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DESIGN AND DEVELOPMENT OF AUTOMATED SOLDERING ROBOT MACHINE

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Abstract *- The Soldering Robot Machine was a clever, portable automated PCB assembly equipment that was the subject of this research project. The tool uses Arksoft Mach3 and Aspire software to drill and solder holes using the G-Code programming language. The researchers used a descriptive and experimental design method, drawing on their experience integrating hardware and software, and they iteratively tried and failed to create the device. PCB enthusiasts, designers, and experts evaluated the Soldering Robot Machine to determine its usability, functionality, portability, reliability, and efficiency. The obtained results from the evaluation were utilized to describe the device, ascertain its functionality, and establish its acceptability. The device was described, its functionality was established, and its acceptance was established using the evaluation findings that were received. Various electronic and electrical components were used o build the device, and experimental design showed it has successfully located processes and performed drilling characterization, proving its potential for PCB manufacture.*

Keywords – *Arksoft Mach3, Aspire software, G Code, PCB assembly, Soldering Robot Machine*

INTRODUCTION

Humans' capacity for production has continued to improve as a result of the widespread usage of machines in businesses, particularly since the industrial revolution and technical advancement. By automating industrial processes, machines can increase productivity while reducing production time [1]. However, efficient equipment use is crucial for sustainable development. For industries that use automation and manipulation, researchers have put forth a variety of designs and methodologies [2]. The workforce has been redirected by automation into tasks that call for human critical thinking skills. This allows people to work more skillfully while leaving the labor-intensive and repetitive jobs to robots and machinery that is suited for them [3].

The Soldering Robot Machine is an automated soldering machine. Its working principle is to complete the soldering procedure using robotic movements [4]. Electronic component assembly and soldering have been transformed by automated soldering robot devices. To simplify soldering and boost efficiency, they use cutting-edge robotics technology, accurate motion control, and intelligent soldering capabilities. Cameras, sensors, and image processing algorithms are used by vision systems to precisely identify solder junctions and find flaws [5, 6, 7]. Due to their ability to operate constantly without getting taking breaks, these machines are more efficient, resulting in shorter production times and higher output. Automated soldering robot machines provide a safer working environment while increasing efficiency, consistency, and precision [8, 9, 10].

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OBJECTIVES OF THE STUDY

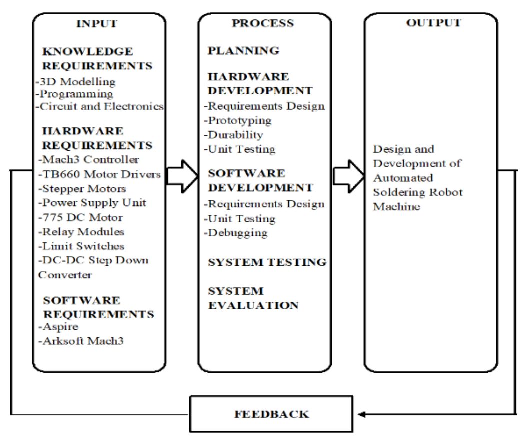
The objective of the project "Design and Development of Automated Soldering Robot Machine" is to make a fully CNC-Based automated device machine by undergoing specific processes such as drilling and soldering pin headers to create a final product of Soldered PCB pin headers. The system is economical and may contribute safety to the people's health which will be the operators by reducing human contact to the presence of toxic fumes in the immediate area surrounding the one soldering. This takes a toll on one's health if exposed to it for extended periods of time.

This may also improve the productivity or increase of quality of drilling and soldering of PCB production by creating a machine that could automate the said processes controlled via a host laptop based on the template provided by the user. The machine may also ease the amount of work and the cycle time between operations shortened by the end-user by automatically doing most of the processes and reducing human intervention to create the final product. The Soldering Robot Machine is accessible to the end-user through the use of a laptop with installed application needed. The application must be able to provide Gerber to G-code program, information about the positioning and calibration of the stepper motors [11]. The Mach3 Controller would be the platform for providing the bridge to interconnect most of the Soldering Robot Machine functions [12].

