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Jebb et al.

[11] **3,763,479**

[45] **Oct. 2, 1973**

[54] **COMPUTER INPUT/OUTPUT EQUIPMENT**

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Dec. 22, 1970 Great Britain 60,860/70

[52] **U.S. Cl.** **340/172.5,** 346/29

[51] **Int. Cl.** **G01d 9/00**

[58] **Field of Search** ..... 346/29; 33/1 M, 18 R, 33/23 C, 24 R; 235/151.11, 197; 340/172.5

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Primary Examiner—Gareth D. Shaw
Attorney—Karl W. Flocks

[57] **ABSTRACT**

A digitising table unit for use with a digital computer having two parallel table surfaces with a digitising pen on the top table surface and a bug below that surface movable along *x* and *y* axes by servo-motors coordinated with the pen, and retractable pen means on the bug to engage the lower table surface to trace out a representation on the lower table surface with encoding of the bug position in signals to the computer.

23 Claims, 18 Drawing Figures

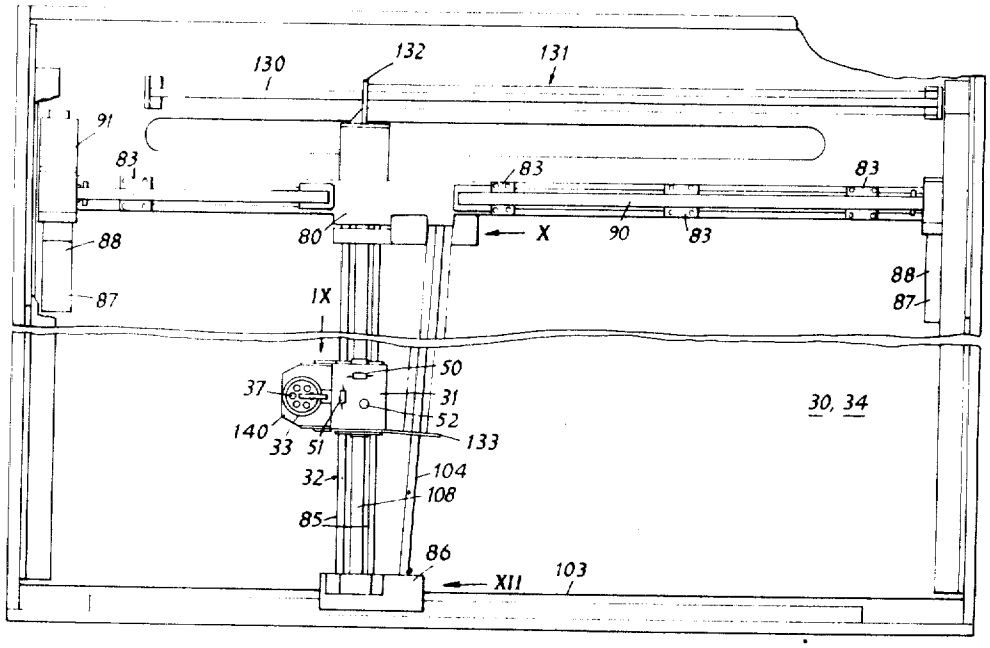
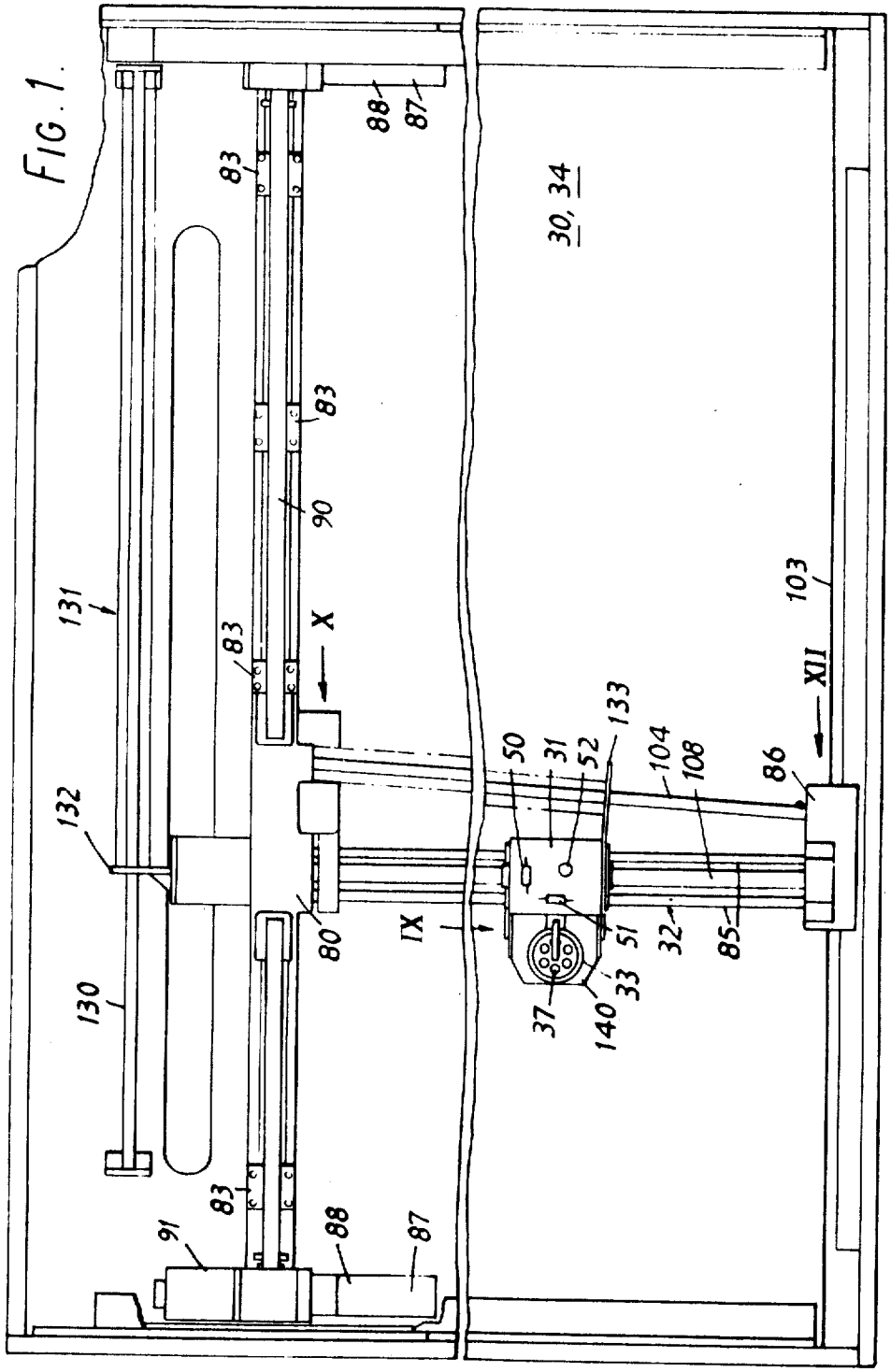


FIG. 1.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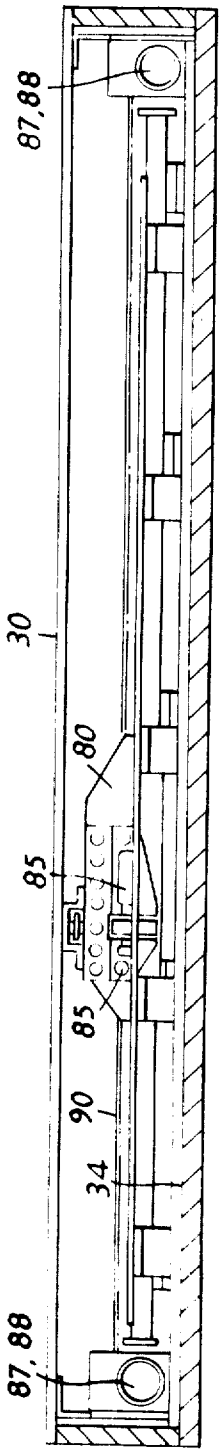
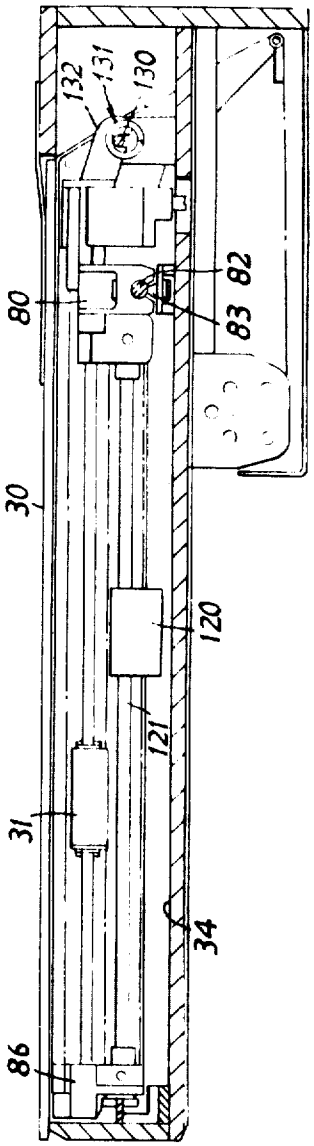


FIG. 2.



