

# LabVIEW Simulation for Electroplating Process of Plated-Through Hole (PTH) in Multilayer Printed Circuit Board (PCB)

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**Abstract.** Plated-through hole (PTH) is important part which connect between one layer and other layers in printed circuit board (PCB) multilayer. PTH is commonly made by electroplating process with copper as based conductive material. This research objective to develop the electroplating process in which mass of copper generated using LabVIEW which is used together with Faraday's law of electrolysis. The results described how to work the electrolysis during electroplating process and the copper mass that adhere in hole and surface multilayer PCB. The results was displayed in LabVIEW interface. On the other hand, experiment of electroplating process is also conducted to form PTH and to determine mass of copper in PCB multilayer. The results showed that PTH was successfully formed in PCB multilayer with electroplating process. The copper mass adhered in multilayer PCB using LabVIEW simulation is not much different with mass of copper experimentally.

## 1. Introduction

Electroplating is one of the hardest surface adjustment technologies for pre-treatment product. Besides used in electrochemical impedance of lithium battery [1], electrochemical reaction and electric current are applied in this electroplating for making metal coatings. The coating materials frequently used in electroplating are silver, gold, tin, zinc, cadmium, copper, nickel, chromium, and so on [2]. Electroplating is widely used in electronics, aerospace, automotive [3], microelectronic mechanic system (MEMS) technology [4,5,6] and engineering industries. This electroplating has many advantages such as corrosion prevention, aesthetic finishes, coating component [3], lower resistivity, better anti-electromigration ability, and higher thermal exchange rate [7].

The electroplating results that consist of surface smooth, copper grain, and resistivity are affected by many parameters such as electric field distribution, electric current density, temperature and stirring style [8,9]. In copper electroplating, the most dominant factor is the current density because the electrodepositing speed and the grain size are decided by the current density [10]. The copper electroplating is commonly used in printed circuit board (PCB) manufacturing [11,12]. The double layer and multilayer PCB need the electroplating process to make the conductive surface in plated-through hole (PTH) [12].

In order to learn more about the electroplating process in multilayer PCB, the simulation of electroplating process is needed. In this study, LabVIEW simulation is utilized to learn the electroplating process in multilayer PCB. LabVIEW is applied together with Faraday's law of electrolysis.

## 2. LabVIEW Simulation

LabVIEW programs are also called virtual instruments. A LabVIEW virtual instrument consists of a front panel, a block diagram, and a connector pane. A front panel is considered as a user interface. In front panel, the user can insert the inputs (sliders, knobs, values entered from the keyboard, push buttons, selector switches) and the outputs (indicators, LEDs, graphs, strip charts, sounds) [13].

A block diagram is considered as a LabVIEW program. Block diagrams integrate terminals, subVIs, functions, constants, structures, and wires, which transfer data among other block diagram objects. Furthermore, a connector panel is a set of terminals on the icon that corresponds to the controls and indicators of a VI, similar to the parameter list of a function call in text-based programming languages [13]. In this research, LabVIEW is applied together with Faraday's law of electrolysis as in equation (1) [3].

$$m = \frac{A}{n} \frac{I t}{96500} \quad (1)$$

Where  $m$ ,  $A$ ,  $n$ ,  $I$ ,  $t$ , and 96500 are mass of deposited material (gram), atomic weight of deposited material, valency of deposited material, applied current (Ampere), time (s), and Faraday's constant (Coulomb/gram), respectively [3].

## 3. Experimental procedure

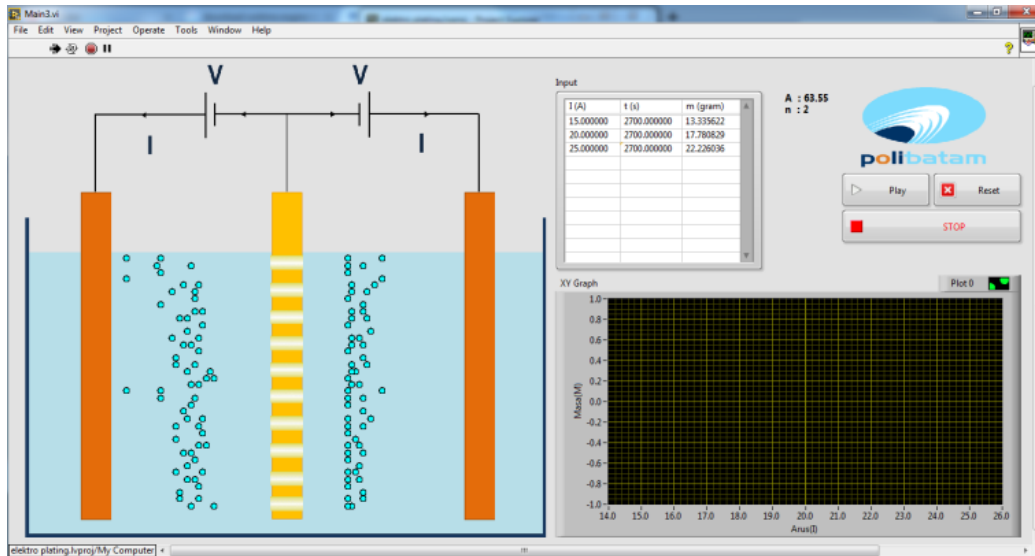
The mass value of copper which it adheres on printed circuit board (PCB) and plated-through hole (PTH) surface is also determined with the experiment. The experiment was conducted through some steps such as PCB design, preparing material, pressing the FR-4 material, drilling, brushing, cleaning, immersing in the conductive carbon, drying, electroplating process, cleaning, drying, and measurement of copper mass.

