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N7H2 N7S

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GB 2180342 A GB 2143660 A EP 0434314 A2
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(54) Abstract Title

A means for determining the x, y and z co-ordinates of a touched surface

(57) The force applied to the surface can be determine by the use of suitably plan force sensitive devices A,B,C,D which are positioned in such a manner that by a ratiometric comparison of their relative levels of measured force, it is possible to determine the relative position of the point of contact where the force is applied. In this manner it is possible to determine the x and y co-ordinates of the point of applied force relative to an arbitrary datum on the surface.

Since the amount of force applied to the surface can also be determined by summing the individual forces measured by a number of suitably positioned force sensitive devices, it is possible to infer z axis information as related by the total amount of applied force. In this way x, y and z co-ordinate information can be inferred from the point of contact and degree of force applied to the surface.

The force sensors are piezo-resistive devices (figs 3 and 4) and the system may be incorporated into touch screens or graphic tablets (figs 5 and 6).

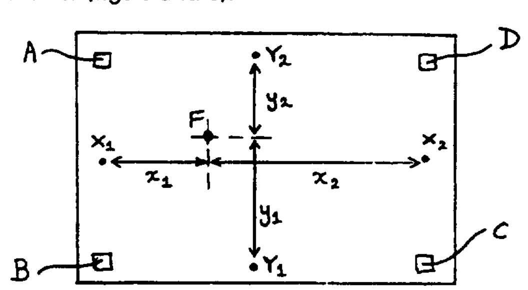

Figure 2a

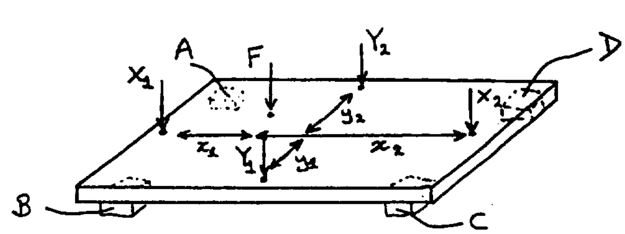

Figure 2b

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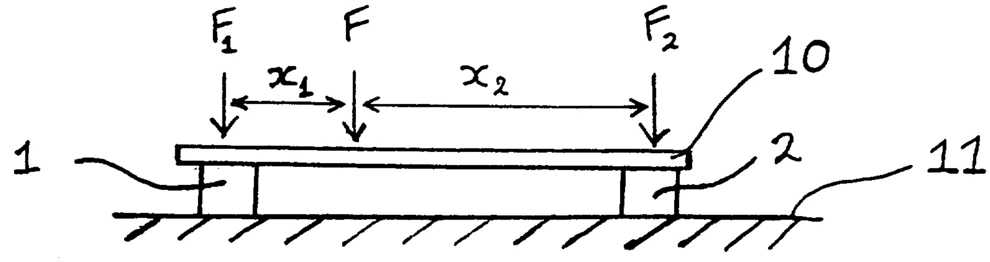