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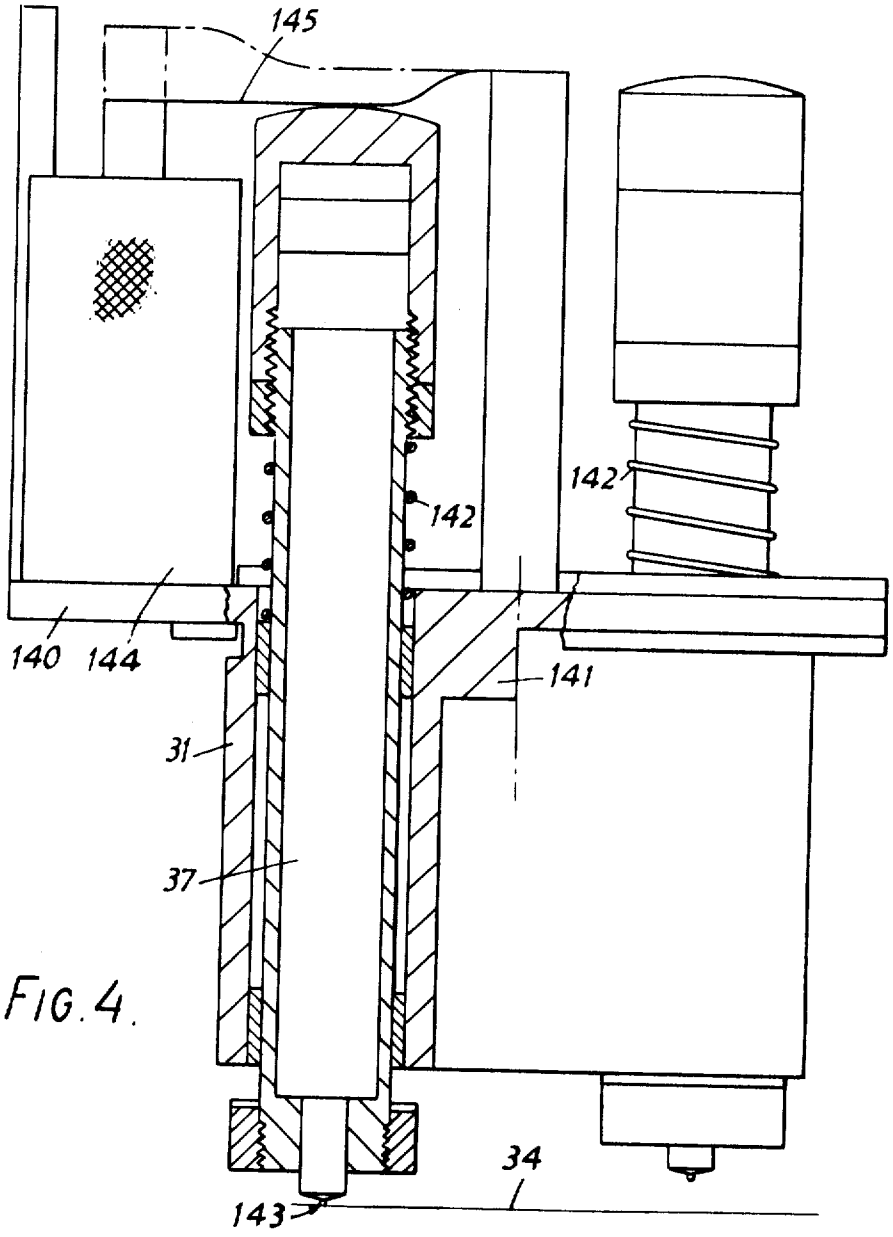
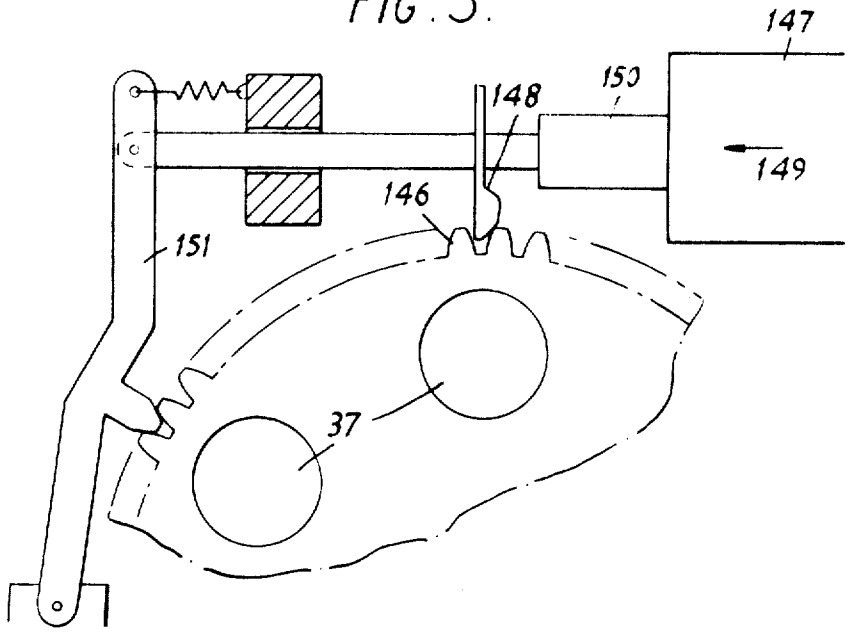


FIG. 4.

FIG. 5.



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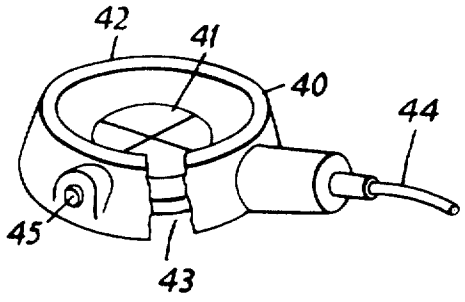


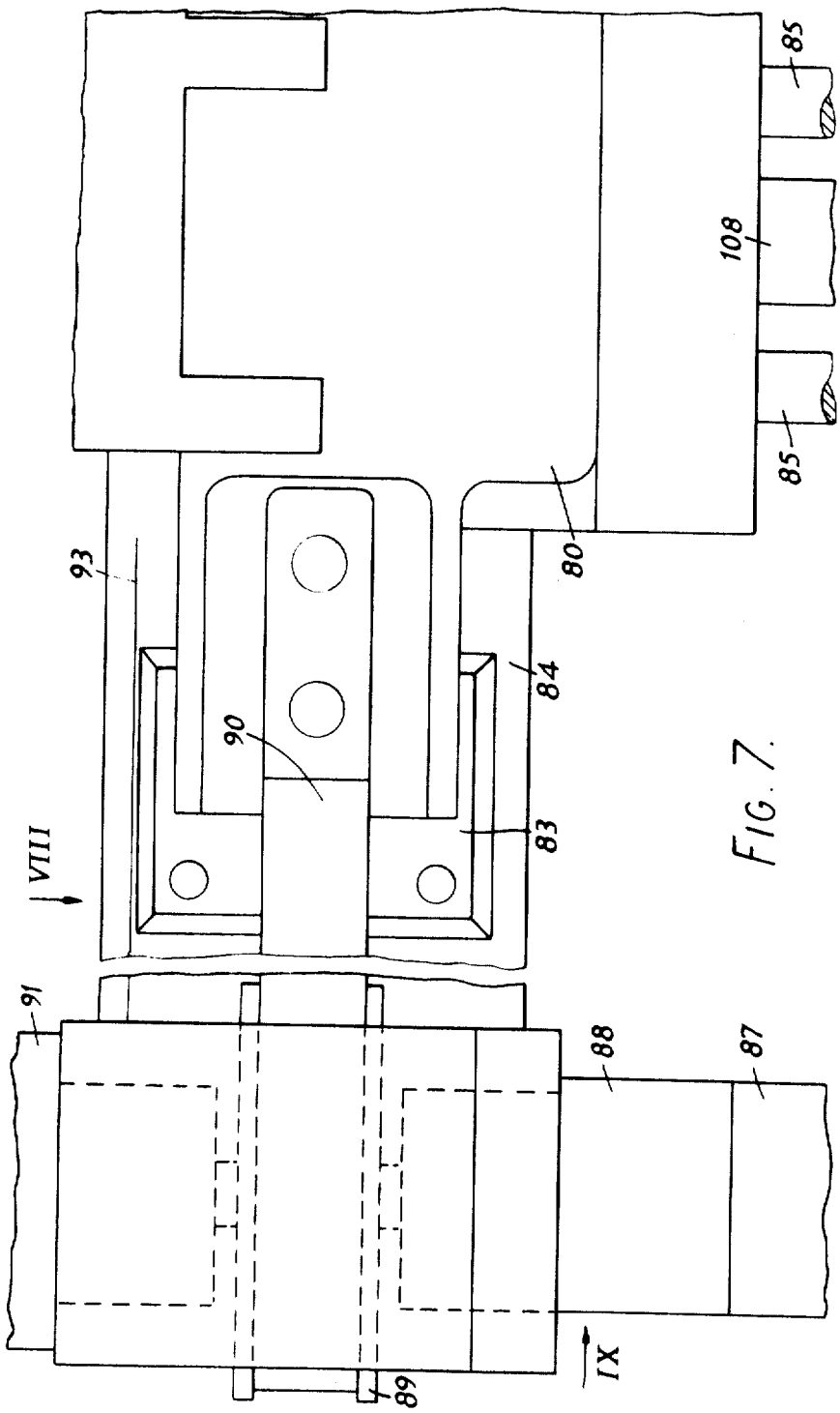


FIG. 7.

