Jurnal Teknologi

Full Paper

On-Chip Droplets Sensing using Capacitive Technique

Mohamad Faizal Abdullah[a], P. L. Leow[a*], M. A. Abd Razak[a], F. K. Che Harun[a]

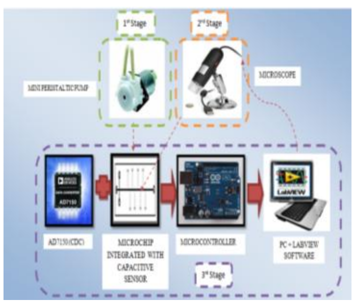
[a]*Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*

*Corresponding author: leowpl@fke.utm.my

Article history

Received :31 May 2012
Received in revised form :10 October 2012
Accepted :5 January 2013

Graphical abstract



Abstract

Significant attention has been given on the development of droplets-based microfluidic system because of its potential and apparent advantages. Beside the advantages of reducing the sample volume, it's also offer less time consuming for the analysis. Optical and fluorescence among the famous method that was used in detection of droplets but they are normally bulky, expensive and not easily accessed. This paper proposed a simple, low cost and high sensitivity for droplets sensing in microfluidic devices by using capacitive sensor. Coplanar electrodes are used to form a capacitance through the microfluidic channel. The design of eight pair of electrodes was used to detect the presence of a droplet. Changes in capacitance due to the presence of a droplet in the sensing area is detected and used to trigger the microscope to capture the image of detected droplets in microchannel. The measurement of droplets detected and counting are displayed through a LABVIEW interface in the real time.

Keywords: Capacitive sensor; microfluidic sistem; LABVIEW; simply, low cost and high sensitivity

Abstrak

Perhatian telah diberikan terhadap pembangunan titisan berasaskan microfluidic sistem keranaia mempunyai berpotensi dan kelebihan yang sangat jelas. Seperti yang diketahui kelebihannya seperti dapat mengurangkan isipadu sampel, ia juga menawarkan menjimatkan masa untuk analisis sesuatu sample. Optik dan pendafluoran adalah antara kaedah yang sering digunakan dalam pengesanan titisan tetapi mereka biasanya besar, mahal dan tidak mudah untuk digunakan. Kertas kerja ini mencadangkan yang kaedah yang ringkas, kos rendah dan sensitiviti tinggi bagi pengesanan titisan dalam peranti microfluidic dengan menggunakan kapasitif sensor. Elektrode sesatah digunakan untuk membentuk satu kapasitan melalui saluran microfluidic. Reka bentuk lapan pasangan elektrod telah digunakan untuk mengesan kehadiran titisan. Perubahan dalam kemuatan disebabkan kehadiran titisan di kawasan penderiaan dikesan dan digunakan untuk mencetuskan mikroskop untuk menangkap imej titisan yang dikesan dalam saluran microfluidic. Graf and bilangan titisan yang dikesan dipaparkan melalui LabVIEW dalam keadaan yang berterusan.

Kata kunci: *Capacitive sensor; Microfluidic system*; LABVIEW; Ringkas, kos rendah dan sensitiviti tinggi

1.0 INTRODUCTION

In the sensing system, the detection issues arise when sensing systems are miniaturized. The reduced analysis volumes mean a reduction in detection volumes, decreasing the number of analytes available for detection and making it more difficult to detect them [1-3]. Sensitivity and scalability to smaller dimension are two main factors that must be considered before choosing the suitable detection method for the microfluidic devices. Electrochemical is not suitable to be use because it does not fulfill this requirement where sensitivity portable system are compulsory[3]. In this study,capacitive sensor was choosing in detecting the presence of droplets in microchannel because it's always cost effective , good sensitivity and suitable for electrically conducting or insulating liquids[4]. Besides that the design of the capacitive sensor is simple[5] compared to other methods such as optical and fluorescent technique.

2.0 PROBLEM STATEMENT

Nowadays the microfluidic devices commonly use to conduct biomedical research and create clinically useful technologies [6-8]. With more and more fluidic functions available on this microchips and ever decreasing the sample volume, the necessity for high performance detection has never been more relevant[6].

