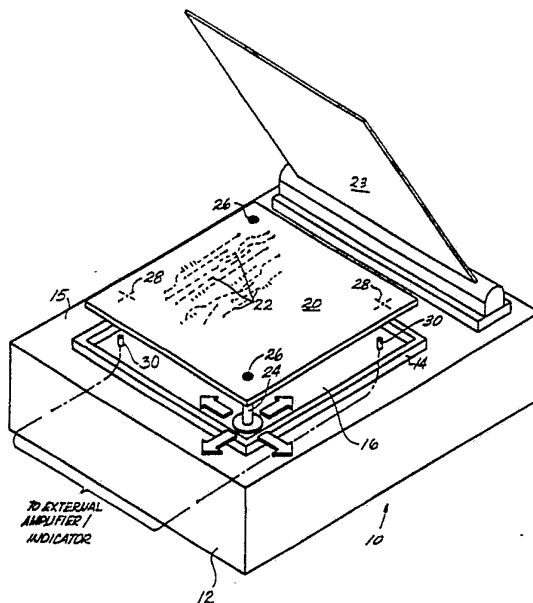




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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| <b>(51) International Patent Classification <sup>5</sup> :</b><br><br><b>H04N 7/00, G01R 15/12</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>A1</b> | <b>(11) International Publication Number:</b> <b>WO 91/19392</b><br><br><b>(43) International Publication Date:</b> 12 December 1991 (12.12.91)                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>(21) International Application Number:</b> PCT/US91/03688<br><br><b>(22) International Filing Date:</b> 24 May 1991 (24.05.91)<br><br><b>(30) Priority data:</b><br>528,957                      25 May 1990 (25.05.90)      US<br>648,453                      31 January 1991 (31.01.91)      US<br><br><b>(71) Applicant:</b> EVERETT/CHARLES CONTACT PRODUCTS, INC. [US/US]; 700 East Harrison Avenue, Pomona, CA 91767 (US).<br><br><b>(72) Inventors:</b> SWART, Mark, A. ; 1616 Carmel Circle West, Upland, CA 91786 (US). JOHNSTON, Charles, J. ; 411 Los Gatos, Walnut, CA 91789 (US). VAN LOAN, David, R. ; 2664 Shady Ridge Lane, Diamond Bar, CA 91765 (US).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           | <b>(74) Agents:</b> MAXWELL, Walter, G. et al.; Christie, Parker & Hale, 350 West Colorado Boulevard, P.O. Box 7068, Pasadena, CA 91109-7068 (US).<br><br><b>(81) Designated States:</b> AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).<br><br><b>Published</b><br><i>With international search report.</i> |
| <b>(54) Title:</b> TEST FIXTURE ALIGNMENT SYSTEM<br><br><b>(57) Abstract</b><br><br><p>A test fixture for testing printed circuit boards includes an array of test probes (18) held in contact with a pattern of test points in a circuit array (22) printed on the circuit board (20). The circuit array is positioned with respect to a fiducial mark (28) on the board (20), and a tooling pin hole on the board (20) is aligned with the circuit array. The fixture includes a tooling pin (24) inserted in the tooling pin hole to hold the circuit array (22) in a fixed position relative to the test probes (18) during testing. The fiducial mark (28) is sensed, and an optical reading shows misalignment of the test points on the board relative to the probes. The tooling pin (24) is adjusted on the fixture (10) to move the board (20) relative to the probes (18) to correct misalignment. The alignment of the board (20) on the fixture (10) can be optically sensed by a lens system (104), fiber optic image conduit (72), light source (96, 98), an image enlarger (60) and video probe (70), that produces images of the fiducial mark and a known zero reference point on a TV monitor (118).</p> |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |



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**TEST FIXTURE ALIGNMENT SYSTEM****Cross-Reference**

This is a continuation-in-part of application  
Serial No. 07/528,957, filed May 25, 1990.

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**Field of the Invention**

This invention relates generally to the field of  
automatic test equipment, and more particularly, to a  
system for aligning printed circuit boards with a test  
fixture used in the automatic testing of circuit  
boards.

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**Background of the Invention**

In the automatic testing of printed circuit  
boards, conventional spring-loaded test probes are  
typically mounted on a test fixture, and the circuit  
board under test is held in pressure contact with the  
spring probes to provide electrical contact between  
diagnostic or testing equipment and circuits on the  
board under test. Each test fixture typically contains  
a base or probe plate having an array of spring probes  
dedicated to the board under test. Identical circuit  
boards are then aligned with the fixture and tested,  
one at a time, to determine whether there are any  
defects in the circuits printed on each board.

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During testing, the spring probes must be  
correctly aligned with test points in the circuits

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1 printed on the board under test. This requires correct  
alignment of the board on the fixture so that the  
spring probes are automatically registered with  
5 corresponding test points in the circuit array printed  
on each board. In order to align the board with the  
probes, the customary practice has been to first drill  
tooling pin holes in the circuit board. Drilling is  
done by the board manufacturer, and usually a pair of  
10 tooling pin holes are drilled in diagonally opposite  
corners of the board. During testing, tooling pins in  
opposite corners of the fixture are positioned in  
corresponding tooling pin holes to automatically align  
the board with the array of test probes on the fixture.  
This procedure requires that the tooling pin holes be  
15 drilled accurately in the board by the board  
manufacturer, so that when each board is later mounted  
on the tooling pins, the test probes will automatically  
register with the circuits printed on the board when  
the test probes are brought into pressure contact with  
20 the board during testing.

Printed circuit boards made by a given  
manufacturer are usually produced in lots, and boards  
within a given lot will tend to produce a certain  
misalignment, from tolerance error, when boards within  
25 that lot are mounted on a fixture. Alignment  
tolerances will tend to vary from lot to lot with a  
given manufacturer. The same board made by a different  
manufacturer also tends to have different tolerance  
variations and misalignment errors from lot to lot.

30 Printed circuit boards typically have a pair of  
"fiducial marks" printed in the margin of the board at  
known reference positions relative to the circuit array  
or "artwork" printed on the board. The fiducial marks  
are printed on the board by the board manufacturer, and  
35 the fiducial marks are used as a guide for the  
manufacturer's drilling of the tooling pin holes at  
locations on the board that will automatically align

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1 (hopefully) the board to the test probes when the board  
is mounted on the tooling pins.

There are drawbacks to using these procedures for  
aligning a printed circuit board with a test fixture.  
5 Mechanical tolerances are involved in (1) positioning  
of the drilling tool in the drilling machine, (2)  
positioning of the tooling pin holes drilled in the  
printed circuit board with respect to the artwork on  
the board, and (3) positioning of the tooling pins on  
10 the fixture with respect to the tooling pin holes in  
the board. Because of these tolerance accumulations,  
the test probes often do not precisely register with  
the test points in the circuit array printed on the  
board. This problem is magnified by tolerance  
15 variations in board lots from different manufacturers.  
The problem also is compounded by advances in the art  
of printed circuit board technology, where printing of  
circuits with finer lines and narrower circuit spacings  
requires more accurate registration of the test probes  
20 with the circuits under test. At the present time, for  
example, it is common for test probes to be misaligned  
within a range of 0.005 to 0.008 inch in a typical test  
fixture; more accurate alignment is desirable, and the  
present invention provides techniques for achieving  
25 greater alignment accuracy.

#### Summary of the Invention

Briefly, the present invention provides a system  
for accurately positioning a printed circuit board on  
30 a test fixture so that a pattern of test points in a  
circuit array printed on the board is precisely  
registered with an array of corresponding test probes  
on the fixture. Advantages of the alignment system  
include its ability to produce extremely accurate  
35 alignment quickly and easily, low manufacturing costs,  
reduced time and cost involved in the internal  
alignment (calibration) of the fixture's system

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1 components, and interchangeability with different fixtures.

5 One embodiment of the invention provides a test fixture for testing printed circuit boards in which the fixture is the type having an array of test probes held in contact with a pattern of test points in a circuit array printed on the board. The circuit array is positioned on the board with reference to a fiducial mark or other reference point on the board. A tooling pin hole or other alignment device on the board is positioned on the board with reference to the circuit array. In one embodiment, the tooling pin hole is positioned on the board with respect to the circuit array, using the fiducial mark as a positioning guide for the drilling tool. The test fixture includes a tooling pin for registering with the tooling pin hole or other alignment device on the board to hold the printed circuit array in a fixed position relative to the test probes on the fixture. The fiducial mark is sensed by sensing means on the fixture for producing an output which represents the alignment or misalignment of the test probes on the fixture with respect to corresponding test points in the circuit array on the board. The position of the tooling pin on the fixture is adjustable to move the board relative to the fixture and thereby correct misalignment of the test probes relative to the circuit array on the board. The sensing means output indicates the amount and direction of movement of the tooling pin and board to a corrected position on the fixture necessary to precisely align the test probes with the circuit array on the board. The tooling pin is then locked in its corrected position for holding the printed circuit board in its properly aligned position on the fixture.

35 In one embodiment of the invention, the fiducial mark (or any other indexing reference on the board) is sensed by optical sensing means which can comprise a

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1 bore scope, an optical fiber image sensor, or a lens system and video probe assembly.

The lens system and video probe may be used with or without the optical fiber image sensor which conveys  
5 an image of the fiducial mark to the lens system and video probe.

A visual reading of the alignment or misalignment can be produced by an optical system having means responsive to the optical sensor for producing an  
10 enlarged image of the fiducial mark. Display means within the optical system also produce an image of a reference mark that provides a calibrated known zero reference point which, when compared with the enlarged image of the fiducial mark, produces an indication of  
15 the alignment or misalignment of the test probes relative to the circuit array on the board. In one embodiment the zero reference point is adjustable so it can be calibrated into the display system independently of the system optics. During use, the tooling pin and  
20 board are moved relative to the fixture, while observing the display images of relative movement between the fiducial mark and the reference mark, so that optical alignment of the two marks precisely registers the test probes on the fixture with  
25 corresponding test points in the circuit array on the board.