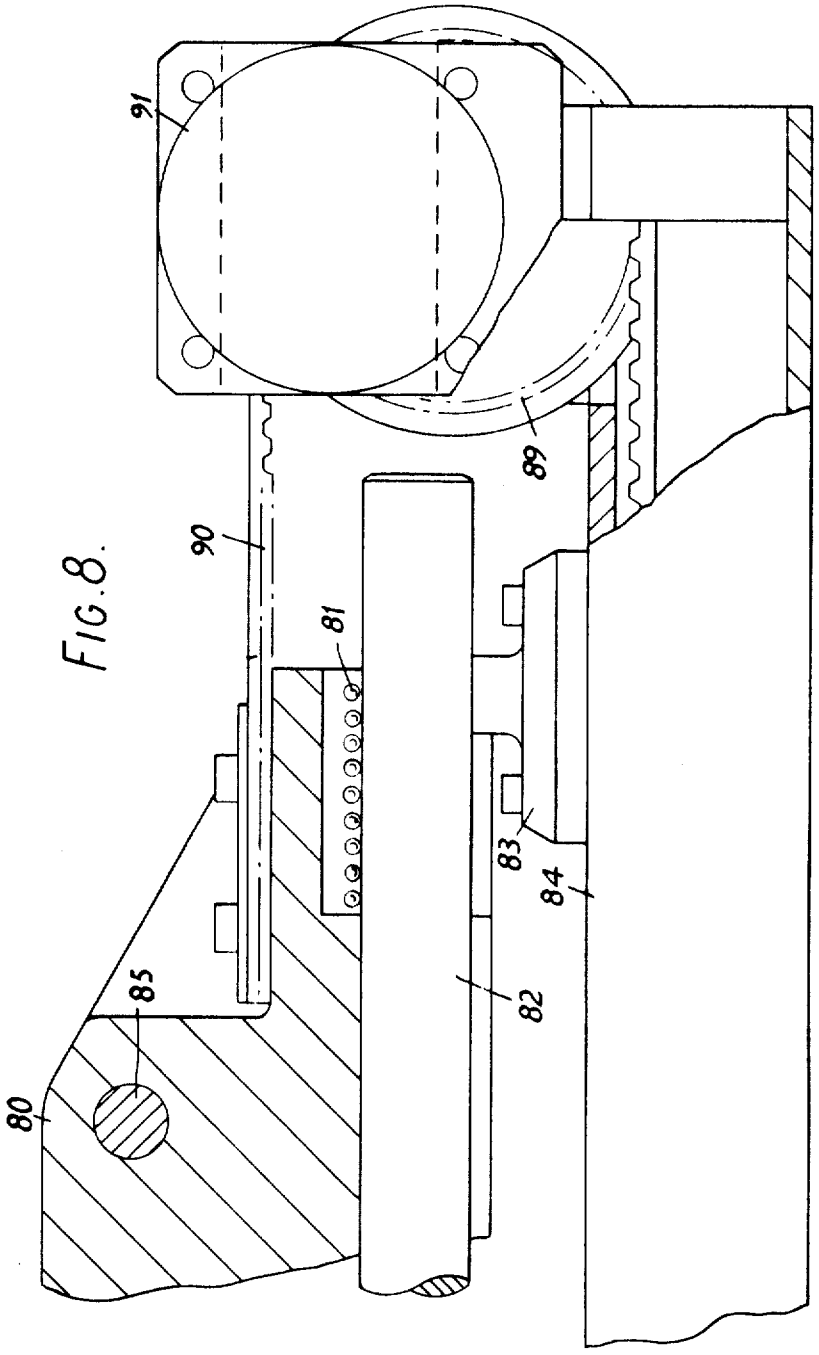
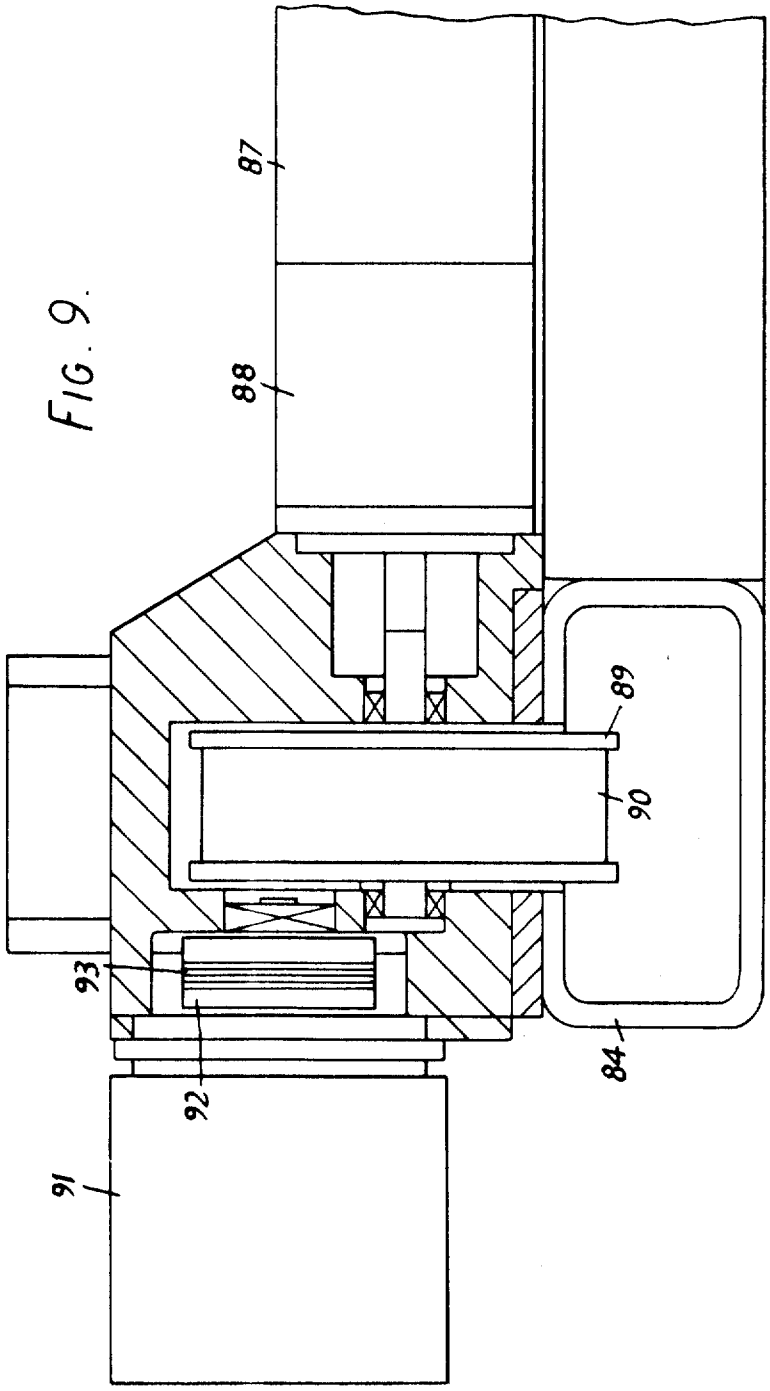


FIG. 8.

FIG. 9.



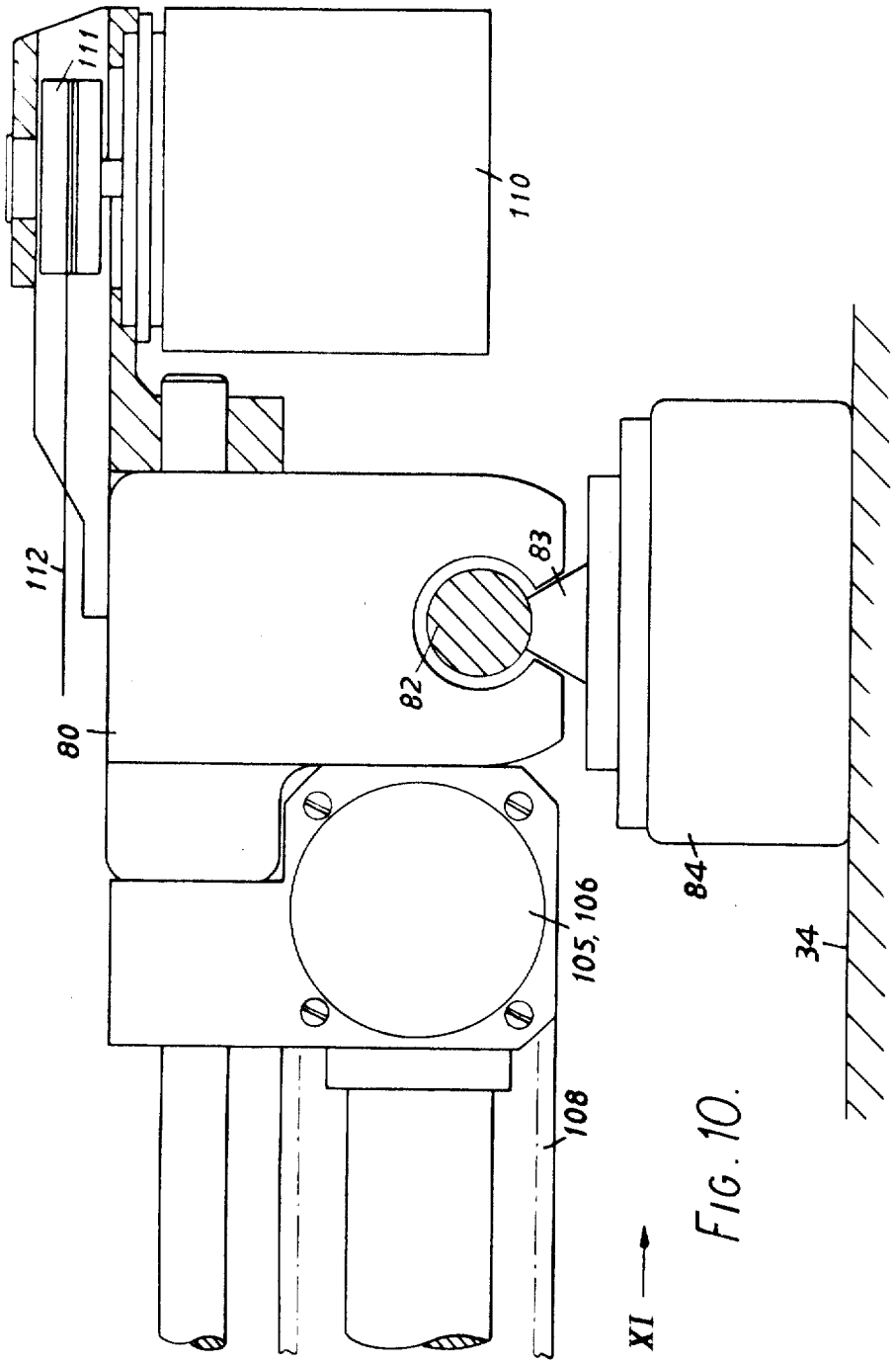


FIG. 10.

