I J C T A, 9(31), 2016, pp. 45-52 ISSN: 0974-5572

Integrated Monitoring and Control System For Lab on a Chip

Lee X.Y.*, Sulaiman N., Abdul Halin I.*** and Yunus N.A.******

ABSTRACT

A monitoring and control system for a Lab on a Chip (LoC) is used to monitor the behaviors and electrical characteristics of particles and microdroplets placed on a chip with varying electrical field produced by manipulating the frequency and amplitude of the electrical signal that are supplied to the chip. A normal monitoring system consists of bulky instruments such as signal generator, measuring equipment for characterizing the electrical behavior of microdroplets, microscope for constant observation of microdroplets, probe station to steadily hold and electrically probe the chip, and a computer for controlling the system and processing data. This paper addresses the implementation of portable system based on National Instruments (NI) myRIO-1900 and LabVIEW software. Direct Digital Synthesizer (DDS) is used to generate the signal up to 60MHz. While the National Instruments (NI) myRIO-1900 is used to extend the functionality. A user friendly Graphical User Interface (GUI) is also developed in the LabVIEW software to ease the task of the researcher. Hence, the system is projected to have more accurate and precise signal control for monitoring and controlling the particle.

Keywords: Lab on a chip; Direct Digital Synthesizer; Graphical User Interface; LabVIEW; Microdroplet Monitoring System.

1. INTRODUCTION

The activity of analyzing and monitoring small particles in micro- or even nanoscale is performed is usually applied in life sciences and biomedical studies. The operating electrical signal is normally ranging from hertz (Hz) to megahertz (MHz) at amplitude up to $20V_{pp}$ depending on the operation of the Lab on a Chip (LoC) [1, 2]. Some common operations include particles separation, detection and analysis of microfluidics, delivery, alignment and positioning of micro particles [3, 4]. Dielectrophoresis (DEP), biosensors, electrorheological (ER) actuators and electroosmotic pumps are some of the examples of devices and processes which involved microfluidics and require electrical manipulation and detection devices, which need electrical signal to energize [5, 6, 7].

The setup of the particle monitoring system for the LoC requires instruments such as frequency generator to supply electrical signal, oscilloscope for output measurements, and also a microscope for observing and analyzing the reaction of microdroplet or microparticles. The instruments and the stage or probe station are usually bulky, big in size and not portable. Hence, a much more portable, easier handling and user-friendly system is developed to ease the work of researchers. This allows researcher to focus on carrying out the experiments at any locations.

* Student, Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang UPM, Selangor. Malaysia, *Email: xinyi0906@yahoo.com*

** Senior Lecturer, Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang UPM, Selangor. Malaysia, *Email: nasri_sulaiman@upm.edu.my*

*** Senior Lecturer, Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang UPM, Selangor. Malaysia, *Email: izhal@upm.edu.my*

**** Senior Lecturer, Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang UPM, Selangor. Malaysia, *Email: amziah@upm.edu.my*

In the development of the particle monitoring system, which is the continuation and improvement from the one implemented in [8], the National Instruments (NI) myRIO-1900 is used to control the DDS AD9851 for generating signal with frequency up to 60MHz. It also performs measurements on the device under test (DUT), perform image processing on the particles that are captured from digital microscope and provides control and monitor through personal computer (PC). GUI is developed and integrated all the systems in a single screen on PC, which makes the system more user-friendly and easy to use.

2. METHODOLOGY

The function of signal generation, oscilloscope, monitoring and image processing are integrated into the LoC system. The major components of the design consist of the DDS AD9851 for signal generation and NI myRIO for constructing the remaining parts of the LoC system. Besides, a GUI is also implemented into the LoC system for user input and observes output. The flow chart of the system is as shown in Figure 1.