In one form of the invention, a visual display of the alignment or misalignment of the board is produced by a miniature video camera system mounted to the  
30 fixture. Preferably, there are at least two video camera systems mounted below opposite corners of the circuit board. In one embodiment, the video cameras and their image-conveying optical systems are removable from the fixture to enhance interchangeability from  
35 fixture to fixture. Each video camera has optical means focused upon a corresponding fiducial mark on the board, and each video camera has its output coupled to

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1 a video monitor. A reference index display, preferably  
obtained from a cross-hair generator or the like,  
superimposes the reference index on the image of the  
fiducial mark displayed on the video monitor. The  
5 reference index display is set at a calibrated known  
zero position representing precise alignment of the  
artwork on the board with respect to the test probe  
field. Changing the position of the movable tooling  
pin moves the board, causing the image of the fiducial  
10 mark to move on the display relative to the cross-hair.  
Alignment of the fiducial mark with the cross-hair on  
the video monitor automatically produces precise  
alignment of the board to the probe field on the  
fixture. This calibration is achieved independently of  
15 system optics.

In one embodiment, the video camera lens system  
has a surrounding light source produced by optical  
fibers for illuminating the fiducial mark on the board  
being aligned. The camera lens system produces an  
20 image of the illuminated fiducial mark which is  
transmitted by an optical fiber conduit and focusing  
lens to a video camera and converted to an enlarged  
video image display, which enhances accuracy of the  
alignment procedure.

25 Another form of the invention provides a reference  
board having artwork representative of circuits on the  
board under test. This form of the invention avoids  
use of means for enlarging the image of a fiducial mark  
or other board reference point. The reference board is  
30 preferably first aligned to the test fixture so the  
artwork on the reference board is perfectly aligned  
with the array of test probes on the fixture. A board  
under test then can be overlaid on the reference board  
to align the artwork on the board under test with the  
35 artwork on the reference board. The two boards are  
then affixed to one another to prevent relative  
movement between them, and the reference board is then

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1 aligned with the fixture. Movable tooling pins on the  
fixture are moved to a position in alignment with  
tooling pin holes or other alignment devices on the  
board under test. The tooling pins are locked, the  
5 reference board is removed, and the artwork on the  
circuit board under test is then automatically aligned  
with the probe field on the fixture. Circuit boards  
within the same manufacturer's lot then can be mounted  
to the fixture for testing, using the adjusted  
10 positions of the tooling pins for alignment of the  
board.

The present invention provides accurate means for  
aligning the test probes with the circuits on the board  
such that tolerance accumulations prevalent in the  
15 prior art testing procedures are greatly reduced,  
resulting in greatly improved testing accuracy. The  
circuit board alignment system also is reasonably  
inexpensive to manufacture and easily and accurately  
used by those involved in the testing of circuit  
20 boards. Since the zero reference calibration system is  
independent of system optics, calibration procedures  
are handled quickly and easily and at a reasonably low  
cost. The optical system and calibration techniques  
also are easily interchangeable with different  
25 fixtures.

These and other aspects of the invention will be  
more fully understood by referring to the following  
detailed description and the accompanying drawings.

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1     **Brief Description of the Drawings**

FIG. 1 is a perspective view illustrating a test fixture with an adjustable alignment system according to principles of this invention.

5     FIG. 2 is a fragmentary cross-sectional view illustrating an adjustable tooling pin mounted on the fixture.

FIG. 3 is a top view taken on line 3-3 of FIG. 2.

10    FIG. 4 is a cross-sectional view taken on line 4-4 of FIG. 5 and showing a locking nut for the adjustable tooling pin.

FIG. 5 is a top view of the locking nut.

15    FIG. 6 is a diagrammatic representation of means for adjusting the tooling pin and means for locking the tooling pin with the locking nut.

FIG. 7 is a schematic diagram illustrating components of an optical system for amplifying and displaying means for aligning a circuit board with test probes on the fixture.

20    FIG. 8 is a schematic representation illustrating visual indications of indexing means for use in aligning the printed circuit board to the fixture.

25    FIG. 9 is a fragmentary cross-sectional view illustrating one embodiment of a test fixture containing an optical test fixture alignment system.

FIG. 10 is a fragmentary cross-sectional view illustrating an alternative embodiment of the test fixture containing a video camera in an optical test fixture alignment system.

30    FIG. 11 is a fragmentary cross-sectional view similar to FIG. 10, but showing the fixture rotated to an open position.

35    FIG. 12 is a semi-schematic cross-sectional view illustrating components of a miniature video camera system for imaging test fixture alignment.

FIG. 13 is an elevation view taken along 13-13 of FIG. 12.

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1           FIG. 14 is a schematic functional block diagram  
illustrating electronic components of the test fixture  
alignment imaging system.

5           FIG. 15 is a perspective view illustrating an  
alternative technique for aligning a circuit board with  
a test fixture.

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1        **Detailed Description**

FIG. 1 illustrates a test fixture 10 which can represent any test fixture of the type used in the automatic testing of printed circuit boards. In the  
5        illustrated embodiment, the fixture includes a housing 12 and a rectangular compressible gasket 14 mounted on an upper face 15 of the housing. The rectangular gasket mounts a circuit board 20 to the fixture and defines the exterior peripheral boundary of a region  
10        within the fixture that mounts an array of spring-loaded test probes 18. The probes are represented schematically in FIG. 7 and are also shown in FIGS. 9-11. The test probes are mounted in a desired pattern on a probe plate 25 within the fixture  
15        to match the pattern of test points in circuits printed on the circuit board 20 under test. The printed circuit board includes a printed circuit array 22 formed by conventional artwork techniques. In the  
20        illustrated embodiment, the circuit array 22 is printed on an underside of the board which faces an array of test probes that project through holes in a movable top plate 16. The gasket 14 is mounted to the top of the moving top plate 16 as shown best in FIG. 9. The moving top plate holds the circuit board 20 parallel  
25        the array of test probes. Individual test points within the circuit array 22 on the board are contacted by corresponding test probes during automatic testing of the circuits on the board.

In a preferred test fixture arrangement, the probe  
30        plate 25 and the moving top plate 16 are drilled with holes on a pattern that matches the test points in the circuit array on the board under test. The test probes are then mounted in the pattern of holes on the probe plate. The test probes project up through the holes in  
35        the moving top plate 16, which is spring-mounted to the probe plate 25. The drilled probe plate and the top plate are dedicated to a particular board under test,

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1 and identical circuit boards are tested one-by-one on  
the fixture. To test a different circuit board, a new  
probe plate and moving top plate are drilled with a new  
hole pattern, and a new array of probes are used for  
5 testing the board on what otherwise is the same  
fixture.

Although the invention is described with reference  
to circuit boards having an array of printed circuits,  
such as "bare boards" as they are known in the art, the  
10 fixture alignment system of this invention also can be  
used for testing "loaded circuit boards" to which  
circuit components, such as integrated circuit packages  
and the like, are mounted.

Once the printed circuit board 20 is mounted on  
15 the fixture, a hinged door 23 is closed over a cavity  
containing the circuit board, and vacuum pressure is  
applied to resiliently bias the spring probes into  
contact with corresponding test points in the circuit  
array printed on the board, in a manner familiar to  
20 those skilled in the art. A typical means of applying  
pressure can be through vacuum applied to the cavity to  
seal the board 20 to the gasket 14 during testing. The  
vacuum draws the board and the moving top plate 16 down  
toward the array of test probes 18 on the probe plate  
25 25. Continuity or lack of continuity between the  
various test points in the electrical circuits on the  
board are detected by an external electronic test  
analyzer (not shown) electrically coupled to the test  
probes for use in measuring whether the circuit board  
30 is functional or for identifying defective circuits.

During testing, a pair of movable tooling pins 24  
mounted in diagonally opposite corners of the probe  
plate 25 are registered with corresponding tooling pin  
holes 26 drilled in diagonally opposite corners of the  
35 circuit board 20. (Only one of the movable tooling  
pins is shown in FIG. 1; the other is obscured by the  
printed circuit board.) By positioning the tooling

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1 pins in the tooling pin holes, the board is mounted in  
a fixed position parallel to the fixture base, so that  
the test points in the circuit array 22 can be  
5 automatically with corresponding test probes 18 for  
testing the circuits on the board. Use of tooling pins  
inserted in the tooling pin holes is one example of a  
means for mounting the board to the fixture.  
Alternatively, tooling pins on the fixture can be  
engaged with other alignment devices on the board to  
10 hold the board in a fixed position as the fixture. On  
example is a tooling pin with a right angle recess that  
engages a right angle corner of a board. Other means  
of aligning the board to the fixture are possible.

As mentioned previously, the tooling pins do not  
15 necessarily produce the desired precise alignment. The  
tooling pin holes are drilled in the board by the board  
manufacturer. Fiducial marks 28 are printed on the  
board by the board manufacturer, and these marks, shown  
in diagonally opposite corners of the board, provide a  
20 known reference point or indexing mark with respect to  
the artwork printed on the board. (The fiducial marks  
shown on the top side of the board in FIG. 1 are  
actually visible from the underside of the board.) The  
board manufacturer aligns the drilling tools with  
25 respect to the artwork on the board, using the fiducial  
marks as a reference, and the tooling pin holes are  
positioned (drilled) on the board with reference to the  
fiducial marks. However, in practice, mechanical  
tolerance accumulations are generated from positioning  
30 the board in the drilling machine, positioning the  
drilling tools in the drilling machine, drilling the  
tooling pin holes, and registering the tooling pins on  
the fixture with the drilled tooling pin holes. Thus,  
the tooling pin holes drilled in the board may not  
35 precisely register the spring probes with the artwork  
on the board when the tooling pins are inserted in the

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1 tooling pin holes and the board is brought into  
pressure contact with the probes.