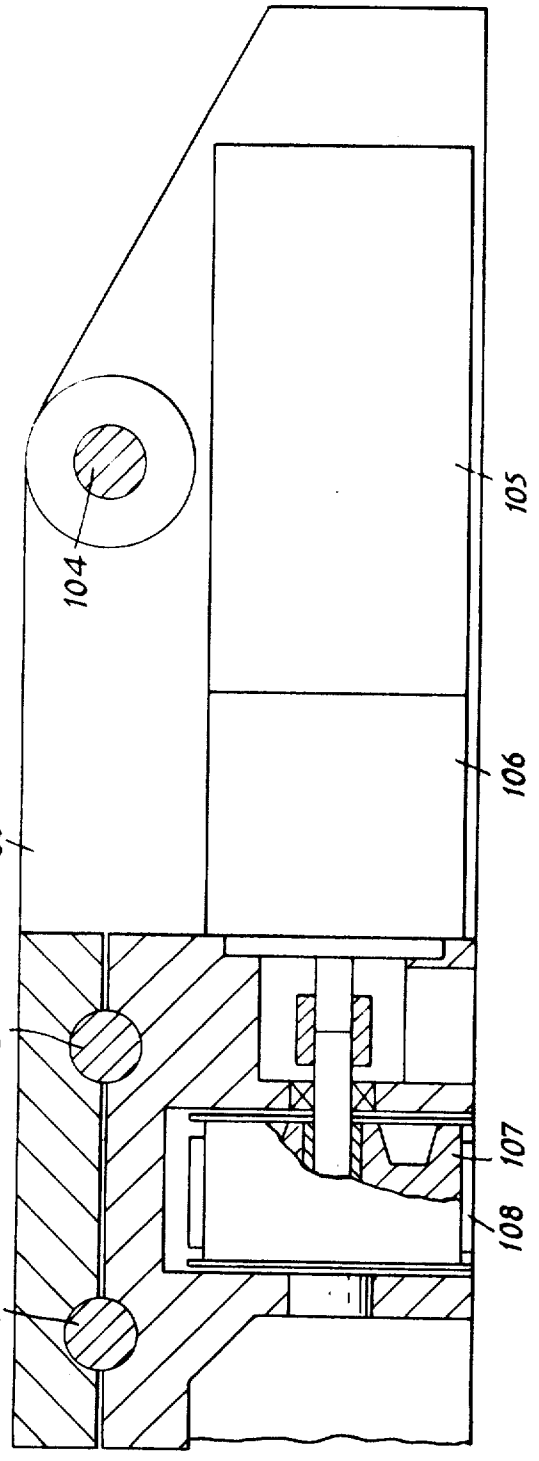


FIG. 11.

FIG. 12.

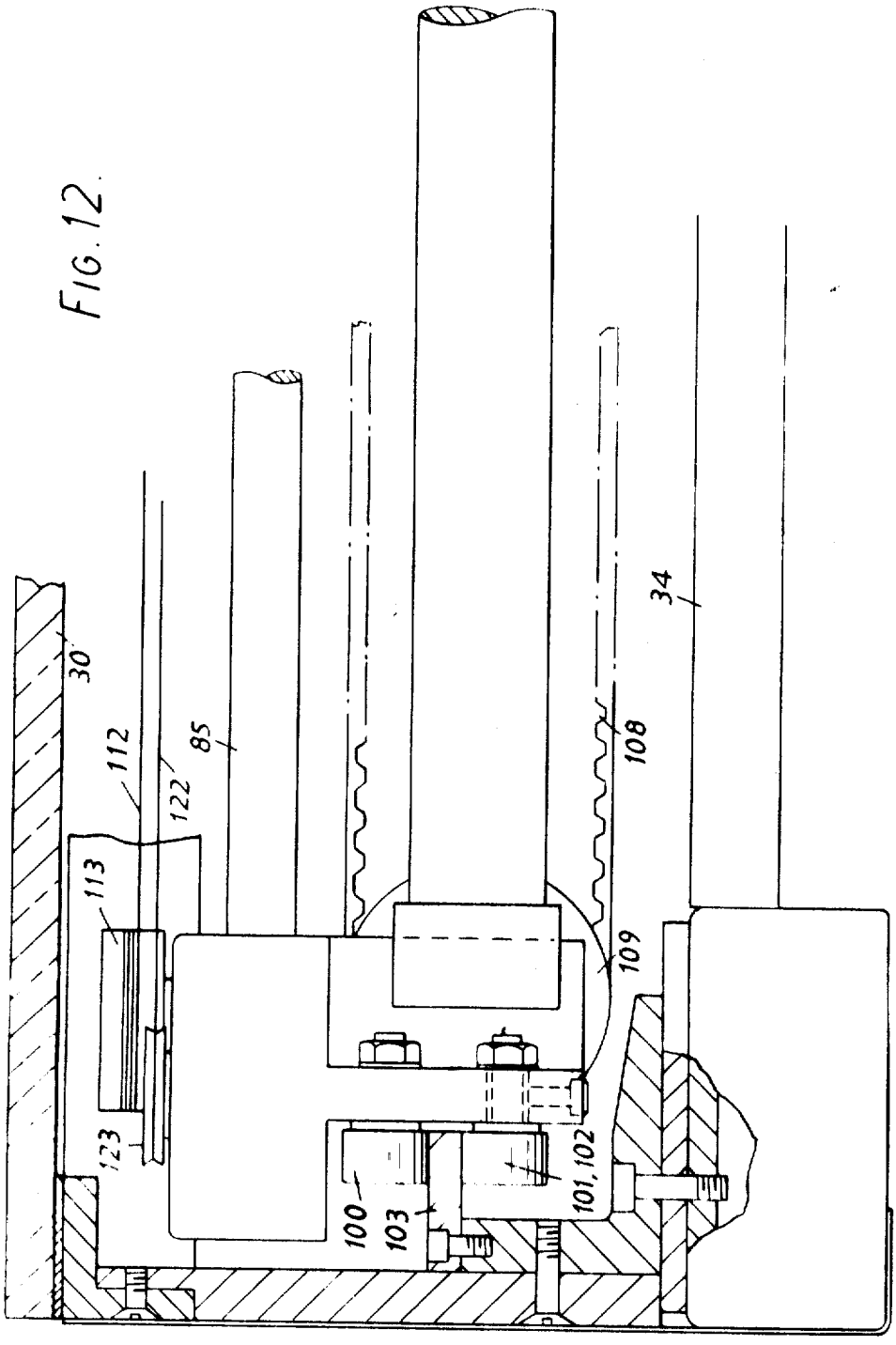


FIG. 13

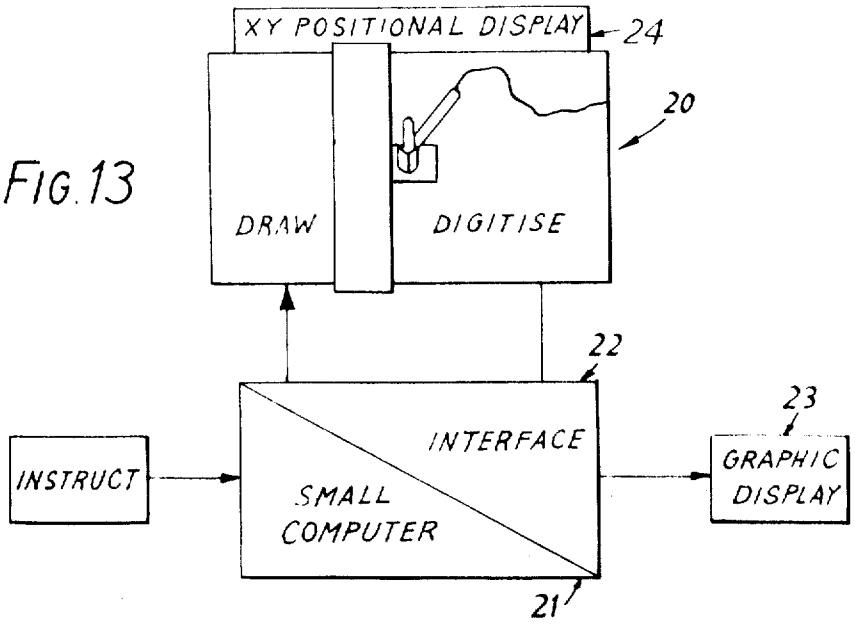

XY POSITIONAL DISPLAY
24
20
DRAW
DIGITISE
22
23
INTERFACE
INSTRUCT
SMALL
COMPUTER
GRAPHIC
DISPLAY
21

FIG. 14.

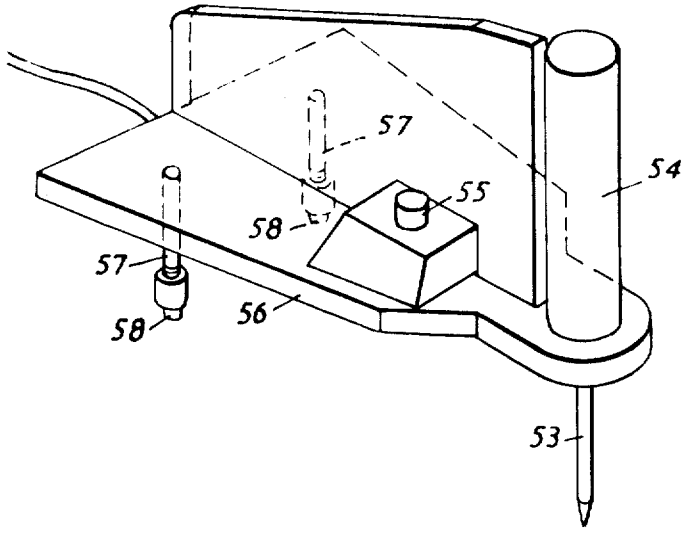

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FIG. 15.