Controlling droplets traffic therefore requires real time detection and manipulation of droplets in multiple locations[9]. Optical and fluorescence among the famous method that used in detection of droplets but they are normally bulky, expensive and not easily accessed[2]. In this study, we present a simple, cost effective[10] and high sensitivity sensor design that uses capacitance change to measure the presence of droplets in the microchannel.

■3.0 METHODOLOGY

This study requires development in both hardware and software. Altium Designer Software was used to design the hardware part such as PCB circuit and capacitive sensor. Both of this hardware is fabricated according to the schematic design

3.1 System Flowchart

Figure 1 shows flowchart of study process and Figure 2 shows the schematic representation of on-chip automatic droplets sensing using capacitive technique. This system is divided into 3 stages. First stage is Mini peristaltic pump was control fluid flow to producing droplets through the microchannel. Next is capacitive sensing will detect the presence of droplets in the sensing area and the change in capacitance due to the presence of droplets the pass through detection point was measured. Off the self capacitive to digital converter AD7150 that controlled by microcontroller will be extracted from the signal at the electrode. The AD7150 was programmed to the output the real time capacitance measurement signal and displayed on computer through a LABVIEW interface. For the last stage, once the computer received the data of the measurement that was sent by microcontroller, microscope controlled by the LABVIEW will automatically capture image of detected droplets in microchannel. The application of the image of droplets actually can be used for the cell counting.

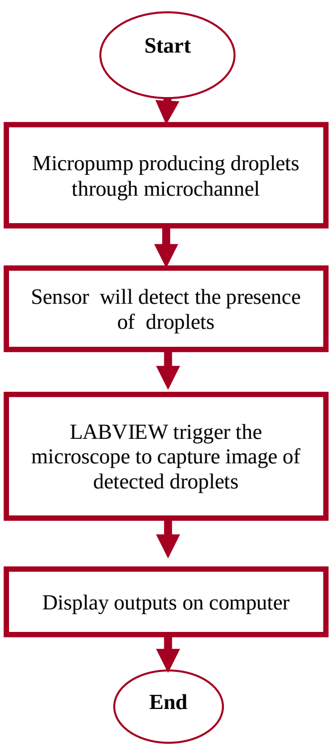


Figure 1 Process of the study

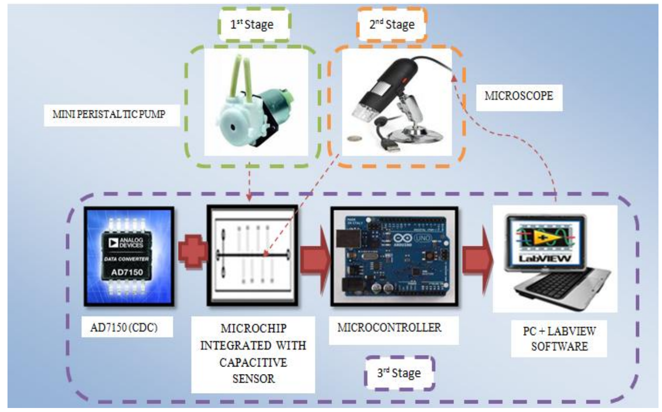


Figure 2 Schematic representation on-chip droplets sensing using capacitive technique

3.2 Prototype Design

Printed Circuit Board or known as PCB is the board employ in this study. PCB builds more proper and compact size of the prototype compared to strip board, donut board or proto board. The positions of components in the prototype circuit using PCB also become neater and orderly. PCB design involves software programming and hardware development.

3.2.1 PCB Software Programming

Draw a Schematic Layout

The schematic is a logical diagram that simply contains pictures of symbols representing all the components in the design and lines indicating connections between these components. The shape of components and direction of these lines will not impact the final prototype design because the schematic design is only for prescribe the lines connection begin and end. However, schematic designers will typically attempt to draw their lines neat and orderly for human-readability purposes. In brief, the schematic design function is nothing more than a list of all the components in the design, and the connections (nets) between those components.

Figure 3 shows a schematic layout that has been drawn in schematic document.