5 The fixture 10 provides means for overcoming the  
drawbacks of the conventional practice of aligning a  
circuit board under test with a test fixture. The  
fixture 10 includes an alignment system having a means  
for movably positioning the tooling pins 24 on the  
probe plate 25, together with sensors 30 on the probe  
plate for use in sensing the position of the fiducial  
10 marks 28 on the board under test. The movable tooling  
pins allow the board to be moved manually relative to  
the probe field on the fixture. The sensors detect  
movement of the fiducial marks as the printed circuit  
board is moved into alignment with the probe field, and  
15 an enlarged image of each fiducial mark is displayed to  
assist in precise manual alignment of the board to the  
probes on the fixture. The fiducial marks are sensed  
by the sensors 30, and images of the marks are produced  
and are observable in relation to an image of a  
20 corresponding known zero reference point used as a  
reference index in an optical alignment and display  
system. The tooling pins 24 are manually movable to  
move the board while observing corresponding movement  
of the fiducial mark on the display, so the board can  
25 be moved to accurately align each fiducial mark 28 with  
a displayed reference point. This movement  
automatically positions the test points in the circuit  
array 22 in precise alignment with corresponding spring  
probes on the fixture base. FIGS. 2 through 6  
30 illustrate a preferred system for adjustably mounting  
the tooling pins to the fixture base. Separately, the  
sensors 30 are mounted in fixed positions on the  
fixture base in diagonally opposite corners and in  
alignment with the fiducial marks 28 or any other  
35 indexing marks of the board under test. The sensors  
30 and the reference indexing and optical alignment  
system are described in more detail below.

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1           Referring now to FIGS. 2 through 6, adjustment of  
the tooling pin positions will now be described. Each  
tooling pin 24 comprises a rounded upright board-  
5           locating pin with an enlarged rounded base 32 having a  
flat annular bottom surface 34. The diameter of the  
tooling pin matches the diameter of the tooling pin  
hole drilled in the board so the board can be  
10           positioned on the tooling pin. An elongated  
cylindrical shank portion 36 of a pin fastening member  
extends downwardly from the underside of the rounded  
base 32. The shank has an outside diameter similar to  
15           the outside diameter of the tooling pin, and the axis  
of the shank is aligned with the vertical axis through  
the tooling pin. The shank is positioned in a mounting  
hole 38 in the probe plate or fixture base 25. The  
20           mounting hole is oversized relative to the outside  
diameter of the shank, so the shank portion of the  
locating pin can have 360° freedom of movement within  
the fixture hole. During this movement, the rounded  
base 32 of the locating pin completely covers the hole  
25           and provides a support base for holding the tooling pin  
at all times in a vertical upright position. The  
bottom of the pin fastening member has an externally  
threaded section 40 that projects down from a bottom  
30           face 42 of the fixture base. The tooling pin is held  
in place in the fixture base by an internally threaded  
locking nut 44 tightened onto the externally threaded  
bottom section 40 of the fastening system. By rotating  
the locking nut onto the projecting bottom portion of  
the fastening member during assembly, the tooling pin  
35           can be held in a fixed orientation with respect to the  
top plane of the fixture base.

          During assembly, and after the locking nut has  
been tightened against the bottom face of the fixture,  
35           a dowel pin 46 is then placed in a narrow passageway 48  
in the fixture bottom adjacent the shank portion 36 of  
the tooling pin 24. The dowel pin is preferably

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1 adhesively bonded or otherwise rigidly affixed in the  
passageway to hold the dowel pin in a fixed position,  
with a lower portion of the dowel pin projecting from  
the bottom face 42 of the fixture base, adjacent the  
5 locking nut 44. The projecting lower portion of the  
dowel pin is contained within a narrow recess 50 in the  
locking nut. The tooling pin 24 is movable relative to  
the fixture base by engaging the flats on a wrench (not  
shown) with flats 52 at the top of the tooling pin, and  
10 by turning the wrench to rotate the tooling pin about  
its axis. This loosens the tooling pin from its  
fastened connection to the locking nut and allows the  
entire tool pin assembly to be moved in any direction  
within the hole 38 relative to the fixture base. Once  
15 the tooling pin has been moved to a desired position,  
the tooling pin then can be locked to the base by  
turning the tooling pin, using the wrench applied to  
the flats 52 from access provided above the fixture  
base. The dowel pin 46 engages the recess 50 in the  
20 locking nut 44 to prevent rotation of the locking nut  
as the tooling pin is being tightened to its locked  
position. The upper portion of the tooling pin 24  
extends through an oversized hole in the top plate 16  
(see FIGS. 9 and 10) so the tooling pin can be moved on  
25 the fixture base (probe plate 25) without moving the  
top plate when the board is moved.

Alignment of the printed circuit board to the  
array of test probes will now be described. The  
sensors 30 comprise any type of sensing device that can  
30 sense the location of the fiducial marks 28 on the  
board and provide an output signal representative of  
the sensed position of the fiducial marks. Since the  
fiducial marks are printed at known reference positions  
relative to the artwork printed on the board, the  
35 fiducial marks provide a precise reference point with  
respect to the locations of the test points within the  
circuit array printed on the board. The sensors 30

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1 preferably comprise optical sensors which optically  
sense the positions of the fiducial marks and produce  
an output which is processed by an external image  
5 enlarger and display system that amplifies and displays  
enlarged images of the positions of the fiducial marks  
relative to corresponding known zero reference points  
which are also displayed.

In a preferred alignment technique, a known zero  
reference is first established. Preferably, a  
10 reference board known as a "gold board" is used to set  
the zero reference. The gold board is a replica of a  
printed circuit board having its fiducial marks (or  
other indexing marks) perfectly set to positions on the  
board with reference to the position of the artwork on  
15 the board. The gold board preferably has two fixture  
pins, referred to as "gold pins," in its opposite  
corners to represent the perfectly set fiducial marks.  
The gold board also has fixed tooling pins positioned  
on the gold board for perfect alignment of the gold  
20 board to the fixture. The gold board is mounted on the  
fixture by inserting the tooling pins of the gold board  
into fixed tooling pin holes on the fixture, which  
correctly aligns the gold board to the fixture. This  
produces perfect alignment of the fiducial marks (the  
25 gold pins) on the gold board with the fixture and its  
probe field. (The gold board has clearance holes for  
receiving the movable tooling pins 24 so the gold board  
can be mounted to the fixture independently of the  
location of the tooling pins 24. No circuits are  
30 printed on the gold board since the gold board is used  
only for alignment purposes.) The sensors 30 are then  
used for sensing the positions of each gold pin and  
displaying an enlarged image of the gold pin on a  
display or monitor. The images of the gold pins are  
35 preferably displayed on separate monitors, although  
they could be displayed together on one monitor.  
Separately, a cross-hair generator is used to form a

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1 cross-hair image on the display to represent a perfect  
zero alignment of the board to the fixture. A separate  
cross-hair image is superimposed over the image of each  
5 gold pin displayed on the monitor. The optical sensing  
system is then aligned to the gold pins on the gold  
board using the images displayed on the monitor. The  
gold board remains fixed with respect to the fixture  
and the images of the cross-hairs are moved  
electronically until each cross-hair registers  
10 perfectly with the enlarged image of a corresponding  
gold pin displayed on the monitor. This precisely  
aligns the image display system to each fiducial mark  
(the gold pins) on the gold board, so that the settings  
of the cross-hair zero points represent perfect  
15 alignment of the artwork on the circuit board related  
back to the probe field on the fixture. The gold board  
is then removed from the fixture. Thereafter, circuit  
boards placed on the fixture tooling pins are aligned  
with the zero-tolerance-error reference points  
20 represented by the images of the cross-hairs on the  
monitor. When a circuit board is first placed on the  
fixture, any misalignment of the artwork relative to  
the probe field is represented by a misalignment of  
each fiducial mark relative to its corresponding  
25 cross-hair zero point that represents zero tolerance  
error. The movable tooling pins are then loosened, the  
board is moved manually, and the monitor is observed to  
align each sensed fiducial mark with its corresponding  
cross-hair reference. This automatically and precisely  
30 aligns the artwork on the board to the array of probes  
on the fixture.

The separate calibration board (gold board) and  
electronically adjustable cross-hair generator  
calibrate alignment of the fixed zero reference point  
35 to the fiducial mark imaging system, independently of  
system optics. This greatly reduces the cost of the  
alignment system when compared with a system in which

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1 the fixed reference is built into a lens system for  
imaging the fiducial mark.

5 The optical sensors 30 can be in various forms.  
In one embodiment, each sensor may comprise an optical  
fiber sensor. (Other sensing devices are described  
below.) A preferred optical fiber sensor comprises a  
coaxial optical fiber sensor having a monofilament  
10 optical fiber core, and a separate outer optical fiber  
tube made of a bundle of tiny optical fibers positioned  
around the periphery of the core. The monofilament  
optical fiber core can act either as a light emitter or  
receiver, and the outer peripheral optical fiber tube  
acts as the receiver for the emitter or vice versa.  
The emitter and receiver are insulated from each other,  
15 and an external imaging system sends a signal to one  
optical fiber conduit which produces an optical signal  
that reflects off the board. The other optical fiber  
conduit picks up the reflection from the board. The  
optical signal passes the fiducial marks and produces  
20 one type of reflection, whereas when the optical signal  
is centered on the fiducial marks, the reflections are  
interrupted and a different reflected light signal is  
sensed. Thus, the optical fiber and its imaging system  
acts as a transceiver to detect one type of light  
25 signal when there is misalignment with the fiducial  
mark and another type of light signal when alignment is  
produced.