At the beginning of the system shown in Figure 1, the user will enter the desired frequency and phase of the signal in the developed GUI, which will be displayed on the Personal Computer (PC).From the GUI

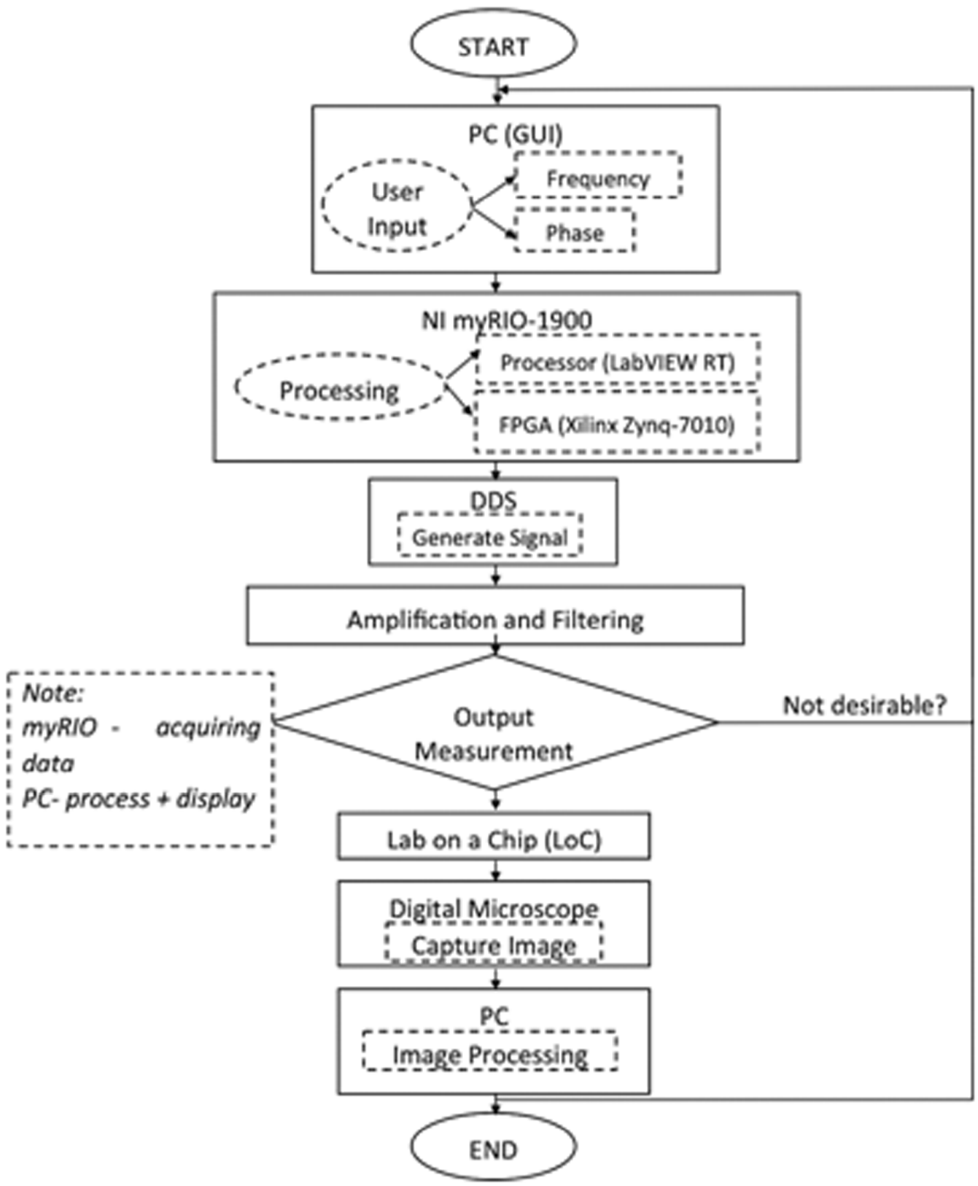


Figure 1: The flow chart of the designed system

then send the user input data to NI myRIO-1900 (the core of the system) for processing and transmit the required control signals to DDS. Throughout the process, the myRIO runs in Real-Time (RT) operating system and uses FPGA to compute the values of frequency and phase. It is executed in binary numbers and converted into digital signals for controlling the DDS. In other words, myRIO acts as the interface between the user (from PC) and the system (DDS). The DDS upon receiving the digital signals from myRIO would then generate the desired signal. In order to produce a higher quality signal, the signal generated is passed through signal conditioning circuitry such as amplification and filtering process. Finally, the digital microscope will capture the image on the LoCand send feedback to the PC for further processing to enable the user to observe the flow of the particles more accurately in the GUI. The process can be repeated by changing the input in the GUI until desirable results are obtained. The input devices of the NI myRIO-1900 include digital microscope and Personal Computer (PC) while the output devices include the DDS AD9851 chip with amplifier circuitry.

