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Fabrication Process of Electronic Circuit Boards for the Sensor System to Monitor Water Quality at Aquacultural Farming Ponds

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***Abstract* – In this study, the fabricated sensor system could assess some basic parameters of aquaculture water such as pH, temperature, salinity, dissolved oxygen (DO) concentration, alkalinity, oxidation-reduction potential (ORP), NH_3^+ and NO_3^- concentration. Then the sensor system could update online the measurement data to the cloud storage via 3G or internet connection. Shirmp farm owners could get these results by their mobile phones or tablets and make the adjustment to create the comfortable environment for shirmp growth in their ponds. The controlling electronic circuit boards are the most important parts of the sensor system and they need to be carefully studied to improve the sensor fabrication technology. In this paper, the printing circuit boards (PCB) of the sensor system were fabricated and tested for assess quality of aquaculture water. The sensor system with the fabricated PCB was then tested with some standard samples such as pH or OPR solutions. The sensor system showed a good performance with the measurement results compared with the results measured by commercial sensors.**

***Keywords* – Aquacultural Water, Printed Circuit Boards, Sensor System.**

I. Introduction

An electronic circuit consists of various electronic components such as resistors, capacitors, diodes and transistors connected by a wire then an electric current running inside it [1]. Previous electronic circuits were often designed on the Breadboard, which helps the designer easily to refine the circuit. Those electronic circuits were used in computation, data transmission and signal amplification. Today, electronic components are soldered on a printed circuit board (PCB) to form a complete circuit instead of connecting via wires [2, 3] (Figure 1).

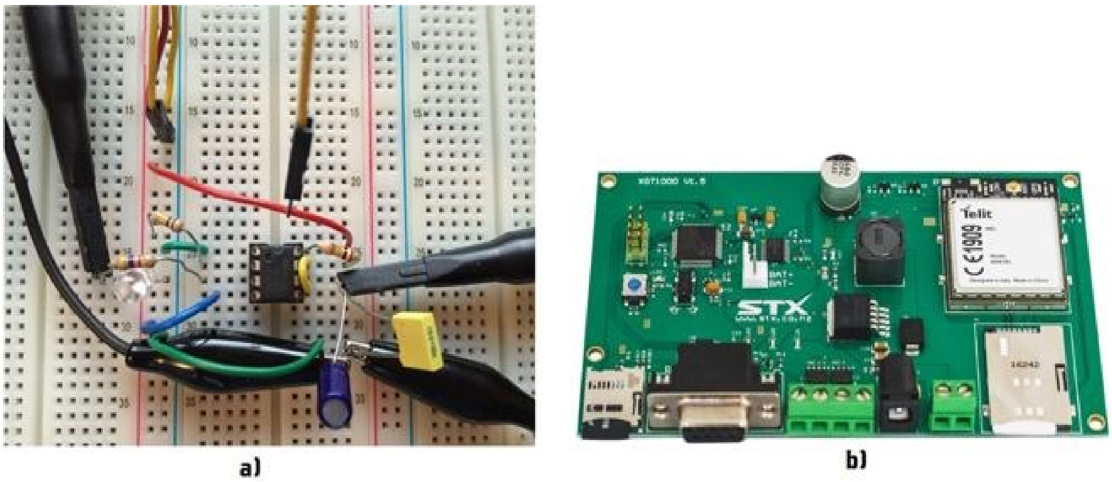

Fig. 1. a) Breadboard and b) Printed Circuit Board (PCB) [4, 5]

The PCBs often have different sizes, number of electronic components and complexity depending on their design and using purpose (Figure 2).