Alternatively, the optical sensing device of the  
optical fiber type can comprise a pair of side-by-side  
30 optical fibers for emitting and receiving light signals  
to detect the position of the fiducial marks.

FIG. 9 illustrates another embodiment of a sensor  
30 which comprises a pair of fiber optic probes 66  
mounted to a fixture in alignment with fiducial marks  
on the board 20. The fiber optic probes are preferably  
35 flexible image conduits each comprising as many as  
80,000 pixels, to transmit an image of the fiducial

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1 mark to the exterior of the fixture for further  
processing. The fixture in FIG. 9 also shows flexible  
optical fiber image conduits 68 transmitting images to  
remote display systems. In aligning the printed  
5 circuit board 20 to the fixture, the board is mounted  
on the tooling pins 24. The fiber optic probes 66 can  
be spring biased for spring-pressure contact with the  
underside of the board, or they can be used in  
combination with a lens system to focus on the fiducial  
10 marks on the board under test. Each of the tooling  
pins 24 is loosened, allowing the board to be moved  
manually relative to the fixture base and probes 18.  
This moves each fiducial mark relative to its  
corresponding optical sensor 30. Preferably, alignment  
15 is carried out by adjusting the position of one tooling  
pin until its related fiducial mark is properly aligned  
with a corresponding cross-hair (zero tolerance error  
reference point) on the monitor, and then adjusting the  
position of the other tooling pin to move its related  
20 fiducial mark into alignment with its related  
cross-hair. The external optical position detecting  
and imaging system can include retroreflective optical  
sensors for receiving external light signals conducted  
by the fiber optic probes. The underside of the board  
25 under test can be covered by a solder mask that  
reflects a given color of light picked up by the  
optical fiber sensors. The fiducial marks can be  
visible through the solder mask. The optical sensors  
on the external unit receive an external optical signal  
30 which is displayed in one color on the screen of a  
monitoring device from light reflected from the solder  
mask. When the fiducial marks are sensed by the  
optical fiber sensors (from movement of the board into  
the proper alignment position), the optical light  
35 signals change to a different color indicating  
alignment of the optical sensors with the respective  
fiducial marks. Alignment of each fiducial mark with

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1 a corresponding optical sensor is indicated on the  
imaging system, after which each tooling pin on the  
fixture is locked in a fixed position on the fixture  
base, for holding the board in its correctly aligned  
5 position.

In an alternative imaging system, a fiber optic  
probe 66 focuses on a fiducial mark and the opposite  
end of each optical probe is plugged into a second  
camera lens system used in displaying the fiducial mark  
10 on a remote monitor.

In another form of the invention, each optical  
sensor 30 can comprise a corresponding bore scope for  
producing a visual image of the location of the  
fiducial marks 28 relative to a known indexing mark  
15 produced by the external optical detecting and imaging  
system. The bore scope can be a type of optical  
detector using a matrix of optical fibers similar to  
pixels that form an image of an object in the field of  
view of the bore scope sensor. The bore scope is set  
20 at a fixed distance from the underside of the board  
because it has a fixed focal length lens to focus the  
light reflected from its field of view.

To properly align the board with the fixture, the  
board is placed on the tooling pins so that the board  
25 can be held at the correct set distance from each bore  
scope or other focusing optical device. The tooling  
pins are loosened at first so that the board can be  
moved manually relative to the fixture when the bore  
scope or other optical device is used for sighting the  
fiducial marks on the board. (The rectangular gasket  
30 14 on which the board rests has sufficient clearance to  
allow shifting of the board relative to the top plate  
16 and the probe field.) The board is then aligned  
using the imaging system which is best understood by  
referring to FIGS. 7 and 8. Each fiducial mark 28 is  
35 viewed through an eyepiece 54 which displays a  
cross-hair or other fixed zero reference indication

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1 generated in the optical display system. When the  
board is moved to position the fiducial mark close to  
the field of view, the bore scope or other optical  
device picks up the image of the fiducial mark which  
5 can be viewed in the eyepiece in reference to the fixed  
zero reference mark. The fiducial mark and the fixed  
reference mark can be enlarged and displayed on the  
screen of a video monitor 56 for use in accurately  
positioning the board on the fixture. The image  
10 enlarging and display system can include an image  
adapter 58 which senses the visual output from each  
eyepiece and adapts the images from both bore scopes  
into a display showing each fiducial mark in relation  
to its corresponding fixed zero reference cross-hair.  
15 The output from the image adapter is applied to a video  
enlarger 60 for enlarging the image of each reference  
cross-hair with its corresponding fiducial mark. An  
external camera 62 receives the image enlarger output  
for transmission to the video display terminal 56.  
20 FIG. 8 illustrates the video output on a screen of the  
video unit 56 which includes the enlarged image of a  
fiducial mark 28 detected by the optical sensor 30 in  
relation to a fixed zero reference cross-hair 64 in the  
imaging system.

25 By moving the circuit board relative to the  
fixture via the movable tooling pins, the position of  
each fiducial mark can be aligned with respect to its  
corresponding fixed reference mark 64. The screen of  
the video unit 56 can be observed as each tooling pin  
30 is manually moved through its 360° freedom of rotation  
until the fiducial marks on the board and the two sets  
of cross-hairs are properly registered. Each tooling  
pin is then locked in place on the fixture to  
automatically and precisely align the test points of  
35 the circuit array on the board with the test probes 18  
on the fixture. The display shown in FIG. 8 is  
duplicated on a separate monitor for each fiducial mark

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1 and its related zero reference cross-hair. The board  
is moved while simultaneously monitoring all displays  
until all fiducial marks are aligned.

There are several possible means for setting the  
5 imaging system's fixed reference mark (the cross-hair  
64) at a known zero position that will automatically  
align the test probes with the circuit array on the  
board when the image of the fiducial mark on the board  
is aligned with the image of the cross-hair reference.  
10 The preferred procedure is to use the calibration  
board, also referred to previously as a "gold board,"  
which represents a zero alignment error when mounted to  
the test fixture. The gold board generates a zero  
alignment error with the test probes when tooling pins  
15 at diagonally opposite corners of the gold board are  
fitted into corresponding holes located on the test  
fixture at known fixed positions relative to the probe  
field. The external imaging system contains an  
electronically adjustable cross-hair generator to align  
20 separate cross-hairs with the reference marks or pins  
on the gold board so that zero alignment error is  
produced within the imaging system. This zero  
tolerance error is then calibrated electronically into  
the cross-hair imaging system. During testing, the  
25 gold board is replaced with each board under test, and  
enlarged images of the fiducial marks on a board being  
tested are displayed. The tooling pins on the fixture  
are loosened and each board is then moved to a position  
that will align its fiducial marks with the fixed  
30 reference cross-hairs set by the calibration system, to  
automatically align each board to the probe field on  
the fixture.

The image adapter is preferably arranged to  
display each tooling pin position reference with  
35 respect to a corresponding fiducial mark, as depicted  
in FIG. 8, in which case a separate monitor is used for  
each fiducial mark alignment; or a split screen

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1 arrangement can be used in which both sets of reference cross-hairs and fiducial marks are displayed on one screen.

5 FIGS. 10 and 11 illustrate a further embodiment of an optical sensor and alignment system in which each optical sensor 30 comprises a separate miniature camera lens and video probe assembly 70 mounted to the fixture, adjacent the probe field, for viewing toward the board under test. The separate camera lens and  
10 video probe assemblies each are removably mounted to the fixture base. Each assembly includes a lens, optical fiber image conduit, light source, video camera, image enlarging lens and connection to an external video monitor, all of which are removable from  
15 the fixture base. This arrangement enhances interchangeability with other fixtures.

Each camera lens and video probe assembly 70 includes a narrow cylindrical camera lens and optical fiber image conduit 72 mounted to a video camera 74.  
20 The image conduit 72 is comprised of a bundle of thousands (in one embodiment, 80,000) pixels or optical fibers in a manner similar to the optical probes 66 described previously. The lens and image conduit 72 are mounted in an elongated tubular video probe  
25 receptacle 76 affixed to the fixture base 25. The camera lens, optical conduit and video probe assembly extends downwardly under the base 25 of the fixture and into a hollow interior region 78 of the fixture housing. The camera lens, optical conduit and video  
30 probe assemblies mount to diagonally opposite corners of the base for alignment with corresponding fiducial marks on the underside of the board under test. The optical fiber image conduit 72 of each video probe and its corresponding lens are aligned with a separate  
35 enlarged hole 80 in opposite corners of the probe panel 16, for focusing on corresponding fiducial marks on the board. FIG. 11 illustrates how the fixture base 25 can

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1 pivot to an open position to gain access to the hollow  
interior region 78 of the fixture housing for mounting  
the camera and video probe assemblies in the  
receptacles 76 affixed to the base.

5 The fixturing arrangement shown in FIGS. 10 and 11  
represents one embodiment in which the camera lens and  
video probe assemblies 70 are mounted inside the  
fixture housing, below the circuit board under test.  
The fixturing arrangement shown in FIG. 9 represents an  
10 alternative embodiment in which the camera lens and  
video probe assemblies may be remotely located from the  
fixture (because of space limitations), in which case  
the flexible optical fiber image conduits extend  
remotely away from the fixture for coupling to  
15 corresponding camera probes.

