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MINI-PROJECT REPORT

on

"PCB DEFECT DETECTION USING IMAGE PROCESSING"

Submitted in partial fulfillment of the requirements for the award of the degree

BACHELOR OF ENGINEERING
IN
ELECTRONICS AND COMMUNICATION

Submitted by

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CERTIFICATE

Certified that the Mini-project work entitled **"PCB defect detection using image processing"** carried out by Mr.**G Pavithran (1MV20EC047)**, the bonafide students **of Sir M Visvesvaraya Institute of Technology** in partial fulfilment for the award of Bachelor of Engineering in **Electronics and Communication Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2022-23. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Mini Project work prescribed for the said degree.

Name & Signature of the Guide	Name & Signature of the HOD	Signature of Principal
Dr. V.G. Supriya,	**Dr. V.G. Supriya** ,	**Prof. Rakesh S G**
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Department of ECE	Department of ECE	

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1	
2.	

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

Printed circuit board (PCB) fabrication process is a multidisciplinary process, and etching is the most critical part in the PCB manufacturing process. Etching is the process, where the copper board will undergo 'peeling' process, where the circuit layout will be preserved while the rest of the copper background will be washed out. In order to minimize scrap caused by the wrongly etched PCB panel, inspection has to be done in early stage. The traditional way to inspect any defect is visually employing human operators. This process is not time consuming but also highly prone to errors due to humans' factors. The next trend then is to use machine vision inspection system. However, all of the inspections are done after the etching process where any defective PCB found is no longer useful and is simply thrown away. Since etching process costs 70% of the entire PCB fabrication, it is uneconomical to simply discard the defective PCBs. Hence, this project proposes an automatic visual inspection on the PCB before the etching process so that any defect that could be found on a PCB would be able to be reprocessed. Although many algorithms are available in defect detection, both contact and non-contact methods [M. Moganti et al 1996], none is able to classify these defects. Contact method tests the connectivity of circuits but unable to detect major flaws in cosmetic defects [S. H. Indera Putera et al 2012]. Non-contact uses methods such as ultrasonic and x-ray imaging to detect anomalies in the circuit design, both cosmetic and functional [S. H. Indera Putera et al.2012]. The use of manual labor to visually inspect each PCB is no longer viable since it is prone to human errors, time consuming, requires large overhead costs and results in high wastage [M. Moganti et al. 1996].

Moganti divides the methods for PCB defect detection in to three groups:
1)Referential Approach 2) Non Referential Approach and 3) Hybrid Approach.
In this paper the defect identification can be done by using the hybrid method. The Hybrid technique increases the efficiency of the system.

PCB defects can be categorized into two groups: Functional defects and cosmetic defects. Performance of the PCB gets affected by the functional defects. Cosmetic defects affect the appearance of the PCB, but can also jeopardize its performance in the long run due to abnormal heat dissipation and distribution of current [1]. However, in along period, the PCB will not perform well since the improper shape of the PCB circuit pattern could contribute to potential defects. Thus, it is crucial to detect these two types of defects in the inspection phase. Figure 1.1 shows an artificial defect-free PCB image pattern. Figure 1.1 shows the same image pattern as in with a variety of defects on it. The printing defects and anomalies that will be looked at, for example, are breakout, short, pin hole, wrong size hole, open circuit, conductor too close, under etch, spurious copper, mousebite, excessive short ,missing conductor, missing hole, spur and over etch. These defects are shown in Figure 1.1.1