Figure 1

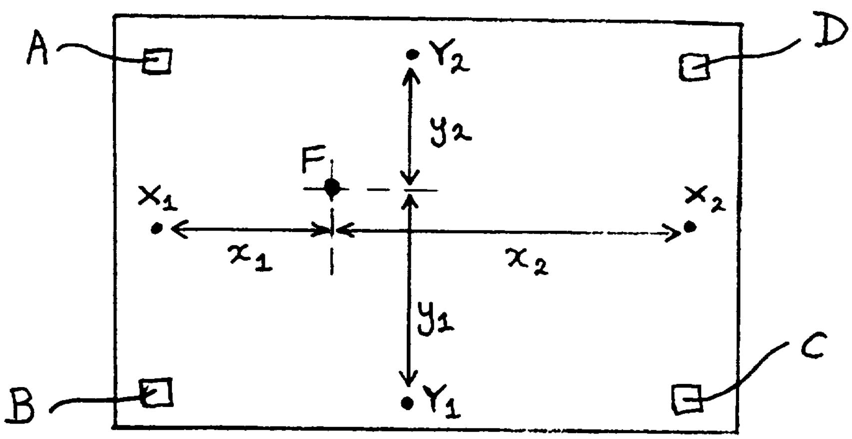


Figure 2a

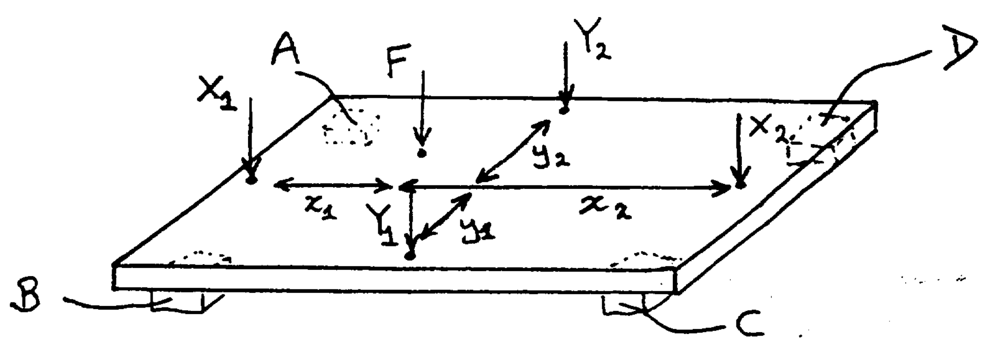


Figure 2b

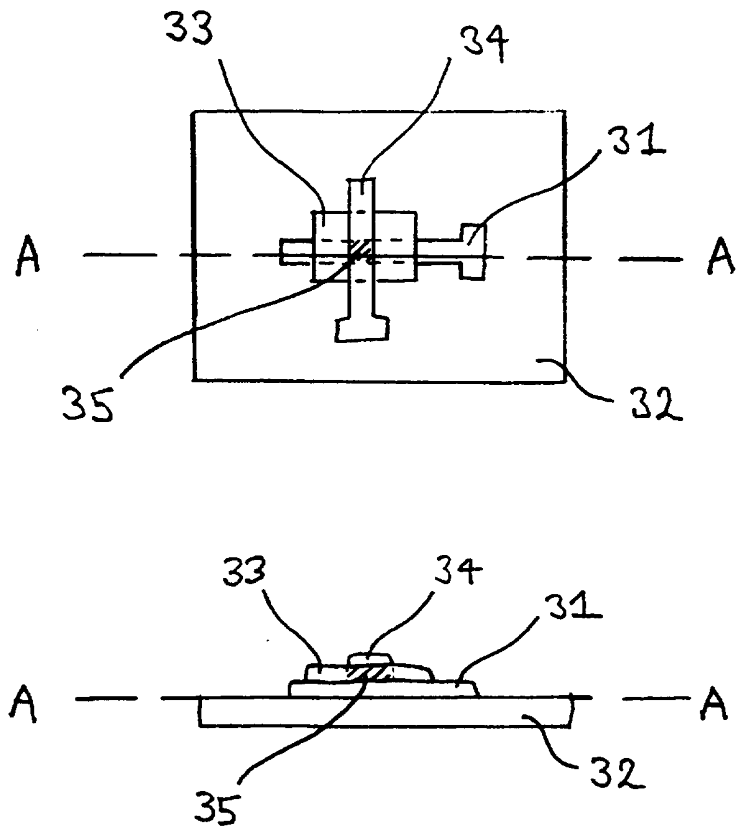


Figure 3

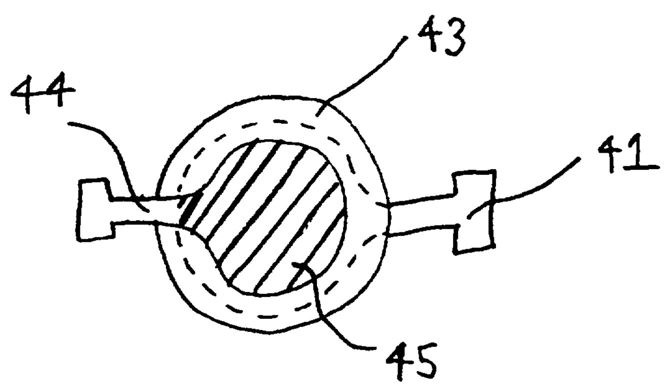


Figure 4

Figure 5a

