Measurement of Smart Driver on Thermal Bubble Inkjet Printhead

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Abstract

This paper describes the measurement of thermal inkjet driver chip has a number of uses in the technology: D-Flip Flop logic control circuit on printhead verify for addressing nozzles by de-multiplexer FPGA device pre-check, high voltage NMOS driver characteristic by HP4145B instrument, OES/ITRI setting design goals to monitor droplet orbit, the stream of frozen images was then acquired by a CCD camera, the evolution of droplet velocity for different time frames, droplet trajectory provides an overall picture of the droplet ejection trajectory, while the droplet ejection sequence provides the more detail evolution of droplet formation and ejection. Droplet properties, such as ejection speed, droplet size, directionality, satellite droplets, flying distance and frequency response, we introduce some of the data showing current trends in thermal inkjet performance and life. The droplet ejection of our multiplexer printhead with 12 um diameter diameter nozzle has been characterized at a frequency over 19.8 kHz, 5 pL of ejected droplet volume.

Introduction

The Integrated Multiplexer and Driver on inkjet Head (IMDH) measurement block of the multiplexer inkjet chip as shown in Figure 1. There are three important parts, first part is a multiplexer block, logic function process for addressing jets in this block. In general, the function work the same as multiplexer in digital integrated circuits. Each such combined structure (complex logic gate) can be realized in CMOS as follows: the AND terms are implemented by series-connected NMOS transistors, and the OR terms are implemented by parallel-connected NMOS transistors. The input variables are applied to the gates of the NMOS (and the complementary PMOS) transistors. Thus, the multiplexer part of inkjet head is consist of nested series-parallel connections of NMOS and PMOS. The multiplexer circuit of inkjet chip have to a serious in – parallel out function. D-Flip Flop logic control circuit on printhead verify for addressing nozzles by de-multiplexer FPGA device pre-check, and logical analysis. second part is a high voltage driver block. The high voltage NMOS driver measurement by HP4145B instrument. third part is a droplet ejection observation.

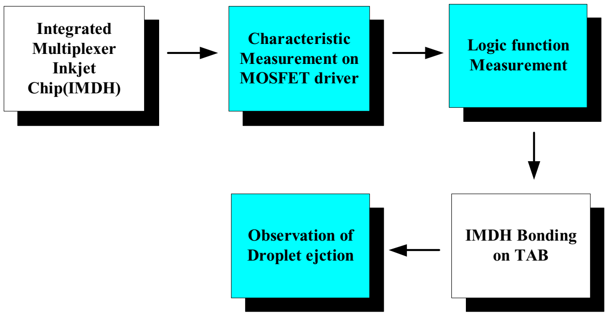


Figure 1. Measurement block of the multiplexer inkjet chip

The thermal micro-actuator used in ink jet printheads is the world's most successful micro-system, it is sold million times.[1] It offers a high potential in a large area of other applications where micro-dosing of different liquids is required. A detailed understanding of the dynamics of the thermal printhead is relevant for further improvement of this micro-actuator. A short heating pulse drives a micro-heating element and heats a thin liquid layer on the heater up to the thermodynamic limit of superheating of the liquid, the socalled spinodalian limit, within a few microseconds.

Then, the liquid evaporates explosively and the expanding bubble accelerates the liquid column above the heater and ejects a droplet through a nozzle with a diameter of approximately 15µm. The boiling can be understood as phase transition of second order.[2] In the case of water and ink the spinodalian limit is approximately 300°C. For many other applications, e.g. the ejection of fuel in engines or the injection of drugs in minimal invasive surgery, droplet ejection against overpressures or hydrodynamic pressures is necessary. The dynamic model allows the evaluation of the potential of such thermal micro-actuators. For the complex dynamics in this micro-system rigorously expressed by nonlinear partial differential equations a state space representation was derived using integral methods. Despite of the model reduction the state space representation contains all important physical effects. This description is possible because all less significant influences are neglected. The input function of the model is the heating power. The thermal diffusion, the thermodynamics of the bubble, the conservation of energy, and the flow of the liquid column have been taken into account.

The droplet ejection of our multiplexer printhead with 12 um diameter diameter nozzle has been characterized at a frequency over 19.8 kHz, 5 pL of ejected droplet volume.

Measurement

The multiplexer inkjet chip include a high power voltage driver to drive thermal micro-actuator. The high voltage NMOS driver measurement by HP4145B instrument. The breakdown voltage is beyond 12 V as shown in Figure 2 the V_{TH} (sub-threshold) is 1.2V as shown in Figure 3.