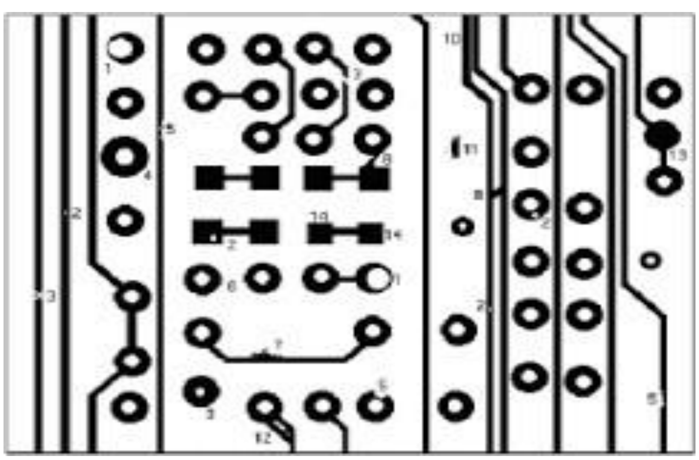

Figure 1.1.1 An Example of Defective PCB Patterns

CHAPTER 2
PROBLEM STATEMENT

Production of the printed circuit board (PCB) is one of the important key components in the most of the electronics industries. The latest existing technology is advanced to full digital implementation; it is envisioned that the manufacturing of PCB will ever growing. It is very important to produce the PCB with zero-defects. This is to ensure a high quality PCB that translates to reliable and quality digital end products. Initially, the bare PCBs (PCB without components attached to it) were inspected randomly using manual inspection system, which involves human operators. This technique is quite costly since it is highly error-prone due to human error. So it is essential to provide an alternative inexpensive and comprehensive defect detection technique. The basic technique of the proposed technique is to detect the defect based on the digital image of the PCB using image processing techniques. The objective of this project thus is to provide an alternative inexpensive and Comprehensive defect detection technique.

This technique uses a very expensive machine that checks the conductivity of the PCB using probes. However, the limitation of this technique is it can only detect defects that are based on either shorts or open. So it is essential to provide an alternative inexpensive and comprehensive defect detection technique. The basic technique of the proposed technique is to detect the defect based on the digital image of the PCB using image processing techniques. The objective of this project thus is to provide an alternative inexpensive and Comprehensive defect detection technique.

CHAPTER 3

LITERATURE SURVEY

[1] Ismail Ibrahim, Syed Abdul Rahman Syed Abu Bakar, Musa Mohd Mokaji, Jameel Abdulla Ahmed Mukred, Zulkifly Md Yusof, Zuwairie Ibrahim, Kamal Khalil, Mohd Saberi Mohamad: There are different methods for inspection of PCB.A individual operator inspect defect by looking at board in a manual inspection. But this method was yielding a poor result. Automatic optical inspection is preferred method for inspection of PCB. An automated visual printed circuit board (PCB) inspection is used to reduce problems occurred due to manual inspection. In research works mentioned in [1].

[2] Wu, Wen-Yen, Mao-Jiun, J. Wang and Chih-Ming, Liu: For instance, the work carried out by Wen-Yen did the direct subtraction of the reference to the test image to produce Positive (P), Negative (N) and Equal (E) pixels. Defects detected on P and N pixels. After that, defect classification is done based on P, N and E pixels. In current scenario PCB is inspected either for component inspection or for track inspection of fabricated PCB.

[3] Sanveer Singh, Manu Bharti: Inspection system explained in [3] is for missing components or wrongly placed components in PCB. Defect detection and classification and localization method explained in [4] uses mathematical morphology and image processing tools. Besides the need to detect the defects, it is also essential to classify and locate these defects so that the source and location of these defects can be identified.

If there is a fault in PCB then it results in a wastage of money of which is paid for manufacturing process of PCB. In this paper defect detection technique for PCB film is focused. The method explain in the paper can be applied for bare PCB images to detect faults due to etching, as PCB inspection after etching is also important.

[4] Malge P.S, Nadaf R.S: To reduce the cost, the bare PCBs should be inspected before PCB manufacturing. In mass production of PCBs, the inspection of PCB is necessary, especially for high level complexity of boards. There are different methods for inspection of PCB.A individual operator inspect defect by looking at board in a manual inspection. But this method was yielding a poor results. In research works mentioned in paper by Ismail Ibrahim and others Automatic optical
inspection is preferred method for inspection of PCB. An automated visual printed circuit board (PCB) inspection is used to reduce problems occurred due to manual inspection[3] Defect detection and classification and localization method explained in paper published by Malge, uses mathematical morphology and image processing tools. Besides the need to detect the defects, it is also essential to classify and locate these defects so that the source and location of these defects can be identified.

CHAPTER 4
OBJECTIVES

I. **Product quality**: Defect detection during manufacturing processes is a vital step to ensure product quality. The timely detection of faults or defects and taking appropriate actions are essential to reduce operational and quality-related costs. The quality of PCBs will have a significant effect on the performance of many electronic products. Bare PCB is a PCB without any placement of electronic component, which is used along with other components to produce electric goods.