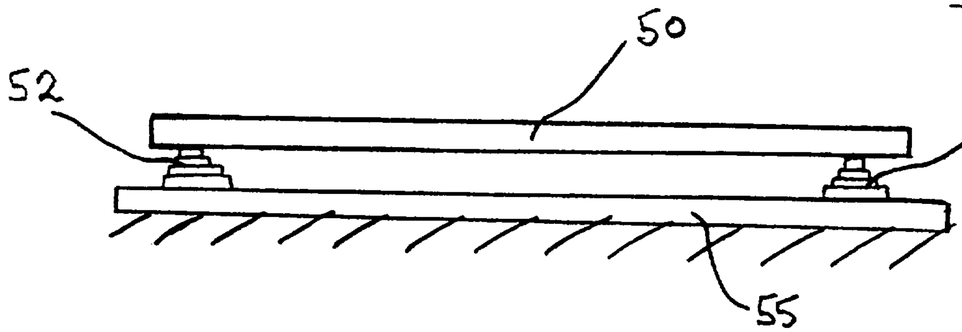
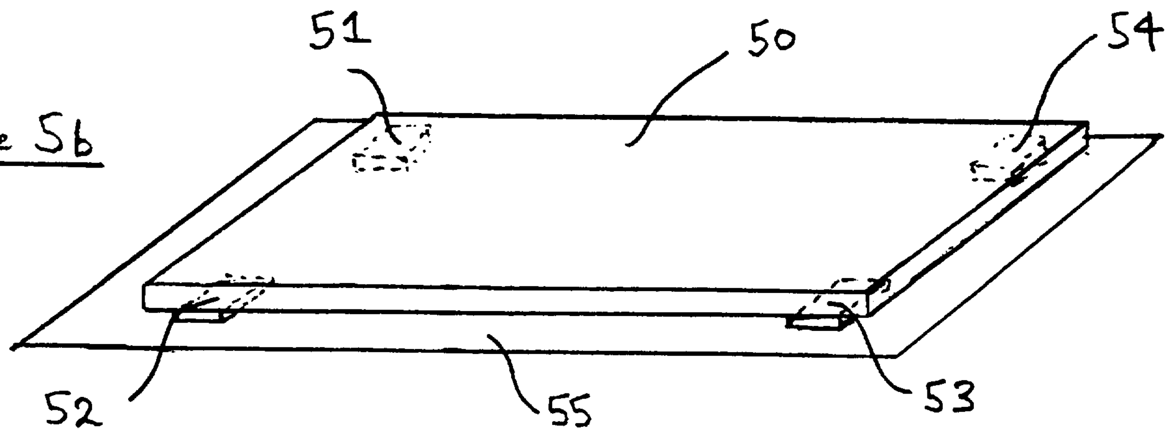


Figure 5b



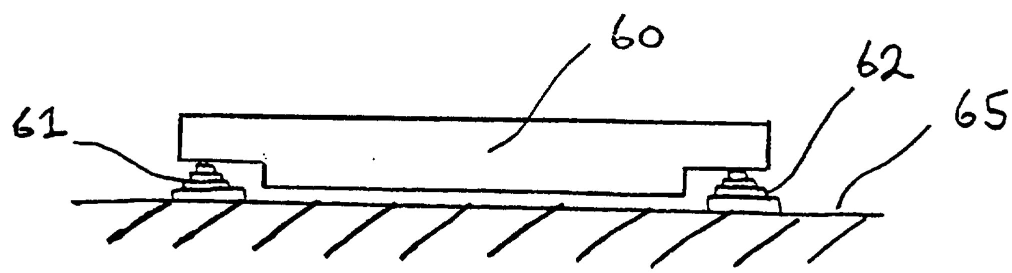


Figure 6

A means for determining the X, Y, and Z co-ordinates of a touched surface.

Introduction.