3. RESULTS AND DISCUSSION

The integrated controlling and monitoring on LoC system was successfully implemented by using NI myRIO-1900 and LabVIEW 2014. Figure 2 shows the final hardware prototype of the system. The system consist of two pairs of output signal ports, sine wave output ports and square wave output ports. The sine wave output can generate frequency in the range from 0 to 60MHz with adjustable amplitude. While the square wave output ports can generate frequency in the range from 0 to 1MHz with fixed amplitude of 10Vpp. The LoC would be placed on the stage and input signal is supplied by using probes to create contacts between the LoC pads and the signal generator. A microscope is set up perpendicularly to the stage to monitor the activities on the LoC.

A new user-friendly interface GUI system is an important element in this LoC monitoring system to allow users to control the inputs and to observe the outputs at the same time. Figure 3.2 shows the GUI developed in PC using LabVIEW. The GUI on the PC can be divided into two sections, which are DDS signal generation on oscilloscope shown in Figure 3(a) and the image observation under digital microscope shown in Figure 3(b). Figure 3(a) is the DDS AD9851 signal generation setting where it allows the user to enter the desired frequency and phase of waveform while the oscilloscope allows the user to display and

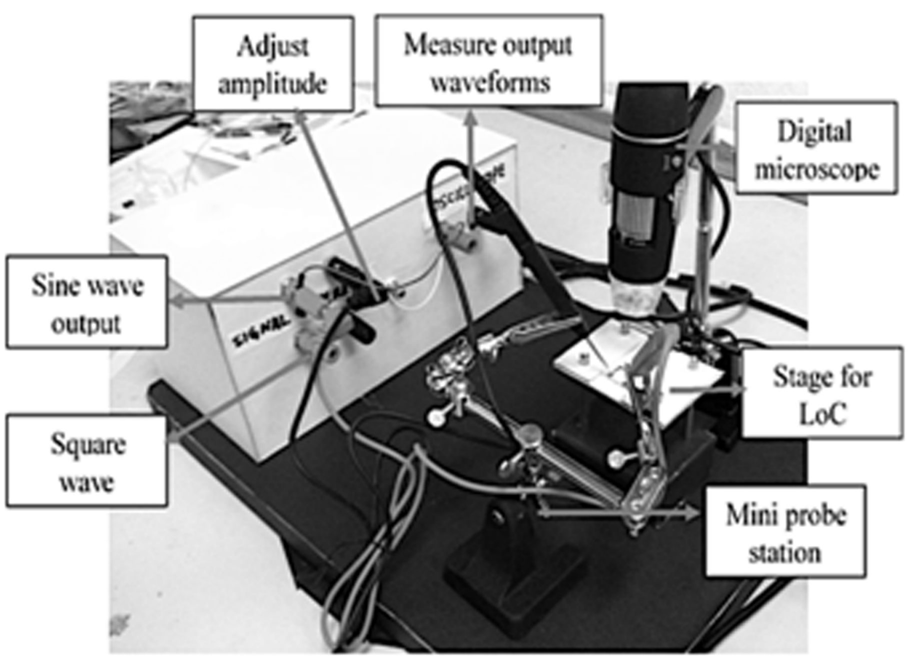
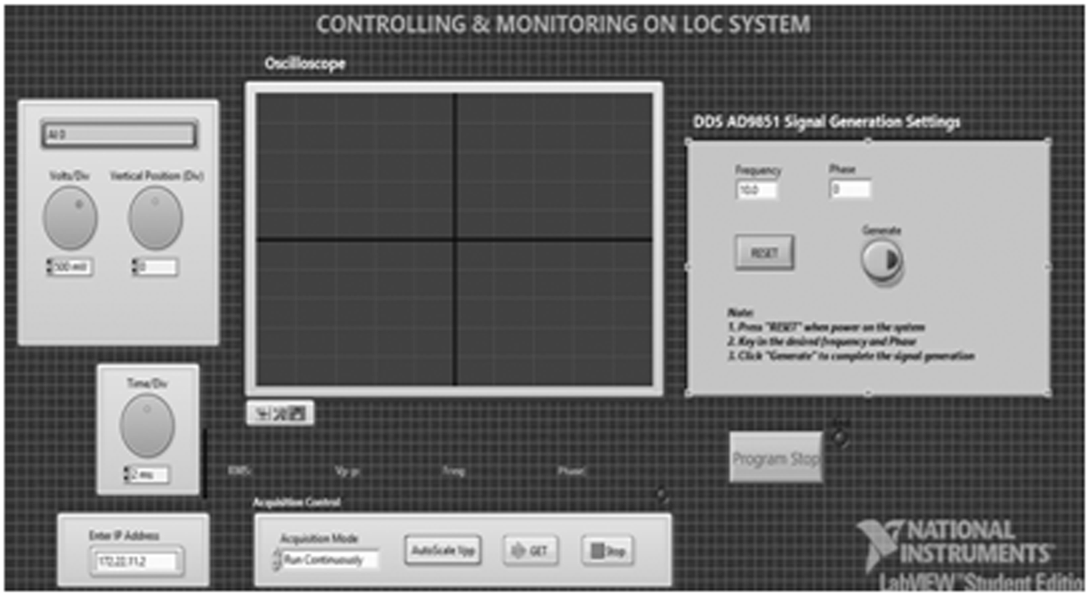
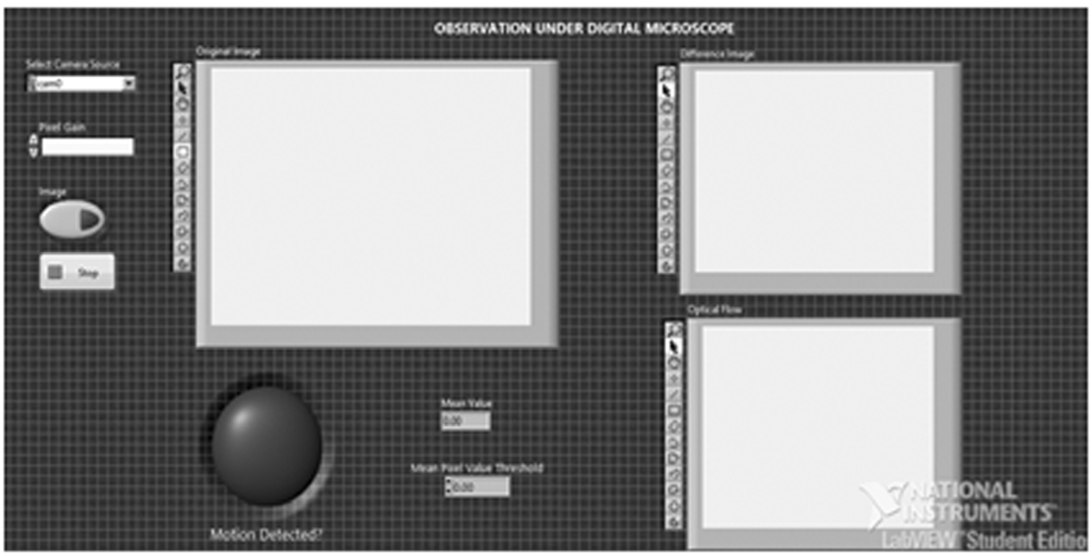


