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A Smart Automated Embedded Based PCB–Bare Board Testing Machine Design and Development using Flexible Flying Probe

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Abstract

Background/Objectives: To design an automated embedded based flexible flying probe for testing PCB bare board more accurately which is one of the toughest challenge in manual testing. **Methods/Statistical Analysis**: Embedded based flexible flying probe can precisely position a probe on test points with high accurateness achieved by means of micro-stepping motors and linear laser encoders. The probe is moved horizontally and vertically based on the command passed by stepper motor which in-turn get the information from the prototype in format of Gerber file. First the flying probe checks the connectivity between two points then if the connectivity is good it will check the next track. **Findings:** This novel invention of flying probes are developed from new-fangled and novel thought intended to produce fasten testing speed, improved access, and enhanced error coverage. During the testing process if the machine determines some problem in the connectivity, it read the problem and send the error report on the PC display. From the error report, we can identify the fault placed in the PCB. A log file with test results is generated & stored on the PC. Fault details are sent to display unit of PC. The PC displays the matching accuracy and fault detection. The experimental result was conducted on 3 different PCB Bare board and the testing result shows the 92% accuracy and 18% false detection rate. It is compared with the jig board tester which produces less result compared to the proposed technique. The chief confront of this proposal is low down equipment and dispensation cost, absolute testing accurateness and capability to position close to faults and faults that may source irregular breakdowns. **Applications/Improvements:** This machine can be used for testing any type of PCB board. This proposed work develops a smart flying probe to test PCB which will significantly decrease test times therefore increasing productivity.

Keywords: Embedded, Automatic, Flying Probe, Micro Stepping Motors, Printed Circuit Board (PCB)

1. Introduction

In traditional way of testing bare PCB board the mirror image pattern is used as registration to determine short circuits on wiring pattern of it[1]. A test jig is equipped by mounting a insulation material pattern above the flexible conductive screen by maintaining a small distance away from the PCB of same pattern in order to detect particular defect location. It is done by scanning the pattern with help of the roller which forces these two patterns into make contact by passing current from the screen side to side in the wiring board at some scan. Prerequisites are prepared to examine involuntarily X and Y coordinated positions of a fault spot into a register. This innovation mainly concentrates on techniques for finding location short circuits in bare PCB, testing equipments and more precisely about printed circuit wiring board testers.

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1.1 Preamble to Printed Circuit Board

Conventionally etching and photographic process are used to develop printed circuit wiring boards by means of resist to characterize blueprints in a conductive layer, unwanted conductive pattern may suppose to appear in between wanted conductive patterns due to small etching/photographic errors or during resist breaks down. This may result in arcing between conductors and capacitance which are pointed as circuit impedances. Whilst automated visualized testing of PCB is also adapted to determine deviation in wiring patterns but this type of methodology often leads to substandard in terms of cost and some defects are difficult to identify visually and more over due to tiredness of an inspector may influence erroneous test results.

Consequently an entirely consistent test system for tracing short circuits and near short circuits has not been here before presented. This paper put forth the aforementioned art in PCB tester's disadvantages by considering to develop a novel automated PCB tester designed and implemented with the help of flying probe to triumph over the complexity and versatility in automated PCB testing.

For single or double sided PCB probing a test contains marks constantly by maintaining the PCB in constant listing subsequently to a nest plate constantly attached to a main frame. Hinged cover is used for top frame and bottom frame are disposed above and below the main frame. A top bed of nails is attached fixed and on the upper side of PCB a clamp plate with through holes corresponding to targets are fixed. The bottom frame has statically connected thereto a bottom bed of nails whose probes can stick out through nest plate openings relating to targets on the PCB underneath. Top and bottom frames are moved vertically toward the PCB which is detained statically and in registered alignment with the nest plate and for the period of jig actuation.

The PCB manufacturing prolongs to espouse progressively superior levels of incorporation and accomplishing greater levels of component density. As an outcome, the tolerances on PCB gathering become tighter. This reasons an augmented need for consistent and precise visual assessment of PCB boards[2-4].

To determine defect on PCB using automated visual technique[5] developed a neural network based classifier using the method of binary morphological image processing and Learning Vector Quantization (LVQ) neural network to segment input PCB images into essential primeval patterns, including it, by conveying, normalizing and classification of patterns is deployed.

