

## **METHOD AND APPARATUS FOR CHECKING MISSING PARTS, MISSING LEADS AND LEADS NOT BENT**

### **Field of the Invention**

The present invention relates to a method and apparatus for inspecting printed circuit boards whereby automated inspection is needed to ensure product functionality.

### **Description of the Prior Art**

In today's competitive era, automation, quality control and process control are constantly emphasised. It is necessary to ensure product reliability, provide warranty to customers and reduce production of scrap parts. Automatic machine vision inspection of product is one choice for affording the above.

Most electrical components used in printed circuit boards (PCB's) have leads by which connections, usually formed by solder welds, are provided to the printed circuit.

Visual (manual) inspection of components leads after the process of manual insertion, automatic insertion, or both, on a plated through hole printed circuit board, is a routine and mundane task. However, it is necessary and important to carry out the inspection before the soldering process as there are frequent occurrences whereby the leads are only partially inserted, leads inserted but not bent, or particular parts and components are not inserted or missing. Such a problem presents an application for the area of computer vision inspection. Through automated inspection of the leads, automatic classification of each of the following is desired to be carried out:

- (a) leads fully inserted through the hole, therefore PCB ready to solder;
- (b) leads fully inserted through the hole and supposed to be bent but not bent;
- (c) leads partially inserted, thus considered as missing;
- (d) leads not inserted, thus considered as missing; and
- (e) when all leads belonging to a particular part or component are found to be considered as missing, then it is also classified as a missing part.

It is also desirable for such vision system to incorporate features to detect for missing surface mounted devices (SMD's).

#### Summary of the Invention

In accordance with one aspect of the present invention there is disclosed a method for inspecting a printed circuit board to detect missing parts, missing leads, and leads which are not bent, said method comprising the steps of:

illuminating, from an acute angle, a surface of the printed circuit board from which leads and parts are expected to be viewed;

forming an optical image of the said printed circuit board from normal to said printed circuit board and converting the said optical image into an illuminance signal;

creating and positioning a window around one or more topological feature intensity profile of said illuminance signal;

measuring the value of each of a first predetermined set of attribute(s) associates with the feature(s) of said intensity profiles inside each window;

comparing the measured value of each said first predetermined set of attributes to a separate set of reference values, each attribute representing the value of the corresponding said predetermined attributes with no missing part(s) or missing lead(s) or lead(s) inserted but not bent that are present and establishing the types of defects when the measured value of said first predetermined set of attributes differs from the corresponding said reference value by more than a predetermined tolerance.

In accordance with another aspect of the present invention there is disclosed apparatus for inspecting printed circuit boards to detect missing parts, missing leads and leads not being bent, said apparatus comprising:

a stage for supporting the printed circuit board(s) with the leads or parts or both on the printed circuit board facing an image acquisition means;

one or more illuminator(s) supported away from the printed circuit board for illuminating the printed circuit board(s) from an acute angle to a surface of the printed circuit board(s) from which said leads and parts are expected to be seen;

(first) image acquisition means supported in a position of registration with the illuminator(s) and trained on the surface of the printed circuit board(s) for sensing the intensity of the reflected beams of light to produce an (first) output signal which varies with the said intensity of the reflected beams;

a system with processing means coupled to said image acquisition means for processing the output signal of the said image acquisition means to detect no lead(s), lead(s) inserted but not bent, and no parts by:

(a) creating a window around each of one or more feature intensity profiles in said output signal;

(b) measuring the value of each member of a predetermined set of attributes associated with the features of said intensity profile inside each window;

(c) comparing the measured value of each said predetermined set of attributes to a separate set of reference values, each attribute representing the value of the corresponding said predetermined set of reference values with no missing lead(s), no missing part(s) and no lead(s) bent; and

(d) establishing the types of defects when the measured value of the said first predetermined set of attributes differs from the associated said reference value by more than predetermined tolerance.

In the described embodiments, the first principle adopted is that the light ray emitted from the illuminator(s), at an acute angle to the printed circuit board, is reflected off the surface of the printed circuit board, leads, and parts. One or more camera(s) are arranged in fixed positions, to register image reflected rays of the illuminator(s) from assigned fields of view, if the camera(s) are placed and orientated in the 3D space such that the reflected ray are admitted by the camera projective axis.