Figure2: Hardware prototype of the system



(a)



(b)

Figure 3: (a) GUI for LoC monitoring system (b) Image observation under digital microscope

measure the output waveform after amplification. The summary of each control and indicator used in Figure 3(a) is explained in Table 1. Figure 3(b) shows the control and indicator used for the GUI of image processing after monitoring and observing the reaction captured from LoC experiment. The summary of Figure 3(b) is explained in Table 2.

An additional hardware of DDS AD9851 is integrated into the system in order to achieve higher frequency up to 60MHz. The DDS AD9851 chip module is able to generate two types of waveforms, which are sine wave and square wave. Table 3 shows the sine wave and square wave (waveform is not shown) with output amplitude of approximately 1Vpp from DDS AD9851 measured using oscilloscope. From the data tabulated, the maximum frequency to generate a good sine wave is 60MHz, whereas the maximum frequency to generate a good square wave is 1MHz. These range of frequencies are suitable for the work in LoC.

Due to the output amplitude of generated sine wave is too low ($1V_{pp}$) shown in Table 3.3, an amplification and filtering circuitry is added to amplify the signal. Table 4 shows the comparison of the frequency response

Table 1
Summary of Control and Indicator used in DDS Signal Generation and Oscilloscope

Control /Indicator	*Types*	*Description*
Frequency, Phase	Numeric Control	Allow user enter desired values.
Reset, Generate	button	For reset DDS and generating output signal from DDS
Oscilloscope	Waveform graph	Display output waveform
volt/div, time/div, vertical position/div	Knob	Adjusting the waveform properties display in the oscilloscope
Vpp, Vrms, Frequency, Phase	Numeric indicator	Display measurement of signal acquire from oscilloscope
Get, Stop, AutoscaleVpp	button	Controls for acquisition process
Running mode in acquisition control	Selector button	Select the acquisition mode either run once or run continuously.
IP address	String control	Enter IP address for myRIO to make connection to PC.