The prepared material was FR-4 PCB material, distilled water, conductive carbon (black hole solution), and copper (II) sulfate pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , meltex). The first step created a stack from 3 FR-4 PCB materials with glue and pressing to make four layers of PCB. The pressing process was conducted at 12 bar with temperature 170 °C for 30 minutes. The second step was the drilling process which it works following the PCB design. The PCB design was created using Altium (PCB design software). The third step was brushing and cleaning. The distilled water was used during brushing and cleaning. The fourth step is immersing the PCB surface in the conductive carbon solution (black hole solution) for 5 minutes and drying at 80 °C for 10 minutes. The fifth step is the electroplating process. Before the electroplating process is running, the multilayer PCB was weighed with the scale (Kern FCB bench scale). The electroplating process was conducted for 3 similar PCB, but the applied current for each PCB was different in which the applied current was 15 A, 20 A, and 25 A. Each electroplating process needed 45 minutes. Cleaning and drying of PCB was done after the electroplating process is finished. The last step is measurement of copper mass adhering on PCB and PTH surface.

## 4. Results and discussion

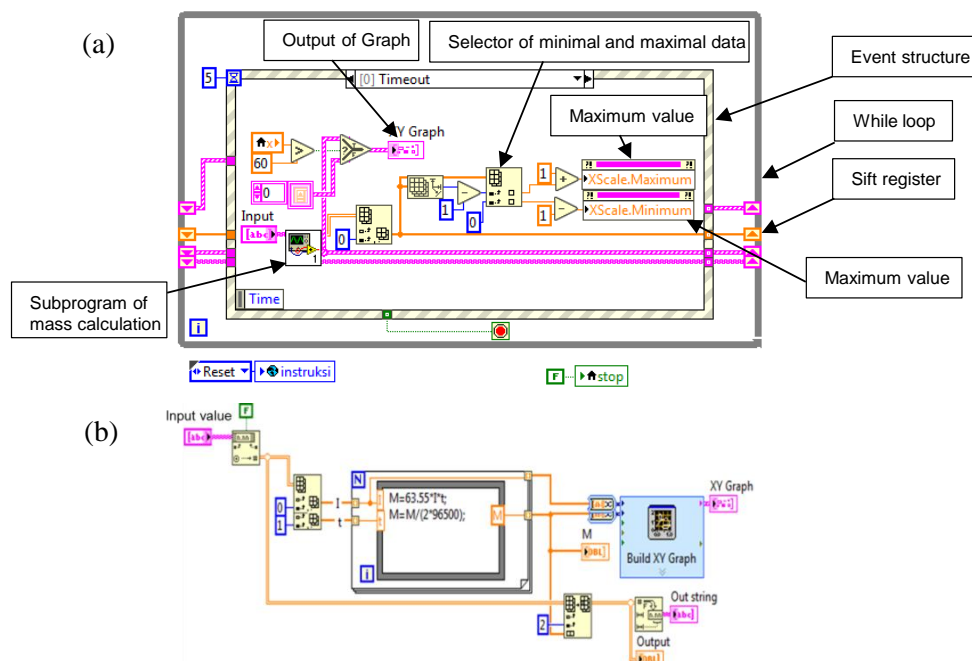
LabVIEW simulation was used to show how to work electrochemically the electroplating process. It simulated the movement of copper ion in copper(II) sulfate ( $\text{CuSO}_4$ ) solution when the electrodes was given the current. On the other hand, LabVIEW program also calculated the copper mass that adhering on PCB and PTH surface. The equation (1) is applied in this calculation.

LabVIEW interface displays the table of input data (current, time, copper mass), the simulation of copper ionic movement, and the graph of calculation results. The graph exhibits the relation of applied current and the copper mass. The front panel also displays other parameters such as atomic weight of deposited material, valency of deposited material, and button for play and stop as shown in figure 1.



