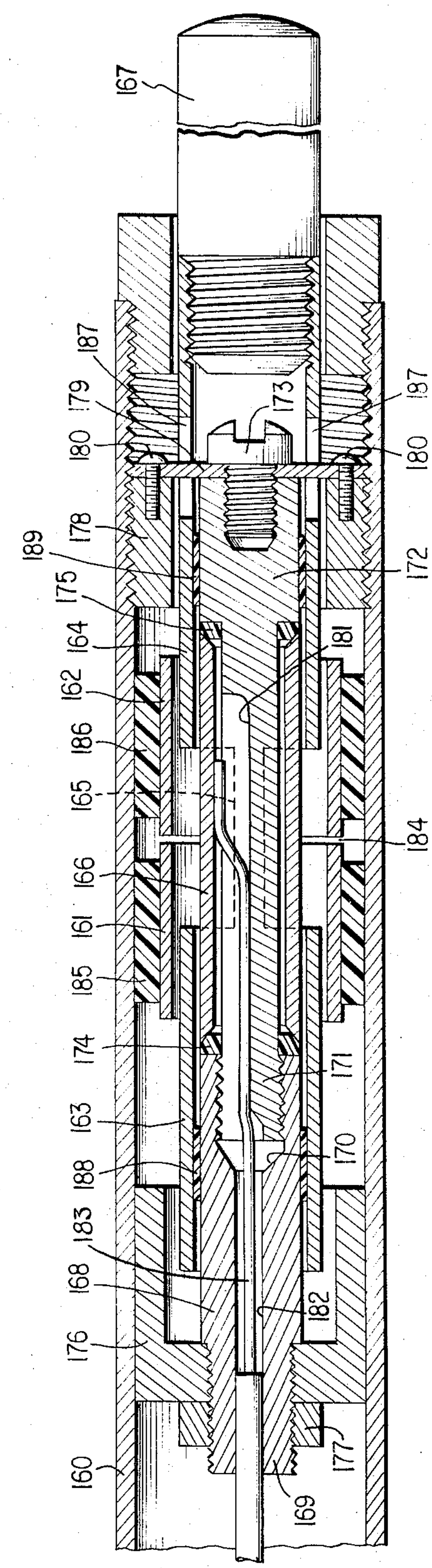
FIG. 11



CAPACITOR TRANSDUCER

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my co-pending application Ser. No. 7,187, filed Jan. 30, 1970, and now abandoned.

BACKGROUND OF THE INVENTION

Capacitance devices are known in which the capacitive coupling between a pick-off electrode arrangement and a pair of exciter electrodes is varied such that a differential effect is attained. In such devices, however, the effects of stray capacitance between the exciter electrodes and the pick-off electrode may be significant, giving rise to inaccuracies, non-linearities or the like which may affect the usefulness of the device particularly in applications such as for measuring relative movements between machine parts. For example, it may be desirable to utilize a differential capacitance device to provide accurate and precise electrical signal outputs in response to minute feeding movements of a machine tool thereby to provide the basis for accurate and precise programming of tool movements so that sequentially produced parts each may be held to close tolerances.

BRIEF SUMMARY OF THE INVENTION

In a preferred embodiment of the invention, an electrically conductive screening plate is used electrically to isolate or decouple a pair of exciter electrodes, on the one hand, and a pick-off electrode on the other hand, except as between discrete areas of the exciter electrodes and an opposed area of the pick-off electrode. For this purpose, the screening plate is connected to ground potential and is interposed between the exciter electrodes and the pick-off electrode to mask the same from each other except through or across the dielectric region, in any operative position of the parts.

BRIFF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a diagrammatic view of a simple form of differential capacitor embodying the invention coupled to a machine tool element;

FIG. 2 is a similar diagrammatic view of a multicycle differential capacitor having provision of calibration;

FIG. 3 is a diagrammatic view similar to FIG. 2 showing a different method of calibration, and an ambiguity resolver;

FIG. 4 is an exploded diagrammatic view of a differential capacitor similar to FIG. 2 except that it is arranged for rotary rather than linear movement;

FIG. 5 is a diagrammatic view of a modification of the capacitors of FIGS. 2 and 3;

FIG. 6 is an exploded diagrammatic view of a different kind of capacitor;

FIG. 7 shows the electrodes of the capacitor of FIG. 6 developed into a plane;

FIG. 8 is a diagrammatic view of parts cut away of a linear differential capacitor embodying the invention;

FIG. 9 is a diagrammatic showing of still a different form of capacitor for detection of linear movement and in which a stationary pick-off member is used;

FIG. 10 is a diagrammatic showing of still another form of capacitor for detection of angular movement or of longer linear movement; and

FIG. 11 is a longitudinal section taken through a preferred embodiment of the device.