FIGS. 12 and 13 best illustrate the detailed  
construction of the camera lens and video probe  
assembly 70. The front of the optical fiber image  
conduit 72 has a double convex lens assembly 82 mounted  
20 in an opaque shield tube 84. A steel tube spacer 86  
mounted behind the double convex lens provides an F-  
stop for the lens in focusing the image on the optical  
fiber image conduit. The lens assembly and optical  
fiber image conduit are mounted in an upright opaque  
25 lens tube 88 held in an opening through a lens mount 90  
at the front of a video camera housing 92. The outer  
lens tube 91 carries a lock nut 93 used for in  
removably mounting the lens and video probe assembly to  
the video probe receptacle 76 on the base.  
30 (Alternatively, the receptacle that holds the video  
probe to the fixture can removably snap-lock into  
position, with a detent that automatically orients the  
optical system rotationally so that movement of the  
board is translated into corresponding movement of the  
35 fiducial mark on the monitor.) The tubular receptacle  
76 on the fixture base contains a tubular opaque fiber  
optic conduit 91 which surrounds and parallels the long

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1 lens tube 88. The two tubes are coaxially aligned,  
leaving an open annular space between the inner tube 82  
and the tubular outer fiber optic conduit 91. A  
plurality of flexible optical fibers 94 (in one  
5 embodiment, 56 separate optical fibers) extend through  
the annular space inside the conduit 91, from near the  
front of the lens tube to a lamp housing 96 on the  
video probe housing 92. A lamp 98 is mounted in a lamp  
holder in a cavity in the housing 92. The optical  
10 fibers 94 are directed from the annular space within  
the coaxial tubes into the cavity within the lamp  
housing for illumination from the light source. This  
is represented schematically at 98 in FIG. 12. The  
optical fibers 94 transmit the light from the lamp to  
15 the tip of the camera lens for forming an optical fiber  
ring 100 (see FIG. 13) which surrounds the lens system  
of the camera. The optical fiber ring produces a  
source of illumination for lighting the surface of the  
board 16, which can be a board under test or the gold  
20 board used for calibrating fixture alignment. The  
camera lenses 82 focus on the fiducial mark and produce  
an enlarged image of the fiducial mark on the optical  
fiber image conduit, along an optical axis 101 through  
the camera lens tube 88. Alternatively, the optical  
25 fiber image conduit 72 can be replaced with a relay  
lens system for optically transmitting an image of the  
fiducial mark to the video camera.

The video probe 74 includes a pair of lenses 102  
and 104 mounted in a tube 105 on the optical axis 101  
30 extending from the opening to the camera lens assembly,  
through the optical fiber image conduit 72 and lens  
mount 90, and into the housing 92 of the video camera.  
The tube 105 is threaded for adjusting the position of  
the lenses on the lens mount 90 to control the distance  
35 between the camera lens 82 and the lenses 102 and 104.  
The lenses 102 and 104 in the video camera comprise an  
achromatic lens and a lens to correct for color

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1 aberrations. The lens pair receive the enlarged image  
of the fiducial mark from the optical fiber image  
conduit and produce an essentially 1:1 image focused on  
a charge-coupled device (CCD) chip 106 contained in the  
5 video probe unit. The CCD chip converts the image from  
the video lenses into digital information processed by  
a video display system shown in FIG. 14. The digital  
signals from the CCD chip are sent to a camera  
controller unit (CCU) 108 shown in FIG. 14 which also  
10 schematically illustrates the camera lens 82 and  
optical fiber image conduit 72, the video camera 74,  
and the fiber optic lamp housing 96 with a power supply  
110 powering the fiber optic light source. A camera  
cable 112 transmits digital signals from the CCD chip  
15 in the video camera to the camera controller unit (CCU)  
108. The video CCU 110 can be a unit such as the EC-  
202 or EM-102 sold by Elmo of Japan. The CCU is  
powered by a conventional AC power source through an AC  
adapter 114 such as the Elmo AC-E12 adapter. A coaxial  
20 video cable 116 from the CCU transmits video signals to  
a TV monitor 118. The camera lens and video probe  
produce an enlarged image of the fiducial mark 28 on  
the display screen of the TV monitor 118. Separately,  
the output of a cross-hair generator 120 is  
25 electronically coupled to the video cable 116 for  
superimposing a video image of the cross-hair 64 on the  
TV monitor. A cross-hair position controller 122  
controls the position of the cross-hair on the monitor.  
The video camera and display system illustrated in FIG.  
30 14 is repeated for each separate reference point or  
fiducial mark sensed on the circuit board. This  
arrangement includes a separate TV monitor for each  
video probe. Separately, a split screen can be used to  
simultaneously display fiducial marks and their related  
35 cross-hair reference.

In using the video camera system for aligning a  
circuit board to the probe field on the fixture, the

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1 fixture is first calibrated with the gold board. The  
video cameras are powered, and the video system  
produces enlarged video images of the gold pins that  
represent each one of the gold board's fiducial marks.  
5 Each cross-hair display is adjusted until the video  
images show the gold pins in alignment with the  
cross-hairs displayed on the monitors. The gold board  
is then removed, and circuit boards are tested one at  
a time on the fixture, with each fiducial mark on the  
10 board being displayed on a video monitor. If a  
fiducial mark is misaligned relative to its cross-hair  
image, the tooling pin positions are simply adjusted  
while moving the board relative to the probe field  
until the fiducial mark images come into alignment with  
15 the cross-hairs. The board is then precisely aligned  
to the probe field on the fixture.

The video camera alignment system produces a  
highly accurate means of adjusting circuit boards  
because alignment can be done rapidly. Since very  
20 minute position adjustments of the board are translated  
into greatly enlarged visual image position  
adjustments, board alignment is highly accurate. The  
miniature video camera assemblies can be part of a  
basic fixturing system which includes the fixture  
25 housing and the video display and monitor. Only a new  
probe plate and top plate need to be drilled for each  
board being tested, along with forming a gold board to  
calibrate the alignment. The camera assemblies then  
mount to the receptacles in the probe plate. The  
30 entire lens and video probe system for forming an  
enlarged image of the fiducial mark is removed from or  
mounted to the base.

FIG. 15 shows another embodiment of the invention  
which provides a system for aligning circuit boards to  
35 the test fixture without use of the optical sensing  
means and means for producing enlarged images of a  
fiducial mark and a cross-hair or other zero reference

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1 point. In the illustrated system, an indexing or  
reference board 130, similar to the gold board  
described previously, is produced to represent a board  
perfectly aligned to the test fixture. The reference  
5 board 130 has a pattern of indexing marks 132  
representing locations of the test points in the  
circuit array on a board under test. A circuit board  
20 to be tested is aligned with the reference board so  
that test points 134 in the circuits on the board under  
10 test are matched to or overlie the test points 132  
printed on the reference board. Preferably, the  
reference board is transparent so that the test points  
of the board 20 can be viewed through the reference  
board to align the test points 132 of the reference  
15 board with the corresponding test points 134 of the  
circuits on the board under test. The two overlying  
boards are then affixed to one another to prevent  
relative movement between them. The reference board  
also has tooling pins 136 or other alignment means  
20 related accurately to the test points 132 on the  
reference board. The reference board tooling pins are  
positioned accurately on the reference board so that  
when the tooling pins 136 are aligned with tooling pin  
holes 138 in the fixture, the reference board alignment  
25 will represent a circuit board accurately aligned to  
the field of test probes on the fixture. The reference  
board also includes cut out regions 140 in diagonally  
opposite corners that correspond to location of the  
movable tooling pins 24 on the fixture. The left side  
30 of FIG. 15 shows the transparent reference board 130  
overlaid on a circuit board 20 being tested, in which  
the test points 132 of the reference board are visually  
aligned with corresponding test points 134 in the  
circuits on the board under test. When the two boards  
35 are perfectly aligned and the two boards are fastened  
together to prevent relative movement, the two boards  
are then flipped over and mounted to the fixture as

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1 shown in the right side of FIG. 15 (in which the  
circuit board 20 and the reference board 130 are shown  
separated for clarity). The reference board is mounted  
5 to the fixture by inserting the tooling pins 136 of the  
reference board in the correctly aligned tooling pin  
holes 138 in the fixture. If there is any misalignment  
between the tooling pin holes 26 of the board under  
test and the artwork on the board, then the tooling  
10 pins 24 in the fixture will not accurately register  
with the tooling pin holes 26 on the board under test.  
In this event, the tooling pins 24 are loosened and  
moved to positions which will correctly register the  
tooling pins 24 with the tooling pin holes 26. The cut  
15 out regions 140 provide clearance for moving the  
tooling pins 24 to their aligned positions. After the  
circuit board is aligned to the test fixture, the  
reference board 130 can be removed, and all boards  
within the same lot can then be tested on the test  
20 fixture using the same tooling pin positions.

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1       **WHAT IS CLAIMED IS:**

5           1.    A test fixture for testing printed circuit  
boards and the like, the test fixture being of the type  
having an array of test probes held in contact with a  
pattern of test points in a printed circuit array on  
the board, the circuit array being positioned on the  
board with reference to a fiducial mark on the board,  
the board also having an alignment device positioned  
thereon in alignment with the circuit array, the test  
10       fixture including:

              a tooling pin for alignment with the  
alignment device on the board to hold the board and its  
circuit array in a fixed position relative to an array  
15       of test probes on the fixture;

              means for sensing the position of the  
fiducial mark on the board to produce an output  
representative of the alignment or misalignment of the  
test probes relative to the circuit array on the board;  
20       and

              means for adjusting the position of the  
tooling pin on the fixture to move the board relative  
to the fixture to correct any misalignment of the  
circuit array relative to the test probes, the sensing  
25       means producing said output to indicate precise the  
movement of the tooling pin to a corrected position on  
the fixture necessary to align the sensing means with  
the fiducial mark to thereby indicate alignment of the  
test probes with corresponding test points in the  
30       circuit array on the board.