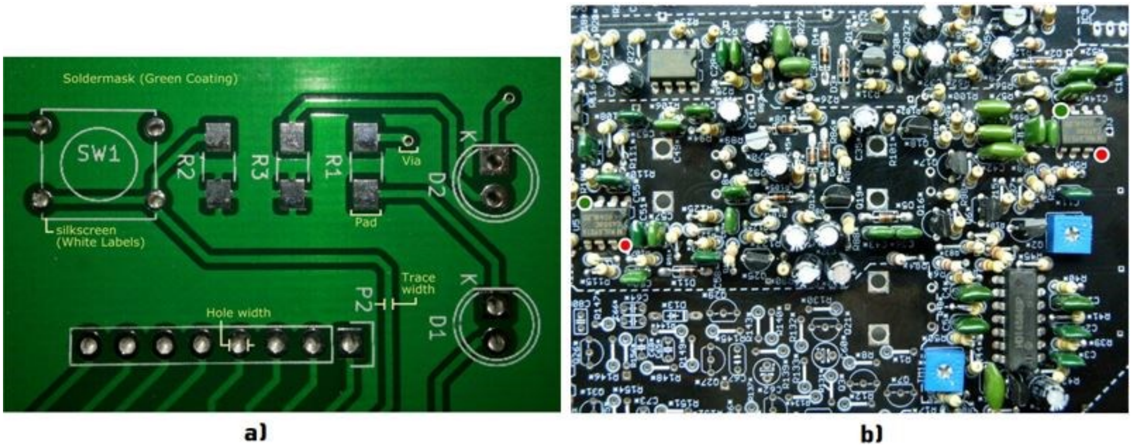

Fig. 2. a) Simple and b) Complex PCBs [6, 7].

As mentioned above, each PCB of a device had separated configuration due to its specific performance requirements. Nowadays, in almost electronic devices such as computers, mobile phones and other digital home appliances, the PCB is considered as the heart which coordinates all operation of the device. In sight of the ever-growing science and technology, the machinery and equipment become smarter [8]. Beside some traditional basic functions, the built-in PCBs now become more and more complex to do the multitasking operation [9]. Therefore, the designation of PCBs is a very important step to build up an electronic device.

Follow this trend, the PCB controller of the sensor systems manufactured by Institute for Nanotechnology (INT), Vietnam National University - Ho Chi Minh City needed to have some effective design method to meet with the actual requirements. Due to that fact, a modern making line for PCB fabrication from Germany was well equipped at INT to help the electronic research group develop the required PCBs.

In INT's the sensor system, the controlling PCB consisted of three main components: the power controller, the measuring signal collector from the eight sensor probes (temperature, pH, salinity, dissolved oxygen concentration, redox potential, NH_3^+, NO_3^-) and the data transfer controller to the web server (Figure 3).

The signal collector received and calculated the electrical signal from the sensors and converted it into readable data. These data were packaged and sent to the data collector and data transfer then would be uploaded to the web server. The battery provided energy to all operations of the system. The power controller managed the battery by using RF remote and prevented the voltage drop.

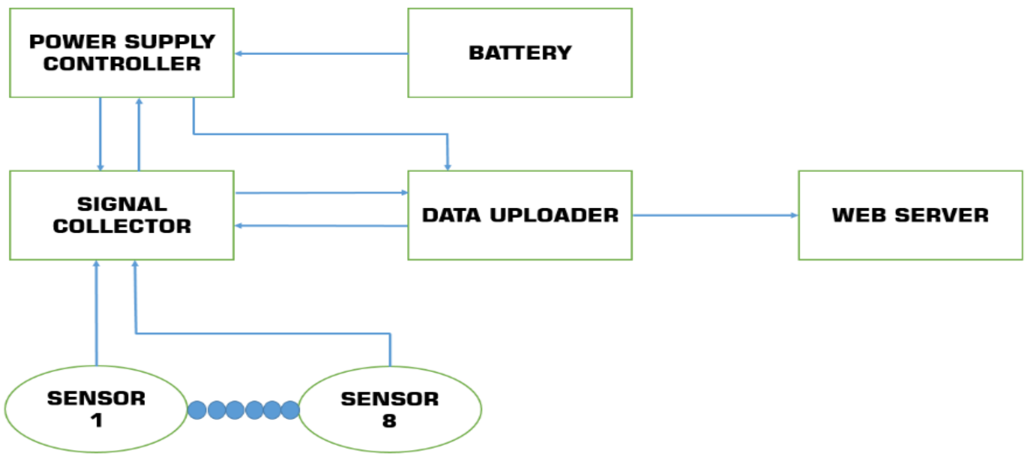

Fig. 3. Block diagram of the INT's the sensor system for assess quality of aquaculture water.

II. Experiments

The fabrication process of the PCBs [10-13] of the sensor system for assess quality of aquaculture water was shown in the Figure 4 below.