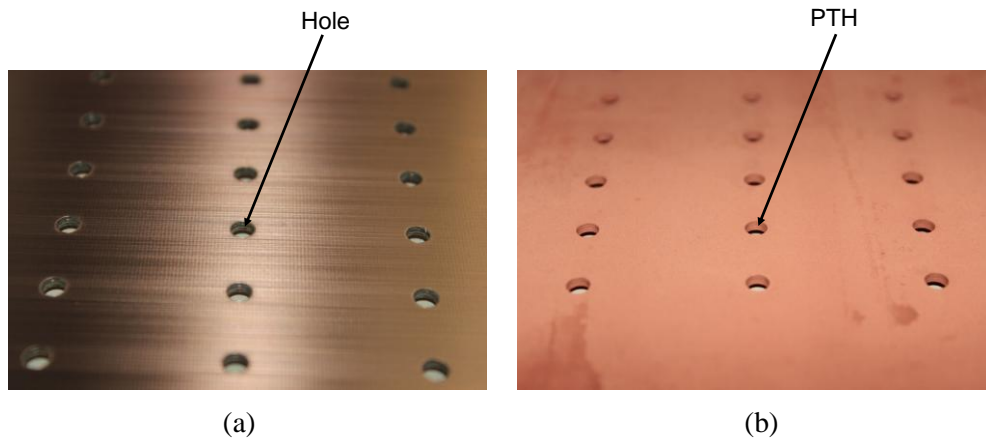
**Figure 1.** Interface of LabVIEW virtual instrument for electroplating simulation.

LabVIEW software utilizes the graphical program language that it is placed in the diagram block. The program receives the input data from the front panel such as parameter data, play button, stop button, etc. All program for electroplating simulation and calculation of copper mass is placed in the diagram block as shown in figure 2.



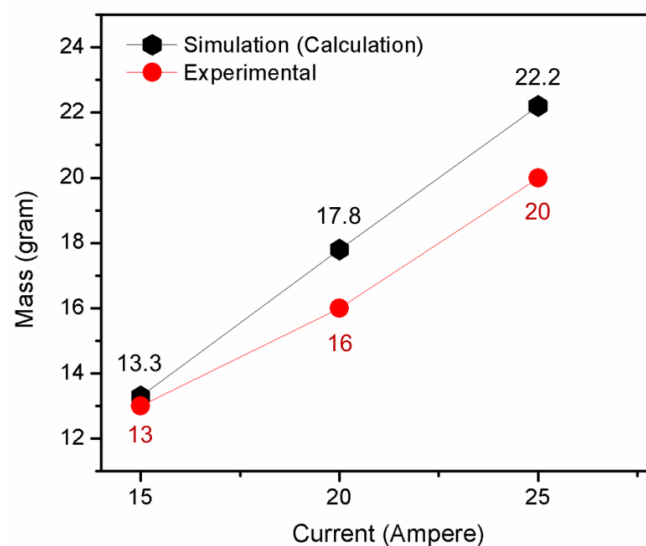
**Figure 2.** (a) Block diagram of LabVIEW virtual instrument and (b) subprogram of copper mass calculation during simulation of electroplating process.

The calculation results of copper atomic mass adhering on the PCB and PTH surface using the equation (1) are 13.3 gram, 17.8 gram, and 22.2 gram for the applied current 15 A, 20 A, and 25 A, respectively. Besides calculation, the copper mass is also obtained from experiment in which it is obtained from difference between the PCB mass before and after the electroplating process. PCB before and after the electroplating is shown in figure 3.



**Figure 3.** Multilayer PCB (a) before and (b) after the electroplating process.

The calculation results are slightly different with the experiment results. The experiment results showed that the copper masses on PCB and PTH surface are 13 gram, 16 gram, and 20 gram for the applied current 15 A, 20 A, and 25 A, respectively. There are slightly different of copper mass between calculation results and experiment results as shown in figure 4. The different results of copper mass are possibly caused by impurity of  $\text{CuSO}_4$  solution and the current difference in amperemeter and reality.



**Figure 4.** The comparison between the calculation and experiment results.

## 5. Conclusion

In this study, the simulation of electroplating process in multilayer printed circuit board (PCB) was successfully created by LabVIEW software. The calculation results of copper mass adhering on PTH and PCB surface are 13.3 g, 17.8 g, and 22.2 g with the applied current 15 A, 20 A, and 25 A,

respectively. Furthermore, the experiment results exhibit that the copper masses are 13 g, 16 g, and 20 g for the applied current 15 A, 20 A, and 25 A, respectively.

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