Table 2
Summary of controls and indicators used in image observation under digital microscope.

Control/Indicator	*Types*	*Description*
Select camera source	Selector button	Select the camera source used in the system
Pixel gain	Numeric control	Adjust the threshold level of the image
Image	button	Enable the image acquiring process.
Is Motion Detected?	Boolean indicator	Indicate there is motion detected in the image
Original Image, Difference Image, Optical flow	Image screen	Displaying image captured from digital microscope.

plotted for DDS compared with the signals generated from Tektronix AFG 3022B function generator. From Table 4, the amplitude of the output waveforms from DDS AD9851 is constant at around 1.06Vpp for frequency until 1MHz. The amplitude start decrease slightly to 810mVpp when frequency increases to 10MHz and drop dramatically at 20MHz. Similarly, the output amplitude from Tektronix stable at 1.0Vpp for frequency until 20MHz and drop dramatically at 25MHz. The maximum frequency that can be generated from Tektronix AFG 3022B is 25MHz. The amplitude of the output signal can be adjusted maximum up to 20Vpp. However, the amplitude of signal decreases beyond 10MHz for both DDS AD9851 and Tektronix AFG 3022B.

Furthermore, as the frequency approaches to the cutoff frequency of the amplifier, the amplifier no longer amplifies signal at a constant gain. The amplifier gain decreases as frequency increases. The roll off of the frequency response is due to the load capacitance, C_L at the output of the amplifier. Theoretically, when the frequency increases, the reactance of C_L is decreased [9]. This results in a low resistant path to ground and hence some signal current is lost thus reducing the output voltage. When the operating frequency reaches the pole, the Bode magnitude will falls with a slope of -20dB/dec.

3.1. Output Measurements Using Myrio

The output scope can be displayed in GUI. The output can be measured and processed by using myRIO instead of oscilloscope. This can be done by acquiring the signal from Analog Input (AI) of the myRIO. Then, the signal is processed in LabVIEW and the graph is plotted as shown in Figure 5.

3.2. Image Observation Using Gui

In monitoring and controlling on LoC system, it is important to observe the reaction of particle after applying signal on LoC. The designed GUI imports an image from the portable digital microscope successfully as shown in Figure 5.

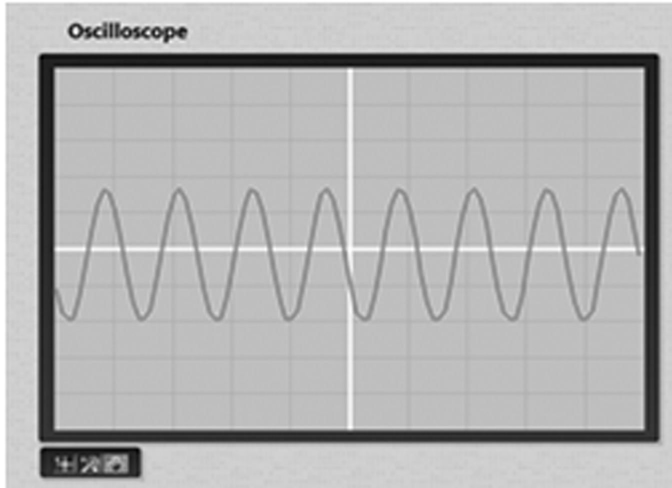


Figure4: Scope for displaying output measurements on GUI

Table 3
Observed output waveforms from DDS AD9851 using oscilloscope

Frequency	*Sine Wave*	*Square Wave*
10kHz	Amplitude: 1.06V_{pp}	Amplitude: 10.3V_{pp}
100kHz	Amplitude: 1.06V_{pp}	Amplitude: 10.3V_{pp}
1MHz	Amplitude: 1.04V_{pp}	Amplitude: 10.3V_{pp}
10MHz	Amplitude: 1.05V_{pp}	The highest frequency is 1MHz.
60MHz	Amplitude: 79mV_{pp}	The highest frequency is 1MHz.