In[6] work presence and absence of defects is PCB image is again determined using used neural network. They used two stages in the former screening process is performed and in the latter stage classification is made using neural network. To train the proposed system the work used 558 sample images. The effect illustrates that pattern matching index is the best screen index in the first stage. During second stage it was shown that more than three indexes must be used to efficiently recognize defects.

In[7] proposed algorithm that can be implemented on bare PCB to identify and to group PCB defects. However, the major limitation of this algorithm is that the proposed algorithm is developed to work with binary images only, whereas the output from the cameras is in gray scale format. Although the conversion can be made from gray scale to binary format imperfection still can be occurred. Thus, this algorithm should be improved to handle the gray scale image format.

In[8] improved PCB inspection system by registering an image registration to resolve the position problem. A noise removal process is intended in such a way that the ensuing imperfections found in this algorithm is precisely accurate while comparing with previous algorithm. Algorithm was effectual to the image processing algorithm developed by Khalid by raising the categorization of 14 defects from 5 to 7 groups. Still the limitation of this algorithm is that it can work only with binary images.

In[9] have done improvement on Khalid's work by grading seven groups. This is prepared by merging image processing and segmentation technique. Every image is segmented into four patterns and then created five fresh images for each pair of segmented suggestion and test images progressed and thus 20 new images produced. Among them seven images were favorable for defects categorization.

In[10] have achieved their goal by improvising the performance of image difference operation by means of consumption time using wavelet transform. While comparing with traditional image differencing techniques the proposed work outcome shows the appealing improvement.

A spatial filtering with wavelet based automated optical visual inspection system is develop in the paper[11] to determine presence of PCB defects. It is done by combing both wavelet image compression effectiveness and spatial filtering. Defects are noticed by subtracting the approximations of reference image wavelet transform and test image wavelet transform trailed by a median filter phase. Lastly, defect image is acquired by figuring the inverse wavelet transform.

In[12] have proposed Tamil character recognition of Bamini Tamil font using Template Matching method. Each line of the text is segmenting with horizontal projection and every character of each line is segmented using connected component processing and each character is segmented using correlated with the preloaded templates of the system. At last maximum correlation judges the character.

The authors in [13]have used Active Appearance Model (AAM) to find the appearance based features in the face image. The proposed feature set Pose and Occlusion Invariant Feature set is used to select the key frames in the video sequence and key frame choice is optimized using unsupervised learning technique Fuzzy Clustering using Bat algorithm (FC-Bat).

In[14] used Proportional Integral (PI) and Proportional Integral Derivative (PID) controller are worked to discover the reactions of the system by using the rectifier output voltage as feedback for closed loop operation.

It is consequently a necessitate to build up an pioneering PCB tester which progresses the recital of existing methods and offer easy, precise test fixtures and methods for locating divergences from preferred Printed circuit wiring patterns. An additional aim is to offer test stuff and methods for accurately recognizing defect locations upon printed circuit patterns to make possible restore. Still an additional purpose is to afford competent and successful widespread foundation for diverse wiring patterns on printed circuit boards. The chief confront is low down equipment and dispensation cost, absolute testing accurateness and capability to position close to faults and faults that may source irregular breakdowns.

2. Machine Overview Explanation

Flying Probe technology is used to automate the testing of printed circuit boards (PCB) that would otherwise have to be tested manually. This proposed work develops a smart flying prober to test PCB which will significantly decrease test times therefore increasing productivity. This proposed machine can accurately place a probe on test points with high accuracy achieved using micro-stepping motors and linear laser encoders. Probing the smallest surface mounted devices is possible.

