Droplet actuation on a digital microfluidic chip using a 5 volt battery

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ABSTRACT

The portability of Digital Microfluidics (DMF) platform explicitly depends on the portability of the high voltage, high frequency supply source used for droplet actuation. In this article, an DC to AC inverter driver circuit is designed and tested that can produce a high voltage high frequency AC output from an input of 5 volt DC supply source. The circuit starts with a timer block that produces a DC pulse signal from a 5 volt DC source. In the second block, the DC pulse signal was used to create an additional DC pulse signal with 180 degrees phase difference from the input. These two signals were used to drive two n-channel logic level Power MOSFETs. Finally, a Cold Cathode Fluorescent Light (CCFL) transformer was driven by the Power MOSFETs. The designed circuit is used to produce 340 V_{p-p} voltage with the frequency of 4.7 kHz out of 5 volt input DC voltage. The output voltage is applied to manipulate and split a droplet of DI water on the DMF platform.

Keywords: digital microfluidics (DMF), CCFL driving circuit, high voltage and high frequency, droplet splitting, droplet manipulation

1 INTRODUCTION

Demands for different biological and chemical assays is one of the major reasons for developing microfluidic systems that can perform biochemical laboratory functions in much cheaper and faster ways than conventional expensive and time consuming laboratory protocols [1]. Digital microfluidics (DMF) is a relatively new microfluidic platform that facilitates users with the ability to manipulate individual droplets on array of electrodes. DMF platform has several advantages over other microfluidic platforms as it is reconfigurable, programmable and needs small working sample [2-4]. Although the size of the DMF chip is in the order of few centimeters, the portability of the platform is still remained a challenge [3,5]. In fact, to actuate droplets on DMF, someone still needs to have a high voltage and high frequency supply [5]. This means, at least a signal generator followed by a high gain amplifier is required for DMF operation. Therefore, eliminating these bulky electrical devices is in demand to enhance the portability of the DMF devices.

In this paper we actuate a droplet on a DMF chip using only a 5 volt DC battery. This goal was achieved by designing and utilizing an inverter electrical circuit that uses a 5 volt DC battery as a supply voltage. The output of the circuit is a controllable high voltage, high frequency AC signal which can actuate a droplet on array of fabricated electrodes. All of the four major fundamental digital microfluidics operators, which are moving, dispensing, splitting, and merging, were successfully performed on DMF platform using this small driver circuit.

2 EXPERIMENTAL SETUP

The schematic diagram of the experimental setup is depicted in Fig. 1. A 5 Volt DC voltage is used as a voltage supply for the interface circuit. The interface circuit is designed to first innvert the DC voltage to an AC signal with a controlled frequency and then to boost the signal amplitude up to a desired high voltage required for droplet actuation on DMF platform. The output high voltage signal of the interface circuit is used to drive the DMF platform. In a typical DMF platform a high voltage AC signal is required where as the power required for running the DMF platform is in the order of microwatt.

3 ELECTRICAL CIRCUIT DESIGN

The schematic of the designed inverter circuit for manipulation of droplets on DMF platform is depicted in Fig. 2. The circuit starts with a timer block that produces a

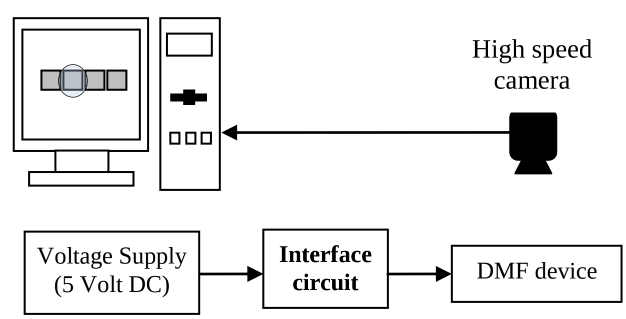

Figure 1. Schematic of the experimental setup.

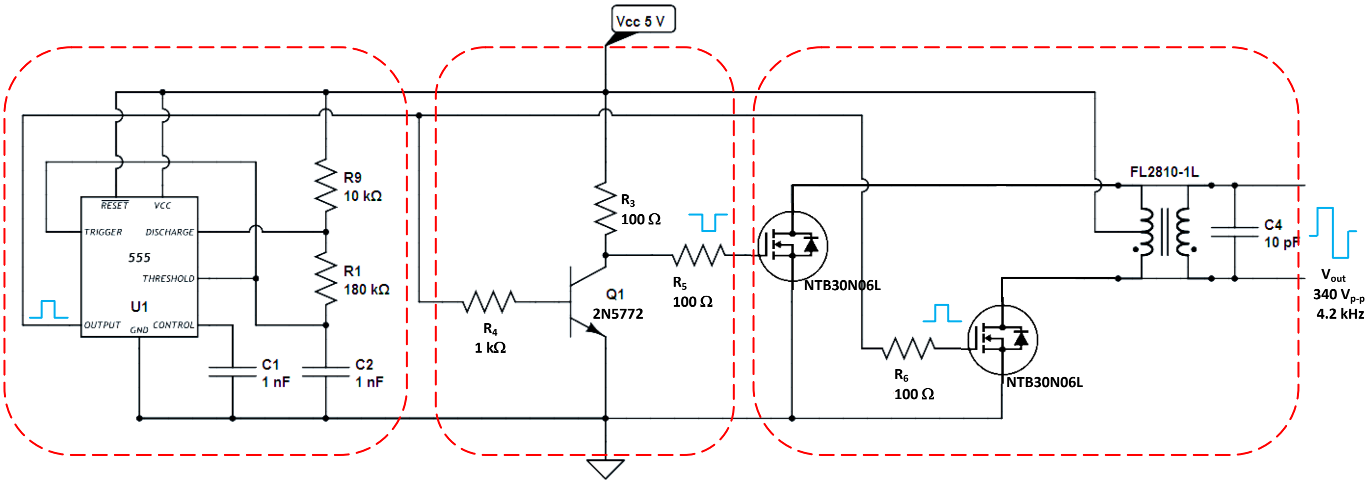

Figure 2. Schematic of the interface electrical circuit used for droplet actuation.