II. **Cost**: In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be inspected. The technology of computer vision has been highly developed and used in several industry applications. One of these applications is the automatic visual inspection of PCBs. The automatic visual inspection is important because it removes the subjective aspects and provides fast and quantitative assessments.

III. **Human Error**: One of the important objective of the project is to reduce the human error and produce error free components. The methodology stated in this project will reduce the human error and assures defect free products.

CHAPTER 5

PROPOSED METHODOLOGY

Printed Circuit Board Defect Detection using Reference Comparison Method:

The reference comparison approach carries out a point-to-point (pixel-by-pixel) comparison with the inspection PCB image and the reference image to identify differences and locate areas of interest for further processing. One of the major advantages of the reference comparison method is that it is intuitive and easy to understand while having the capability of identifying almost all PCB defects. The focus of this study would be to utilize the referential comparison approach to detect defects of PCBs. As mentioned this approach is intuitive and less complex compared to the other approaches.

a PCB defect detection system that used the same methodology "Image Subtraction” but had the capabilities to handle RGB (Red-Green-Blue) images. Once a template image and the defective image in RGB format had been preloaded to the system it would conduct an image preprocessing step where the RGB images would be converted to a binary image using OpenCV's images processing techniques. The main reason for then binary conversion is that the algorithm is only equipped to handle 0 and 1. The two converted images would be compared using the Image Subtraction technique resulting in a new image that contains the defects of the PCBs’ that's been inspected.

BLOCK DIAGRAM:

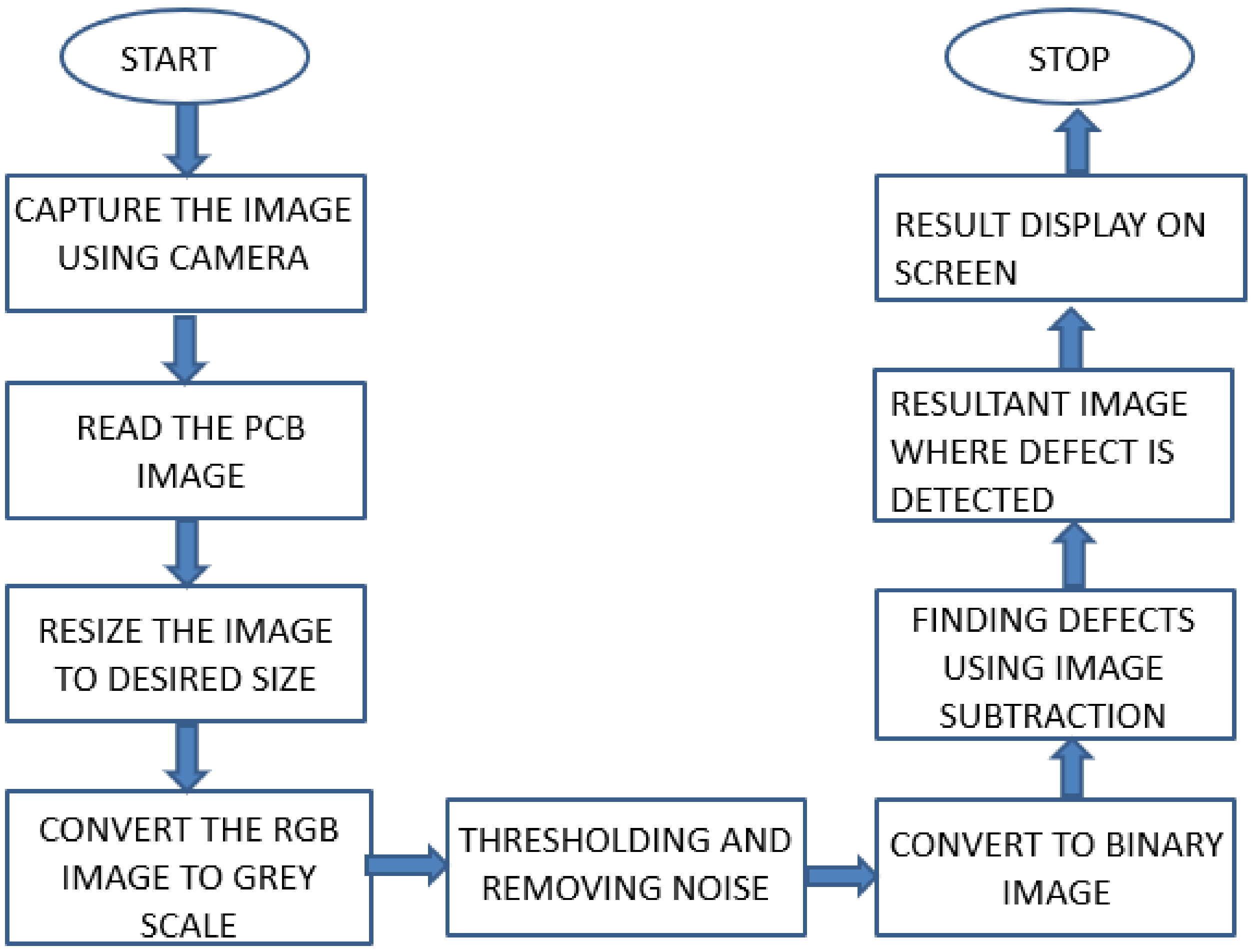

Fig.No.5.1.1 Block diagram

METHOD AND PROCEDURES

I. Image Processing Algorithm and Software

The image acquisition and processing portion of the system were designed using MATLABs' computer vision, and the image processing toolbox. The main goal of the proposed system was to identifying PCB cosmetic deformities, such as breakouts, mouse-bites, pinholes, open-circuits and, under/over etch.

II. Reference image and Inspection Image aquation

The first step in the process is to preload a reference image (AKA templet image) to the system. This can be done by capturing the image during inspection or by uploading an image that was saved on the computer. The reference image would be an image of a defect free PCB that the system would compare the inspection images against. Caution needs to be taken when acquiring images for detection as the differences in lighting conditions can lead to deferent contrast values which would result in false failures. The MATLAB software allows for different image acquisition methods, the software's built-in "image 15 acquisition toolbox" allows for interactive image detection and hardware property configuration, furthermore, it generates equivalent MATLAB code to automate the image acquisition process.

III. Image Pre-Processing

The next step of the process would be the preprocessing stage, where the images goes through a few image processing algorithms to gain a desirable binary image.

i. **Smoothening:** The first step in the image pre-processing stage is smoothening the image,this procedure is also referred to as blurring. Smoothening an image assist in reducing noise and camera artifacts in images.

ii. **Intensity adjustment:** The second step in the image preprocessing stage would be the image intensity adjustment. The numerical data of an image can be observed to the histogram function on MATLAB.

iii. **Thresholding:** During the next step of the image pre-processing stage, the grayscale image would be turned into a binary image. Using the threshold operation, a final decision would be made about the pixels in an image to categorically reject those pixels below or above some value while keeping the others. the resulting image would only contain pixels with vales of either 0 (black pixel) or 1 (white pixel).

IV. Image Subtraction

At the fifth step of the system, the preprocessed inspection and reference images would be compared using an absolute difference operation. A XOR operation would be carried out between the inspection image and the reference image resulting in a temporary image that contains anomaly and/or defect. A pixel-to-pixel comparison would take place, pixel in the reference image (xr,yr) with the pixel of the inspection image (xi ,yi). The following Table 1 depicts the logical operation of the XOR function.

Pixel(xr,yr) Reference images	Pixel(xi,yi) Inspection image	Output
0	0	0
0	1	1
1	0	1
1	1	0

CHAPTER 6

HARDWARE

- **Web Camera:**

Fig.No.6.1.1. web camera

SIFI Pro : Build-in image compression, Automatic brightness adjustment, Automatic color compensation, Manual focus High resolution COMS color sensors, Large window capture size: 640X480/800X600 Auto focus computer camera captures high definition video at a wide-angle of up to 90 degrees, Great for webinars, video conferencing, live streaming, etc. PC or laptop with USB port Pentium 200 or higher CPU, Operation system. Windows XP/ 2000 /2003 / Vista 71 B/ 10, Mac OS, Android and Linux. Fixed regular 60CM focal length, you can freely rotate the lens to adjust.