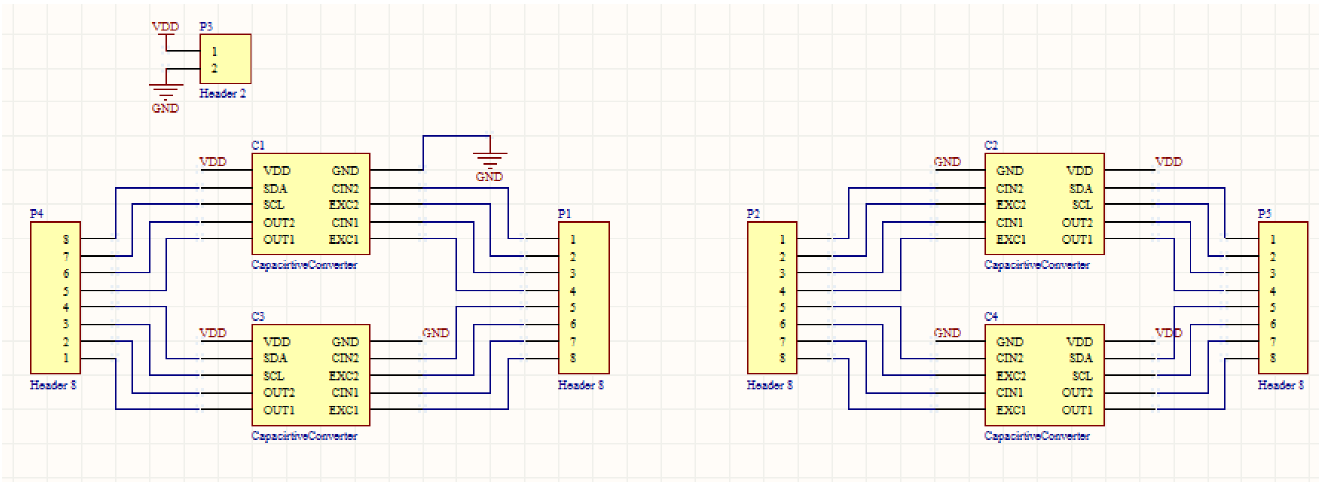


Figure 3 **S**chematic layouts for on-chip droplets sensing using capacitive technique

Design a Footprint

Footprint design is needed once the footprint component used is not present in the library. This footprint design must be really accurate and same with their real size and shape of physical component. If the footprint not matches with the real physical component, it will cause difficulties during soldering process. The footprint has been designed in the PCB library document as shown in Figure 4. After the design has been completed, the footprint will be added into schematic library document as shown in Figure 4. Now, it can be placed on the schematic document

PCB Layout

Once the schematic design was updated, they are imported into a PCB layout program. This PCB layout must be emphasized because it will determine the final prototype physical aspects like a size and shape of the board and location of the components. The proper arrangement of components location will result for the uncomplicated route connection between the components. The route connection in PCB layout can be done either using auto route connection or manual connection. Due to the connection of the PCB layout in this study simple, the auto route connection has been applied.Auto route will automatically connect traces based on the connections defines in the schematic.

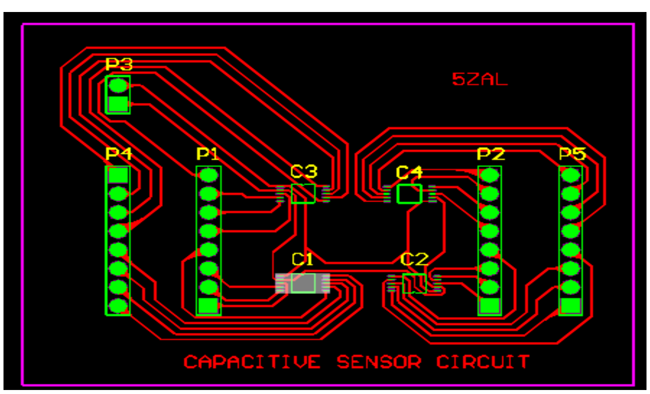


Figure 4 PCB layouts of the prototype on-chip droplets sensing using capacitive technique

3.3 Software Programming

Proper testing capacitive sensor is essential. First of all Arduino was programmed to communicate with AD7150.These integrated circuit supports an I^2C-competibility, 2 wire serial communications. These two wires are called SCL (clock) and SDA (data) and both of them carry all data information, control and addressing to the all connected peripheral device one bit a time over the bus. The SDA wire carries the data, while the SCL wire synchronizes the sender and receiver during the data transfer. To control AD7150 device, first the master must initiates a data transfer by establishing a start condition, defined by a high-to-low transition on SDA while SCL remains high. This indicates that the start byte follows. This 8-bit start byte is made up of a 7-bit address plus an R/W bit indicator.