The invention described here realises a means for determining the position of a point of contact on a surface such that the x and y co-ordinates of the point in the plane of the surface as well as the amount of force applied to the surface at the point, herein referred to as the z co-ordinate, can be determined.

The amount of force applied to the surface can be determined by the use of suitably placed force sensitive devices which are positioned in such a manner that by a ratiometric comparison of their relative levels of measured force, it is possible to determine the relative position of the point of contact of the force on the surface independently of the degree of force applied. In this manner it is possible to determine the x and y co-ordinates of the point of applied force relative to an arbitrary datum on the surface.

Since the amount of force applied to the surface can also be determined by summing the individual forces measured by a number of suitably positioned force sensitive devices, it is possible to infer z axis information as related by the total amount of applied force. In this way x, y and z co-ordinate information can be inferred from the point of contact and degree of force applied to the surface.

The invention described here can be used for a variety of applications including the digitisation of hand-written input where a writing implement is used to apply force to a surface during the act of writing. The co-ordinates of the point of contact of the pen can be tracked by a computer, for example, such that the handwriting can be stored in machine-readable form. It is then possible to utilise the stored co-ordinates of the handwriting for tasks including signature recognition, character recognition and hand-written data entry among others.

The position of a point of contact on a surface can also be determined by the method described here such that the surface can be used as a pointing device, in conjunction with a computer for example.

The digitising surface can be made of a variety of materials including transparent materials such that the surface may be employed as an overlay to a visual display device such as a computer visual display unit, liquid crystal display or other suitable display. Alternatively the digitising surface may be an integral part of the visual display such as the front of a suitably supported liquid crystal display or cathode ray tube for example. Hence the invention may be used as a means of implementing a human/computer interaction by applying force with a finger tip, writing implement or some other form of stylus in the manner typical of a touch sensitive computer screen.

The invention described here is capable of being employed to implement a touch sensitive screen having significant advantages over other existing techniques. These advantages include a high level of resolution (such that small incremental positional changes can be tracked for example), the ability to determine the degree of force used in the touch, an ability to use a variety of pointing objects, including gloved or ungloved fingers, pens, pencils, styli etc., and also the opportunity to use plain glass (or other transparent) materials of various thicknesses in the construction of the touch sensitive screen without the need for any applied layers of sensing materials or special mounting of sensors on the surface. Since the amount of force applied to the surface can be determined to a good degree of accuracy it is also easier to take a decision regarding whether the surface has been touched or not as compared with other touch screen implementations.

A further significant advantage of the invention described here is that it can be used to implement a touch sensitive screen, writing surface or digitiser at a lower cost than that of existing techniques. This lower cost results from a reduction in the complexity of manufacture of a touch sensitive surface realised by this invention.

Summary of the invention.

Figure 1 shows a cross-sectional view of a rigid surface ***10*** supported on two force sensors ***1*** and ***2*** which rest on a support structure ***11*** which acts as a ground state.

Referring to figure 1, the point at which a force F (such as a touch) is applied to the rigid surface ***10*** will determine the relative degree of force experienced by each of force sensors ***1*** and ***2***. The force F will divide between the force sensors as F_1 and F_2 where:

$$F = F_1 + F_2 \qquad \text{\{Eqn. 1\}}$$

and

$$\frac{F_1}{F_2} = \frac{x_2}{x_1} \qquad \text{\{Eqn. 2\}}$$

where x_1 and x_2 are the distances from the point of applied force to force sensors ***1*** and ***2*** respectively.

Hence by measuring the relative levels of force experienced at F_1 and F_2 it is possible to compute the ratios of the distances x_1 and x_2. Also by measuring the total force F as the sum of F_1 and F_2 it is possible to determine the relative distances x_1 and x_2 independently of the degree of force applied. The relative position of the point of contact of the force as a ratio of the distance between the force sensors can be defined by either one of two equations as follows:

$$\frac{x_2}{x_1 + x_2} = \frac{F_1}{F_1 + F_2} \qquad \text{\{Eqn. 3\}}$$

or

$$\frac{x_1}{x_1 + x_2} = \frac{F_2}{F_1 + F_2} \qquad \text{\{Eqn. 4\}}$$

Since the distance $x_1 + x_2$ is known (being the distance between the force sensors ***1*** and ***2***) the position of the point of contact of the force F along the line joining the force sensors is also known.