Table 4
Comparison of amplitude before and after amplification between DDS AD9851 and tektronix AFG 3022B

Input Frequency (Hz)	*Amplitude (V_{pp})* *From DDS AD9851*	*After amplification*	*From Tektronix AFG 3022B*	*After amplification*
10	1.06	20.4	1.00	20.3
100	1.06	20.4	1.00	20.3
1k	1.06	20.3	1.00	20.3
10k	1.06	20.4	1.00	20.3
100k	1.06	20.1	1.00	20.3
1M	1.04	19.8	980m	20.1
10M	810m	2.37	900m	2.27
20M	560m	1.29	1.00	358m
25M	400m	900m	450m	300m
30M	351m	680m	N/A	N/A
40M	235m	260m	N/A	N/A
50M	187m	220m	N/A	N/A
60M	79m	69m	N/A	N/A

The original image is the image captured directly from the laboratory microscope. On the other hand, the difference frames is obtained by finding the difference between the current image frame and the previous image frame. It is used to detect motion changes between the current image frame and the previous image frame.

Figure 3.4: Image captured using digital microscope

4. CONCLUSION

Design, construction and experimental of LoC monitoring and control system are successfully developed and presented in this paper. The system has been in compact, portable and user-friendly solutions. It is successfully implemented using LabVIEW 2014 software and NI myRIO-1900. The system is able to generate AC signal maximum up to 60MHz and highest peak-to-peak amplitude is 20Vpp. The system is also allowing users to measure output waveforms within frequency and amplitude that are good up to 1MHz and 20Vpp respectively. The user-friendly GUI for this system is also implemented successfully. This includes user-friendly front panels to control and obtain the readings from oscilloscope and process images of reaction of particles operate on LoC.

ACKNOWLEDGEMENTS

This work was supported by GP-IBT/2013/9417600 Putra Grant under cluster Applied Sciences and Engineering (ASE), Universiti Putra Malaysia (UPM). It also supported by research group Micro and Nano Electronics System Engineering (MiNES) which involved two laboratories, Advanced Material Synthesis and Fabrication Laboratory (AMSF) and Microelectronic and Nanoelectronic Laboratory (MNL), Department of Electrical and Electronic Engineering, UPM.

REFERENCE

[1] Zheng, L., Brody, J.P. and Burke, P.J., 2004. Electronic manipulation of DNA, proteins, and nanoparticles for potential circuit assembly. *Biosensors and Bioelectronics*, *20*(3), pp.606-619.

[2] Yunus, N.A.M., Nili, H. and Green, N.G., 2013. Continuous separation of colloidal particles using dielectrophoresis. *Electrophoresis*, *34*(7), pp.969-978.

[3] Daw, R. and Finkelstein, J., 2006. Lab on a chip. *Nature*, *442*(7101), pp.367-367.

[4] Liu, Y., Oh, K., Bai, J.G., Chang, C.L., Yeo, W., Chung, J.H., Lee, K.H. and Liu, W.K., 2008. Manipulation of nanoparticles and biomolecules by electric field and surface tension. *Computer Methods in Applied Mechanics and Engineering*, *197*(25), pp.2156-2172.

[5] Allen, M.L., Aronniemi, M., Mattila, T., Alastalo, A., Ojanperä, K., Suhonen, M. and Seppä, H., 2008. Electrical sintering of nanoparticle structures. *Nanotechnology*, *19*(17), p.175201.

[6] Loucaides, N.G., Ramos, A. and Georghiou, G.E., 2008. Trapping and manipulation of nanoparticles by using jointly dielectrophoresis and AC electroosmosis. In *Journal of Physics: Conference Series* (Vol. 100, No. 5, p. 052015). IOP Publishing.

[7] Jiang, Y., Wang, H., Li, S. and Wen, W., 2014. Applications of micro/nanoparticles in microfluidic sensors: A review. *Sensors*, *14*(4), pp.6952-6964.

[8] Wei, T.S., Sulaiman, N. and Yunus, N.A.M., 2014, August. Dual control Direct Digital Synthesizer (DCDDS) for electronic testing and experimental work. In *Engineering Technology and Technopreneuship (ICE2T), 2014 4th International Conference on* (pp. 137-142). IEEE.

[9] Gray, P.R., Hurst, P.J., Meyer, R.G. and Lewis, S.H., 2008. *Analysis and design of analog integrated circuits*. John Wiley & Sons.