DETAILED DESCRIPTION OF THE INVENTION

In general, differential capacitors have a pair of plates which are excited from the two ends of an AC supply, a movable member which may be described as an interpolator, and a pick-off which gives an electrical signal which changes with the position of the interpolator in relation to the excited plates. In many forms of differential capacitor the pick-off is also the interpolator.

In the differential capacitor shown in FIG. 1 exciter plates **11** and **12** are spaced apart by a gap **13** which is oblique to the direction of movement illustrated by arrow **14** of an interpolator **15**, which also acts as a pick-off. The plates **11** and **12** are energized from the two ends respectively of a reference supply comprising a secondary winding **16** of a transformer **17** and it can be seen that the coupling between the interpolator **15** and each of the plates **11** and **12** depends upon the linear position of the interpolator in the direction of arrow **14** by virtue of the changing overlapping plate area. The voltage of this interpolator **15** is a measure of its position and a signal can be obtained from a terminal (not illustrated) connected to it. The interpolator **15** may be surrounded by, but spaced from a shield **20** for minimizing distortion at the ends of the range.

It will be appreciated that the device need not be much longer than the desired range of movement of the interpolator **15**, it being only necessary to provide provision for suitable mechanical bearings and appropriate shielding to define the electric field and prevent distortion by the mounting components, for exmple bearings. For example, if the range of movement is 5 inches, the device could be about 6 inches long. Also the angle of the gap **13** can be chosen in accordance with desired rate of change of the pick-off signal.

A simple means for calibration can be provided by a slope correcting plate **18** extending along the length of the capacitor and separated from the plate **11** by a gap **19**. This plate **18** is energized from a separate secondary winding **21** of the transformer **17**. The coupling between the interpolator **15** and the correcting plate **18** can be adjusted by screwing in or out of conducting mechanical pins **22** toward plate **18** carried by the interpolator **15** to adjust the value of a correcting signal. If a similar arrangement is used at the other side of the capacitor, that is to say a slope correcting plate **23** spaced from the plate **12** by a gap **24** calibration can be effected without moving the electrical center of the capacitor. Further, the plate **23** may be energized from a secondary winding (not shown) of the transformer **17**, and conducting mechanical pins **25** may be provided to adjust the coupling between a plate **23** and the interpolator **15**. Similarly, the coupling capacitance between the pick-off and each reference electrode can be adjusted to a standard value which can be of advantage when operating such transducers in a caliper mode.

Of course with adjustment, the mechanical pins **22** or the energized correcting plate **18**, could be used by itself, rather than together as shown in FIG. **1**.

The interpolator **15**, as illustrated diagrammatically, is connected to a machine tool element **26**, which may be a carriage for supporting a workpiece (not illustrated) or a grinding wheel not illustrated) or the like by mechanical means diagrammatically illustrated as dashed line **27.**

Alternatively, the machine tool element **26** may be mechanically coupled to the exciter electrode assembly **11, 12** etc. while the interpolator **15** is held in a fixed position. Further, in this case, it may be advantageous to arrange for a multiplicity of pick-off elements **15** to be mounted on shield **20** and for a switch system to select the appropriate element **15** depending on the position of the moving exciter electrode assembly **11, 12,** etc. as it moves past the pick-off elements **15.**

The arrangement of FIG. **2** provides for a much greater linear movement, for example, 16 inches, and in this case the two exciter plates are of complementary saw-tooth shape as shown at **28** and **29** separated by a gap **30.**