Secondly, the intensity of the illumination is variable by a control knob. By doing so, it is therefore possible to vary the illumination to achieve an intensity level at which the contrast of the leads, and parts can be differentiated from the tracks and markings on the printed circuit board. Hence, the respective regions on the image can be segmented as well as highlighted. At any instance, those leads that are not fully

inserted, that are inserted but not bent, and parts that are missing, generate a different image profile as compared to a PCB with all parts and leads fully inserted and bent (a "GOOD" PCB).

By the above described configuration, the camera(s) image the reflected ray(s) from a assigned field of view. The intensity of the illumination is variable by a control knob. The highlighted and segmented region are then input to the "classifier" which outputs the result as either "GOOD", or missing part(s), missing lead(s) generally classified as "NOT GOOD".

#### Brief Description of the Drawings

Figure 1 is a cross-sectional view of part of a printed circuit board;

Figure 2 shows an automatic system of the preferred embodiment for detecting missing leads and missing parts;

Figure 3 shows the system of Figure 2 integrated with the other peripheral units;

Figure 4 shows the apparatus for a standalone system of another embodiment for detecting missing leads, and missing parts;

Figure 5 shows the principle upon which the described embodiments are based where each ray of light from a ring light is reflected from the specular surface of the leads and parts such that the angle of incidence ray is equal to the angle of reflected ray;

Figure 6 illustrates a series of sketches in two dimensions of a plurality of leads which are "Good" and a plurality of leads which are "Not Good" or missing leads;

Figure 7 illustrates a series of sketches in two dimensions of parts which are classified as "Good" and cases which are classified as "Not Good" or missing parts;

Figure 8 shows a flowchart of the teaching process prior to the inspection of a new model of a printed circuit board; and

Figure 9 shows a flowchart of the inspection program for the automatic system executed by the vision processor to inspect the unknown quality of leads and parts of a piece of printed circuit board.

#### Detailed Description of the Best Mode of Performing the Invention

Referring to Fig. 1, a component or part 1 is mounted on a printed circuit board 2 by inserting a number of leads 3a through respective holes 4 of the printed circuit board 2. It is important and desired that the leads 3a of the part 1 are fully inserted through the holes 4 of the printed circuit board 2 before the soldering process. If any of the leads 3a are bent, or otherwise not inserted through the hole 4, it will result in no electrical contact made between the lead 3a and a conductive pad 5a of the PCB surrounding the hole 4. When all the leads 3a belonging to the part 1 are bent, the part 1 will not be considered mounted to the printed circuit board 2 and would usually drop away from the printed circuit board 2. Missing parts are also due to cases of empty loading cartridges or machine insertion errors. Further, one of the causes of weak solder joints is where the leads 3a are partially inserted and can thus cause premature failure of the printed circuit board 2.

A surface mount device (SMD) is illustrated as a part 6 which is mounted on the printed circuit board 2 by placing corresponding leads 3b firmly on top of the pad surface 5b. The part 6 can be firmly held to the printed circuit board 2 by applying sufficient adhesive substance either on the body of the part 6 or on the printed circuit board 2.

Figure 2 shows the apparatus for the automatic system of one embodiment for detecting missing leads 3a or 3b and missing parts 1 and 6. The apparatus comprises a motor 7 and a conveyor 8 which transfer the printed circuit board 2 in the X-direction as illustrated so as to enable all area of the printed circuit board 2 to be inspected. The conveyor 8 also acts as a supporting means to the printed circuit board 2. The motion of the motor 7 is controlled by a programmable motion control unit 9.

One or more image acquisition devices or line scan video cameras 10 are trained on the surface of the printed circuit board 2. The video cameras 10 can be

either mounted with their optical axis substantially normal to the inspection surface of the printed circuit board 2, or at any other suitable position where the optical path can be altered (eg. reflected) by some optical means such as mirrors, prisms etc. accordingly (not shown). In some cases, it is required to have multiple video cameras 10 to inspect the whole printed circuit board 2.

Between the printed circuit board 2 and the cameras 10 are positioned one or more illuminator(s). If linear illuminators (not shown) are used, the illuminators are arranged in such a way so as to best circumscribe the optical axis of the video cameras 10. A ring light 11 as illustrated is the most suitable illuminator found by the present inventors to be used to circumscribe the optical axis of the video camera(s) 10. The intensity of the illuminance can be controlled by a dimmer controller and adjustable by using a dimmer knob, (not shown, but well known in the art).