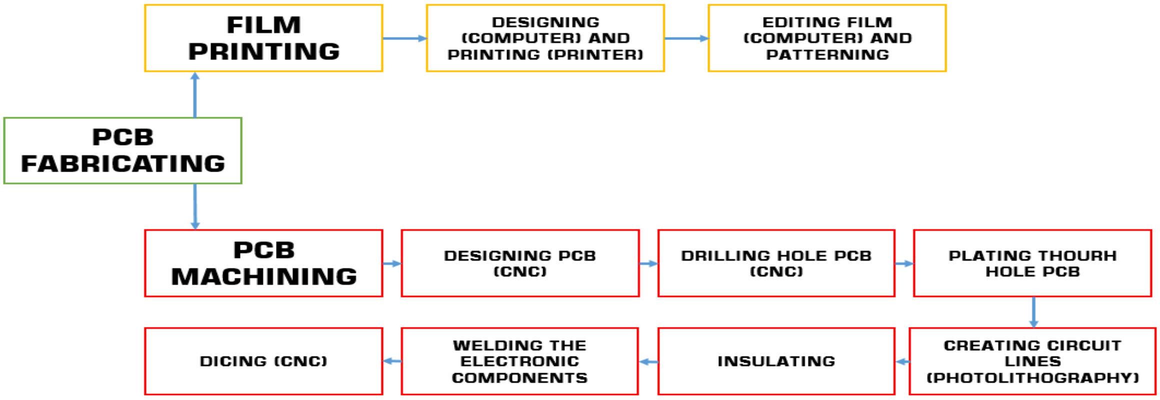

Fig. 4. Block diagram of PCB fabrication process of the sensor system.

The PCB design was created on the computer by Orcad 17.2-2016 software [14, 15]. After that, Isocam 5.0 software [16] was used to create a negative film for the printers and CNC equipment. This negative film was then re-edited by Gerber 2BMP and Film star softwares to get the file with the best resolution.

The film was printed with the film printer Film Star Plus, Bungard Elektronik, Germany, then was washed with a board washing machine RBM 300, Bungard Elektronik, Germany. Then it was put in the development chemical solution for 1 minute. The developed film was washed again with water and then transferred to the storage compartment.

The copper coated PCB was drilled with the CNC equipment (CCD/2, Bungard Elektronik, Germany) to make the holes which then plated by electroplated equipment Compacta 30, Bungard Elektronik, Germany to connect the circuit between the top and bottom faces of the board.

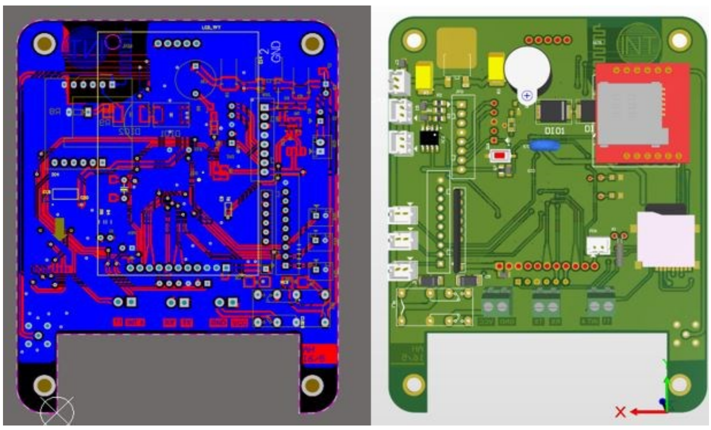

Fig. 5. Initial design of the top and bottom faces of PCB on computer.

The board was cleaned then rolled with a dry photoresist layer. The printed film was used to create image on this photoresist layer. The liff-off process used a mixture solution of Na_2CO_3 250 g, 25 liters of H_2O at a temperature of 45ºC in about 3 minutes. After obtaining the conductive lines, the PCB was covered with an insulating coating ("greening" layer). The image and name of the electronic components were then printed on the PCB with the same process.

The PCB finally was cut to the required shapes, coated with a solder paster and the electronic components were welded. Finally, it was annealled for 200 seconds at 180ºC then 60 seconds at 230ºC to dry the solder paste.