The interpolator **15A** comprises a plate **31** genrally similar to the interpolator **15** of FIG. **1** in conjunction with a second similar plate **32,** by a non-conductive mounting member diagrammatically illustrated at **33,** to move with it and spaced so that the plate **31** will be moving over the central part of one inclined gap or ramp as shown at **34** while the other plate **32** is moving over the peak **35** joining two ramps. Then the second plate **32** will be moving over the central part of the next ramp **36** while the first plate **31** is moving over the peak **35.** A simple electrically - or cam-operated switch **37** is arranged to switch a signal from either lead **38** or lead **39** connected respectively to the interpolator plates **31** and **32** to an output terminal **40** depending on which plate is over the central part of a ramp in the position of the interpolator concerned. The plates **28** and **29** are energized from an AC source by a pair of leads **41.**

As with the emboidment of FIG. **1,** calibration corrections can be made by use of correcting plates **42** and **42A** along the edges of the capacitor, and plate **42** can be arranged to be connected to a selected tapping, for example **43,** on a secondary winding **44** of a transformer **45** by operation of a selector switch **46.** The switch **46** can be selected by an appropriate cam (not illustrated) or by an electrical logic circuit (not illustrated) and the tap that will be selected will depend on the correction required for the particular ramp **34** or **36** over which the interpolator plate **31** or **32** is moving when the cam or logic-circuit controlled switch is operated. There will be a similar arrangement for the correcting plate **42A** which may include an additional secondary winding **47** and a switch **48.** It will be appreciated, that the interpolator **15A** may be mechanically coupled to a machine tool element in a similar manner to interpolator **15** as shown in FIG. **1.**

The arrangement of FIG. **3** shows how calibration correction can be affected in a different way by having a plurality of correcting plates **49, 49A,** etc. one for each of the ramps **50, 51,** etc. Each will be connected to an appropriate tap on a secondary winding (not illustrated) or to separate taps on secondary windings such as **44** and **47** as illustrated in FIG. **2.** FIG. **3** also shows how ambiguity between the various ramps can be avoided by additional elongated wedge like plates **52** and **53** with its individual pick-off plate **54** ganged, by a non-conductive mounting member diagrammatically illustrated at **57,** to move with the plates **58** and **59** and connected to a circuit (not illustrated) for indicating the number of complete ramps covered or cycles moved, along the length of the capacitor. Plates **58** and **59** are ganged together by the member **57** and comprise an interpolator **15B.** The capacitor illustrated in FIG. **3** includes two exciter plates **55** and **56** separated by a saw-tooth gap **60.** The two exciter plates are energized from an AC source via a pair of leads **61.**

The interpolator **15B** may be mechanically coupled to a machine tool element in a similar manner as interpolator **15** as shown in FIG. **1.**

FIG. **4** shows how the capacitor can be arranged to detect angular or rotary movements. In this case the exciter plates **62** and **63** have complementary saw-tooth edges separated by a gap **64** and disposed around the periphery of a cylindrical shell **77.** They are energized from a secondary winding **65** of a transformer **66,** and the interpolator **15C** includes plates **67** and **67A** arranged on a rotor **68** to turn about the axis **69** of the device. It is believed that the analogy to the embodiment of FIG. **2** will be so clear that further description is not necessary and of course correcting plates **70** and **71** can be added in the same way as described. It is preferred that the angle between successive cycles of the saw-tooth will represent **60** angular degrees as indicated at **72** to produce **6** cycles in one revolution. While a pair of pick-off plates **67** and **67A**, one for each of adjacent ramps are shown, it may be advantageous to provide two pairs of interpolator plates 180° apart in order to provide corrections for slight eccentricity or other mechanical inaccuracy as illustrated by additional interpolator plates **73** and **74.** The capacitor may include the calibration correction plates **70** and **71** separated from the exciter plates **62** and **63** by gaps **75** and **76** and arranged on the ends of the cylindrical shell **77.** Of course, separate calibration correction electrodes may be provided for each ramp as illustrated in FIG. **3,** and additional wedge-like plates and a pick-off plate can be provided for indicating the number of ramps moved as illustrated in FIG. **3.**

It will be appreciated that the capacitor illustrated in FIG. **4** may be arranged so that interpolator **15C** is mechanically coupled to a machine tool element or the like and thereby be suitable to provide signals indicative of the angular displacement or motion of the machine tool element or the like.