The ring light 11 illuminates the plated through leads 3, and the parts 1 and 6 from an underside of the PCB 2 at an acute angle to the surface of the printed circuit board 2. The video cameras 10 sense the intensity of the upwards reflected light and produce an output signal which varies accordingly with the intensity.

The video cameras 10 are coupled to a machine vision processor 12 which has one or more micro-processors (not shown), and which processes the output signals of the video cameras 10 to detect missing leads 3 and missing parts 1 and 6 and leads inserted but not bent. In addition, the machine vision processor 12 also serves as a host computer and interface with the motion controller 9, and interfaces with the user via a monitor 13 displaying both text and video images, by means of user inputs such as a keyboard and track ball (not shown).

Referring to Figure 3, all the apparatus shown in Figure 2 is provided as a single unit represented by an automatic system 14 which is integrated with the other peripheral machines. A loader 15, including a mechanical arm, pushes out the printed circuit board 2 from a rack (not shown), to the platform of a incoming conveyor unit 16. The loader 15 can house a number of racks waiting in sequence for their printed circuit board 2 to be automatically pushed out to the conveyor 16.

The conveyor 16 delivers the printed circuit board 2 to the conveyor 8 of the automatic inspection machine 14. More than one printed circuit board 2 can be transferred by the conveyor 16. The printed circuit board 2 will only be fed to the system 14 when the system 14 is ready to inspect a new printed circuit board 2 for missing leads 3, leads 3 inserted but not bent, and parts 1 and 6.

After the inspection process, the printed circuit board 2 is transferred out of the system 14 into a sorter 17. The sorter 17 sorts the printed circuit board 2 according to "Good" and "Not Good" designation. From here, a "Good" printed circuit board 2 is either be transferred to the next stage of the assembly process (not shown) or to a conveyor 18 in line with a stacker 20. The printed circuit board 2 is then be pushed into a empty slot of the rack housed in the stacker 20. On the other hand, a "Not Good" printed circuit board 2 is transferred to a conveyor 19, and manually removed for rework purposes. Often, a separate stacker 21 is interfaced with the conveyor 19 for rework to be done at a later time in a fully automatic configuration.

The described system 14 configured with the peripherals 15, 16, 17, 18, 19, 20 and 21, is generally intended to be put on-line with other production processes. However, the apparatus can be reconfigured to be used as a standalone unit. Figure 4 shows the apparatus for a standalone system in accordance with another embodiment for detecting missing leads 3 and missing parts 1 and 6. The apparatus comprises a jig 22 to hold the printed circuit board 2. The number of image acquisition devices or line scan video cameras 10 that are trained on the surface of the printed circuit board 2 very much dependent on the size of the PCB 2. Each video camera 10 produces an image of a designated section of the printed circuit board 2. The video cameras 10 can be either mounted with their respective optical axis substantially normal to the inspection surface of the printed circuit board 2, or at any other suitable position where the optical path can be altered (eg. reflected) by some optical means such as mirrors, prisms etc. accordingly (not shown). The standalone system also has a ring illuminator 11, machine vision processor 12, video monitor 13, dimmer controller and knob, serving the same functions and purposes as described earlier.

Referring to Figure 5, the principle of operation of the above described embodiments is to assume that the angle of incidence rays 23 from the illuminator 11 are reflected from the specular surface of the through hole leads 3 such that the angle of incidence rays 23 are equal to the corresponding angle of reflected rays 24. The video camera 10 will image the reflected rays 24 if it is placed and oriented in the three dimensional space such that the reflected rays 24 are admitted by the video camera 10 projected axis. Hence with the video camera 10 fixed in the three dimensional space, the features of the leads 3 can be enhanced by placing the illuminator 11 in three dimensional space such that the incident rays 23 are at an acute angle, and such that the acute angle of incidence rays 23 is equal to the angle of reflected rays 24 with respect to the specular surface normal of the leads 3. For an ideal lead 3, the video camera 10 will image a bright visual signature 25 of a pattern which corresponds to the surface area of the lead 3. Also note that the image of the lead 3 is very much saturated whereas the surface of the printed circuit board 2 image a very much darker 26 reflection.

Similarly, the incident rays 23 which are at substantially normal angles will strike the surface of the parts 1 and 6, and printed circuit board 2, which faces the video camera 10, and such surfaces will be imaged as darker regions. However, the top surfaces will be imaged as darker regions. However the top surfaces and the edges of parts 1 and 6 will appear brighter than the printed circuit board 2, but will not appear as bright as the surface of the leads 3. The image profile is the projection of three dimensional surface feature on the printed circuit board 2 to the two dimension image plane.