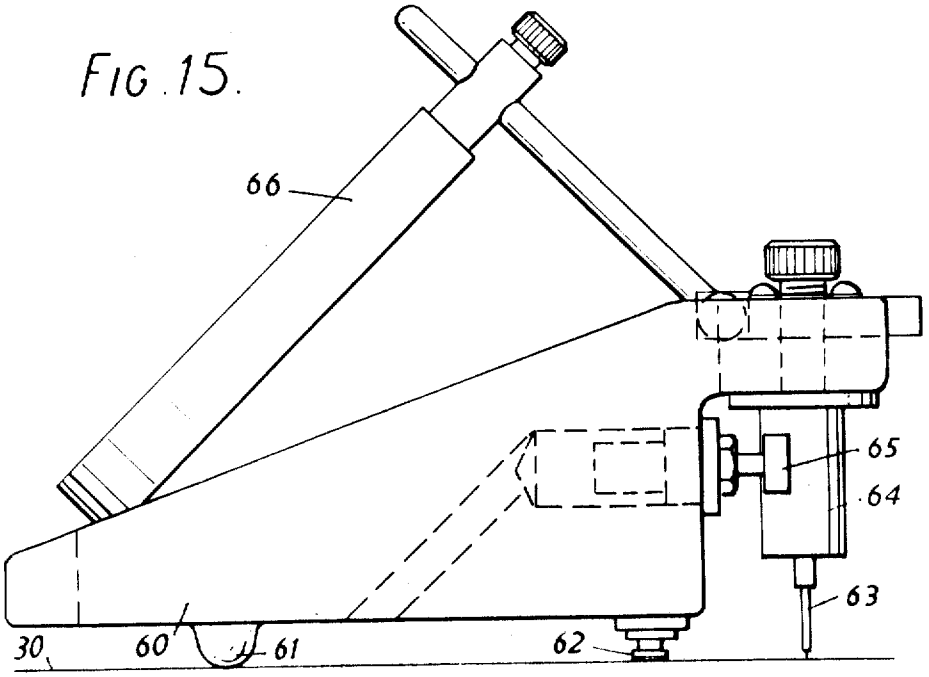


FIG. 16.

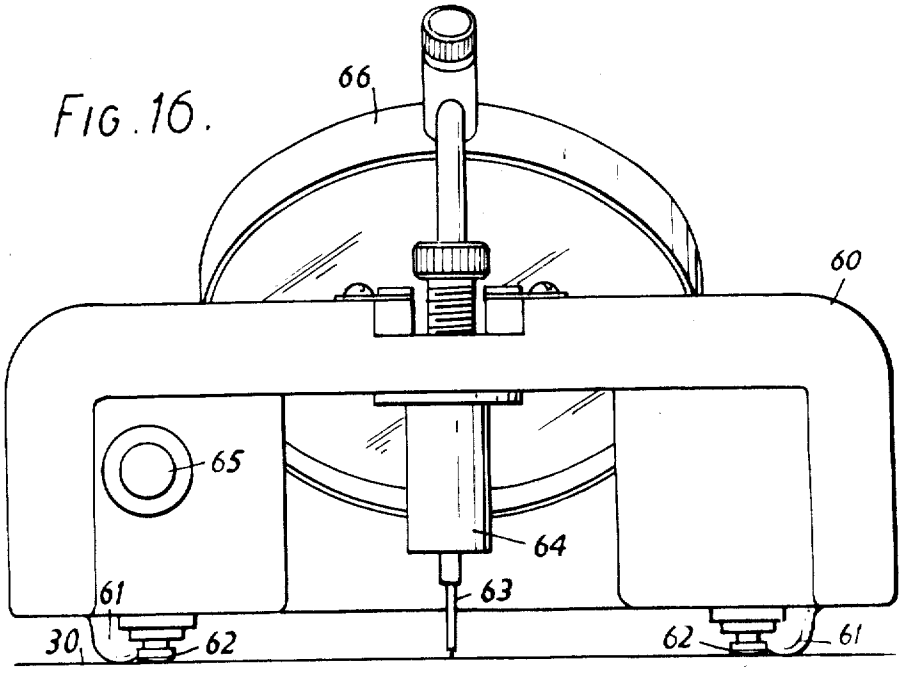
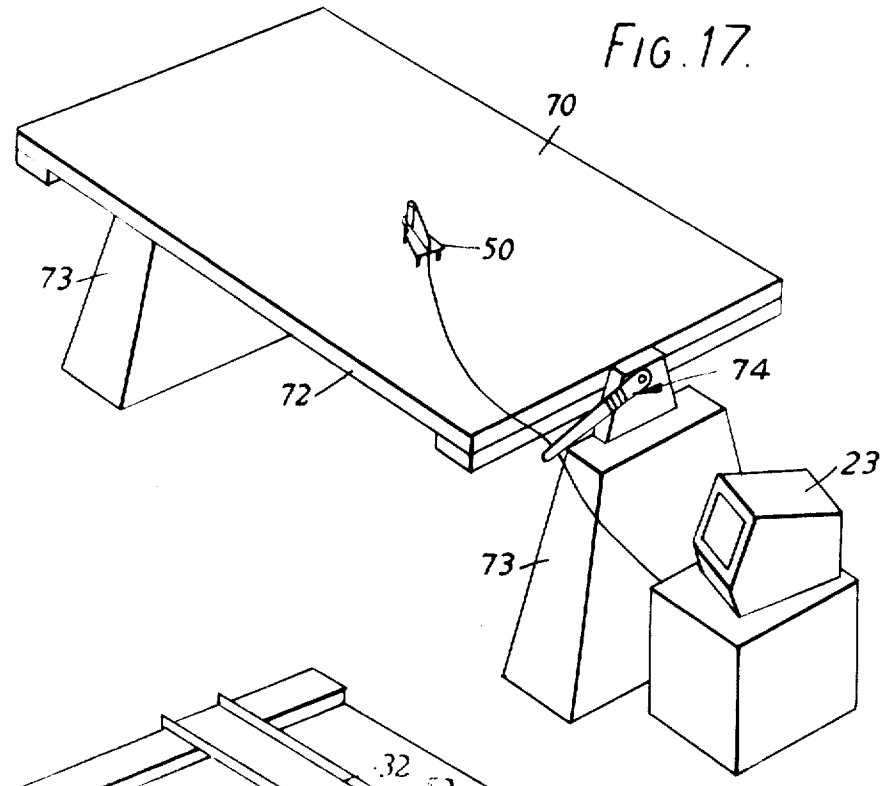


FIG. 17.



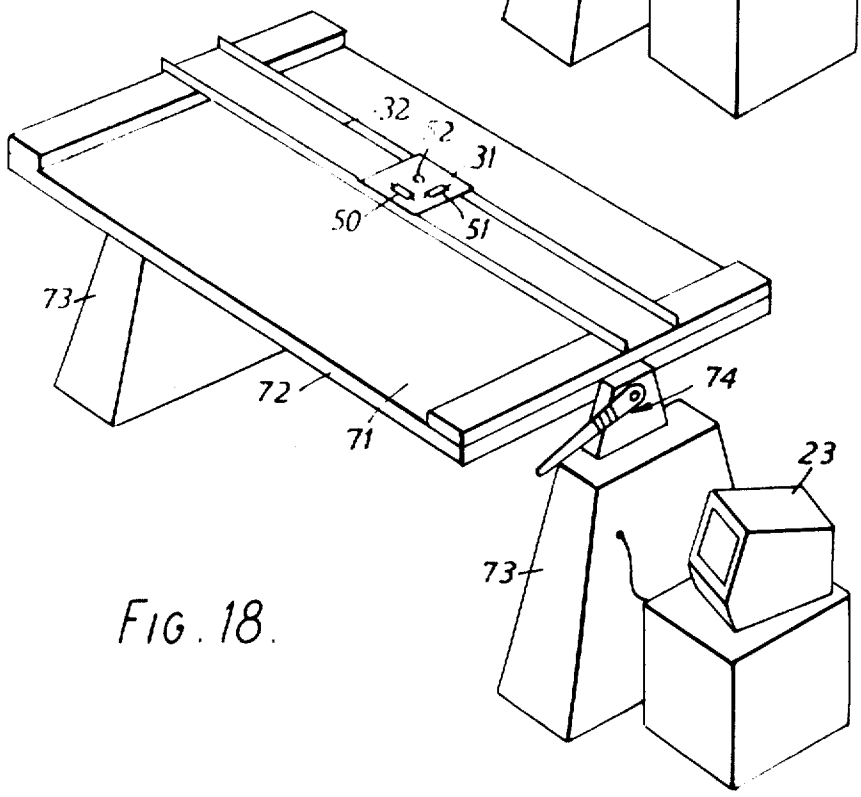


FIG. 18.

COMPUTER INPUT/OUTPUT EQUIPMENT

BACKGROUND OF THE INVENTION

This invention relates to a fully inter-active computer aided design system and provides an input/output digitising/drawing table for connection "on-line" to a computer through a suitable interface.

At the present time, in a variety of fields of application, more and more use of computers is being attempted for assisting in design or planning operations. With this in mind, attempts are being made to commit the contents of engineering drawings, or other data sheets such as plans of buildings, planning layouts of piping or electrical wiring, or even maps of sites of areas of country, to the memory storage of a computer, so that the computer may be called upon at a subsequent time to give a "print-out" or "draw-out" of that data in the form of a drawing on a co-ordinate drawing table.

Various methods have been proposed for translating the information taken from a drawing into a suitable encoded form for assimilation by a computer, one such method being the use of a digitising table.

Such a digitising table would comprise a surface upon which a drawing or other plan sheet may be placed together with a free probe or "digitising pen" which could be used to point to particular items or positions on the drawing. The table would include means to sense the position of the "pen" at any chosen instant of time and convert that position into x and y co-ordinates with respect to an origin on the surface of the table, and to encode those x and y co-ordinates into electrical signals for subsequent transmission to the computer.

In previously proposed systems the data was digitised and committed to long term memories stores in the computer, such as magnetic tape, and would be used to produce a drawing at a later date with the computer controlling a separate output table on which a "pen" or other marking instrument was driven across a drawing sheet by suitable x and y and co-ordinate servo-motor systems.