              2.   Apparatus according to claim 1 including  
means for locking the tooling pin in its adjusted  
position on the fixture for holding the board in a  
corrected position to register the test probes with the  
35       test points of the circuit array during a subsequent  
diagnostic circuit test of the circuits on the board.

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3. Apparatus according to claim 1 in which the alignment device comprises a tooling pin hole drilled in the board.

5

4. Apparatus according to claim 1 in which the board has a pair of spaced apart fiducial marks; the fixture includes a pair of spaced apart tooling pins each for registering with corresponding alignment devices spaced apart on the board; and a separate one of said sensing means for sensing the position of a corresponding fiducial mark.

10

5. Apparatus according to claim 1 in which the sensing means comprises an optical fiber sensor for producing an image of the fiducial mark.

15

6. Apparatus according to claim 5 in which the optical fiber sensor includes a lens, and further including a video probe assembly responsive to an image formed by the lens for displaying an enlarged image of the fiducial mark.

20

7. Apparatus according to claim 1 in which the sensing means comprises a lens system and video probe, and said output is produced by means converting an image of the fiducial mark to an enlarged video image representative of said alignment or misalignment.

25

8. Apparatus according to claim 7 in which an enlarged image of the fiducial mark is displayed on a video monitor for comparison with an adjustable indexing mark electronically produced on the monitor to indicate the correct alignment position of the probes relative to the circuit array.

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1           9. Apparatus according to claim 1 in which the  
tooling pin adjustment means comprise a tooling pin  
mounting hole in the fixture adapted to provide  
substantially 360° freedom of movement of the tooling  
5           pin relative to the sensing means on the fixture, and  
locking means adapted to hold the tooling pin in a  
fixed adjusted position in the tooling pin hole.

10           10. Apparatus according to claim 9 in which the  
tooling pin is threaded into locking means comprising  
a locking nut, and means for preventing relative  
rotation between the nut and the fixture as the tooling  
pin is rotated to tighten it into the locking nut.

15           11. Apparatus according to claim 1 in which the  
tooling pin is movable on the fixture relative to a  
fixed position of the sensing means thereon for  
aligning the sensing means with the fiducial mark.

20           12. Apparatus according to claim 1 in which the  
sensing means comprises an image focusing and enlarging  
means which are removably mounted to a fixed position  
on the fixture.

25           13. A test fixture for testing printed circuit  
boards and the like, the test fixture being of the type  
having an array of test probes held in contact with a  
pattern of test points in a printed circuit array on  
the board, the circuit array being positioned on the  
30           board with reference to a fiducial mark on the board,  
the board also having an alignment device positioned  
thereon in alignment with the printed circuit array,  
the test fixture including:

35           a tooling pin for alignment with the  
alignment device on the board to hold the board and its  
circuit array in a fixed position relative to an array  
of test probes on the fixture;

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1                    optical fiber sensing means mounted in a  
fixed position on the fixture for sensing the fiducial  
mark on the board and producing a first image that  
represents the position of the fiducial mark;

5                    means for producing a second image that  
represents a fixed reference position with which the  
fiducial mark position can be aligned to register the  
test probes with the test points on the board; and

10                   means for adjusting the position of the  
tooling pin on the fixture to thereby move the board  
relative to the fixture to align the first and second  
images and thereby align the test probes with the test  
points.

15                   14. Apparatus according to claim 13 in which the  
optical fiber sensing means includes:

20                   a lens for forming an image of the fiducial  
mark, and an optical fiber image conduit for  
transmitting the image, the lens and image conduit  
being removably mounted to the fixture; and including  
video means responsive to the transmitted image for  
displaying an enlarged image of the fiducial mark  
relative to the second image for indicating correct  
aligned position of the test points relative to the  
25                   test probes.

30                   15. Apparatus according to claim 13 in which the  
optical fiber sensing means further includes an optical  
fiber ring surrounding the optical fiber conduit and  
lens for illuminating the fiducial mark.

35

1           16. Apparatus according to claim 13 in which the  
board has a pair of spaced apart fiducial marks; the  
fixture includes a pair of spaced apart tooling pins  
each for registering with corresponding alignment  
5           devices spaced apart on the board; and a separate one  
of said sensing means for sensing the position of a  
corresponding fiducial mark.

10           17. Apparatus according to claim 13 in which the  
tooling pin adjustment means comprise a tooling pin  
mounting hole in the fixture adapted to provide  
substantially 360° freedom of movement of the tooling  
pin relative to the sensing means on the fixture, and  
locking means adapted to hold the tooling pin in a  
15           fixed adjusted position in the tooling pin hole.

20           18. Apparatus according to claim 13 in which the  
means for forming the second image representing said  
fixed reference position comprises means for forming an  
adjustable second image electronically produced on a  
monitor to indicate correct alignment of the probes  
relative to the current array on the board.

25           19. A method for testing printed circuit boards  
on a test fixture of the type having an array of test  
probes held in contact with a pattern of test points in  
a printed circuit array on the board, the circuit array  
being positioned on the board with reference to a  
fiducial mark on the board, the board also having an  
30           alignment device positioned thereon for alignment with  
the circuit array, the method comprising:

aligning the tooling pin on the fixture with  
the alignment device on the board to hold the board and  
its circuit array in a fixed position relative to the  
35           test probes on the fixture;

sensing the fiducial mark on the board and  
producing a visual output representative of the

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1 alignment or misalignment of the test probes relative  
to the test points in the circuit array printed on the  
board;

observing the visual output produced by  
5 sensing of the fiducial mark to thereby indicate the  
movement of the tooling pin and the board to a  
corrected position on the fixture necessary to register  
the sensing means with the fiducial mark to thereby  
align the test points in the circuit array with  
10 corresponding test probes on the fixture; and

adjusting the position of the tooling pin on  
the fixture and in the plane of the board, while  
observing said visual output, to move the board  
relative to the sensing means on the fixture to correct  
15 misalignment of the circuit array relative to the test  
probes.

20. The method according to claim 19 in which the  
sensing means comprise an optical fiber image sensor,  
20 and the visual output is an enlarged image of the  
fiducial mark conveyed by the optical fiber sensor and  
displayed on a monitor.

21. The method according to claim 19 in which the  
25 tooling pin is adjusted by:

placing the tooling pin in a tooling pin  
mounting hole in the fixture adapted to provide  
substantially 360° freedom of movement of the tooling  
pin relative to the sensing means on the fixture;

30 moving the tooling pin and the tooling pin  
hole until the sensing means indicates corrected  
alignment of the circuit array relative to the test  
probes; and

thereafter locking the tooling pin to the  
35 fixture for holding the board in the corrected  
position.

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1           22. The method according to claim 19 in which the  
board has a pair of spaced apart fiducial marks; the  
fixture includes a pair of spaced apart tooling pins  
each for registering with a corresponding alignment  
5           device on the board; and including producing said  
visual output for each fiducial mark and moving each  
tooling pin on the fixture to move the board to the  
corrected position.

10           23. The method according to claim 19 including  
calibrating the sensing means by electronically  
adjusting the position of a fixed reference point  
representative of correct alignment of the test probes  
and the test points on the board, and adjusting the  
15           position of the tooling pin to move the image of the  
fiducial mark into alignment with the fixed reference  
point.

20           24. A test fixture for testing a printed circuit  
board, the test fixture comprising:

          a base;

          an array of test probes on the base to be  
aligned with test points in a circuit array on the  
board, the circuit array being positioned on the board  
25           with reference to one or more indexing marks on the  
board;

          means on the base for holding the board in a  
fixed position relative to the array of test probes on  
the base;

30           sensing means on the base for sensing the  
position of the indexing mark on the board as the board  
is mounted to the base to produce a measurement of the  
alignment or misalignment of the test probes relative  
to the test points in the circuit array on the board;  
35           and

          means for adjusting the position of the  
circuit board relative to the base to produce a

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1 corresponding change in said measurement to thereby  
indicate the change in position of the board relative  
to the base necessary to correct the misalignment and  
correctly align the test points in the circuit array  
5 with the test probes.

25. Apparatus according to claim 24 in which the  
sensing means comprise an optical fiber sensor and a  
visual display responsive to the optical fiber sensor  
10 output for producing a visual display of said  
measurement.

26. Apparatus according to claim 24 in which the  
sensing means comprise:  
15 a camera lens and video probe assembly; and  
means responsive to an output of the video  
probe assembly for producing a visual reading of said  
measurement; and in which the visual reading is  
produced by means converting an output of the video  
20 probe to a video image representative of said alignment  
or misalignment.

27. Apparatus according to claim 26 in which the  
camera lens and video probe are removably mounted to  
25 the fixture base.

28. Apparatus according to claim 23 in which an  
enlarged image of the indexing mark is displayed on a  
video monitor for comparison with an electronically  
30 adjustable indexing mark produced on the monitor to  
indicate the correct alignment position of the probes  
relative to the circuit array.

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1           29. A method of testing a printed circuit board having an array of test points in a printed circuit aligned on the board with reference to a fiducial mark on the board, the method comprising:

5           mounting the board to a fixture base having an array of probes for contact with corresponding test points in the circuit on the board;

          producing an optical image of the fiducial mark from an optical sensor mounted in a fixed position on the fixture base adjacent the array of test probes;

10           producing a fixed reference indication representative of accurate alignment of the circuit test points and the test probes; and

          moving the printed circuit board relative to the fixture base to bring the optical image of the fiducial mark into alignment with the fixed reference indication to accurately align the test points on the board with corresponding test probes on the fixture.