Figure 6 shows a plurality of illustration of two dimensional side view sketches of leads which are classified as "Good" and leads which are classified as "Not Good" either the leads are missing, not inserted or not being bent. The image profile of a straight through the lead 27 when viewed from the top constitutes two annular shapes 28,29. The top of the lead 27 is projected to the centre 28 of a dark region annular shape 29. For a bent lead 30, a visual signature 31 corresponding to the top surface of

the lead 30 with respect to the video camera 10 is projected to the centre of dark region annular shape 32. Leads 27 and 30 are acceptable and classified as "Good" by the system. If lead 27 is supposed to be bent, it should have the visual signature of 31, then it is classified as "Not Good".

When cases such as 33, 34, 35 and 36 occur, the corresponding image profile will be that shown as 36, 37, 38 and 39. The visualisation of cases such as 33 and 34 are very much dependent on the extent the corresponding leads 40 and 41 have been inserted through the hole 4 or the extent the leads 40, 41 and 42 have been correctly bent during the process. All the four cases 33, 34, 35 and 36 are not acceptable and are classified as "Not Good" by the system.

Figure 7 shows a plurality of illustration of two dimensions sketches of parts which are classified as "Good" and cases which are classified as "Not Good" or missing part. The image profile of a SMT resistor part 43, has two semi-bright regions 44 and 45. A portion of each semi-bright region 44 and 45 is surrounded by a much brighter region 46 and 47. The regions 46 and 47 are joined by two very thin bright outlines 48,49 representing the edge feature of the resistor part 43. In the case of SMT capacitor part 50, it will have similar image profile as the image of the SMT resistor part 43 except that the regions 51,52 are joined by a thick bright outline 53 and 54. For the SMT condenser part 55, one semi-bright region 56 is bigger than the other one 57 and the brighter regions 58 and 59 are joined 60 and 61.

For SMT parts such as diodes, transistors etc. having gull wing leads 62, the image profile is made up of small bright regions 63 corresponding to the number of leads 62 for each part. If any part is missing, the image profile will be other than the image profile of the surface of printed circuit board 64.

Figure 8 shows a flowchart of the teaching process prior to the inspection of a new model of the printed circuit board 2. Firstly, the data of the printed circuit board 2 is loaded into the system 14 at step 65. Components' data such as circuit number, location, orientation, pitch etc. is saved in a computer aided design file at step 66. From the computer aided design file, the co-ordinates of components is then converted

to pixel representation at step 67. In step 60, if necessary, the amount of overlaps between one video camera 10 field of view with others video camera 10 field of views is calculated. Step 68 also takes care of allocating all the components to the respective image frame corresponding to the video camera 10 to be inspected.

In step 69, the machine vision processor 12 is programmed to create a window around each image of the leads. The number of windows to be created for each part is dependent on the intensity profile of the part as described earlier on. After generating all the windows for all the components, the user can modify and fine tune the location of an individual window at step 70. When all necessary modifications are made, the location of component windows is then saved in a reference file, step 71. The file is then loaded prior to the inspection of the printed circuit board 2.

Figure 9 shows a flowchart of the inspection program for the automatic system 14 executed by the vision processor 12 to inspect the unknown quality of leads and parts of a piece of printed circuit board 2. The inspection routine commences with step 72 when a piece of the printed circuit board 2 is transferred to the conveyor 8 of Figure 2. The conveyor 8 then moves in the X-direction to the predefined first location in step 73. After step 73, in step 74 each respective video camera 10 captures the image of the area of the printed circuit board 2 within its field of view. If there are more images to be captured a decision made in step 75, the conveyor 8 transfers the printed circuit board 2 to the next position in order for the next image(s) be captured in set 76. If there are no images to be captured, step 76 is skipped. Segmentation is to be carried out in step 77.

After step 77, step 78 is executed whereby a window is created enclosing leads and parts intensity profile whereby the data is obtained from the computer aided file created during teaching process.

Once the windows are created, predefined attributes such as area, mean, connectivity, perimeter, brightness etc. are measured in step 79. Once completed measuring the attributes, a comparison is made in step 80 with the value of the attributes established earlier so as to identify any leads and parts classified generally as

"Not Good". Further classification is carried out according to the type of parts defects as seen in Figures 4 and 5.