MATERIALS AND METHOD

This research study provides an overview of the procedures employed by the researcher to gather relevant information for the study. The information encompasses both hardware and software aspects, along with the methodology used in developing the project. The hardware utilized in the project includes various electronic and electrical materials, while the software involves the implementation of specific programs. The researcher adopted a systematic approach to gather the necessary data and employed appropriate methodologies to ensure the successful creation of the project. This research study serves as a comprehensive summary of the information gathering process, shedding light on the hardware, software, and methodology aspects employed throughout the study.

Figure 1 shows the system approach (Input-Process-Output System) was used in describing the study's conceptual framework. The knowledge requirements of the system are 3D Modelling, Programming and Circuit and Electronics. The hardware requirements of the designed project consist of Mach3 Controller, TB6600 Motor Driver Module, and Stepper Motors, Power Supply Unit, 775 DC Motor, Relay Modules, Limit Switches and DC-DC Step Down Converter. The software requirements for the system are Aspire and Arksoft Mach3. In processing the requirements of the system, by means of planning, hardware and software development, testing and evaluating the design project is entitled "Design and Development of Automated Soldering Robot Machine".



(Fig.1) Conceptual Framework

Figure 2 shows the flow of the device. The process begins with the insertion of a PCB into the device while the PCB design is loaded into Mach3 software and sent to the Mach3 controller. The Mach3 controller then provides data and commands to the stepper drivers, which

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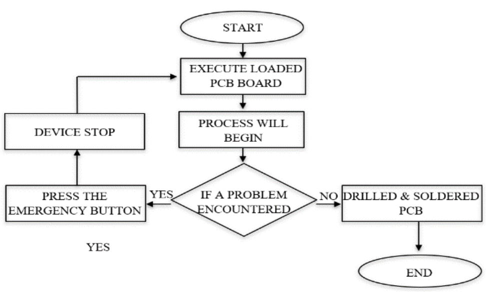
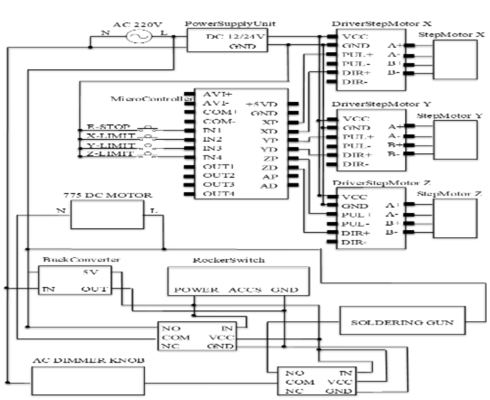
in turn control the stepper motors. During the drilling process, the device may encounter issues. If the emergency button is pressed, the device will stop and require recalibration in the Arksoft Mach3 software. If the drilling process is completed without any issues, the output will be a drilled PCB. Next, the soldering switch must be pressed to proceed to the next step. When the soldering switch is activated, the AC knob will prepare the soldering lead, and the PCB layout will be loaded into the soldering software. The soldering process will then commence. During the soldering process, the device may encounter issues. If the emergency button is pressed, the device will stop and require recalibration in the Mach3 soldering software. If the soldering process is completed without any issues, the output will be a soldered PCB.



(Fig.2) Flowchart

Figure 3 illustrates a schematic diagram of the system's hardware modules. The Mach3 microcontroller was interconnected with an TB6600 modules to interact with the stepper motors. Lastly, limit switches will send a signal that will stop the axis from trying to move past the end of its travel range.



(Fig.3) Schematic Diagram

Illustrated in figure 4 is the perspective view of the proposed design for the Design and Development of Automated Soldering Robot Machine.

(Fig.4) Machine design: Isometric View

Project Testing and Evaluation:

The system was tested functionality at each of the features. If the system does not perform as expected, troubleshooting will be performed and corrections will be made. Each of the system was tested for consistency with its intended function.