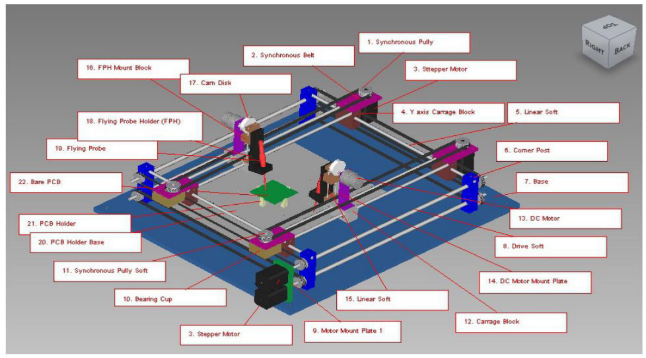


Figure 1. Overview of Flying Probe Machine

Figure 1 shows the overview of the machine. The base is used to fix all the devices including PCB holder base. The four comer posts are fixed in the four corners of the base. The linear soft connected with the comer post to the four corners of the base. The linear soft connected with the comer post to the four sides. Two synchronous pulleys are connected with linear soft. The pulleys are used to move the FPH mount block with all directions. The main pic microcontroller board is connected with four stepper motor driver board connected with four stepper motors through connectors. The PC is connected to the main board through RS232 cable. The two FPH mount block is the main part of this machine, because we connect two flying probes with this. The flying probes are used to check the connectivity between the two corners of the tracks in the PCB board. The carriage block is fixing on the linear soft and the synchronous pulleys is connected with synchronous belt. The synchronous belt moving the FPH mount block according to the received data from the main board. In the carriage block, the DC motor mount plate is connected, that is used to fix the DC motor on that, the driver soft is connected with that to drive the DC motor. The DC motor connected with the cam disk. According to the rotation of the DC Motor the cam disk will rotate. Flying probe is connected with flying probe holder (FPH). The first half rotation of the DC motor the cam disk push the flying probe down, at that time the probe touch on the PCB board testing point and the second half rotation of the DC motor the cam disk push the flying probe down, at that time the probe touch on the PCB board testing point and the second half rotation of the DC motor the cam disc push the flying probe up.

At the same time two flying probes touching on the PCB boards two edges of the same track. First the flying probe check the connectivity between two points then if the connectivity is good it will check the next track. In case, if some problem is in the connectivity, it read the problem and send the error report on the PC display. The bare PCB placed on the PCB holder & the PCB holder is placed on the PCB holder base. In this we can check different size of bare PCB boards. In this machine we check the single sided PCB board. If we want to check double sided PCB board, we want to set one more module in the bottom side like the same. The bare PCB is placed on the PCB holder, and we move the flying probe in the vertical and horizontal directions through stepper motor. According to the stepper motor rotation the synchronous belt will move the flying probe (FPH) mount block in vertical and horizontal directions and the DC motors are used to move the flying probe up and down. The y-axis carriage block is used to move the FPH mount block in Y-axis, the x-axis carriage block is used to move the FPH mount block in X-axis. Motor mount is used to fix the stepper motor. For example we take one bare PCB board, then we design the same pcb diagram in the Orcad software and after that it converted into Gerber file, it will send to the main board through RS 232. The program coding will fuse on the pic microcontroller, according to the program from pic microcontroller the flying probe check the connectivity in the PCB board, if any problem in the connectivity it will produce error report on the computer display. From the error report, we can identify the fault placed in the PCB. In this method the main advantage is, testing time consumption is more compare to other testing methods and low expensive compare with other testing machine.

3.1 Block Diagram Description

In this proposed work we introduced an enhanced testing bare pcb board using electrical test flying probe method. The power supply unit distribute the supply to all other modules connected in this and regulate the supply to all modules. In this the voltage level is 24 volt but the pic microcontroller and RS-232 working in 3.3v, memory, I2C, all i/o devices, home position sensor, the optical sensor and stepper motor driver working in 5 volt. In this block diagram (Figure 2) the dotted lines represents the connectivity between the power supply to all modules. We connect a trans receiver to change the voltage from 24 volt to 3.3v&5v signals.

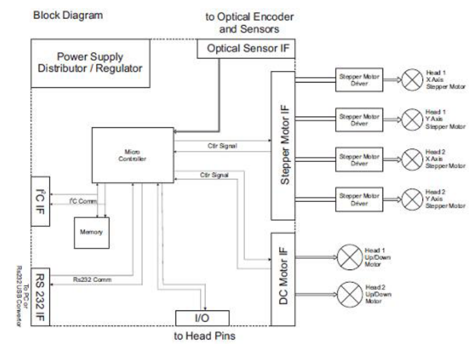


Figure 2. Block Diagram of PIC Microcontroller.