- **Holder:**

Fig.No.6.1.2. holder

You can make live stream, online lesson, YouTube videos, cooking video, videography, photography, vlogging, video shooting and find your own hidden innovation talent. Overhead *Mobile stand :* Brolaviya Stand is Perfect for watching movies & enjoying music in the bedroom, cooking in the kitchen, exercising in the gym and working in the office.*Adjustable stand:* Compatible with all smart phones screen. Product length is 29.5 inch in total.*Quality over Quantity:* Brolaviya stand is made of high- quality solid Iron metal makes product sturdy enough to hold mobile firmly.

- **PCB BOARDS:**

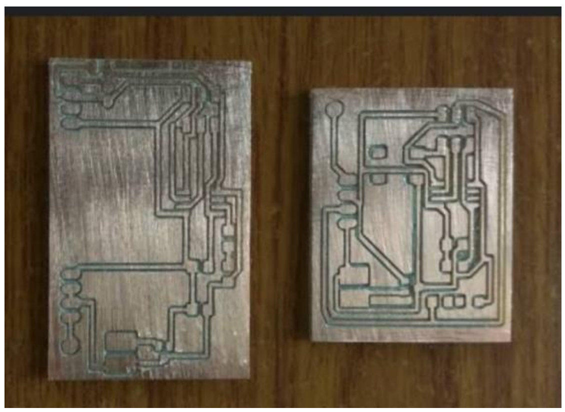

Fig.No.6.1.3. PCB

Printed circuit board is a medium used to connect electronic components to one another in a controlled manner. It takes the form of a laminated sandwich structure of conductive and insulating layers: each of the conductive layers is designed with an artwork pattern of traces, planes and other features (similar to wires on a flat surface) etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.[1] Electrical components may be fixed to conductive pads on the outer layers in the shape designed to accept the component's terminals, generally by means of soldering, to both electrically connect and mechanically fasten them to it. Another manufacturing process adds vias: plated-through holes that allow interconnections between layers.

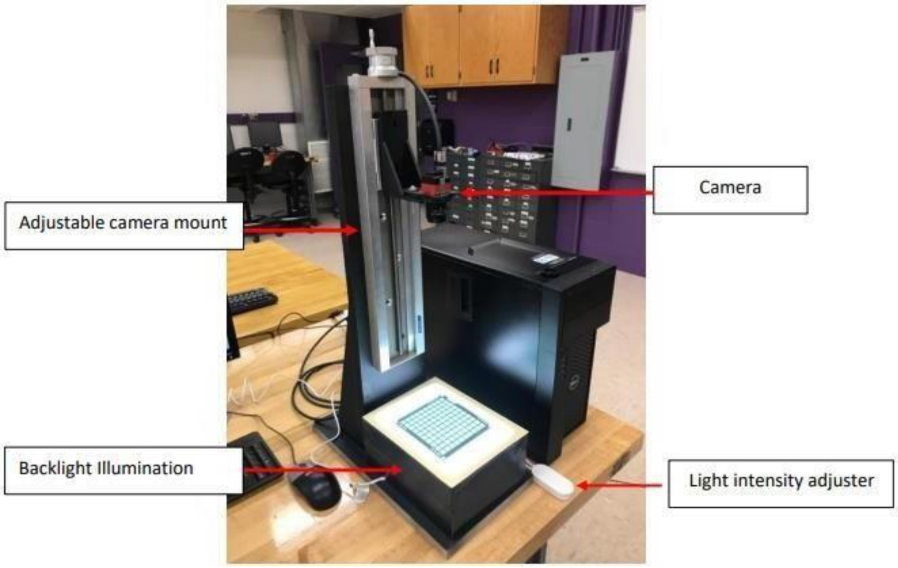

Fig. NO.6.1.4 (The PCB defect detection system, Display to the left of the image, Backlight and the camera fixture at the center, and the central processing unit to the right)