A further proposal which has been used in this field is the provision of a cathode ray tube display connected to an output of a computer, and associated with a "light pen" with which a picture or drawing can be "drawn" on the face of the cathode ray tube leaving behind an illuminated trace. Such display systems have been of two basic types; one using a storage type of cathode ray tube, in which the trace is maintained on the face of the tube, by physical characteristics of the phosphors, for a period of some hours, and being only erasable by means of flooding the whole phosphor face with electrons from within the tube; and the other being the video type of display in which the cathode ray tube face is continually scanned by an electron beam in the manner of a television picture, with the display or picture drawn thereon being re-created at each frame of the scanning. The first of these systems suffered from the difficulty of erasing and correcting a drawing in that the whole picture had to be re-drawn up to the point of the error each time an erasure and correction was required, and both of these systems can suffer from difficulties in establishing accurate dimensional and co-ordinate positions to scale on the drawing. The second of the systems also suffers from the considerable disadvantage that it consumes a large capacity of core store within the computer simply to maintain a picture of any

complexity on the face of the tube as it is scanned. It can be seen that the capacity of core store consumed is proportional to the resolution of the picture and has been typically of the order of 12K to 16K bits of store capacity which has been a handicap not only in the capital cost but in the operation of more sophisticated programmes during use of the display.

Both these previous systems have also suffered the disadvantage that a permanent or "hard" copy of a drawing could only be obtained photographically from the face of the tube, or an additional plotter.

It is an object of the present invention to alleviate the disadvantages of the previous systems.

SUMMARY OF THE INVENTION

Accordingly, in one aspect, the present invention provides an input/output digitising/drawing table unit for connection on-line to a computer, comprising a first or digitising table surface, a freely moveable digitising pen which may be placed at any chosen position within the area of said first table surface, a bug mounted below said first table surface to be moveable along x and y axes by means of servo-motors to a position corresponding to the position of said digitising pen when it is placed on said first table surface, encoding means by which the x and y co-ordinates of the position of said pen on said first table surface may be converted to electrical signals for transmission to a computer, a second table surface occupying a plane parallel to that of said first table surface and a retractable pen mounted on said bug whereby movement of said bug may trace out a representation on said second table surface under the control of a computer.

According to a further aspect, the present invention provides a table unit of the preceding paragraph connected on-line to a digital computer through a suitable interface.

According to yet a further aspect, the present invention provides the combination of the preceding paragraph with the computer programmed to receive and store co-ordinate information of positions on said first table surface selected with said pen, together with instruction data relating to those points, and subsequently to control said bug and said pen in movement over said second table surface to produce a representation in accordance with that co-ordinate information and instruction data.

Preferably in the combination of the preceding paragraph, the first table surface is provided with a menu card delineating a plurality of distinct areas within which said pen may be placed, each said area being associated with a particular instruction for the computer, and the computer is arranged to locate that part of its programme associated with that one of said plurality of said area within which said pen may be placed.

According to yet a further aspect, the present invention provides in the combination of either of the preceding a visible display on a cathode ray tube of the contents of stored digitised information.

According to yet a further aspect, the present invention provides a programme for the computer in the combination of the last four paragraphs.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to promote a fuller understanding of the above, and other, aspects of the present invention, some embodiments will now be described, by way of

example only, with reference to the accompanying drawings in which :

FIG. 1 is a plan view of an input-output table,

FIG. 2 is a side view in part cross-section of the table of FIG. 1,

FIG. 3 is an end view in part cross-section of the table of FIG. 1,

FIG. 4 is a more detailed side view in part cross-section taken of the pen carrier of the table of FIG. 1 taken on the arrow IV of that Figure,

FIG. 5 is a plan view of the pen index mechanism of FIG. 4,

FIG. 6 is a schematic perspective view of a digitising pen or index for use with the table of FIG. 1,

FIG. 7 is a plan view of the left hand *x*-axis drive servo of the table of FIG. 1,

FIG. 8 is a part cross-sectional view on the arrow VIII of FIG. 7,

FIG. 9 is a part cross-sectional view on the arrow IX of FIG. 7,

FIG. 10 is a part cross-sectional end view of the mounting of the *y*-axis gantry of the table of FIG. 1, taken on the arrow X of that Figure,

FIG. 11 is a part cross-sectional view on the arrow XI of FIG. 10,

FIG. 12 is a part cross-sectional end view of the *y*-axis gantry guide of the table of FIG. 1, taken on the arrow XII of that Figure,

FIG. 13 is a schematic block diagram of the table of FIG. 1 coupled with a small computer and a display tube,

FIG. 14 is a perspective view of a further type of digitising pen for use with the table of FIGS. 1 to 3,

FIG. 15 is a side view of yet a further type of digitising pen for use with the table of FIGS. 1 to 3,

FIG. 16 is an end view of the pen of FIG. 15,

FIG. 17 is a perspective view of a further input/output table, and

FIG. 18 is a perspective view of the table of FIG. 17 in a different position.

DESCRIPTION OF PREFERRED EMBODIMENTS

In this embodiment of the invention, a dual purpose input/output table indicated generally at **20** in FIG. 13 is connected "on-line" to a small computer **21** by means of an interface **22**.

The table **20** is shown in more detail in FIGS. 1 to 12 and comprises an upper digitising table surface indicated at **30** which is preferably, though not essentially, transparent. Immediately below the surface **30** a bug **31** is mounted for traverse along a gantry arm **32** in a direction across the table, which in subsequent discussion will be designated the *y* axis; and the gantry arm **32** is itself mounted for longitudinal traverse along the table, in a direction which in subsequent discussion will be designated the *x* axis. The bug **31** is provided with a pen carrier indicated generally at **33** supported below it and arranged to carry a plurality of retractable pens **37** or other marking instruments, which may preferably be in the form of ballpoint pens.

A further or lower table surface **34** is provided to occupy a plane parallel to that of the table **30** and immediately below the bug **31** so that as the bug **31** is traversed in the *x* or *y* direction the pen **37** carried thereon can trace out its path on a sheet of paper or other material laid on the surface of the table **34**.

FIGS. **7, 8** and **9** show in more detail the arrangements for the mounting and servo drive of the gantry arm **32**. The gantry arm **32** comprises an upper housing **80** which is mounted by means of re-circulating ball bearings **81** for traverse along the *x*-axis on a rail **82** which is of circular cross-section. The rail **82** is supported at one edge of the table by a series of posts **83** on a rectangular section tube **84** which is itself supported on the lower drawing surface **34**. The housing **80** carries a pair of circular cross-section bars **85** which extend across the table in the direction of the *y*-axis to a support housing **86** at the far edge of the table. The bars **85** form a slideway for the bug **31** for its movement in the *y*-axis, the bug **31** being supported on the bars **85** which are of circular cross-section by means of re-circulating ball bearings.

A servo motor **87** with associated reduction gearing **88** is mounted at each end of the rail **82** for the *x*-axis drive of the housing **80**. Each servo motor **87** is arranged to drive an associated toothed pulley **89** which engages with a tooth belt **90** extending in a loop from one side of the housing **80** over the two pulleys and back to the other side of the housing **80**.

On the left hand side of the table as seen in FIG. 1 a digital position encoder **91** for the *x*-axis is mounted opposite the servo motor at that end, and is provided with a grooved pulley **92**. A fine close tolerance steel wire **93** is wound several turns around the pulley **92**; and is looped over a suitable pulley at the opposite end of the rail **82** with the ends of the wire being attached to respective sides of the housing **80**. Thus it can be seen that movement of the housing **80** along the *x*-axis causes proportional rotation of the pulley **92** and thus drives the encoder to produce an output signal representative of the position of the bug **31** in the *x*-axis.

The support housing **86**, as best seen in FIG. **12**, is provided with a set of three rollers **100, 101** and **102** which are arranged to engage with and run along a fixed rail **103** to guide the lower end of the gantry arm **32**. A further bar **104** extends between the housing **80** and the support housing **86** at an angle to the bars **85** to afford rigidity of the gantry arm **32** in the *x*-axis direction.

A single servo motor **105** with associated gearing **106** is mounted in the housing **80** to drive the bug **31** along the gantry arm **32** in the *y*-axis direction. In the embodiment shown the servo motor **105** drives a toothed pulley **107** and a tooth belt **108** is looped around that pulley and a pulley **109** carried in the support housing **86** with the ends of the belt being attached to respective sides of the bug **31**. As best seen in FIG. **10**, a position encoder **110** is mounted with its axis vertical on the housing **80** with an associated grooved pul'ey **111**. A close tolerance steel wire **112** is wound around the pulley **111** looped over a pulley **113** on the support housing **86** with the ends of the wire being attached to respective sides of the bug **31**. Thus it can be seen that the bug **31** is driven in the *y*-axis direction and its position in that axis converted to an electrical signal in a similar manner to that described for the *x*-axis. A counterweight **120** is provided for the bug **31**, the counterweight sliding on a bar **121** between the housing **80** and the support housing **86** and being coupled to the bug **31** by means of a wire **122** which is looped over suitable pulley **123** on the housing **80** and support housing **86**.

In one preferred arrangement, the toothed belt **108** is replaced by a steel wire and the pulleys **107** and **109**

are replaced by suitable matching pulleys. This enables the use of smaller pulleys making for a more compact assembly, while maintaining a smooth drive from the servo motor to the bug **31**.

In order to make electrical connection to the housing **80** a cable guide is provided in the form of a bar **130** of circular cross-section extending parallel to the rail **82** and cables are coiled around that bar as indicated generally at **131** in FIG. **3**, and attached to an arm **132** carried on the housing **80**. Cables between the housing **80** and the bug **31** may similarly be coiled around the bar **104** to be attached to an arm **133** on the bug **31**.

The encoders may be of optical grating types, synchro-resolvers or of any type by which the physical position of the bug may be resolved into electrical signals, and the representation may be in decimal or binary code digital form, but is preferably in binary code ready for assimilation by the computer. Again, the encoders may be of an integrating type giving a continually counted summation of incremental movements of the bug in either direction along the *x* and *y* axes, or may preferably be of an absolute position indicating type giving an absolute read-out of the position of the bug irrespective of initial setting.

It will of course be appreciated that the belt or wire and pulley system for moving the bug along the *x* and *y* axes may be replaced, in known manner, by any suitable means for achieving the traverse of the bug and gantry, such as lead screws or rack and pinion mechanisms.

The output from the digital encoders is also used to drive a visible digital read-out **24** mounted on the table so that the user may see the *x* and *y* co-ordinates of the bug **31** at any time.