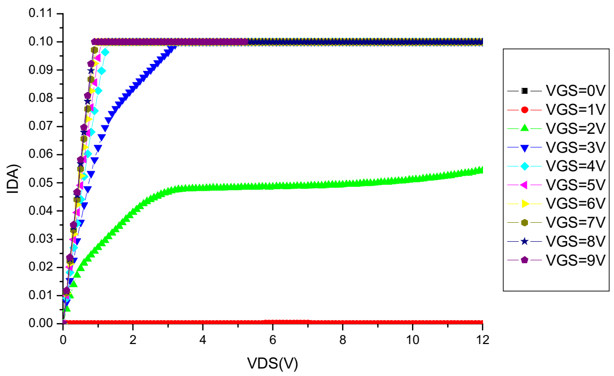


Figure 2. Output characteristic of a enhancement-mode n channel MOSFET drive

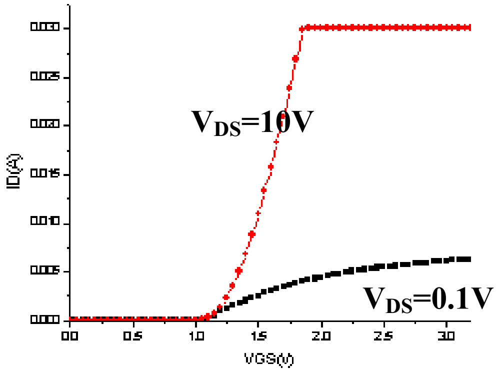


Figure 3. V_{TH} (sub-threshold) of a enhancement-mode n channel MOSFET drive

The control circuit on printhead verify for addressing nozzles by multiplexer logic simulation (Figure 4.). The integrated multiplexer and inkjet printhead.There are four kinds of printing tape, type 1 is a sequence for Nozzle 1、2、3、…up to Nozzle n, type 2 is a sequence for Nozzle n、(n-2)、(n-4)、…down to final Nozzle 2, type 3 is a sequence for Nozzle 1、3、5、…up to final Nozzle, type 4 is a sequence for Nozzle (n-1)、(n-3)、(n-5)、....down to final Nozzle 1, The ASIC design for the smart chip have to simulate the function work, we used FPGA verify.

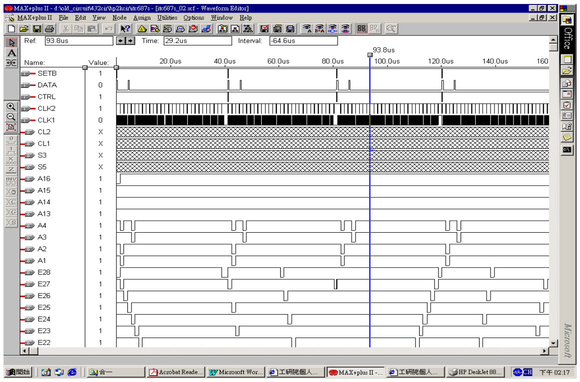


Figure 4.The multiplexer logic simulation

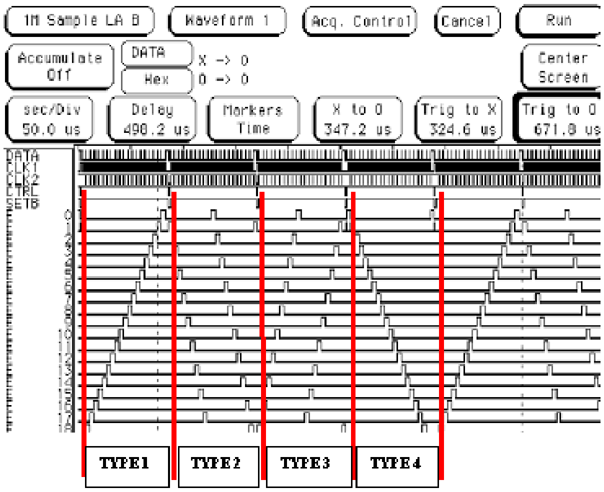


Figure 5. The Logic Analysis signal

In the Logic Analysis equipment, we observe the ASIC input and output relationship is shown in Figure 5. The input signal include "DATA、CLK1、CLK2、CTRL、SETB" and output signal is match ASIC design waveform. The ASIC design and logic analysis result is matched. From the verify measurement, the CMOS logic circuit is success in the inkjet chip.[3]

By identifying the model with measurements of the movement of the ejected liquid column realized with high speed cine photomicrography the calculation of the pressure propagation in the bubble was performed and is presented in this paper. The ejection was generated by a heating pulse with a length of 3µsec and an amplitude of 7.5W. Investigations of the nucleation process in the ink chamber show that the nucleation starts 3.1µs after the beginning of heating. The visualization of the droplet ejection can be seen in Figure 6. A short heating pulse drives a micro heating element and heats a thin liquid layer on the heater in less than 3usec up to more than 300°C. At a normal pressure of 1 bar water reaches the thermodynamic limit of superheating, the so-called spinodalian limit, at a temperature of approximately 312°C. Water has been used as the fluid for all experiments reported here. When a fluid reaches the spinodalian limit the liquid evaporates explosively.[4,5] The expanding bubble accelerates the liquid column above the heater and ejects a droplet through a nozzle with a diameter of 12 um.