CHAPTER 7
SOFTWARE

CODE:

```
clc
clear all
close all
warning off
%set webcam
w=webcam('USB Camera');
% activate webcam
y=preview(w);
pause(2)
%take photo
x=snapshot(w);
x1=im2gray(x);
x2=imgaussfilt3(x1);
%imwrite(x2,'reference.jpg')
y=imread('reference.jpg');
y1=im2gray(y);
y2=imgaussfilt3(y1);
[g c d]=size(x2);
y2=imresize(y2,[g,c]);
subplot(1,3,1)
imshow(y2);
title('pcb image without any defect')
subplot(1,3,2)
imshow(x2);
title('image of pcb which is manufactured')
subplot(1,3,3)
imshow(x2-y2);
title('error')
```

REQUIRED SOFTWARE TOOLS:

- **Image Acquisition Toolbox**: image Acquisition Toolbox™ provides functions and blocks for connecting cameras to MATLAB®. It includes a MATLAB app that lets you interactively detect and configure hardware properties. The toolbox enables acquisition modes such as processing in-the-loop, hardware triggering, background acquisition, and synchronizing acquisition across multiple devices .

- **Image Acquisition Toolbox Support Package for OS Generic Video Interface**: image Acquisition Toolbox™ Support Package for OS Generic Video Interface enables you to acquire images and video from DirectShow® (Windows®), Gstreamer (Linux®), AV Foundation (Mac) video capture devices directly into MATLAB® .

- **Image Processing Toolbox**: Image Processing Toolbox™ provides a comprehensive set of reference-standard algorithms and workflow apps for image processing, analysis, visualization, and algorithm development. The toolbox supports processing of 2D, 3D, and arbitrarily large images.

- **MATLAB Support Package for USB webcams**: With MATLAB® Support Package for USB Webcams, you can connect to your computer ’ s webcam and acquire images straight into MATLAB. Functionality is provided to preview live images, adjust acquisition parameters, and take snapshots either individually or in a loop.

Overall system performance

The PCB defect detection system was created using the reference comparison methodology, where a defect free reference PCB image gets compared with an inspection PCB image at a pixel level. Any deference between the pixels would be considered a defect or an anomaly. As mentioned in the literature review there are known drawbacks of the system that could produce false failures and during the testing of the system many of these issues were encountered. During the test of the system under ideal conditions where the reference image and inspection image had exact same lighting condition, same contrast level and same orientation the detection of the true defects were at a 100%. The algorithm was capable of detecting all 14 defects and the highest false positive rate was at 22.2%.

The reason for the high performance are the limitations of variables that could cause the images to be preprocessed differently When switching from an ideal testing condition to real-life testing condition the true capabilities of the image preprocessing stage gets tested. With the reference image and the inspection image getting captured through an industrial camara with the in- house-built illumination system, the possibilities of the lighting conditions varying depending on the placement of the specimen, the high noise level of the camara input, dust particles contaminating the test area, unaccounted anomalies in the test specimen can cause variation in the output of the preprocessed image.

These mentioned reasons can cause false positive rates to be higher and undetected true defects to increase as well. The defect detection capability of the system was still at a desirable rate with 5 out of 7 specimens resulting true defect detection at a 100%. The remaining test specimens was not able to detect all defect resulting 9.09% and 50% of the true defects getting passed undetected. Furthermore, the real-life condition test resulted many false positives, and some were as high as 65%.

The defect detection system was tested in both ideal and real-life conditions to understand it's capabilities and limitations and it was evident that the reliability of the system gets affected significantly in real-life testing conditions, as mentioned above the image preprocessing algorithms been utilized can greatly affect the outcome of the defect detection system.

For example, during the stages where the inspection image and reference image gets smoothened (blurred) and intensity adjusted in order to reduce undesirable image noise, details of defects can get eliminated, furthermore during the thresholding step even more details of the image can get distorted. These reasons can lead to defects getting passed undetected.During testing it was further noticed that variable such as the threshold value, structuring elements size, or image registration method can behave differently with different test specimens being used.

CHAPTER 8

EXPECTED OUTCOMES OF THE MINI-PROJECT

The PCB defect detection system was created using the reference comparison methodology, where a defect free reference PCB image shown in Fig.No.8.1.1 gets compared with an inspection PCB image shown in Fig.No.8.1.2. Any deference between the image would be considered a defect or an anomaly which will be the resultant image shown in Fig.No.8.1.3. During this study, the designing and development of a PCB defect detection system was undertaken with the intent to assist small-scale PCB manufacturers with low volume and high mix manufacturing systems to automate their PCB defect detection process. An algorithm was proposed using MATLABs' image processing toolbox that incorporated PCB defect detection using reference comparison approach.