In this paper 24FJ128GA106 PIC Microcontroller is used, this microcontroller is based on PIC 24FJ256GA110 Family. It has 64-pins and it is based on Harvard architecture. It accessed on 24 bit. It was first introduced by the company Microchip's. The PIC 24F CPU core offers a wide range of enhancements. The microcontroller connected with the I2C IF, RS232IF, Stepper motor IF, DC Motor IF, I/O, OPTICAL, in this first we design the pcb circuit to the orcad software and it will convert all the details into Gerber files after that we send all information to the microcontroller. We design the program in microcontroller that will access the movement of the arms, then that information will be given to the stepper motor driver and dc motor through I2C, the I2C and RS232 are working in serial communication from that we can send and receive the data to all devices. Here the memory connected to the microcontroller that will save all the information about the pcb circuit design. In this project we connect 4 stepper motor driver that access the head1 X-axis and head1 Y-axis, head2 x-axis and head2 y-axis according to the information from the microcontroller, these heads are moving x and y position, through this we can test the pcb, and the dc motor is connected with the testing probe that will detect the holes connectivity, first we placed the bare pcb board in between the moving arms, then we check the connectivity, finally it produce the error report to the microcontroller, the microcontroller will send the error report to the pc through RS-232 then the pc display the o/p status in the monitor. Optical sensors are connected with the flying probe that will sense the connectivity between the two holes in the pcb board. The Gerber file will give all information and connection between the pcb, that information send to microcontroller then the microcontroller send that information to stepper motor driver, in this the i2c is connected with the memory and microcontroller through i2c we send all information from microcontroller to stepper motor driver and receive the status of the head to microcontroller. The dc motor connected with the head and the optical sensor connected with flying probe. According to the dc motor rotation we can move the probe up and down. The first half dc motor rotation the probe move to up position and the another half dc motor rotation the probe move to down position.

The memory store the Gerber file data and it send the data to microcontroller through i2c cable. The microcontroller connected with the computer through RS232 cable in between the pc and the microcontroller we connect a transceiver to convert the data logic to TTL logic. We connect a db9 connector to connect pc to microcontroller. If we want to send any other input and output apart from this we can use the I/O to head pins.

3.2 Flowchart

Figure 3 depicts the flowchart of the overall flow the automated flexible flying probe working mechanism.

3.3 Main Board Description

The Main board design is shown in Figure 4. Power supply connector is used to give 24V input to the board. Two regulator IC'S are connected. First regulator is used to give 3.3V supply to Pic 24FJ128GA126 Microcontroller and the second regulator is used to give 5V supply to other devices, both are DC to DC convertors. Through RS232 we can send Gerber files to application software. In this paper we use MICRO C software to write program coding's. The program fuse on the pic microcontroller, through this program coding's we access the stepper motor and DC motor. Here the RS232 transceiver IC is used to convert the TTL logic into digital logic, these data send to Pic microcontroller. Four stepper motor driver control connectors are used to connect four stepper motor driver board on the main board. The PIC 24FJ128GA126 Microcontroller IC is used to store the program, according to the coding's we can rotate the stepper motor and DC motor, through that we can check the bare PCB board through flying probes.

The home position detection connector is used to detect the ideal position of the bare PCB board which we want to test. Three optical sensor connectors are used to give information to the board. Two DC Motor connectors are used to send commands from PIC to DC motor, through this we can on and off the DC motor. The six general purpose I/O pins are used in that we use two pins to access the CAM disc, the cam disc is connected with Hall Effect sensors. According to the comments from PIC, the DC motor will on and off. The cam disc connected with probe is connected with cam disc and DC motor. The 1st half DC motor rotation the cam disc push the flying probe up. In this we connect 2 flying probes, at the same time 2 flying probe check two points in a same track. If any problem in the connection it will send error report on the display, if there is no problem between the connections it will check the next testing point.

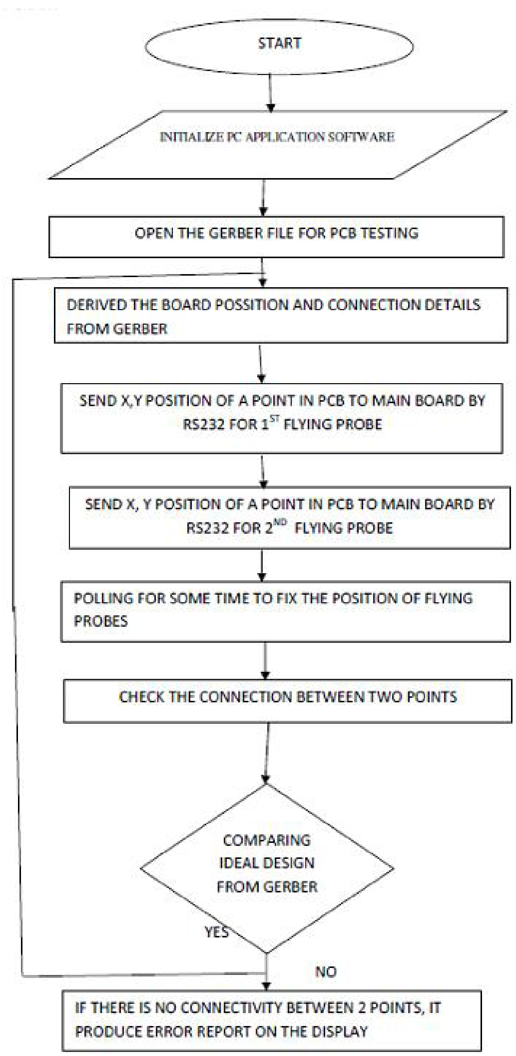


Figure 3. Flow chart of flexible flying probe working mechanism.