FIG. **5** shows an alternative arrangement with multi-ramp tracks but without having an interpolator comprising two pick-off plates spaced apart along the length of a single track.

It will be seen that there are three tracks having respective exciter plates **78** and **79, 80** and **81,** and **82** and **83** separated respectively by saw-tooth gaps **84, 85** and **86** and energized from secondary windings **87, 88** and **89** of a transformer (partially illustrated). The first two tracks have gaps **84** and **85** which are of the same pitch, but are phased displaced by a quarter of a pitch. The interpolator **15D** comprises pick-off electrodes **90, 91** and **92** which are ganged by means including shield **93** to move together over the respective tracks. Each electrode consists of a pick-off plate spaced within the shield **93.** The tracks are separated by earthed strips **94,** and earthed strips **95** are provided adjacent the endmost electrodes **78** and **83.**

It can be seen that the pick-off electrode **90** will be moving over a ramp of its track as the pick-off electrode **91** is moving over a peak of its track and vice versa, so that by appropriate mechanical or electrical switching (not illustrated) or by appropriate alternate energization of the tracks a continuous signal can be derived from the two pick-off electrodes **90** and **91.**

The third pick-off electrode **92** is merely for avoiding ambiguities and its track has the gap **86** which has a greater pitch than the gaps **84** and **85** associated with the first two tracks.

In an alternative arrangement the shield **93** may take the form of an apertured screen which does not have the pick-off electrodes **90,91** and **92** in its apertures, and is arranged to move along the tracks and is positioned between a set of fixed pick-off electrodes in spaced face-to-face relation with the tracks. The aperture in a screen, in this alternative arrangement, varies the coupling between each pick-off electrode and the exciter electrodes of respective tracks as it moves along the tracks. In this instance, outlet leads are connected to fixed pick-off electrodes rather than to moving electrodes.

In the capacitor of FIG. **6** the interpolator **15D** includes pick-off electrode assembly **96** arranged to move axially within a cylindrical shell **97.** The pick-off electrode comprises an external cylindrical conducting surface **98** on a cylindrical member **99.** The exciter electrode arrangement consists of conducting surfaces **100** and **101** with complementary saw-tooth-like shapes separated by gaps **102** as can be seen best from the developed view in FIG **7.** As the pick-off **96** moves over the range of measurement **103** (FIG. **7**), the coupling with one of the surfaces **100, 101** will increase and the coupling with the other of the surfaces **100, 101** will decrease. The division of the exciter plates into two teeth each allows some compensation for slight eccentricity in assembling the pick-off electrode **96** with the cylindrical shell **97.** Electrical connections to the conducting surfaces **100** and **101** are provided respectively by a wiring arrangement **104** and **105.**

It will be appreciated that the interpolator **15D** may be mechanically coupled to a machine tool element **106** or the like as diagrammatically illustrated by dashed line **107.**

The differential capacitor of FIG. **8** has a pair of exciter capacitor plates **108** and **109** each insulated from and laced around the inner cylindrical surface of a fixed cylindrical housing **110** the two of them being connected across the ends of a secondary winding **111** constituting a reference AC supply and forming part of a transformer **112.** There is a short annular gap **113** between the plates **108** and **109.**

A pick-off signal representative of the linear position of an interpolator **15E** shown as connected to a stylus **114** is derived from a fixed pick-off electrode **115** in the form of an elongated cylinder coaxial with the plates **108** and **109** and extending throughout the major part of the combined lengths of the plates being symmetrically disposed in relation to the plates. The pick-off electrode **115** is connected to a pick-off terminal or lead **115A.**

The interpolator **15E** whose movement is to be detected comprises a gap **116** between the components of an electrically conducting cylindrical shell screen consisting of two conducting shells **117** and **118** separated by the gap **116** but held together by a web **119** of uniform width, and electrically connected together. They are disposed coaxially with the rest of the capacitor surrounding the pick-off electrode **115** and within the plates **108** and **109.** The gap **116** between the facing edges of the conducting shells **117** and **118** of the screen is substantially wider than the gap **113** but less than the length of the pick-off electrode **115.** The screen consisting of shells **117, 118** and web **119** is earthed.