Also provided with the table is a "digitising pen" indicated generally at **40** and which, in one form shown in FIG. **6**, comprises a transparent window having a pair of cross-wires **41** marked thereon in a holder **42**. An electric coil **43** is wound in the holder **42** around the cross wires **41** to be accurately centered therewith. The coil **43** is provided, by way of a wandering lead **44**, with a 400 c/s alternating electric current from a source within the power supplies (not shown) of the table. The arrangement is such that the pen **40** may thus be placed at any given point indicated by the cross-wires **41** on the surface of the table **30**, and at that point the coil **43** establishes an alternating electromagnetic field beneath the table **30**.

The bug **31** is provided with two sensing coils **50** and **51** aligned respectively with the *x* and *y* axes to detect the magnetic field of the coil **43**. The electrical circuitry of the servo-motors of the bug **31** is so arranged that the coils **50** and **51** provide an error signal in respect of each axis when the bug **31** is not accurately centered beneath the cross-wires **41** of the pen **40**, and the error signals are used, after suitable amplification, to drive the servo motors to correct that error and thus position the bug beneath the cross-wires **41**. A third coil **52** is provided on the bug **31** by which the bug **31** may be locked onto the pen **40** when the bug is correctly positioned beneath the pen.

The servo motor amplifiers are provided with suitable damping means whereby the two servo systems are stable and it can thus be seen that the system provides for the bug to follow the pen **40** to any position within its scope of movement beneath the table **30** in a continuous manner. During such movement and when the bug is stationary beneath the pen **40**, the digital encoders on the *x* and *y* axis servo motors give a digital read-out of the position of the bug and thus of the pen **40** on the table **30**. The pen **40** is provided with a push button **45** which is connected, by way of the wandering lead **44** to the digital read-out circuits so that on pushing the button **45**, the instantaneous read-out position of the pen **40** taken from the *x* and *y* axis digital encoders may be transmitted to the computer **21**.

Thus it can be seen that by placing the cross-wires **41** upon any co-ordinate point on the table **30**, allowing the bug **31** to center itself beneath the cross-wires, and then pushing the button **45**, the co-ordinates of that point may be transmitted to the computer.

The pen **40** may take other forms in which the cross-wires **41** are replaced either by a more precise pointer or probe, or even by a pen such as a ballpoint pen, so that the pen **40** may also be used to draw a visual representation on a sheet of paper or other material carried on the table **30** at the same time as the digital co-ordinate positions of various points on the representation are being transmitted to the computer.

The servo motors driving the bug on the *x* and *y* axis together with their respective position encoders are also arranged so that on transmission of a changing co-ordinate position from the computer **21** to the table **20**, the bug **31** may be continuously driven to assume a position corresponding to that co-ordinate information, carrying with it the pen **37** to make a corresponding representation on a sheet carried on the table **34**.

The pen carrier **33** is mounted on the side of the bug **31** to be indexable about a vertical axis to bring a selected arc of the pens to an operative position beside the bug. The carrier is mounted on a bracket **140** which is pivotally mounted on the bug **31** about a horizontal axis to allow for lifting of the pen carrier to service the pens. The carrier **33**, as best seen in FIG. **4**, comprises an indexable disc **141** which carries six pens **37**. Each of the pens is spring loaded to a retracted position by means of a coil spring **142**. The pens **37** shown in FIG. **4** are of a capillary tube nib ink type, but as discussed previously they may be of any other suitable type; and it is intended that each pen should be filled with a different coloured ink. Indexing of the carrier **33** brings each pen successively to an operative position indicated at **143**. A pair of solenoids **144** are mounted on the bracket **140** at the position **143** and on energisation operate on a lever **145** which is pivotable to engage the top of a pen **37** at that position and drive it down against the associated spring **142** to operate on the lower table surface.

As best seen in FIG. **5**, the carrier **33** is provided with a toothed portion **146**. A solenoid **147** is provided to move a ratchet pawl **148** in the direction of arrow **149**, on energisation by means of a push rod **150**. The ratchet pawl **148** is in engagement with the toothed portion **146** and thus operation of the solenoid achieves incremental movement of the carrier **33**. A locking pawl **151** is provided, resiliently biassed into engagement with the toothed portion **146** to hold the carrier in a given index position. The locking pawl **151** is released by the solenoid push rod **149** before the pawl **148** is engaged, lost motion being provided between the pawl **148** and a shoulder on the push rod to that purpose.

The solenoids **144** and **147** are energised under the control of the computer in use so that the desired pen

37 is brought into operation at any given time in operation of the table to draw out from the computer, the appropriate number of pulses being supplied to the solenoid **147** to index the carrier **33** and the solenoids **144** being energised to bring the selected pen **37** into use.

Thus it can be seen that the table **20** provides both the input and output facility for graphical representations to be transmitted to and taken from the computer **21** in digital form. The shaft encoders of table **20** are connected to the computer **21** by means of an interface system indicated at **22** in FIG. **13**, which in this embodiment is an internationally agreed interface system based on the United Kingdom Atomic Energy Authority Harwell 7,000 Series and referred to by the code name CAMAC. The interface system **22** is provided to achieve compatability electrically and logically between the systems of the table **20** and the computer **21.**

The computer **21,** which in this embodiment is a Digital Equipment Corporation Serial PDP8/E, is provided with an input tape facility for the operating programme, and an output tape facility upon which digitised information is stored on a long term basis, and on which digitised information may be removed from the computer for use "off-line," if this last facility is desired.

A portion of the surface of the digitising table surface **30** is set aside for a "menu card." The area of the menu card is divided up into small rectangular blocks to which are assigned individually various items of instruction for the computer. Thus if the digitising pen is placed on a particular menu card rectangle and the push button **45** operated the computer is directed to that part of its programme associated with carrying out the instruction ascribed to that rectangle of the menu card. The computer is programmed to distinguish between the various instructions on the basis of the co-ordinate position of the pen being within the corners of the prescribed rectangle associated with that instruction.

The various standard drawing features such as straight lines, circles, arcs or other curves are made the subject of menu card items so that they may be digitised by digitising their end points, centre and a point on the radius as appropriate and entering the appropriate instruction from the menu card.

In order that the menu card may be readily changed to provide different sets of instruction items, for instance when changing from one branch of technology to another, the menu card is preferably in the form of an overlay for the appropriate portion of the table **30,** and is preferably associated with an individual programme tape for the input tape facility of the computer. In this way the different programme routines necessary to carry out different instruction items may be readily associated with not only the menu card, but the co-ordinate position within the menu card. Further programme facilities can be incorporated so that the menu card can be temporarily shifted to an area of the table near an item being digitised.

In a typical sequence of operation, the digitising pen may be utilised to digitise and feed into the computer the details of a straight line between two points. It is arranged that to do this the digitising pen is first placed on the appropriate area of the menu card corresponding to the instruction "draw a straight line (between two points)," and that instruction is then entered in the computer by operation of the button **45.** The pen is then placed successively on the two points and their co-ordinates are entered into the computer. The part of the programme for the computer associated with that instruction, which is located on the programme tape under the control of the computer, is devised to ensure the realisation that the two following co-ordinate positions are the ends of the line and that the line is required between them. The digitised information together with the appropriate output drawing instructions are transferred to the core store of the computer to build up there into blocks. When a point is reached that the accumulated information in the core store fills a prescribed sized block of core store capacity, it is arranged that the block of information is transferred under the programme to the output tape for long term storage.

At any chosen time the "draw out" of digitised information within the computer may be initiated. In order to achieve this, the computer is provided with an output programme which may be carried on the same tape as the menu card instruction programme, and which has appropriate sections associated with the output requirements of each menu card item and arranged to present the co-ordinate information which has been digitised at the output of the computer in a form suitable for the table bug to follow. This co-ordinate information output which is in the form of demand co-ordinates for the bug position at any instant of time, is compared with the co-ordinates of the bug **31** as indicated by the encoding devices on the *x* and *y* axis and the result of this comparison is used as an error signal to drive the *x* and *y* servo motors to move the bug to the position demanded by the computer at any instantaneous time. The output programme for the computer is provided with appropriate sub-routines to interpolate the necessary output co-ordinates in 0.1 mm. increments to produce a continuous line drawn feature in accordance with the chosen instruction item. The appropriate operation of the retractable pen is also initiated by the output of the computer so that a drawing which has been digitised may be completely reproduced on a sheet of paper or other suitable material placed on the lower table **34.**

Thus it can be seen that this embodiment provides an interactive input/output table for the computer with which it is possible to digitise information, and on which a visual output may be drawn. The programme of the computer is arranged so that a draw-out of information may be obtained whether it is in the core store or in long term storage on the output tape of the computer.

By building up suitable menu card items together with appropriate programme routines, it is possible to reduce the work involved in preparing a drawing. Any item required on a drawing which is standardised, such as a pipe fitting, a nut or bolt, or such as circuit symbols in electrical diagrams, or the like, may be made the subjects of a menu card item so that to digitise such an item it is only necessary to digitise its required position and enter the appropriate instruction from the menu card.

In order to digitise alpha-numeric symbols for reproduction on a drawing, the symbol may be digitised point by point, as if it were part of the drawing, or the symbols may be made the subject of menu card items. As a further alternative, the digitising pen may be provided with a small keyboard by which such alpha-

numeric information (or other menu card items) may be keyed into the computer together with the co-ordinates of the position of the pen which are entered in the same manner as discussed previously.

The menu card also preferably includes erasure routines so that previously entered portions of a drawing may be erased from the computer stores.

As an alternative to the tape input on the computer itself for the input and output programme sections associated with the menu card items, the input/output table unit may be provided with a separate tape unit, preferably of a type to receive cassettes of tape bearing the input and output programme sections for the menu card items.

Referring again to FIG. 13, a cathode ray tube display 23 may also be driven from an output of the computer. This display may be of the storage tube type with the trace being written and re-written for data already digitised and in the computer store, so that a visual representation of digitised data is presented and maintained as a drawing or plan is digitised. As an alternative the tube display may be used to show the content of a previously digitised drawing so that erasures and alterations may be considered and made to the data stored in the computer with the effect of those alterations being visible on the display tube, or being visible as drawn out on the second table 34 under the control of the computer.