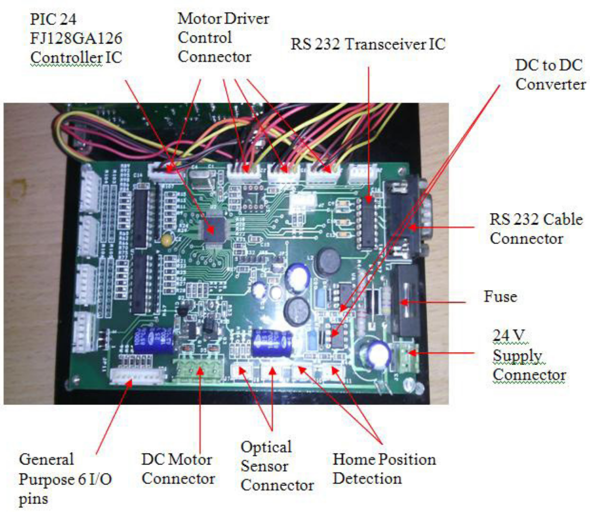


Figure 4. Main board description.

3.4 Stepper Motor Driver Board

Power supply connector is used to set 24v supply and GND to the driver board it is shown in Figure 5. Fuse is used to maintain the current level, the fuse is used to maintain the current level up to 2.5 to 3amps. Motor connector is a six way connector, its used to connect the stepper motor. SLA7062 Driver IC is used to drive all stepper motors, it's the main device to drive the motor through the flying probes. The two current sense resistors are used to decide the current level of the motors. Two speed set/preset connectors are used to set and preset the speed level. I^2C connector is used to get the data from main board and that information given to the pic 16f73 microcontroller, I^2C will give information about the motor step movement to the pic microcontroller. The microcontroller will control the stepper motor according to the information from I^2C connector. The UART connector is used to send data serial mode. The control connector is used to set the device in automatic mode through this we can access the stepper motor automatically. I^2C slave address dip switches are used to access that connector.

4. Overall Diagram of Board Connection

The Figure 6 shows that the main board is connected to the flexible flying probe and to the PC through the stepper motors. Input data can be in Gerber RS274D, Gerber RS274X, IPC-D-356A, or Probot-HLS formats. The testing probe is connected with tip holder assembly. The first half rotation of the DC motor the cam disc push the flying probe down. Two flying probe's touching on the PCB Board's two edges of the same track. The PCB to be tested is designed using orcad software and stored as a Gerber file format. The information about Gerber file is send to the main board through RS 232. PIC controller is coded according to it the flying probe check the connectivity in the PCB board, if any problem in the connectivity it will produce error report on the computer display. From the error report, we can identify the fault placed in the PCB. A log file with test results is generated & stored on the PC. Fault details are sent to display unit of PC. The PC displays the matching accuracy and fault detection.

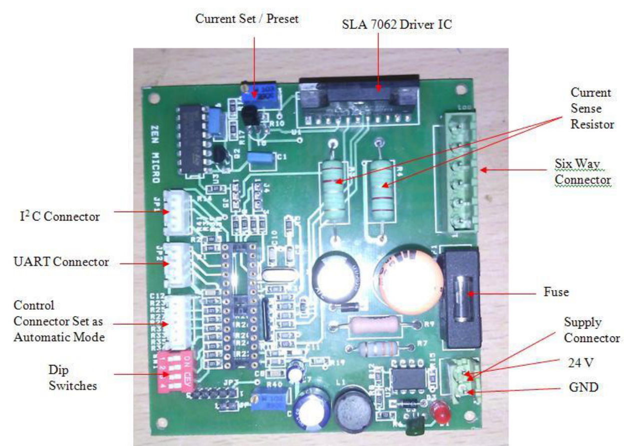


Figure 5. Stepper Motor Driver Board.