After the completion of step 80, step 81 checks whether there are any images to be captured. If it is not the last image, the inspection program control goes back to step 73. The cycle continues until the last image of the printed circuit board 2 is captured and checked. The inspection program ends in step 82.

The flowchart of the inspection program for the standalone system have all the steps of the automatic system step except step 73 and 74. The printed circuit board is placed in a jig 22 instead of a conveyor.

Many of the different prior art systems available commercially are very expensive, complex and difficult to operate. Furthermore each prior art approach to solve the problem has its own limitation, eg. during imaging stage, small but important features can be missed and not be able to classify the type of defect.

The described embodiments provide a system which is low in cost and simple to set up and operates. The illuminators arrangement enable selective features of the leads and parts to be highlighted. Hence printed circuit board tracks detail can be easily segmented.

The foregoing describes only a number of embodiments of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention.

CLAIMS:

1. A method for inspecting a printed circuit board to detect missing parts, missing leads, and leads inserted but not bent, said method comprising the steps of:

illuminating, from an acute angle, a surface of the printed circuit board from which leads and parts are expected to be viewed;

forming an optical image of the said printed circuit board from normal to said printed circuit board and converting the said optical image into an illuminance signal;

creating and positioning a window around one or more topological feature intensity profile of said illuminance signal;

measuring the value of each of a first predetermined set of attribute(s) associates with the feature(s) of said intensity profiles inside each window;

comparing the measured value of each said first predetermined set of attributes to a separate set of reference values, each attribute representing the value of the corresponding said predetermined attributes with no missing part(s), missing lead(s), or lead(s) inserted but not bent, that are present and establishing the types of defects when the measured value of said first predetermined set of attributes differs from the corresponding said reference value by more than a predetermined tolerance.

2. The method according to claim 1, wherein information on the positioning of the window generated around each said feature intensity profile is retrieved from a data bank.

3. The method according to claim 1, wherein only the illuminance corresponding to the regions inside each window is analysed.

4. The method according to claim 1, comprising the further step of controlling the intensity of illumination of the printed circuit board.

5. Apparatus for inspecting printed circuit boards to detect missing parts, missing leads and inserted leads not being bent, said apparatus comprising:

a stage for supporting the printed circuit board(s) with the leads or parts or both on the printed circuit board facing an image acquisition means;



one or more illuminator(s) supported away from the printed circuit board for illuminating the printed circuit board(s) from an acute angle to a surface of the printed circuit board(s) from which said leads and parts are expected to be seen;

(first) image acquisition means supported in a position of registration with the illuminator(s) and trained on the surface of the printed circuit board(s) for sensing the intensity of the reflected beams of light to produce an (first) output signal which varies with the said intensity of the reflected beams;

a system with processing means coupled to said image acquisition means for processing the output signal of the said image acquisition means to detect no lead, lead inserted but not bent, and no parts by:

(a) creating a window around each of one or more feature intensity profiles in said output signal;

(b) measuring the value of each member of a predetermined set of attributes associated with the features of said intensity profile inside each window;

(c) comparing the measured value of each said predetermined set of attributes to a separate set of reference values, each attribute representing the value of the corresponding said predetermined set of reference values with no missing lead(s), no missing part(s) and no lead(s) inserted but not bent; and

(d) establishing the types of defects when the measured value of the said first predetermined set of attributes differs from the associated said reference value by more than predetermined tolerance.

6. The apparatus according to claim 5, further including second acquisition means supported in a position of registration with the illuminator(s) and trained on a second surface of the printed circuit board(s) for sensing the intensity of the reflected beams of light and to produce a second output signal which varies with the said intensity of the reflected beams.

7. The apparatus according to claim 5, further including a stage for supporting the printed circuit boards, said stage being motorised to move in the X-axis lying in the same plane as the printed circuit board.



8. The apparatus according to claim 7, further including a conveyor system which acts to deliver the printed circuit boards to the apparatus.

9. The apparatus according to claim 7, further including a conveyor system which acts to receive the printed circuit boards from the apparatus.

10. The apparatus according to claim 8, further including an arm to push out the printed circuit board in the rack to a conveyor system.

11. The apparatus according to claim 9, further including an arm to push the printed circuit boards on the conveyor system, platform into the rack.