III. Results and Discussions

3.1 *Visual Assessment of the Fabricated PCB*

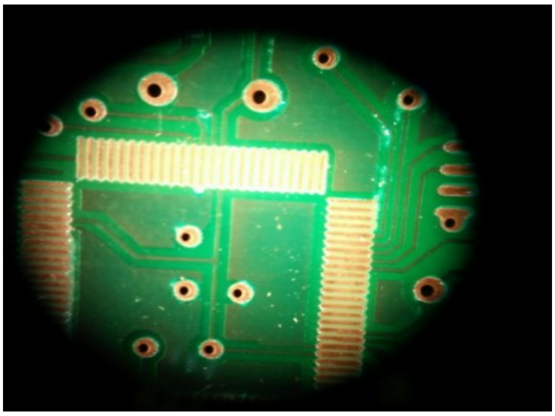

Fig. 6. The PCB was observed by a microscope.

Visual assessment results showed that the fabricated PCB was well prepared. It was not short-circuited. With some small-sized components, it was necessary to observe with a microscope (Figure 6). The results in Figure 5 showed that the circuit lines were not distorted. The copper coating of these lines was not blistered, which reduced its cross section. The hole was not skewed. The circuit line and the electronic components pins were not stuck together. The fabricated PCB was not warped and there were no contamination or oxidation spots on its surface (Figure 7).

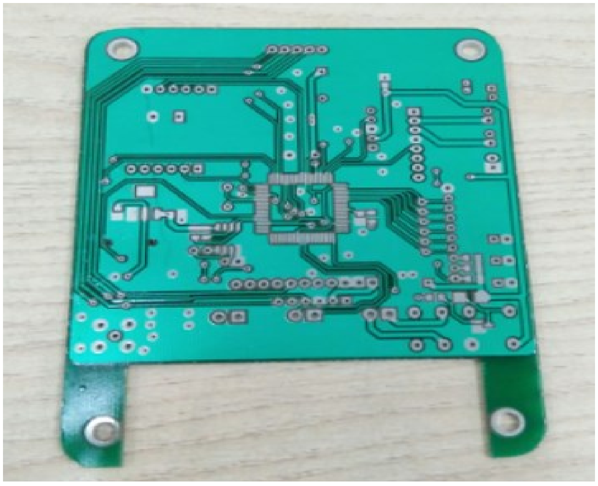

Fig. 7. The fabricated PCB shape and structure

3.2 *Conductivity Test Results of the Fabricated PCB*

The test results by a VOM meter in pulse mode were used to check the quality of some plated-through holes on the PCB. If this results was of 0 so that the holes were well-plated.

The VOM meter was also used to check the distance between the circuit lines. In case the circuit lines were broken, the current value would be zero. If the circuit lines stick to the component pins, the voltage value would be zero (Figure 8).

Thirdly, it was needed to test the impedance of some important circuit lines. This step was very important because it affected the signal quality of the sensor system especially in case of two circuit lines connecting the two poles of pulse oscillator quartz for processor. If the impedance of these two circuit lines was much different, it might lead to an unstable operation. The allowable difference of impedance between these two circuit lines was less than 0.2 Ω (Figure 9).