DC pulse signal from a 5 volt DC source. In the second block, the DC pulse signal was used to create another DC pulse signal with 180 degrees phase difference from the input. These two signals were used to drive two n-channel logic level Power MOSFETs. Finally, a Cold Cathode Fluorescent Light (CCFL) transformer was driven by the Power MOSFETs. The frequency and voltage at the secondary side of the CCFL transformer can be easily controlled by changing the capacitance values in the timer block. The values of the electrical components of the circuit shown in Fig. 2. are optimized for producing a 340 $V_{p\text{-}p}$, 4.7 kHz AC signal at the output.

4 FABRICATION PROCESS

The DMF device consists of two glass plates. The bottom plate is a copper coated glass slide on which the electrodes are patterned by photolithography. As dielectric layer, a thin layer of photoresist S1805 (MicroChem Corp.) was spin coated on top of the patterned electrodes at 2000 rpm for 60 seconds and was baked 30 minutes at 95 °C. A Layer of Teflon AF 1600 solution (Dupont) of a concentration of 1 wt% was then span coated on top as a hydrophobic layer at 2500 rpm for 60 seconds and baked for 2 hours at 95°C. An ITO coated glass slide covered by a Teflon layer (same as the bottom plate) is utilized as the top plate. The experiments were captured by an Apo-zoom microscope (Leica Z6 APO) equipped with a high speed camera.

5 EXPERIMENTAL PROCEDURE

The tests were done on an array of 5 electrodes, each of which has a surface area of 2 mm × 2 mm. The applied potential is set to have a frequency of f = 4.7 kHz with the amplitude of 340 $V_{p\text{-}p}$. The gap between the two plates is fixed with a par of spacers with the size of h = 200 µm. For all experiments a DI water droplet is dispensed on the array of electrodes on the bottom plate and the top plate is placed on the top of them over a pair of spacers. Two different volumes of 1.2, and 0.8 µL are considered for droplet transport on DMF. The electrodes are sequentially actuated to manipulate the droplet toward each electrode.

In the case of splitting, 1.2 µL DI water is dispensed on the chip. Then the droplet is transported to the middle (third) electrode. Finally, the two side electrodes are actuated for 0.5 s. The experiment is repeated 5 times for each case.

6 RESULTS AND DISCUSSION

The DI water droplet is readily manipulated on the DMF chip with using a 5 volt DC source and the designed interface circuit (shown in Fig. 2). Fig. 3a shows the snapshots of a 0.8 µL droplet transport on an array of electrodes. Splitting of a 1.2 µL DI water droplet is performed on the same array of electrodes. The voltage is applied to the two side electrodes for 0.5 sec. As a result, the original droplet splitted to two daughter droplets. The snapshots of droplet splitting is shown in Fig. 3b.

7 CONCLUSION

Droplet manipulation and splitting was achieved with a 5 volt DC battery. A simple inverter circuit is designed to change the low DC voltage (5 volt) to a high AC voltage (4.7 kHz with the amplitude of 340 $V_{p\text{-}p}$). The designed circuit has three main blocks. In the first part a timer block is designed to create a DC pulse signal with desired frequency. In the second block, the DC pulse signal was used to create another DC pulse signal with 180 degrees phase difference from the input. These two signals were used to drive two n-channel Power MOSFETs. Finally, a Cold Cathode Fluorescent Light (CCFL) transformer was driven by the Power MOSFETs.

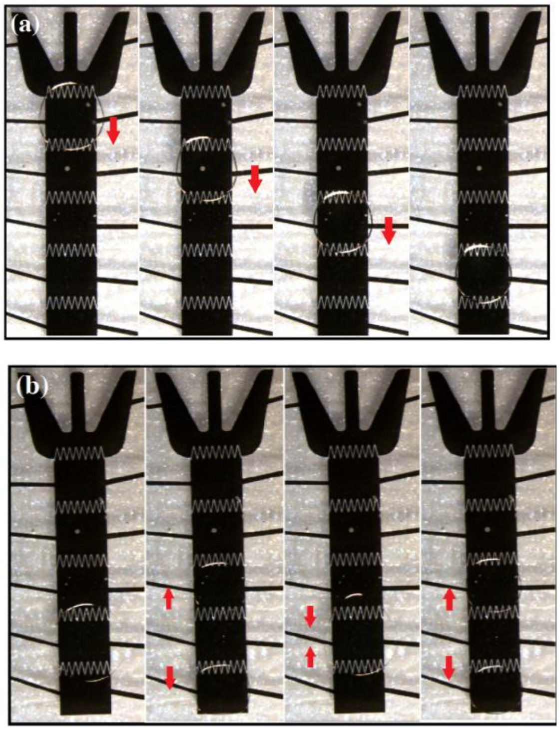

Figure 3. Actuating a DI water droplet using a 5-volt DC battery (a) moving the droplet on an array of DMF electrodes, (b) splitting the droplet into two sister droplets.

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