It will be appreciatpd that the position of a gap **116** in a screen between either exciter plate **108** or plate **109** and the pick-off electrode **115** will determine the coupling between the plates and the pick-off electrode **115** so that as linear movement takes place of the stylus **114** with the sreen, the coupling of the pick-off electrode **115** to one of the exciter plates **108** and **109** will increase while the coupling to the other will decrease and accordingly a differential output signal can be obtained from the terminal **115A** representative of the linear position of the stylus **114.**

The arrangement has the advantage that both the exciting reference supply and the pick-off signal are connected to fixed terminals while the moving electrical component only has to be grounded through some sort of flexible connection so that slip rings are not necessary for the signal output.

It will be appreciated that rather than being connected to a stylus or in addition to the stylus, the interpolater **15E** may be connected or coupled to a machine tool element or the like so that the output from terminal **115A** may represent the position or movement of the machine tool element with respect to a workpiece or another part of a machine tool.

A preferred embodiment of the invention according to the principles shown in FIG. **8** is illustrated in FIG. **11** wherein a housing **160** of the transducer corresponds to the housing **110** of FIG. **8**; exciter electrodes **161** and **162** correspond to the plates **108** and **109**; the screening means comprises portions **163, 164** and an interconnecting web **165** corresponds to the shells **117, 118** and a web **119**; the pick-off electrode **166** corresponds to the electrode **115**; and the stylus **167** corresponds to the stylus **114.**

The pick-off electrode **166** is carried by a support assembly which includes a tubular member **168** having an externally threaded reduced end portion **169** and an internally threaded counterbore **170** at its other end. A spindle or rod member **171** is provided with external threads and is engaged at one end in the counterbore **170** whereas its opposite end is in the form of an enlarged head **172** provided with a threaded recess receiving the screw fastener **173.** The pick-off electrode **166** is electrically isolated from the spindle **171** by means of bevelled washers **174** and **175** of a nonconductive material. The washers **174** and **175** locate the pick-off electrode **166** radially when the member **168** and the spindle **171** are threaded together.

The housing **160** receives a cylindrical support plug **176** having a central opening through which the threaded end portion **169** projects and a nut **177** firmly attaches the entire support assembly within the housing **160.** At its opposite end, the housing **160** is internally threaded and receives a threaded anchor ring **178** which supports the opposite end of the spindle **171** through the medium of a strap or guide post **179** which is held against the head end of the spindle **171** by means of the aforementioned fastener **173.** Screw fasteners **180** secure the opposite ends of the guide post **179** to the ring **178.**

The spindle **171** is provided with a longitudinal groove **181** of sufficient depth more or less and in alignment with a bore **182** of the tubular member **168** and thereby to provide a continuous passage through which a condutor **183** extends for connection to the pick-off electrode **166.**

The exciter electrodes **161** and **162** present a gap **184** and are located within the housing **160** by means of respective bushings **185** and **186** of non-conductive material. The bushings **185** and **186** are of substantially equal lengths and the pick-off electrode **166** is essentially centered longitudinally with respect to them and may extend somewhat beyond the opposite ends thereof, as shown. The pick-off electrode **166** is of course substantially concentric with respect to the exciter electrodes **161** and **162.**

The screening means includes the two electrically conductive portions **163** and **164** which define an aperture or a dielectric region therebetween through or across which discrete areas of the two exciter electrodes **161** and **162** provide a capacitive coupling with the opposed area of the pick-off electrode **166.** The portions **163** and **164** extend well beyond the opposite ends of the pick-off electrode **166** so as always to mask the exciter electrodes **161** and **162** from the pick-off electrode **166** except for the capacitive coupling allowed as aforesaid. Thus, stray capacitive coupling between the electrodes **161** and **162** or connecting leads to the exciter electrodes **161** and **162** and to the pick-off electrode **166** is prevented such as might detrimentally affect the pick-off signal produced by the differential capacitance effect as the screening means is shifted longitudinally during measurements. Thus, it will be seen that the coupling path is a clearly defined area directly through a single dielectric region to permit the capacitor to operate with extreme precision, without the need to provide a direct electric connection to obtain an output signal which is a function of the position of the relatively moving member.