In a further arrangement the display 23 may be in the form of a scanned video display tube in which the presentation is re-written by each scan. In this arrangement it is envisaged that the video display should be obtained from a recorded video magnetic tape loop with each scan or frame of the video display being written from the stored data in the computer. As a further development of this arrangement, the computer is programmed so that when a moveable mechanism layout is digitised and displayed, each frame of the display may be written on the video tape with the mechanism in successive positions or configurations that it may assume, with the result that the mechanism may be shown in motion on the display tube. Again with the use of a colour tube, the display can be made in colour.

FIG. 14 shows an alternative form of digitising pen which is particularly useful for sketching or drawing an item or layout on a sheet on the digitising surface 30 while at the same time entering the co-ordinate of salient points of the sketch or drawing. This pen comprises a body 56 having two feet 57 which are provided with rotatable balls 58 so that the pen may be easily moved over the table surface 30. At a point to make up a triangular support with the feet 57, a pen 53 is provided, preferably of a ball point type. The pen is also provided with an electrical coil 54 concentric with the pen 53, and a push button 55 to enter data as discussed above with respect to the pen 40. The provision of the three point support by the balls 58 and the pen 53 ensures that the pen and the coil 54 remain normal to the surface 30 in use; thus avoiding errors which would arise in the positioning of the bug 31 if this criterion was not met, from misorientation of the magnetic field from the coil 54.

FIGS. 15 and 16 show a further type of digitising pen which is particularly arranged for high precision digitising. This pen has a body 60 arranged to be supported on the table surface 30 by two fixed feet 61 and two resiliently mounted feet 62. It is provided with a finely pointed stylus 63 which may preferably be tipped with a sapphire tip to make and retain a fine point. An electrical coil 64 concentric with the stylus 63 is also mounted on the coil together with a push button 65 both of which perform the same functions as the corresponding items on the pens discussed above. In use the body 60 of this pen is rocked on the feet 61 which are rounded to that purpose, compressing the feet 62 to bring the stylus into contact with the table surface 30. The resilient feet 62 are adjustable and are pre-set to ensure that the stylus 63 and its coil 64 are accurately normal to the table surface 30 when the stylus point is in contact therewith. In order that the user may clearly observe the positioning of the stylus on the table surface 30, the body 60 is cut away in plan view and a magnifying lens 66 mounted thereon to afford a view of the stylus point from above and the left as seen in FIG. 6, and above and behind as seen in FIG. 7.

FIGS. 9 and 10 shown an alternative arrangement of the input/output table unit in which the first or digitising table surface 70 and the second or draw-out table surface 71 are on opposite faces of a single table board 72. The board 72 is pivotally mounted at each end on a stand 73 and locking means 74 is provided at one end whereby the table board 72 may be held either with the surface 70 upwards as shown in FIG. 9 for digitising, or with the surface 71 upwards as shown in FIG. 10 for reproducing digitised information in a draw-out.

Other features of this table unit arrangement may be similar to those discussed above for the previous table unit and are given the same reference numerals.

The table board 72 must be of a material which is non-magnetic so as not to interfere with the influence of the coil of the digitising pen 50 upon the sensing coils of the bug 31 which is on the other side of the table board. It has been found that a paper honeycombe structure with suitable facing surfaces and inpregnated with synthetic plastics materials will fulfil these requirements whilst also affording the desirable dimensional stability for the board.

On either arrangement for the table unit, drawing paper may be provided in a continuous roll for drawing out digitised information. A supply roll (not shown) and a take-up roll (not shown) are mounted on or adjacent the second table surface so that the roll of paper may be passed over that surface between them. The computer output programme is arranged to index the paper, by means of a suitable servo-system so that successive digitised drawings or plans may be drawn out on the roll automatically. Suitable interlocking arrangements are provided to prevent operation of the bug 31 in the draw-out mode when the paper is indexing, and to cater for when the paper runs out.

In an alternative arrangement of the gantry arm 32, the housing 80 is supported on the rail 82 by means of air bearings to further reduce the friction and "stiction" of the housing on the rail. The bug 31 may also be supported by air bearings on the bars 85, air being supplied to those bearings by means of suitable flexible piping. Again the three roller support of the housing 86 on the rail 103 may be replaced by air bearings. It is considered that air bearings are particularly advantageous in the support and guidance of the gantry arm 32 in view of the considerable mass thereof, but small improvements are gained from the use of air bearings for the bug 31 on the gantry arm.

In an alternative arrangement of the bug and pen, the sensing coils **50** and **51** and the third coil **52** may be mounted in the pen on index member **40**, and the sensing coil **43** may be mounted on the bug **31** to produce an exactly equivalent arrangement to that discussed above.

The first or digitising table surface **30** is hingedly mounted so that it may be raised to provide access to the mechanism of the bug drive and position encoders, suitable counter balance means being provided to facilitate this.

What we claim is :

1. A digitising table unit, comprising a first or digitising table surface, freely movable digitising index member which may be placed at any chosen position within the area of the first table surface, a bug mounted below the first table surface to be movable along *x* and *y* axes by means of servo-motors to a position corresponding to the position of the digitising pen when the pen is place on the first table surface, encoding means arranged so that the *x* and *y* coordinates of the position of the bug and therefore the pen is converted into electrical signals indicative of that position, a second table surface occupying a plane parallel to that of the first table surface and located in a position below the area of the first table surface, and retractable pen means mounted on the bug and engageable with the second table surface whereby movement of the bug may trace out a representation on the second table surface.

2. A table unit as claimed in claim **1**, including an *x* axis slideway aligned in said *x* axis, a gantry arm slidably mounted on said *x* axis slideway, and a *y* axis slideway on said gantry arm, said bug being slidably mounted on said *y* axis slideway.

3. A table unit as claimed in claim **2**, wherein said gantry arm and said bug are slidable on said slideways by means of re-circulating ball bearings.

4. A table unit as claimed in claim **2**, wherein said gantry arm is slideable on said *x* axis slideway by means of air bearings.

5. A table unit as claimed in claim **2**, wherein said *x* axis and said *y* axis servo motors each drive said gantry arm and said bug respectively by way of a flexible looped element extending around a pair of pulleys disposed one at each end of the respective slideway, said looped elements being attached respectively to the gantry arm and the bug, and one of the pairs of pulleys being driven by the respective servo motor.

6. A table unit as claimed in claim **5**, wherein said looped element is a toothed belt.

7. A table unit as claimed in claim **5**, wherein said looped element is a flexible wire.

8. A table unit as claimed in claim **2**, wherein said encoding means comprises an *x* axis rotary encoder and a *y* axis rotary encoder, and said encoders are each driven respectively from said gantry arm and said bug by means of a flexible looped element extending around a further pair of pulleys disposed one at each end of the respective slideways, said looped elements being attached respectively to the gantry arm and the bug and one of the respective pairs of pulleys driving the respective encoder.

9. A table unit as claimed in claim **8**, wherein said looped element is a close tolerance steel wire.

10. A table unit as claimed in claim **8**, wherein each said looped element is wound around the respective one of said pairs of pulleys for a plurality of turns.

11. A table unit as claimed in claim **2**, wherein said bug is provided with a moveable counter balance weight.

12. A table unit as claimed in claim **1** comprising an indexable pen carrier mounted on said bug and a plurality of pens in said carrier, said carrier being indexable under the control of a computer to bring a selected one into operation.

13. A table unit as claimed in claim **1**, wherein said index member is provided with an electric coil arranged to create a magnetic field, and said bug is provided with a sensing coil aligned in said *x* axis and a sensing coil aligned in said *y* axis to detect said magnetic field and provide signals indicative of an error in the position of said bug relative to said index member for the control of said servo motors.

14. A table unit as claimed in claim **13**, including a third electric coil disposed on said bug whereby said bug may be locked magnetically to said index member when in correct relative position thereto.

15. A table unit as claimed in claim **1**, wherein said bug is provided with an electric coil arranged to create a magnetic field, and said index member is provided with a sensing coil aligned in said *x* axis and a sensing coil aligned in said *y* axis to detect said magnetic field and provide signals indicative of and error in the position of said bug relative to said index member for the control of said servo motors.

16. A table unit as claimed in claim **15**, including a third electric coil disposed on said index member whereby said bug may be locked magnetically to said index member when in correct relative position thereto.

17. A table unit as claimed in claim **1**, wherein said index member includes a window aperture and a pair of cross wires disposed therein for alignment of the member with a selected position on said digitising table surface.

18. A table unit as claimed in claim **1**, wherein said index member includes three point means for supporting it on said digitising surface and one of said points comprises a pen for indicating a chosen position and drawing on said digitising surface.

19. A table unit as claimed in claim **1**, wherein said index member includes means to support it on said digitising surface and a finely pointed member for indicating a chosen position, and further includes optical magnifying means for a user to view the area of the digitising surface beneath said pointed member.

20. A table unit as claimed in claim **1** wherein said first or digitising table surface is provided on a transparent sheet.

21. A table unit as claimed in claim **1**, wherein said first and second table surfaces are provided on opposite faces of a single board, said board being pivotally mounted about a horizontal axis whereby said first or said second table surface may be presented uppermost.

22. A combination comprising a digital computer, an input digitising table and an interface means connecting the table to the computer, the table comprising a first or digitising table surface, a freely movable digitising index member which may be placed at any chosen position within the area of the first table surface, a bug mounted below the first table surface to be movable along *x* and *y* axes by means of servo-motors to a position corresponding to the position of the digitising pen when the pen is placed on the first table surface, encod-

ing means connected to the interface, whereby the *x* and *y* coordinates of the position of the bug and therefore the pen on the first table surface may be converted to electrical signals indicative of that position and transmitted to the computer, a second table surface occupying a plane parallel to that of the first table surface in a position below the area of the first table surface, and retractable pen means mounted on the bug and engageable with the second table surface whereby movement of the bug may trace out a representation of the second table surface.

23. A combination according to claim **22**, wherein a cathode ray tube is connected to said computer for visual display of digitized information in said computer.

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