Three main tests will be performed to determine the consistency of the machine: accuracy, precision and speed. The accuracy test will determine if the machine can replicate the design by conducting continuity test. Accuracy test will determine whether the machine will be able to drill and solder the PCB consistently or not. It will be computed based on the equation below:

$$(\text{Value}/\text{Total Value}) \times 100\% = R$$
$$100\% - P = G$$

Where:
Total Value = Total of Drilled / Soldered Holes
Value = Total of Successful Drilled / Soldered Holes

R = Result

The speed test will determine the estimated time of finish for a specific board size. The result will be the basis of time which will be put into codes. The time consumed producing an output, for each station and the total time will be compared to that of the manual process by examining the same PCB design for a specific board size. The precision test will determine the when repeated determinations (analyses) on the same sample give similar results. When a test method is precise, the amount of random variation is small. The test method can be trusted because results are reliably reproduced time after time. The precision will be calculated using this formula:

$$\text{Average deviation} = \frac{\Sigma \quad |x-m|}{n}$$

Where:
x = each of the experimental values
m = calculated m

Absolute deviation = | x – m |
Where:
n = number of values

RESULTS AND DISCUSSION

The results in terms of drilling and soldering in manual process have a significant difference compared to the automated process. It can also be observed that the lesser number of holes to drill and solder in the PCB, the higher percentage of accuracy of the results get [13].

A. Speed Test:

Table 1: *Drilling Duration Result*

Phase	Manual Method	Automated Method
Test 1	18 min 18 sec	12 min 12 sec
Test 2	18 min 08 sec	12 min 10 sec
Test 3	14 min 52 sec	12 min 08 sec
Test 4	13 min 46 sec	12 min 06 sec
Test 5	13 min 06 sec	11 min 13 sec

Table 2: *Soldering Duration Result*

Phase	Manual Method	Automated Method
Test 1	25 min 7 sec	12 min 12 sec
Test 2	25 min 26 sec	12 min 59 sec
Test 3	31 min 7 sec	14 min 41 sec
Test 4	24 min	15 min 02 sec
Test 5	20 min 32 sec	15 min 28 sec

B. Accuracy Test

After getting the proper timing for each board size, the machine now ready for the accuracy testing. To obtain 100% accuracy the output of the automated PCB machine must pass the continuity test.

Table 3: *Drilling Accuracy Result*

Phase	No of Holes	No of Successful Drilled	Accuracy
Test 1	47	45	95 %
Test 2	47	46	97 %
Test 3	47	47	100%
Test 4	47	47	100%
Test 5	47	47	100%

As indicated in Table 1 and 2, the automated machine speedily finished the process compared to the manual method.

Table 3 shows the data gathered from the tests, using the percentage formula for drilling that was discussed in the previous chapter, the results reached a satisfactory level for drilling which is 98.4% accurate meaning almost all of the holes have been drilled and with only 1.6% mis-aligned detected. The drilling of PCB using Soldering Robot Machine device is effective to use for detecting the pin headers.

Table 4: *Soldering Accuracy Result (Test 1)*

Phase	No of Pins	No. of Successful Soldered	Accuracy
Test 1	47	5	10 %
Test 2	47	8	17 %
Test 3	47	10	21 %
Test 4	47	18	38 %
Test 5	47	20	42%

From the data gathered from the tests, soldering accuracy results got 25.6% meaning that this result suggests that there is room for improvement in the soldering process, which can be achieved by implementing various techniques and best practices.

Table 5: Soldering Accuracy Result (Test 2)

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Phase	No of Pins	No. of Successful Soldered	Accuracy
Test 1	38	19	50 %
Test 2	38	19	50 %
Test 3	38	21	55 %
Test 4	38	22	57 %
Test 5	38	22	57 %

The researchers conducted an alpha test 2 by fixing all the issues that were encountered during alpha test 1. They also applied other algorithms, such as changing the chisel soldering tip from a conical tip during alpha test 1. Additionally, the researchers observed that one of the factors affecting the low accuracy in alpha test 1 was the minimum distance between pin headers, which was too close. As a result, the researchers adjusted the minimum distance to 5.0mm in alpha test 2, compared to 2.5mm in alpha test 1.