To this end, the dielectric region presented between the portions **163** and **164** is positioned always to bridge across the gap **184,** and mechanical means are provided to limit the range of movement of the screening means with respect to the electrodes **161** and **162.** The guide post **179** may function to limit the axial movement of the screening means by virtue of the locations and the finite lengths of slots **187** in the screen portion **164** through which the guide post **179** projects. The slots **187** may be of only slightly greater width than the guide post **179** so as to prevent relative rotation of the screening means and of the stylus **167.**

To locate the screen portions **163** and **164** concentrically with respect to the pick-off electrode **166** and to allow for axial movement of the screen portions **163** and **164,** bushings **188** and **189** are provided on the tubular member **168** and head **172** of the spindle **171,** respectively. It will be understood that the screen portions **163** and **164** are connected to ground potential at the outer end of the bushing **188** or the bushing **189** by a coil spring (not shown) or by other electrical conducting means. The exciter electrodes **161** and **162** are connected in circuit as described in conjunction with FIG. **8.** It will also be understood that the screening means may take the form of a tubular dielectric member having the electrically conductive portions deposited thereon to define an uncoated dielectric region therebetween through which the capacitive coupling takes place. Further, it will be appreciated that the pick-off electrode assembly **96** of FIG. **6** may be relatively fixed and a movable screen, as in FIGS. **8** and **11,** utilized therewith.

FIG. **9** illustrates a differential capacitor similar, in some respects, to that shown in FIG. **1** and shows how the invention can be applied to a device for linear movement in which the exciter plates **120** and **121** and a pick-off electrode **129** are stationary. In this case, two exciter plates **120** and **121** are connected in series across a secondary winding **122** of a transformer **123,** and have complementary edges separated by a gap **124** which is oblique to the direction of movement indicated by arrow **128.**

Each of the exciter plates **120** and **121** is spaced from a pick-off electrode **129,** which may be surrounded by, but spaced from a shield **125.** The interpolator illustrated generally at **15F** comprises a screen **126** having a gap or aperture **127** therein positioned beween the pick-off electrode **129** and the two exciter plates **120** and **121.** The screen is electrically connected to a point of reference potential (ground) by a mechanically flexible connection means or other suitable arrangement.

Movement of the aperture **127** as indicated by the arrow **128** will increase the coupling between one of the plates **120** and **121** and the pick-off electrode **129** and at the same time decrease the coupling between the other plate and the electrode **129** so that the differential output signal can be derived from a terminal (not illustrated) connected to the electrode **129.**

It will be understood that the transducer of FIG. **9,** as is the case with those shown in FIGS. **8** and **11,** is dimensioned such that the grounded screen **126** is interposed between or masks the exciter electrodes **120** and **121** from the pick-off electrode **129** except as between those discrete areas of the exciter electrodes which are coupled through the aperture **127** to the opposed area of the pick-off electrode **129.** By inspection, it will be seen that a similar situation prevails for FIG. **10.**

The shape of the output signal from the electrode **129** may be improved, so far as accuracy is concerned, by providing that exciter plates **120** and **121** be additionally energized respectively from secondary windings **122A** and **122B** of a transformer **123A,** the secondary wingings **122A** and **122B** beng connected in series with the secondary winding **122.** the transformers **123** and **123A** are connected to the same source.

It will be appreciated that the capacitor as illustrated in FIG. **9** may be advantageously provided with a shield and/or slope correcting conductive screws in a similar fashion to the shield **20** and screws **22** shown in FIG. **1.** In this case, the screws would be carried by the screen **126** and be adjustably movable into aperture **127** from an edge or edges thereof which are parallel to the direction of movement.

FIG. **10** illustrates a capacitor in which a three track arrangement is provided. An interpolator **15G** comprises an electrically conductive cylinder **130** having three axially aligned apertures **131, 132** and **133** therein. The interpolator **15G** is operatively arranged to rotate about an axis **134** as illustrated by the arrow **135.** Positioned about and on the outside of the interpolator **15G** are three tracks each of which includes two exciter plates of complementary saw-tooth shape and illustrated as exciter plates **136** and **137, 138** and **139,** and **140** and **141** separated respectively by gaps **142, 143** and **144.** The first two tracks have the gaps **142** and **143** which are of the same pitch, but are phase displaced by, for example, a quarter of a pitch. The pitch of the gap **144** is a greater pitch than the pitch of the gaps **142** and **143**, and is for the purpose of avoiding ambiguities. The electrodes **136** and **137**, **138** and **139**, and **140** and **141** are respectively energized from secondary windings **145**, **146**, and **147** of a transformer **148**.