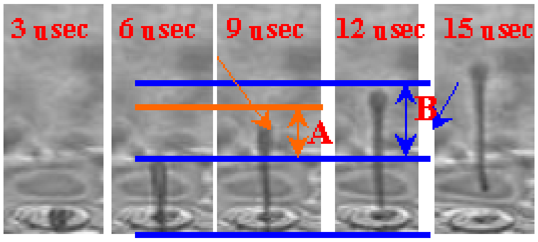


Figure 6. Visualization of droplet ejection

The quantifier used in the expression of length A during 6usec~9usec, The difference droplet aviation length B during 6usec~12usec--the difference length value of the droplet, it is also called an average speed for this area.

The visualization has been performed with pseudo-cinematography. This method is based on the stroboscopic principle and can be applied to reproducible transient processes like the droplet ejection of an ink jet printhead in the first 10μs after beginning of heating. The top surfaces of the droplets can be connected by a straight line; consequently, the velocity *v* of the droplet surface is constant, *v* = 10 m/s. Considering that the liquid starts cutting off at 5 μs it follows that there is a sub-pressure at this time-point in the bubble. Consequently, the time duration of acceleration of the liquid column is between 3.1 μs and 5 μs. The height of the liquid column 4 μs after the beginning of heating can also be extracted from the cinematographic image sequence and is 12.3 μm. The measurements have been performed with a integrated multiplexer inkjet head and bidistilled water has been used to have adequate values for material properties available.

To capture droplet orbit for ink observation, Figure 7 droplet orbit for ink observation-vertical and level rectify, enter ink jet head control program, select drop nozzle and supply the sequence for injection drop, and regulate LED delay time, droplet frequence, and heat time, then modulate the a observation flat-top building to a suitable position, to approve from droplet observation to catch droplet orbit phenomenon. The measurement system could calculate the droplet area, blob length, droplet injection position.

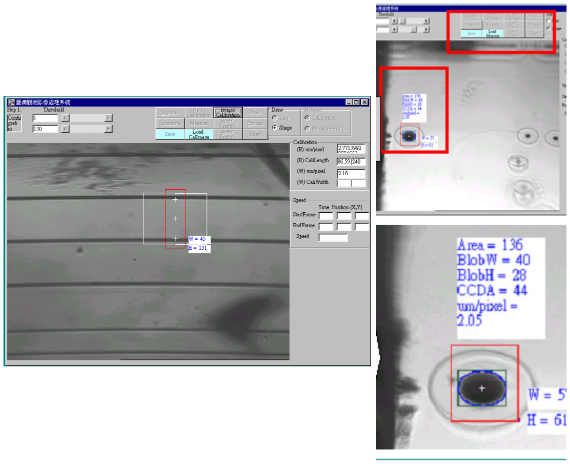
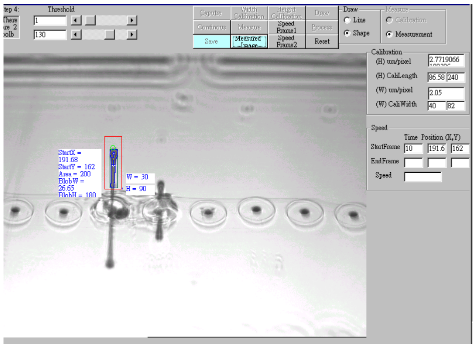


Figure 7. Droplet orbit for ink observation-vertical and level rectify

Observation and Results

OES/ITRI setting design goals to monitor droplet orbit, the stream of frozen images was then acquired by a CCD camera, the evolution of droplet velocity for different time frames, Figure 8 droplet orbit for ink observation-droplet calculate.