From the data gathered, the soldering accuracy results reached 53.8%, indicating that these results were higher compared to the alpha tests due to the recommendations and methods applied.

C. Precision Test

$$\text{Mean} = \frac{(5+8+10+18+20)}{5} = 12.2$$

$12.2 + 0 = 12.2$
$12.2 - 0 = 12.2$

Absolute Deviation
$|5 - 12.2| = -7.2$
$|8 - 12.2| = -4.2$
$|10 - 12.2| = -2.2$
$|18 - 12.2| = 5.8$
$|20 - 12.2| = 7.8$

Range of Precision: 25% to 26%

$12.2 / 47 = 25.95\%$

$$\text{Average Absolute Deviation} = \frac{((-7.2+(-4.2)+(-2.2)+(5.8)+(7.8))}{5} = 0$$

Precision Result : 12.2 ± 0

(Fig.5) Computation of Soldering Precision (Test 1)

Figure 5 shows that based on the data gathered from soldering alpha tests the computation of Soldering Precision of the device. It got achieving a total of 25.95% precision based on the computation indicating that soldering functionality during the alpha tests of the device is need some improvements.

$$\text{Mean} = \frac{(19+19+21+22+22)}{5} = 20.6$$

$20.64 + 0 = 20.64$
$20.64 - 0 = 20.64$

Absolute Deviation
$|19 - 20.6| = -1.6$
$|19 - 20.6| = -1.6$
$|21 - 20.6| = 0.4$
$|22 - 20.6| = 1.4$
$|22 - 20.6| = 1.4$

Range of Precision: 54% to 55%

$20.64 / 38 = 54.21\%$

$$\text{Average Absolute Deviation} = \frac{((-1.6)+(-1.6)+(0.4)+(1.4)+(1.4))}{5} = 0$$

Precision Result : 20.6 ± 0

(Fig.6) Computation of Soldering Precision (Test 2)

On the figure 6 shows that based on the data gathered from soldering final alpha test 2, the computation of Soldering Precision of the device. It got achieving a total of 25.95% precision based on the computation indicating that soldering functionality during the final alpha test 2 of the device which improves and better than the alpha tests after applying other algorithms.

CONCLUSION AND RECOMMENDATION

The research paper focused on designing and developing an automated soldering robot machine for PCB production. The project aimed to create a CNC-based machine that could automate drilling and soldering processes, enhance productivity and quality, reduce human exposure to toxic fumes, and offer a user-friendly interface. The researchers employed various methodologies to address calibration issues and optimize soldering and drilling processes. During testing, adjustments were made to the soldering motor's rotation speed and the soldering gun's placement to ensure proper contact and melting of the soldering lead. The optimal size of the soldering lead and temperature settings were determined for ideal soldering results [14]. Modifications were also made to the drill chuck size and drill bit size to improve stability and prevent breakage during drilling. The results demonstrated that the automated soldering robot machine outperformed the manual method in terms of speed and accuracy. The drilling accuracy reached 98.4% with only 1.6% misalignment, indicating effective detection of pin headers. The drilling precision was calculated to be 98.72%, demonstrating precise functionality. In conclusion, the research paper successfully developed an automated soldering robot machine that demonstrated improved productivity and accuracy in PCB production. The findings provided valuable insights into the feasibility, economic advantages, and quality benefits of implementing automated methods for soldering PCBs. The study also highlighted areas for further improvement in the soldering process.

For the future researchers with their unique ability, skills, talent and knowledge who seek to enhance and improve the study, it is recommended to implement various techniques and best practices such as using the appropriate soldering iron temperature, selecting the right type of solder and flux, ensuring proper alignment of the components, and practicing good soldering techniques.

To the future researchers, they can improve the study's limitation by reaching the system to be more/lesser distance with high accuracy and precision respectively. They can also can explore different methods for improving soldering accuracy, such as the use of automated soldering equipment or the development of new soldering techniques.

Additionally, it is recommended that further analysis should be conducted to determine the root causes of any inaccuracies and to identify specific areas for improvement in the soldering process in order to improve the overall quality and reliability of the device and enhance its performance as well as ensure customer satisfaction.

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