20           30. The method according to claim 29 in which the optical image is produced by an optical fiber image conduit.

          31. The method according to claim 29 in which the optical image is produced by a lens system for focusing on the fiducial mark and forming an enlarged image of the fiducial mark.

25           32. The method according to claim 31 including calibrating the fixed reference indication by electronically adjusting the position of a reference indicator on a monitor and then moving the fiducial mark image into alignment with the fixed reference indication.

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1           33. A test fixture for testing a printed circuit  
board, the fixture having an array of test probes held  
in contact with a pattern of test points in a printed  
circuit array on the board, the circuit array being  
5           positioned on the board with reference to at least a  
pair of fiducial marks on the board, the test fixture  
comprising a base to which the array of test probes are  
mounted, separate optical image conduits mounted in  
fixed positions spaced apart on the base for producing  
10          an image of each fiducial mark, and means for adjusting  
the position of the printed circuit board relative to  
the fixture base and the optical image conduits thereon  
to move the images of the fiducial marks into alignment  
with corresponding fixed reference points thereby  
15          aligning the test points on the board with  
corresponding test probes on the fixture base.

          34. Apparatus according to claim 33 including a  
separate video camera system aligned with each image  
20          conduit for producing separate enlarged video images of  
each fiducial mark and its corresponding reference  
point.

          35. Apparatus according to claim 34 in which the  
25          video camera system includes a lens for focusing and  
producing an image of the fiducial mark, a light source  
and a video camera for producing a video image of the  
fiducial mark; and in which the lens, light source and  
video camera are removably mounted, as a unit, to the  
30          fixture.

          36. Apparatus according to claim 33 in which the  
fixed reference points are each independently  
electronically adjustable to fixed positions  
35          representing correct alignment of the probes to the  
test points on the board.

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1           37. A method for aligning a printed circuit board  
to an array of test probes on a test fixture, in which  
the printed circuit board has an alignment device for  
use in mounting the board to a tooling pin on the  
5           fixture, the method comprising:

          preparing a reference board having an array  
of test points;

          aligning a circuit board under test with the  
reference board so that an array of actual test points  
10          in circuits on the board are aligned with the array of  
reference test points;

          placing both boards in their aligned position  
on the test fixture so that test probes on the fixture  
are correctly aligned with reference test points on the  
15          reference board;

          moving a tooling pin on the fixture to a  
corrected position that registers with the alignment  
device on the board for holding the board in a  
corrected position on the fixture in which the test  
20          probes on the fixture are aligned with the actual test  
points in the circuits on the board;

          removing the reference board for the fixture;  
and

          testing the circuits on the board by  
25          contacting the test probes on the fixture with the test  
points in the circuits on the board.

          38. The method according to claim 29 in which the  
reference board includes a reference tooling pin that  
30          registers with a fixed reference alignment device on  
the fixture for indicating correct alignment of the  
test points in the circuits on the board under test  
with the array of test probes on the fixture.

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1           39. The method according to claim 29 in which the  
reference board is transparent so that the test points  
on one board can be aligned with the test points on the  
other board by visually aligning both sets of test  
5 points.

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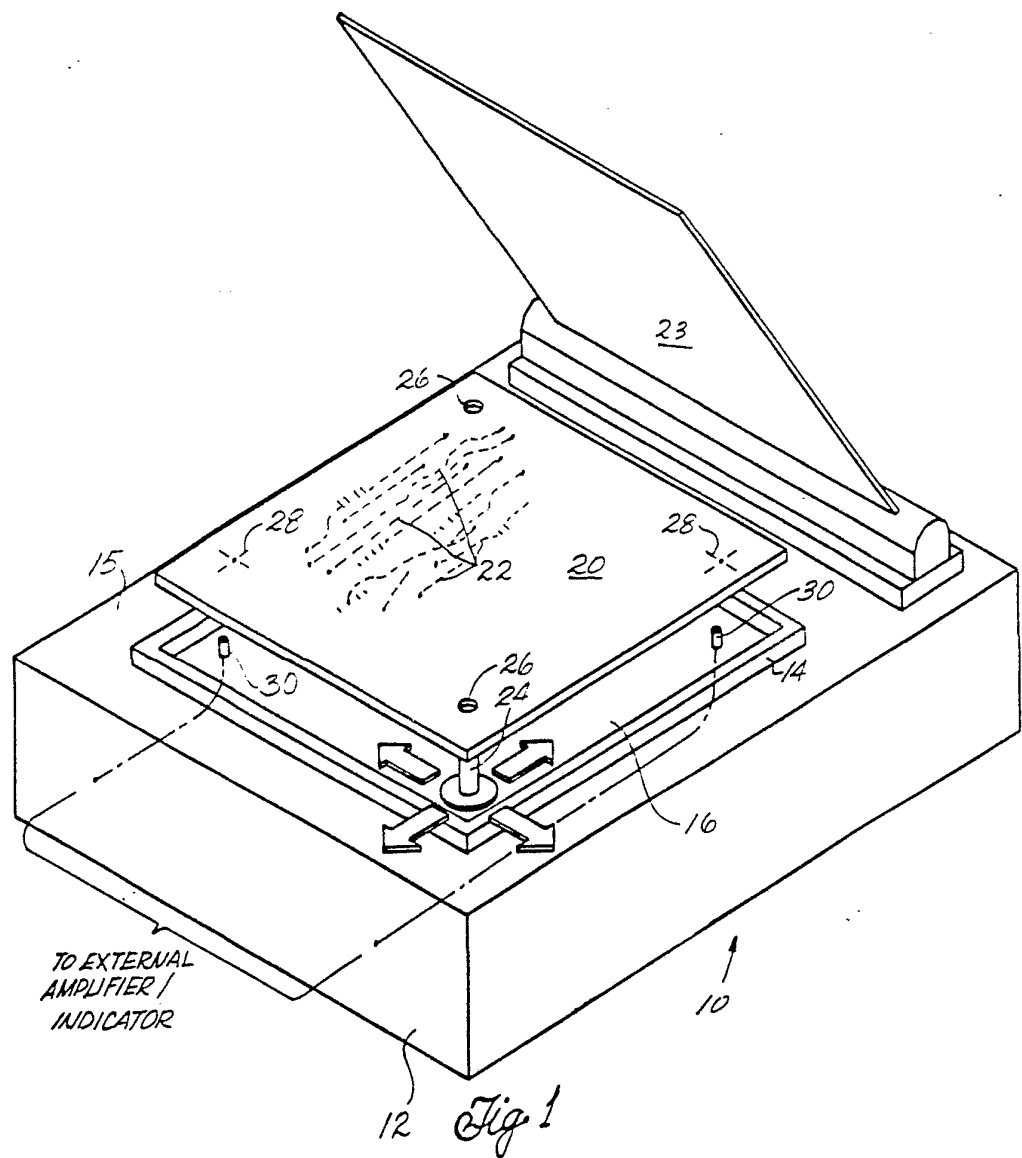
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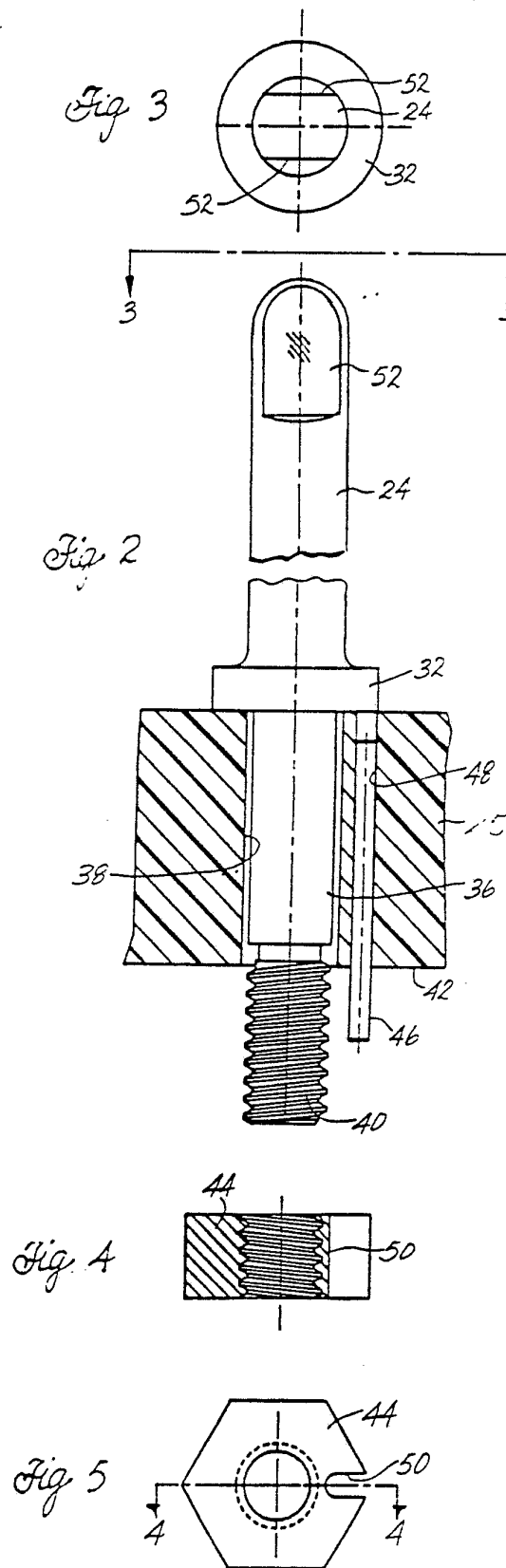
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- 1 / 9 -