All peripherals connected to the bus will respond to the start condition and shift in the next eight bits (7-bit address + R/W bit). The bits then received MSB first. During the ninth clock pulse, the peripheral recognizes the transmitted address responds by pulling the data line low. This is known as the acknowledge bit. The direction of the data transfer was determines by R/W bit. A Logic 0 LSB in the start byte means that the master writes information to the addressed peripheral. In this case, the AD7150 becomes a slave receiver. A Logic 1 LSB in the start byte means that the master reads information from the addressed peripheral. In this case, the AD7150 becomes a slave transmitter. In all instances, the AD7150 acts as a standard slave device on the serial bus.

In this study, LABVIEW is the one of the National Instrument software that was used to display the output through computer.

■4.0 RESULTS AND DISCUSSION

4.1 Integrate Capacitive Sensor with Microfluidic Chip

For detecting the droplets, the microfluidic chip is attached on the capacitive sensor by using epoxy to avoid leaking occur during producing droplets through microchannel by micropump. This chips consist of two inlets (carrier liquid and aqueous liquid) and one outlet for the waste to the reservoir. Figure 5 depicts the complete device for the experimental setup.

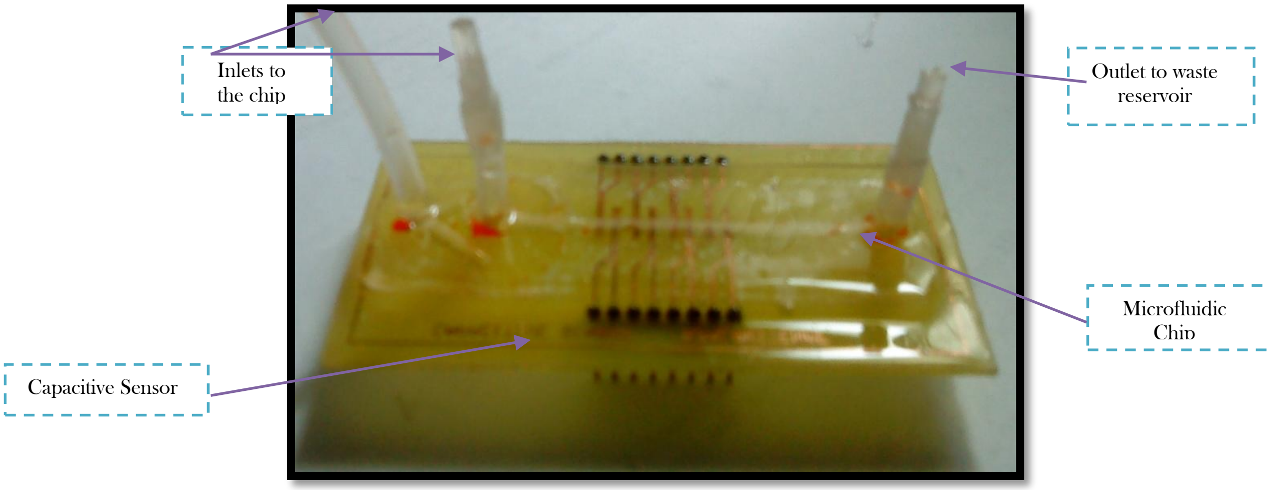


Figure 5 Integrated capacitive sensor with microfluidic chip

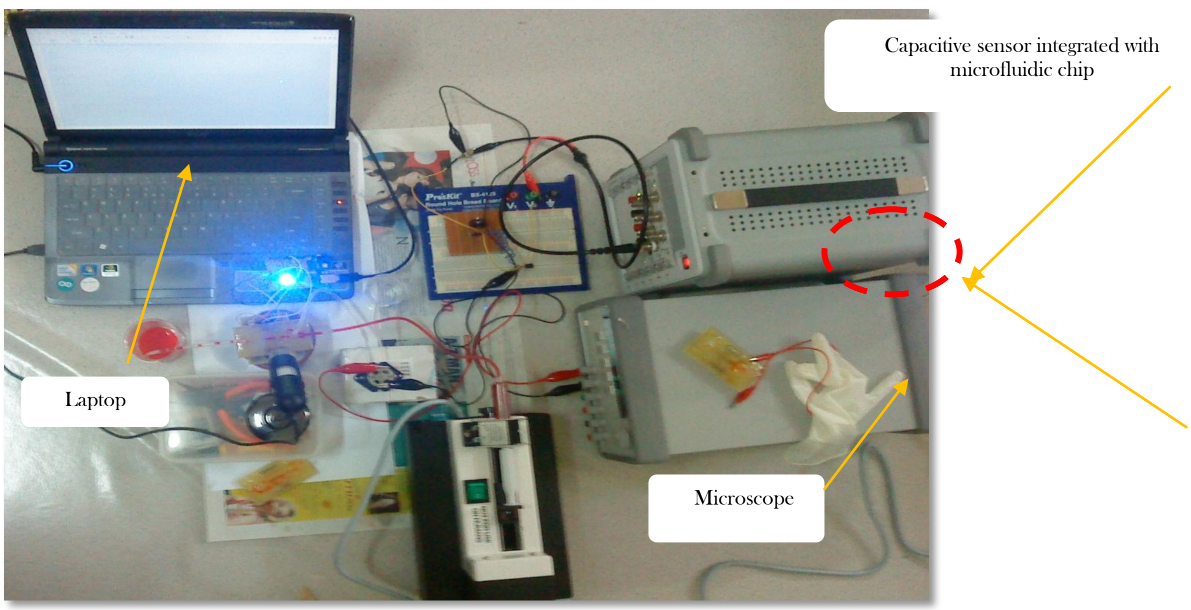


Figure 4 Experimental setup for the droplets formation and detection in a microfluidic device

Figure 3 show the full Experimental setup for the droplets formation and detection in a microfluidic device**.**The most significant thing in this study is the interaction between AD7150 with the microcontroller to extract the signal from electrode.CDC receive the data in capacitance form and then manipulates the signal to digital form for the ease of transmission and display collected data on computer. LABVIEW read all the data that has been sent through by using VISA application. VISA will recognize which port has been used on the computer. After it recognized which port has been used, the VISA will read the data, and process the data. At the end of the process, the waveform chart and Indicator for droplets counting will be display. Figure 4 shows the graphical user interface that was developed is for this system. The result shows capacitive sensor was detected 6 times the presence of droplets that pass through the detection point. The droplets counting were showing in front panel of the system interface.