Figure 2 extends the case described above in two dimensions as follows. If force sensors ***A*,*B*,*C*** and ***D*** are located as shown in figure 2 such that the force experienced by each is proportional to their distance from the point of contact of the applied force ***F***, then it is possible to compute the following:

$$X_1 = \frac{F_A + F_B}{2} \qquad \text{\{Eqn. 5\}}$$

$$X_2 = \frac{F_C + F_D}{2} \qquad \text{\{Eqn. 6\}}$$

$$Y_1 = \frac{F_B + F_C}{2} \qquad \text{\{Eqn. 7\}}$$

$$Y_2 = \frac{F_A + F_D}{2} \qquad \text{\{Eqn. 8\}}$$

where F_A, F_B, F_C and F_D are the levels of force experienced by force sensors ***A*,*B*,*C*** and ***D*** respectively (and the total force $F = F_A + F_B + F_C + F_D$) and X_1, X_2, Y_1 and Y_2 are the components of force ***F*** acting at the midpoints of lines **AB**, **CD**, **BC** and **AD** respectively, as illustrated in figure 2.

In an exactly analogous case to that described previously with reference to figure 1, the relative distances x_1, x_2, y_1 and y_2 shown in figure 2 can be computed as follows:

$$\frac{x_2}{x_1 + x_2} = \frac{F_A + F_B}{F_A + F_B + F_C + F_D} \qquad \text{\{Eqn. 9\}}$$

$$\frac{x_1}{x_1 + x_2} = \frac{F_C + F_D}{F_A + F_B + F_C + F_D} \qquad \text{\{Eqn. 10\}}$$

$$\frac{y_2}{y_1 + y_2} = \frac{F_B + F_C}{F_A + F_B + F_C + F_D} \qquad \text{\{Eqn. 11\}}$$

$$\frac{y_1}{y_1 + y_2} = \frac{F_A + F_D}{F_A + F_B + F_C + F_D} \qquad \text{\{Eqn. 12\}}$$

Hence it can be seen that the relative positions of the point of contact of the applied force ***F*** can be determined independently of the degree of force ***F*** applied to the surface.

The means for determining the level of force at each of the suitably located force sensors can be implemented in a variety of ways. A preferred embodiment is one where a force sensing element consists of a layer of a piezoresistive material deposited onto a substrate in such a manner as to form an electrical resistor. When the resistor is subjected to an applied force, its resistance will change due to the changes in geometry experienced and any piezoresistive effects on the resistivity of the material comprising the resistor.

The relationship between the applied force F and the strain ε experienced by the piezoresistive material is given by:

$$\varepsilon = \frac{F}{a.E} \qquad \{\text{Eqn. 13}\}$$

where a is the area over which the force is applied and E is the modulus of elasticity of the material comprising the resistor.

The relationship between the applied strain ε and the change in resistance δR of an electrical resistor of resistance R ohms, when the strain is applied in the same plane as the electrical current flow through the resistor, is given by the following equation:

$$\delta R/R = \varepsilon(1 + 2\nu) + \delta\rho/\rho \qquad \{\text{Eqn. 14}\}$$

where ν is Poisson's ratio for the material comprising the planar electrical resistor and ρ is the electrical resistivity of the material. By re-arrangement of equation 14, the sensitivity of the strain sensitive resistor can be defined in terms of its gauge factor G as follows:

$$G = (1+2\nu) + (\delta\rho/\rho)/\varepsilon \qquad \{\text{Eqn. 15}\}$$

Where $G = (\delta R/R)/\varepsilon$ and the term $(\delta\rho/\rho)/\varepsilon$ is usually referred to as the piezoresistive coefficient and is determined by the material comprising the resistor and the orientation of the electrical current flow in the resistor relative to the plane in which the force is applied to the resistor.