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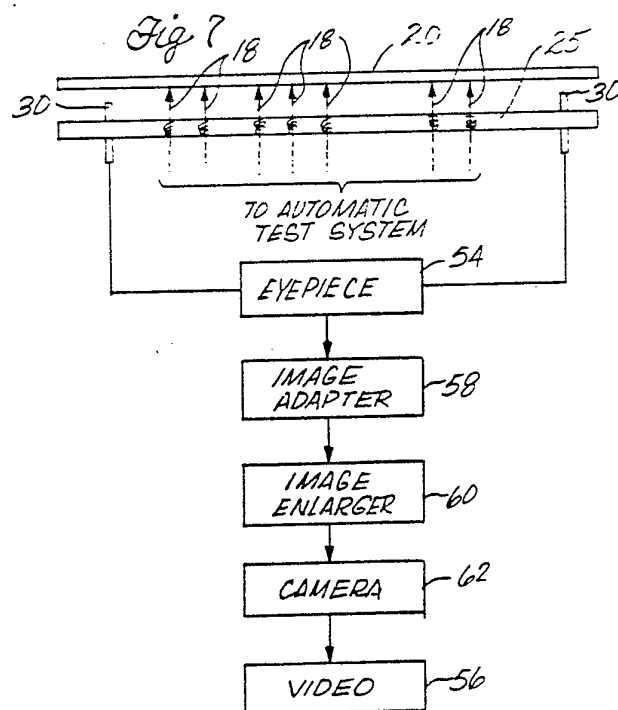
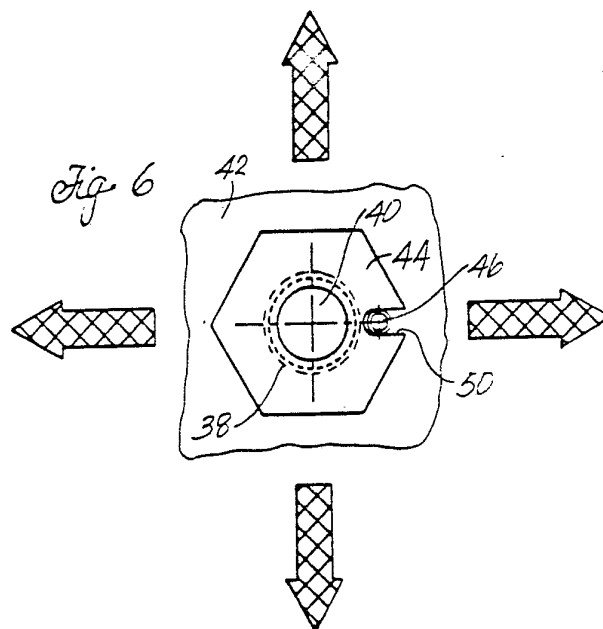
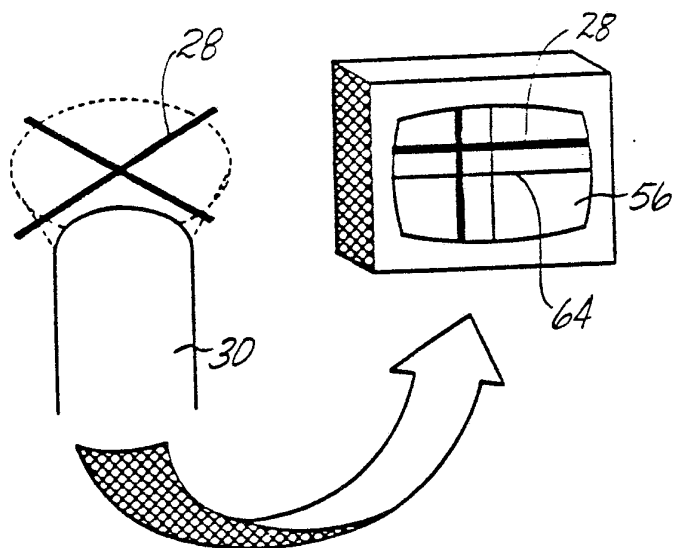


Fig 8





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Fig. 10

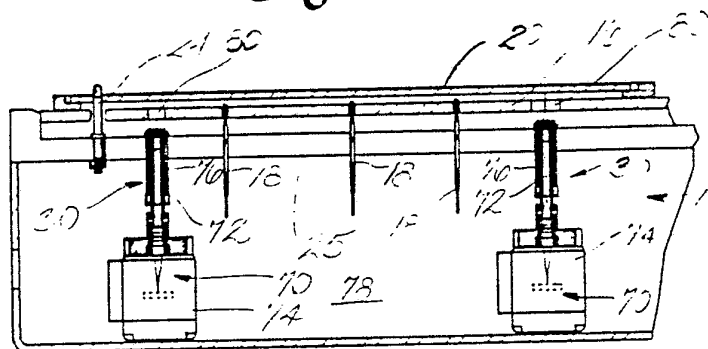
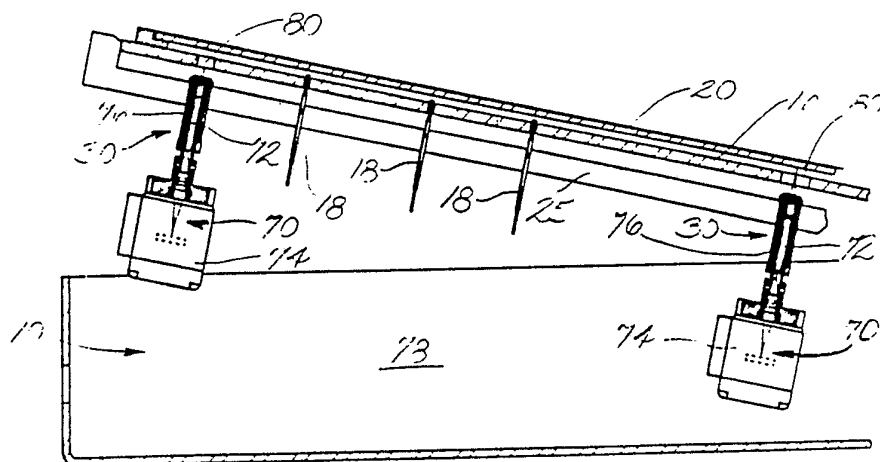


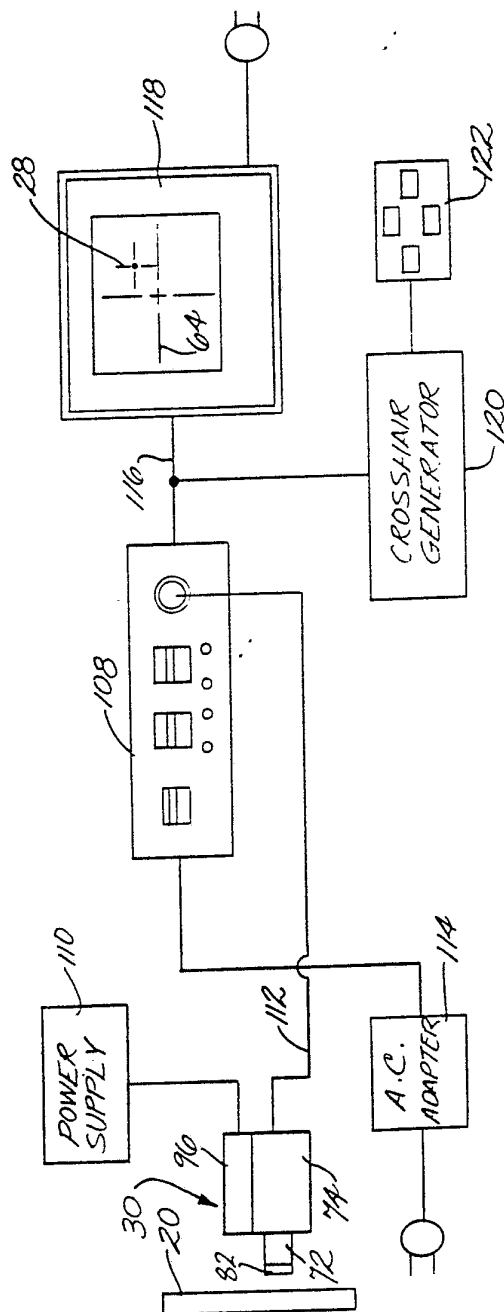
Fig. 11





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Fig. 14





# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/03688

## I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5) HO4N 7/00 ; G01R 15/12  
U.S. C1 358/101 ; 324/158F, 159P ; 356/400

## II. FIELDS SEARCHED

Minimum Documentation Searched \*

Classification System

Classification Symbols

U.S. 324/158, 158P; 358/101; 356/400

Documentation Searched other than Minimum Documentation  
to the extent that such documents are included in the fields searched \*

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No. 1 * |
|------------|------------------------------------------------------------------------------------|---------------------------|
| Y          | US, A 4,820,975 (Diggle) 11 April 1989<br>(see fig. No.1)                          | 1,3-8,12-16,<br>and 19-36 |
| A          | US, A 4,668,982 (Tinnerino) 26 May 1987<br>(see fig. No. 1 and abstract)           |                           |
| A,P        | US, A 4,943,767 (Yokota) 24 July 1990<br>(see the entire document)                 |                           |
| A,P        | US, A 4,962,423 (Yamada et al) 09 October 1990<br>(see the entire document)        |                           |
| Y          | US, A 4,922,434 (fule) 01 May 1990<br>(see fig.2)                                  | 1,3-8,12-16<br>and 19-36  |

\* Special categories of cited documents: 15

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search :

Date of Mailing of this International Search Report :

19 August 1991

International Searching Authority :

20 SEP 1991

Signature of Authorized Officer :

Andie Robinson

ISA/U.S.

Vinh P. Nguyen