Positioned within the interpolator **15G** is a stationary cylinder **149** which has positioned on the outer surface thereof a plurality of electrodes **150**, **151** and **152**. The electrode **150** is associated with the aperture **131** of the interpolator **15G**, the electrode **151** is associated with the aperture **132** and the electrode **152** is associated with the aperture **133** of the interpolator **15G**. It can be seen that the aperture **131** will be moving over a ramp of its track as the aperture **133** is moving over a peak of its track and vice versa, so that by appropriate mechanical or electrical switching (not illustrated) or by appropriate alternate energization of the exciter electrodes **136** and **137**, and **138** and **139** of the tracks a continuous signal may be derived from two of the pick-off electrodes **150** and **151**. The third pick-off electrode **152** adjacent the moving aperture **133** will provide a separate signal for avoiding ambiguities for its track and is associated with the gap **144** which has a greater pitch than the gaps **142** and **143**. It will be appreciated that the tracks may be separated from one another by earthed (grounded) electrodes and further that earthed (grounded) electrodes may be provided ajacent the endmost exciter electrodes **136** and **141** in a manner similar electrically to the capacitor illustrated in FIG. **5**. An appropriate electrically operated or cam-operated switching means (not illustrated) can be arranged to select an output from one each of the electrodes **150** or **151**, and/or **152** depending on the arcuate position of the apertures **131**, **132** and **133** of the interpolator **15G**. The electrically conductive cylinder **130** is earthed (grounded).

The interpolator **15G** may be coupled to a machine tool element or the like so as to provide signals indicative of the angular displacement or motion of the machine tool element or the like.

It is to be understood that in many applications it is very desirable to provide the capacitors of the present invention with an electrostatic shielding for preventing the fields of the capacitor from being adversely affected by extraneous disturbances such as moving bodies or elements or electrical interference.

While the arrangements shown and described above represent illustrative and preferred forms of the invention, it will be readily apparent to one skilled in the art that variations may be made in such arrangements without departing from the scope and spirit of the invention as defined in the appended claims. For example, the capacitor illustrated as cylindrical may be alternatively constructed as flat capacitor and those illustrated as flat capacitors may be constructed as cylindrical capacitors.

Another possible modification is that additional secondary windings may be connected in series with secondary winding **111**, shown in FIG. **8** for feeding a corrective voltage to either or both exciter electrodes **108** and **109** to improve the accuracy or modify the output from pick-off electrode **115**; the arrangement is similar to the corrective arrangement illustrated in FIG **9**.

I claim:

1. In a capacitive transducer, the combination comprising:

first and second exciter electrodes fixedly located in a common plane and having adjacent spaced-apart edges defining an electrical discontinuity therebetween,

a pick-off electrode fixedly located adjacent said first and second exciter electrodes in spaced relation from the common plan thereof and spanning the electrical discontinuity therebetween,

means for connecting said first and second exciter electrodes to sources of different potential to induce a signal on said pick-off electrode indicative of the portions of said first and second electrodes spanned by said pick-off electrode,

a shield located between said pick-off electrode and said first and second exciter elecrodes and connected to a ground potential to prevent a signal from being induced on said pick-off electrode,

said shield having a dielectric aperture therein bridging the electrical discontinuity for permitting portions of said first and second exciter electrodes adjacent the electrical discontinuity to induce a signal on said pick-off electrode,

said shield being movable relative to said first and second exciter electrodes about the electrical discontinuity to vary the portions of said first and second exciter elements inducing a signal on said pick-off electrode to produce a signal responsive to the position of said movable shield, and

said shield being dimensioned to prevent stray capacitive coupling between said pick-off electrode and said first and second exciter electrodes at all positions of movement of said shield.

2. A capacitive transducer as defined in claim **1** wherein said exciter electrodes each are of tubular form and are disposed in end-to-end spaced relation to define said electrical discontinuity and wherein said shield has electrically conductive portions of tubular configuration located in end-to-end spaced relation to define said dielectric region.