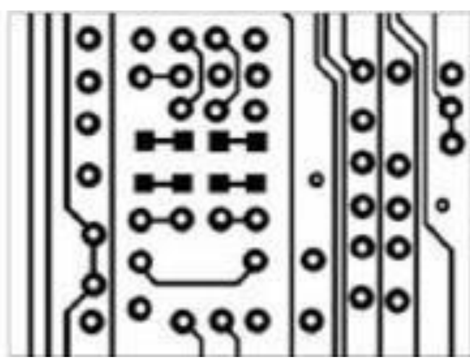

Fig.No.8.1.1. PCB image without any defect

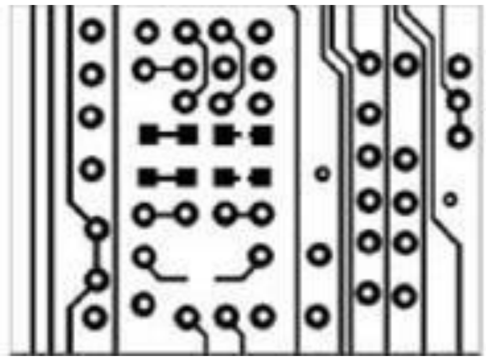

Fig.No.8.1.2. Image of PCB which is manufactured

Fig.No.8.1.3. Error

CHAPTER 9

APPLICATIONS

The quality of PCBs will have a significant effect on the performance of many electronic products. Bare PCB is a PCB without any placement of electronic component, which is used along with other components to produce electric goods. In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be inspected. The technology of computer vision has been highly developed and used in several industry applications. One of these applications is the automatic visual inspection of PCBs. The automatic visual inspection is important because it removes the subjective aspects and provides fast and quantitative assessments. It is responsible for detecting both cosmetic and functional defects and attempts are often made to ensure 100 percent quality assurance for all finished products.

CHAPTER 10
CONCLUSION

With the improvements made in information technology and the accessibility to visual inspection technologies made easier, any PCB manufacturer or a hobbyist with robust algorithms and the right set of hardware can obtain a cheap and relatively reliable PCB defect detection system. During this study, the designing and development of a PCB defect detection system was undertaken with the intent to assist small-scale PCB manufacturers with low volume and high mix manufacturing systems to automate their PCB defect detection process.

An algorithm was proposed using MATLABs' image processing toolbox that incorporated PCB defect detection using reference comparison approach. With the use of a 5.1 Megapixel industrial camera, 25mm fixed focal length lens, and an in-house-built brightfield backlight illumination system I was able to build a system that was capable of detecting cosmetic defects in PCBs.The test conducted during the system verification was helpful in identifying the ideal testing conditions for the system, during further studies a better understating of the system was obtained through identifying the limitation of it.

The Current system’s reliability weighs heavily on the quality of the images being captured, undesirable image noise, variations in the lighting intensity of the illumination system and the alignment differences of the image can cause the system to fail in detecting defects accurately. The results gained through the testing of this system may be sufficient for an experimental prototype system, but in a real production environment the current iteration of the PCB defect detection system would not be usable. However, the following improvement can be suggested for future iterations of the system to obtained more reliable results.

CHAPTER 11

REFERENCES

[1] Ismail Ibrahim, Syed Abdul Rahman Syed Abu Bakar, Musa Mohd Mokaji, Jameel Abdulla Ahmed Mukred, Zulkifly Md Yusof, Zuwairie Ibrahim, Kamal Khalil, Mohd Saberi Mohamad, “A Printed Circuit Board Inspection System with Defect Classification Capability,” International Journal of Innovative Management, Information & Production, Volume 3, Number 1, pp. 82-87, March 2012.

[2] Wu, Wen-Yen, Mao-Jiun, J. Wang and Chih-Ming, Liu. “Automated Inspection of Printed Circuit Boards Through Machine Vision.” 1996 Computers in Industry. Vol. 28. Issue 2. 103 – 111.

[3] Sanveer Singh, Manu Bharti, “Image Processing Based Automatic Visual Inspection System for PCBs,” IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 Volume 2, pp. 1451-1455, June 2012.

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