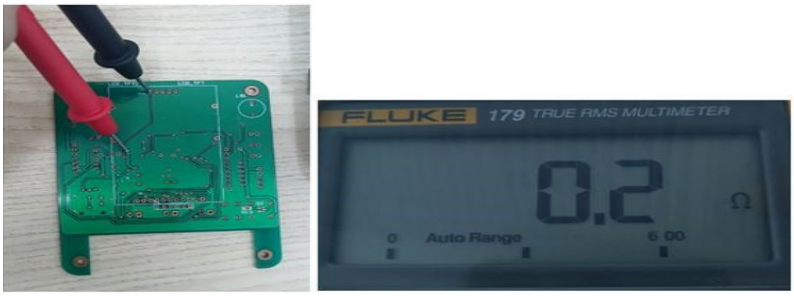

Fig. 8. Testing the impedance of the circuit lines using VOM meter

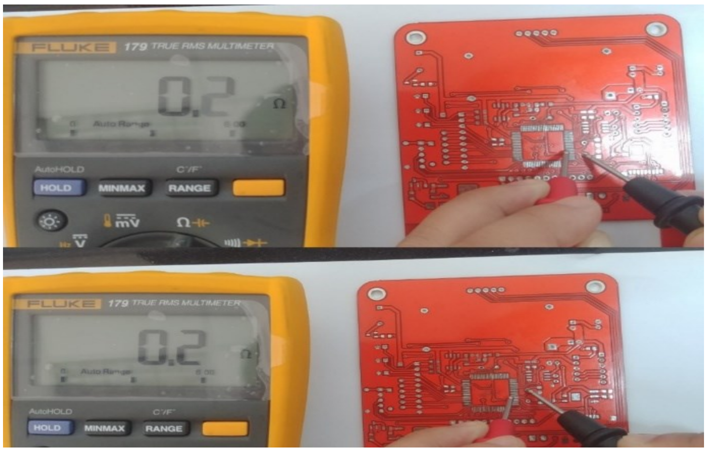

Fig. 9. Testing the impedance of two circuit lines connecting the two poles of pulse oscillate quartz for processor

3.3 *PCB Testing Results after welding the Electronic Components*

3.3.1 *The Voltage, the Load Capacity and the PCB's Temperature Testing Results*

The power supply component was a very important part of the PCB. If the power supplier was not stable, it would lead to an unstable operation of sensor system. In addition, if the load current was too high or too low compared to the operating current of the PCB, it might cause a failure or damage to some other parts on the PCB, reducing the life-time of the sensor system. Therefore, it was needed to do some tests of the output voltage and stability of the power supplier before used it in the PCB.

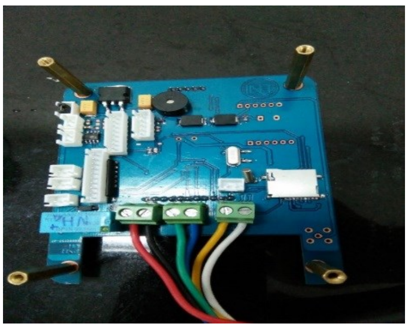

Fig. 10. The PCB after welding process

Testing process was performed by applying a voltage of 8.4 VDC (equivalent to the voltage of the battery system used in the real sensor system) to the PCB. According to the result shown in Figure 11 below, the maximum load current was 148 mA. This value was acceptable in the real operation conditions of the fabricated sensor system.

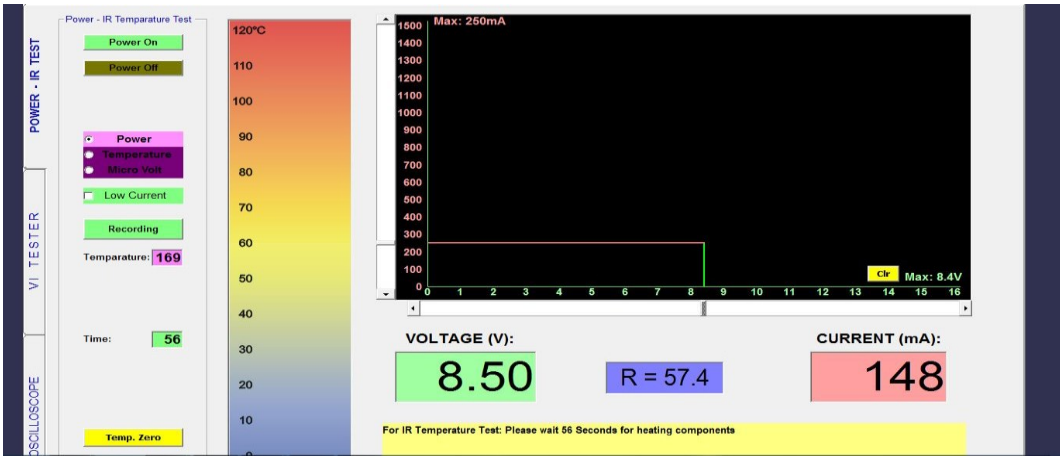

Fig. 11. Load current testing results of the fabricated nano sensor system

In the next step, the load capacity of the PCB was tested. The PCB was operated at full load condition continuously for 10 hours and then the voltage drop was also checked. The results showed that the fabricated PCB in this study worked well with the testing conditions. The supply voltages for the PCB, the LCD and the processor were higher than 4 VDC at all time.