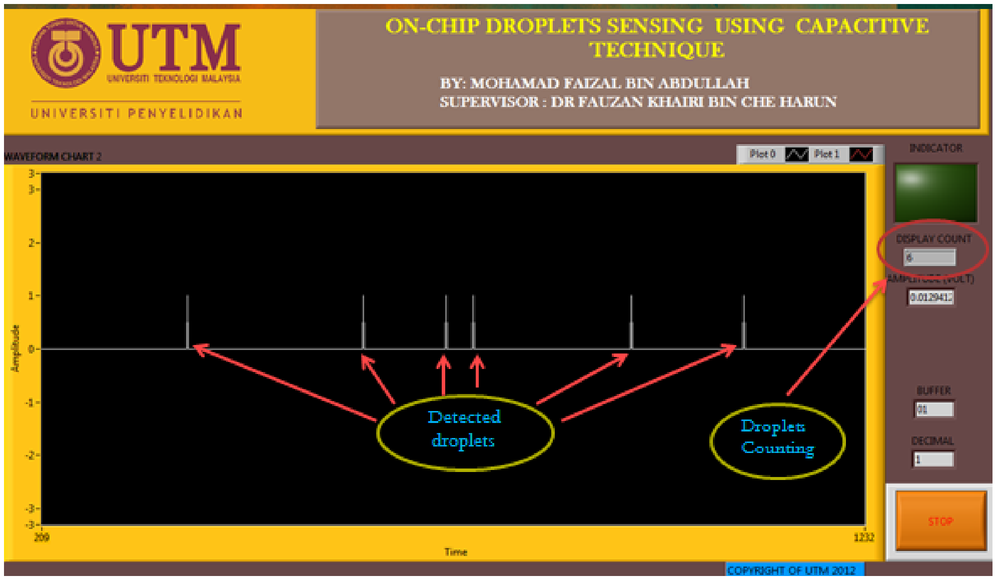


Figure 4 Graphical user Interface

■7.0 CONCLUSION & FUTURE WORK

As a conclusion, a prototype of ON-CHIP DROPLETS SENSING USING CAPACITIVE TECHNIQUE has been successfully developed. Based on the result obtained, it shows that this system achieves the objectives of the study. The communication between the microcontroller and AD7150 was successfully obtained and capable process the data information. LABVIEW interface also was successfully develop and displayed the data information of detection of droplet on computer using USB cable.

In short, this resererch develop not just to detect the presence of the droplets in the microcfluidic system but also can automated droplets counting and capture the image of detected droplets for cell counting purposes.

With the availability of this simple, low cost and high sensitivity detection method using capacitive technique, it is hope the weakness of current available detection method can be solved and provide wide applicability of droplets based of microfluidic system.

For future work, this study can be further improved by fabricating the capacitive sensor by using glass subtrate to make sure microscope can capture the image of detected droplets clearly and designing the capacitive sensor in interdigital finger that not only can be use to detect presence of the droplets but also droplets size and speed.

Acknowledgement

This paper is a part of a publication series on Research and Development in Signal, Image and Sensors in Biomedical Engineering Applications.

References

[1] Nguyen, N.-T., S. Lassemono, and F. A. Chollet. 2006. Optical Detection for Droplet Size Control in Microfluidic Droplet-based Analysis Systems. *Sensors and Actuators B: Chemical.* 11**7**(2): 431–436.

[2] Shrinivasan, S. *et al.* 2007. A Low-Cost, Low-power Consumption, Miniature Laser-induced Fluorescence System for DNA Detection on a Microfluidic Device. *Clinics in Laboratory Medicine*. 27(1):. 173–181.

[3] Kuswandi, B. *et al.* 2007. Optical Sensing Systems for Microfluidic Devices: A Review. *Analytica Chimica Acta.* 601(2): 141–155.

[4] Chen, J. Z. *et al.* 2004. Capacitive Sensing of Droplets for Microfluidic Devices Based on Thermocapillary Actuation. *Lab on a Chip. 4*.(5): 473–480.

[5] Ghafar-Zadeh, E. and M. Sawan. 2010. *Capacitive Sensing Electrodes CMOS Capacitive Sensors for Lab-on-Chip Applications*. Springer Netherlands. 25–33.

[6] Mogensen, K. B., H. Klank, and J. P. Kutter. 2004. Recent Developments In Detection For Microfluidic Systems. *Electrophoresis*. 25(21–22): 3498–3512.

[7] Huo, D.-Q. *et al.* 2010. Recent Advances on Optical Detection Methods and Techniques for Cell-based Microfluidic Systems. *Chinese Journal of Analytical Chemistry*. 38(9): 1357–1365.

[8] Elbuken, C. *et al.* 2011. Detection of Microdroplet Size and Speed Using Capacitive Sensors. *Sensors and Actuators A: Physical*. 171(2): 55–62.

[9] Adams, T. M. and R. A. Layton. 2010. *Introduction to Microfluidics Introductory MEMS*. Springer US. 317–368.

[10] Ghafar-Zadeh, E. and M. Sawan. 2010. *Capacitive Interface Circuits for LoC Applications CMOS Capacitive Sensors for Lab-on-Chip Applications*. Springer Netherlands. 51–90.