In the present invention a preferred embodiment of the piezo-resistive force sensor is where the material comprising the electrical resistor is a thick film resistor paste. This confers several advantages including a sensitivity higher than that of most commercially available resistive strain gauges due to a higher value for the piezoresistive coefficient of the material. Additionally it is possible to fabricate the sensor in such a way as to produce very small surface areas for the electrical resistors onto which the applied force can then be concentrated. This in turn concentrates the stress due to the applied force, and consequently the strain experienced by the force sensing resistor for any given modulus of elasticity.

The orientation of current flow in the resistor may be in one of several planes relative to the applied force which is to be measured. A preferred embodiment of the sensor is one where the force applied and the electrical current flowing through the force sensing resistor are both normal to the plane of the supporting substrate. This mode of operation results in an optimum level of sensitivity due to the fact that the piezoresistive coefficient is maximised whilst the effect of any temperature coefficient of expansion mismatch between the substrate and the materials comprising the force sensing resistor is minimised.

Figure 3 shows a typical embodiment of a piezo-resistive force sensor where a highly conducting layer of material *31* is deposited onto a suitable insulating substrate *32*. A resistive material *33* is then deposited on top of the bottom layer conductor *31* and a further layer of high conductivity material *34* is deposited on top of the resistive material *33*. The conducting layers *31* and *34* may be deposits of a suitably processed thick film paste containing a conductive material such as gold although other materials may be used. A suitable supporting insulating substrate *32* may be made of aluminium oxide although other materials may also be used. The resistive layer *33* may be a suitably processed thick film resistor paste or other strain sensitive material.

The cross-section along the line AA in Figure 3 shows the overlapping nature of the layers which are arranged so as to leave a small area of resistive material sandwiched between the two conducting layers. This area of overlap *35* (shown hatched in figure 3) can be designed to be as small as is necessary for the particular application for which it is intended. This is in order to maximise the amount of stress, and hence strain, experienced by the resistor for any given applied force so as to optimise device sensitivity.

Figure 4 shows an alternative embodiment wherein the geometry of the overlapping layers is arranged to be circular in order to minimise excessive stress concentrations such as could occur with rectangular geometries. The preferred embodiment illustrated in figure 4 shows a circular arrangement of a bottom conducting layer ***41*** onto which the resistive layer ***43*** and a top conducting layer ***44*** have been deposited so as to form an area of overlap ***45*** (shown hatched in figure 4). Other stress concentration avoiding geometries are of course possible particularly ones where square corners or sharp changes in direction of the boundaries of the patterns defining the active area of the sensor are avoided.

Figure 5 shows an embodiment of a touch sensitive surface wherein four force sensors ***51***, ***52***, ***53*** and ***54***, such as described in figure 3 for example, are located between a suitable surface ***50*** such as a sheet of glass (or other suitable material) and a support structure ***55***, or ground state. This support structure may be a computer display for example, or a frame mounted on a computer display, or another sheet of transparent material.

Figure 6 illustrates a further embodiment of the invention wherein the touch sensitive surface comprises a display unit ***60*** such as a liquid crystal display, cathode ray tube or other suitable display with force sensors ***61***, ***62***, etc. being located between the display unit and a suitable support structure ***65***, or ground state. Other placements of the force sensors located between the touched surface and the support structure are of course possible and the number of force sensors employed may also be varied. A suitable support structure may be a part of a computer or display unit such as a frame or casing or any other suitably rigid structure.

The implementation of a touch sensitive surface by means of this invention may of course utilise the measured degree of force applied to the surface as compared to some pre-determined threshold value to determine whether or not a touch has occurred and, similarly, whether or not a pen or other writing implement is in contact with the surface.

Claims.

1. A means for determining the relative position of a point of contact of a force applied to a surface, independently of the degree of force applied, by measuring and comparing the levels of force experienced in suitably located piezo-resistive force sensors also enabling the degree of force applied to a point on a surface to be determined independently of the position of the point at which the force is applied thereby enabling the implementation of a touch sensitive surface such that the point of contact on the surface and the degree of force applied to the surface can be accurately determined with said touch sensitive surface being capable of resolving the degree of force to a level such that determination of a touch can then be decided upon by comparison with some pre-determined threshold value.