The PCB was operated continuously for 5 hours at a normal ambient temperature of 30-34ºC and used the FADOS9F1 equipment to investigate its heat emission process. The temperature graph showed that operated temperature of this PCB did not exceed to 50°C and it did not generate any unusual heat.

3.3.2 *Quatz Test Results*

On the PCB, there were 2 quartzs to generate the pulse for Atmega 2560 processor and DS1307 IC in operation process.

The Oscilloscope PS-200 equipment was used to test the performance of these quarzt components. The oscilloscope was clamped to the 2 pins of the quartz when the PCB was operating. The quartz worked normally if the value displayed on the oscilloscope was equal to the recommended frequency value from the quartz manufacturer. In addition, the measured pulse of the quartz must be in square shape without distortion as showed in Figure 12.

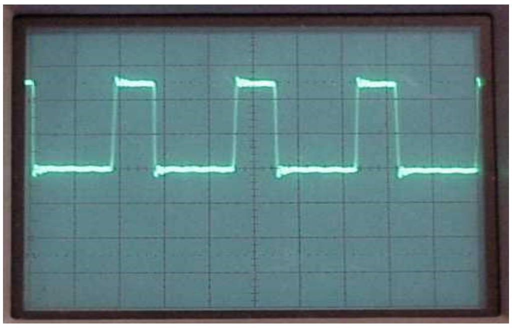

Fig. 12. Measured pulse form of the quartz

3.3.3. *Comparison Results with the reference PCB*

All electronic components were tested before welding on the PCB but some components might be changed or broken due to the effect of the high temperature. Therefore, it was necessary to do a check of the fabricated PCB after connecting all the components. The Tracker 3200S was used to do a comparison test between the fabricated PCB and a reference PCB.

The results in Figure 13 showed that the fabricated PCB in this study had a square pulse wave and there was no difference compared to the reference PCB. So the fabricated PCB in this study was well-prepared.

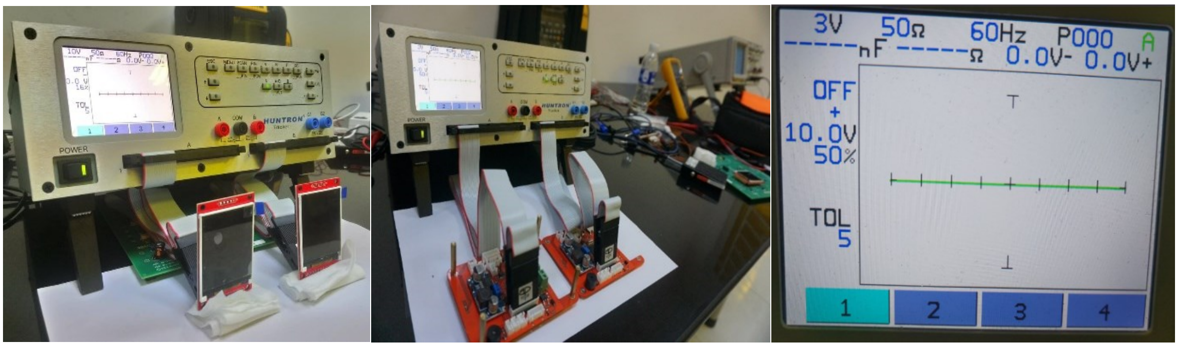

Fig. 13. Comparison test between fabricated PCB (in the left) and reference PCB (in the right)

3.4 *PCB Tests after Loaded Control Program to the Processor*

3.4.1 *The analog Function to Collect Signals from the Sensor*

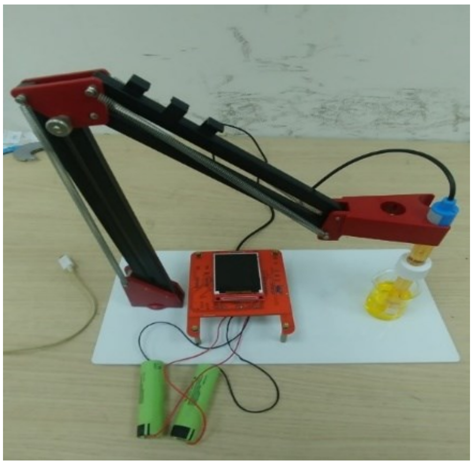

Fig. 14. The PCB was connected to sensors

The comparison test showed the fabricated PCB had the same quality with the reference PCB. For the next step, the control program was loaded to the processor then PCB was connected to the sensor for collecting signals test (Figure 14). When the sensor was dipped in a standard solution, the feedback signals displayed on the LCD were stable for 120 seconds. The results matched with the reference information of the standard solution. Therefore it was possible to conclude that the analog function of PCB to collect signals from the sensor worked well.