3. A capacitive transducer as defined in claim **2** including a tubular housing within which said exciter electrodes are fixed, said pick-off electrode being in the form of an elongated sleeve concentrically disposed with respect to said exciter electrodes, and said shield being of a length to completely mask said exciter electrodes from said pick-off electrode except through said dielectric region.

4. A capacitive transducer as defined in claim **3** including a support assembly located axially within said housing and concentrically locating said pick-off electrode therewithin, and means for slidably supporting said shield on said support assembly.

5. A capacitive transducer as defined in claim **4** including a guide member disposed diametrically within said housing, said shield having slots formed therein for slidably receiving said guide member to prevent rotation of said shield means relative to said housing.

6. A capacitive transducer as defined in claim **1** wherein said pick-off electrode, said exciter electrodes and said shield are in the form of flat plates.

7. A capacitive transducer as defined in claim **1** wherein said exciter electrodes are each of annular form and having zig-zag edge portions disposed in spaced relation to define said electrical discontinuity, said pick-off electrode being concentrically disposed with respect to said exciter electrodes, and said shield being rotatable between said exciter and pick-off electrodes.

8. A capacitive transducer as defined in claim **1** wherein the electrical discontinuity defined by the adjacent edges of said first and second exciter electrodes is a straight gap of uniform width.

9. A capacitive transducer as defined in claim **1** wherein the electrical discontinuity defined by the adjacent edges of said first and second exciter electrodes is a saw-tooth gap of uniform width.

10. A capacitive transducer as claimed in claim **1** including a compensatory electrode means positioned near one of said exciter electrodes and separated therefrom by a gap, said compensatory electrode means being coupled to said pick-off electrode.

11. A capacitive trasducer as claimed in claim **10** including a second compensatory electrode positioned near the other of said exciter electrodes and separated therefrom by a gap, said second compensatory electrode being coupled to said pick-off electrode.

12. A capacitive transducer as claimed in claim **11** including means for varying the coupling between at least one of said compensatory electrodes and said pick-off electrode.

13. A capacitive transducer as defined in claim **1** including a second pair of exciter electrodes defining a second electrical discontinuity therebetween, a second pick-off electrode, and said shield having a second dielectric aperture therein bridging said second electrical discontinuity.

14. A capacitive transducer as defined in claim **13** wherein the electrical discontinuity defined by the adjacent edges of said first and second exciter electrodes is a saw-tooth gap of uniform width.

15. A capacitive transducer as claimed in claim **14** including a compensatory elecrode means positioned near one of said exciter electrodes and separated therefrom by a gap, said compensatory electrode means being coupled to said pickoff electrode.

16. A differential capacitor as claimed in claim **15** including a second compensatory electrode positioned near the other of said exciter electrodes and separated therefrom by a gap, said second compensatory electrode being coupled to said pick-off electrode.

17. A capacitive transducer as defined in claim **1** wherein the electrical discontinuity defined by the adjacent edges of said first and second exciter electrodes is a zig-zag gap along the path of relative movement between said shield and said exciter electrodes, and further including a second pick-off electrode and a second pair of exciter electrodes associated therewith, said second pair of exciter electrodes having adjacent edges defining a second electrical discontinuity therebetween extending at an acute angle of said path of relative movement, and said shield defining a second dielectric aperture therein bridging the second electrical discontinuity between said second pair of exciter electrodes.

18. A differential capacitor as claimed in claim **17** including a compensatory electrode means positioned near one of said exciter electrodes and separated therefrom by a gap, said compensatory electrode means being coupled to said pick-off electrode.

19. A differential capacitor as claimed in claim **18** including a second compensatory electrode positioned near the other of said exciter electrodes and separated therefrom by a gap, said second compensatory electrode being coupled to said pick-off electrode.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,784,897 Dated January 8, 1974

Inventor(s) George Ogilvie Norrie

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

Column 5, line 44, "laced" should read--placed--.

<u>In The Claims</u>

Claims 16, 18 and 19, line 1, "differential capacitor" should read--capacitive transducer--.

Signed and sealed this 16th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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