2. A means as described in claim 1 where each of the piezo-resistive force sensors is formed from a strain sensitive electrically resistive material.

3. A means as described in claim 1 where the applied force is orthogonal to the supporting substrate and the piezo-resistive force sensors are fabricated as planar resistors.

4. A means as described in claim 1 where the applied force is both parallel to the electrical measurement current flowing in planar resistors comprising the piezo-resistive force sensors and orthogonal to the supporting substrate.

5. A means as described in claim 1 where the piezo-resistive force sensors are fabricated as thick-film screen printed resistors.

6. A means as described in claim 1 where the piezo-resistive force sensors are fabricated as a thick-film screen printed material sandwiched between the overlap of two conducting layers.

7. A means as described in claim 1 where the thick-film force sensors are fabricated as circular patterns or other suitable geometries to minimise stress concentrations.

8. A touch sensitive surface as claimed in claim 1 used as a writing surface.

9. A touch sensitive surface as claimed in claim 1 where the surface is transparent such that it may be used as an overlay to a visual display in the manner of a touch sensitive screen.

10. A touch sensitive surface as claimed in claim 1 where the touched surface is an integral part of a suitably supported visual display.

11. A touch sensitive surface as claimed in claim 1 where the degree of force applied to the surface is used to determine the presence or absence of a touch.

12. A touch sensitive surface as claimed in claim 1 used as a writing surface where the degree of force applied to the surface is used to determine whether or not a pen or other writing or pointing implement is in contact with the surface.

Amendments to the claims have been filed as follows

1. A means for determining the relative position of a point of contact of a force applied to a surface, independently of the degree of force applied, by measuring and comparing the levels of force experienced in suitably located piezo-resistive force sensors fabricated as thick-film screen printed resistors thereby enabling the degree of force applied to a point on a surface to be determined independently of the position of the point at which the force is applied and hence enabling the implementation of a touch sensitive surface such that the point of contact on the surface and the degree of force applied to the surface can be determined.

2. A means as described in claim 1 where the force applied to the piezo-resistive sensors is orthogonal to their supporting substrates and the piezo-resistive force sensors are fabricated as planar resistors.

3. A means as described in claim 1 where the applied force is both parallel to the electrical measurement current flowing in the piezo-resistive force sensors and orthogonal to their supporting substrates.

4. A means as described in claim 1 where the piezo-resistive force sensors are fabricated as a thick-film screen printed material sandwiched between the overlap of two conducting layers.

5. A means as described in claim 1 where the thick-film force sensors are fabricated as circular patterns or other suitable geometries to minimise stress concentrations.

6. A touch sensitive surface as claimed in claim 1 used as a writing surface.

7. A touch sensitive surface as claimed in claim 1 where the surface is transparent such that it may be used as an overlay to a visual display in the manner of a touch sensitive screen.

8. A touch sensitive surface as claimed in claim 1 where the touched surface is an integral part of a suitably supported visual display.

9. A touch sensitive surface as claimed in claim 1 where the degree of force applied to the surface is used to determine the presence or absence of a touch.

10. A touch sensitive surface as claimed in claim 1 used as a writing surface where the degree of force applied to the surface is used to determine whether or not a pen or other writing or pointing implement is in contact with the surface.

The Patent Office

12

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Claims searched: 1 to 12

Examiner: Peter Easterfield
Date of search: 22 April 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.6): G06K 11/06, 11/16

Other: Online: WPI, JAPIO, CLAIMS

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,E	GB 2316177 A	(RICHARDS et al)	1,2,8-11
X	GB 2313195 A	(UNIVERSITY OF BRISTOL)	1,2,8-11
Y	GB 2198237 A	(FINCH et al)	1,2
Y	GB 2180342 A	(ALCOM)	1,2,8-11
X	GB 2143660 A	(MATSUSHITA)	1,2,8-11
Y	EP 0434314 A2	(IBM)	10
Y	US 4355202 A	(DECOSTA et al)	1,2, 8-11
X	WO 96/38833 A1	(AVI SYSTEMS)	1,2,8-11

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