3.4.2 *The Power Supply Function to Control the Input and Output Voltages*

The power supply function on the PCB operated normally with the input voltage was of 8.4 VDC and the output voltage was from 4.2 VDC to 5 VDC, without abnormal fluctuations. The temperature of the LM2596 module did not exceed 45ºC (Figure 15) for continuously 5 hours working.

The leakage current reduced battery life was not detected when using a FLUKE 179 meter to measure the total direct current consumption at the power input of the PCB. This measured value was approximately 148 mA (± 5% of error).

Fig. 15. The power supply function test

3.4.3 *The Sending Data to the Server Function*

The PCB was applied an input voltage and did 5 measurements with different standard solutions. After measurements, the data uploaded to cloud storage was checked and it showed correct results with the data displayed on the sensor system LCD. This meant the sending data to the server function of PCB worked normally.

3.5 *Comparison Results of the INT's Sensor System with the reference Sensor System of HEMERA, France*

After the calibration process, the sensor system used the built-in PCB of INT was used to measure some actual water samples. The results were compared with another highly reliable device to check the accuracy and operated ability of the fabricated PCB. The reference equipment used in this test was the HEMERA measurement system, France [17] (Figure 16).

In this test, standard pH solutions from Atlas Scientific LLC., N.Y., US were used to assess the pH measurement accuracy.

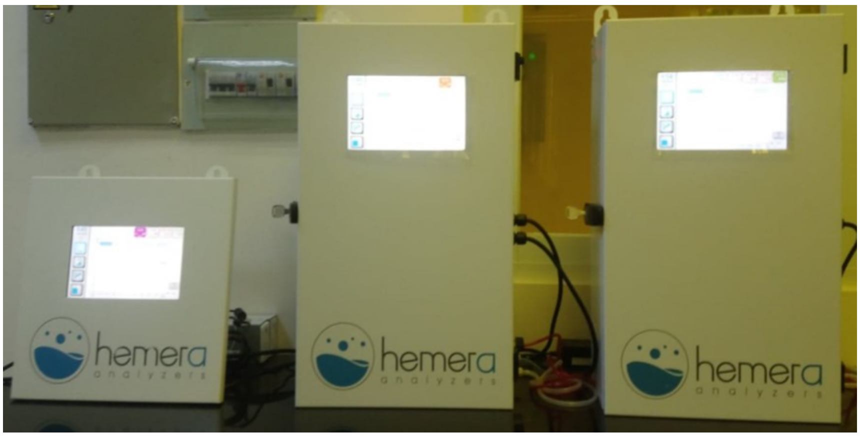

Fig. 16 Reference sensor system of HEMERA, France

a) b)

Fig. 17. The results showed on a) INT system and b) HEMERA system

Table 1. Comparison of pH measurement results performed by the INT and HEMERA sensor systems.

pH	INT sensor results	INT sensor error (%)	HEMERA sensor result	HEMERA sensor error (%)	Relative error (%)
8	8.18	~ +2.25	8.19	~ +2.375	+0.125

The results in Figure 17 and Table 1 showed that the measurement results of the INT sensor system were quite good. In comparison with the reference commercial sensor system from HEMERA, the relative error was +0.125%. This error value was possitive so it could be concluded that the INT sensor was more sensitive than the reference sensor in pH measurement.

IV. Conclusions

In this study, the manufacturing process of PCB for the INT's sensor system was studied and established. The design and fabrication steps were optimized to make the PCB which had the same quality with reference PCB. The operation of the sensor system with the fabricated PCB was tested with some standard samples such as pH or ORP solutions. The production line could be processed with high-demand PCB. The sensor system used this PCB showed a good performance with measuring results which were equivalent to the standard equipment of commercial manufacturers.

Acknowledgements

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