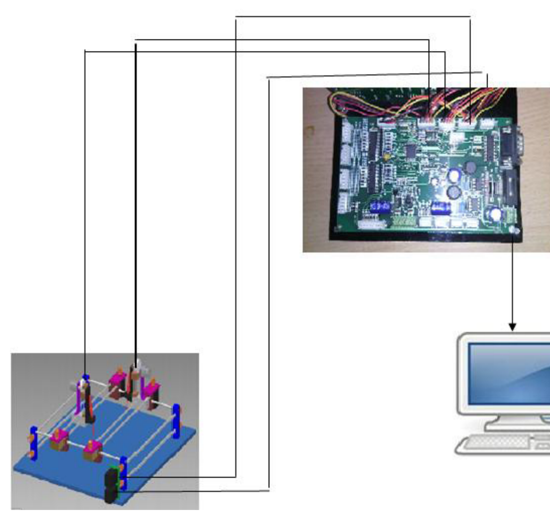


Figure 6. Overall Diagram of the Automated Flexible board connected with other components.

5. Experimental Result

The proposed PCB Bare board tester is compared with the existing jig board and the result shows that the automated embedded based PCB tester produces more accuracy in detection of matching process than the traditional jig board.

5.1 Table 1. Performance Comparisons

The comparison in Table 1 shows that the SAEPCB tester contains 92% accuracy while the traditional jig board tester holds only 78%. The time taken is also very less while comparing the jig board tester.

Table 1. Performance Comparisons

Technique	Accuracy	False Detection rate	Time Taken
Smart Automated Embedded based PCB tester	92%	8%	13 minutes
Jig board tester	78%	22%	More than 1 Hrs

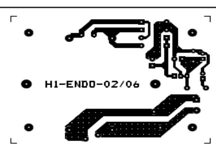
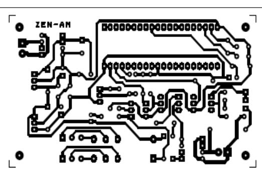
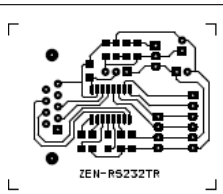
5.2 Table 2. Performance of SAEPCB Tester for Three different PCB Board

The Table 2 shows three different boards with their performance metric. The first board is H1-ENDO-02/06 is a voltage regulator its board area is 49.2cm^2 and it no of net and no of pins are 8 and 45. The no of routes in this board is 27 and the time taken net list test and route test is 45 and 155 seconds respectively. Second board is ZEN-AM is an auto audio mute control its board area is 62.2cm^2 and it no of net and no of pins are 34 and 165. The no of routes in this board is 92 and the time taken net list test and route test is 180 and 680 seconds respectively. Third board is ZEN-RS232TR is a RS 232 Tran receiver is a voltage regulator its board area is 20.1cm^2 and it no of net and no of pins are 20 and 71. The no of routes in this board is 41 and the time taken net list test and route test is 70 and 220 seconds respectively.

6. Proposed Flexible Flying Board Machine Connected with the PC

The Figure 6 shows the original flexible embedded based flying probe machine connected with the pc. The input is

Table 2. Performance of SAEPCB tester for three different PCB Board

PCB Boards	**Name**	**Description**	**Board Area (cm2)**	**No of Net**	**No of Pin**	**No of Route**	**Time to Net List Test (Sec)**	**Time to Route Test (Sec)**
	H1-ENDO-02/06	Voltage Regulator	49.2	8	45	27	45	155
	ZEN-AM	Auto Audio Mute Ctrl	62.2	34	165	92	180	680
	ZEN-RS232TR	RS 232 Tran receiver	20.1	20	71	41	70	220

collected from the Gerber file which is stored in the hard disk of the pc and according to the prototype the probe starts moving horizontally and vertically to scan and check the specified co-ordinates for each track. The final result about the testing board is passed to the pc which displays the success or failure about the board design status.

Figure 7. Proposed Flexible flying board machine connected with the PC.

7. Conclusion

Rapid growth in electronic industry leads to the demand of high quality and speedy inspection process for testing PCB bare board. In traditional testing the manual visual inspection is involved which often results in erroneous due to their tiresome work and lacking knowledge in understanding complexity pattern details. The time complexity and the cost of process also high in manual inspection compared to the automated inspection. This paper aims at developing a efficient and reliable automated embedded based flying probe which increases the defect detection accuracy and decrease time complexity. The experimental result shows that the proposed flying probe can be used for testing any kind of PCB bare board with low cost and less man power which increases the benefit of manufactures.

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