Threshold: 1, 130

(H) um/pixel 2.7719066
(H) CaliLength 86.58 240
(W) um/pixel 2.05
(W) CaliWidth 40 82
StartFrame 10 191.6 162
EndFrame
Speed

StartX = 191.68
StartY = 162
Area = 200
BlobW = 26.65
BlobH = 180
W = 30
H = 90

Figure 8. Droplet orbit for ink observation-droplet calculate

Firing frequency 16kHz of integrated logic function inkjet chip, The visualization of the droplet ejection can be seen in Figure 9. Because the temperature rise is so fast, only a very thin layer of the ink that is in contact with the resistor heats up with it. As that fluid reaches its boiling temperature any small air bubble trapped on the surface will start to grow. However, around the bubble the ink is still heating. When it reaches its superheat temperature limit, the ink can no longer exist in the liquid state because of thermodynamic instability. The ink rapidly vaporizes, creating a pressure wave that acts like a piston to fire the slug of ink in the chamber (with you entrained within it) out of the chamber and through the exit orifice. As the ink slug leaves, air rushes in around it, filling the space that had been occupied by the ink. The air rushes around the ink droplet as the tail breaks off and the ink remaining in the chamber reforms to produce a meniscus, or an air-to-ink interface, which connects by surface tension to the smooth inner walls of the exit orifice.

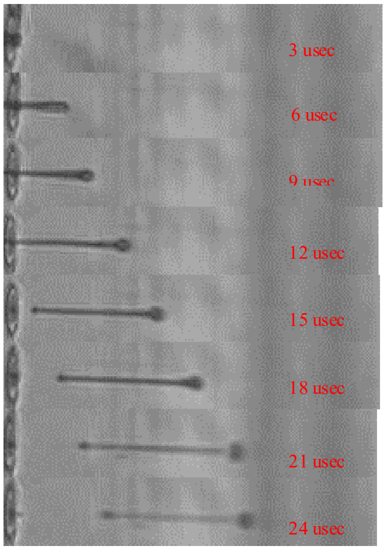


Figure 9. The visualization of the droplet ejection

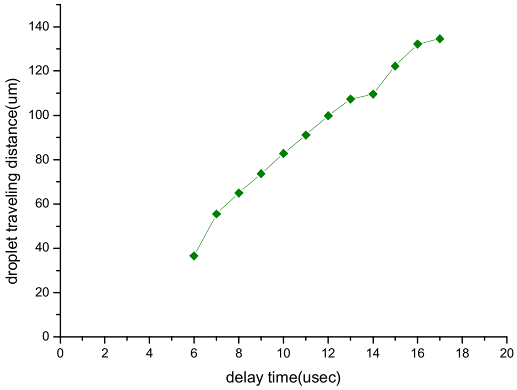


Figure 10. Nozzle A droplet traveling distance(um) to delay time (μsec) sketch

Figure 10 shows Nozzle A droplet traveling distance (μm) to delay time (μsec) sketch, shows the image of simultaneously ejected ink droplets in the nozzle A fired at 16kHz. A good uniformity of drop speed is observed in the figure, however degradation of performance due to heat accumulation was observed. Figure 11 shows Nozzle A instant velocity (m/sec) to instant time (μsec) sketch. This multiplexer ink-jet shows stable ejection characteristics such as drop volume of 5pl and velocity of 10m/s up to 19.8 kHz.

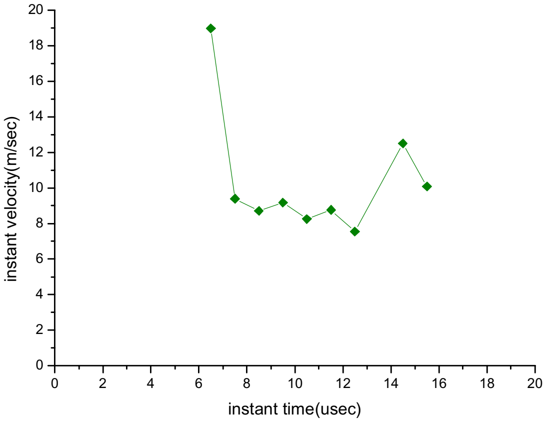


Figure 11. Nozzle A instant velocity (m/sec) to instant time (usec) sketch

Conclusion

The multiplexer inkjet printhead different from tradition only MOS driver on printhead is logic circuit in printhead. So, we must to measurement the serious in-parallel out signal. The number of lines is material in terms of cost and high-density integration of a inkjet head substrate, and a small circuit scale is desirable in order to reduce the area of a chip and to reduce the heat generated as a result of power consumption. However, if the number of input signal lines is reduced by sharing functions and address lines with one another, a decoding circuit will become necessary, thereby resulting in a larger circuit size. Further, the speed of print processing will decrease as a result of decoding operations. In the case of double pulse driving operations, or in the case of insertion of a pulse for driving other heat-generating elements during the interval between the pre-pulse and the main pulse, it will become more difficult to reduce the number of wires.

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Biographies

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