Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.316-317

D-6-3

# A stochastic computing chip for measurement of Manhattan distance

Michihiro Hori[1,a], Michihito Ueda[2] and Atsushi Iwata[1,b].

[1]Graduate School of Advanced Sciences of Matter, Hiroshima University
1-3-1 Kagamiyama, Higashi-Hiroshima-shi, Hiroshima 739-8530, Japan
[a]Tel and Fax: +81-824-22-7358, E-mail: [a] chiro@hiroshima-u.ac.jp, [b] iwa@dsl.hiroshima-u.ac.jp
[2]Advanced Technology Research Laboratories Matsushita Electric (Panasonic) Industrial Co., Ltd.
3-4 Hikaridai, Seika-cho, Soraku-gun, Kyoto 629-0237, Japan
Tel : +81-774-98-2516, Fax:+81-774-98-2515, E-mail: ueda.michihito@jp.panasonic.com

## 1. Introduction

Future technologies will enable to fabricate so small transistors. And electromagnetic noise will affect these transistors seriously. Therefore, conventional deterministic computing system might not be driven correctly. As a way to avoid these problems, stochastic computing systems have been studied [1]. This prominent property is utilization of random noise that is generally regarded as a waste product. Stochastic computing system can execute computing using the representation of analog quantities by pulse densities with random signals. Especially, in the case we don't need complete accuracy of computation, stochastic computing can implement computation efficiently and has the capability of trading off computation time and accuracy without changing hardware. From these viewpoints, the concept of measurement of Manhattan distance based on stochastic computing system was proposed [2]. In this paper, we propose a circuit utilizing arbitrary chaos generators to produce pulse events representing Manhattan distance, and we design a stochastic computing chip for measurement of Manhattan distance.

## 2. Stochastic calculation of Manhattan distance

Firstly, We illustrate the concept of stochastic measurement of Manhattan distance based on stochastic computing system. This system is shown in Fig. 1. This system consists of double comparators and exclusive-OR (EXOR). Input data, which is constant, is compared with random signal value. And reference data, which is constant, is also compared with random signal value. Both of output pulses are injected into EXOR synchronously. Counting output pulses of EXOR, we can calculate the Manhattan distance between input data and reference data. It must be noted that random signal values are distributed uniformly because we would like to relate the number of pulses to Manhattan distance proportionally.

Next, we describe the circuit of stochastic measurement of Manhattan distance based on stochastic computing system. We show the block diagram of the circuit in Fig. 2. We utilize PWM arbitrary chaos generator circuit, which has already been proposed in [3], for generating random signals. And we choose tent mapping because the chaos signals from tent mapping are distributed uniformly. Then we produce analog voltage of tent chaos signals using a switched current source circuit. And to inject outputs from comparator A and B into EXOR simultaneously, we utilize a clock driver and a sampling driver. Accordingly, we can calculate Manhattan distance by counting output pulses of EXOR.

## 3. Chip design

The stochastic computing circuits utilizing arbitrary chaos generator circuits were designed in a 2-poly 3-metal 0.35 mm CMOS technology. The chip layout is shown in Figure. 4. This chip includes 16 circuits based on stochastic computing system. The chip size is 4.9 × 4.9mm sq. The area of a comparator-EXOR part is 85.5 × 165um sq and the area of a chaos generator is 62.5 × 80.5um. The supply voltage is 3.3V and the average power dissipation for one stochastic computing circuit is about 0.4mW.

## 4. Simulation results

We confirmed the operation of the circuit of stochastic computing system using HSPICE simulation. In this simulation, we assumed one stochastic computing circuit and clock frequency of 1MHz. Waveforms of stochastic computing system are shown in Fig. 5. We can see that an output pulse of EXOR appears when the analog value of chaos signal is between the analog value of input data and that of reference data. And we show the linearity of mappings from Manhattan distance to the number of output pulses of EXOR in Fig. 6. The number of output pulses of EXOR is normalized. We can see that the mapping from Manhattan distance to the number of output pulses is implemented efficiently when the number of total steps is more than about 100.

## 5. Conclusions

In this paper, we proposed the architecture of stochastic computing system that implements linear mappings from Manhattan distance to pulse density utilizing chaos generator circuit. We confirmed that stochastic computing system execute this mapping efficiently when the number of total steps is more than about 100.

A stochastic computing chip can be used as an emulator of a future quantum device thanks to stochastic operation. Therefore, these operating systems are also useful for discussing future quantum devices.

## Acknowledgements

The VLSI chip in this study has been fabricated in the chip fabrication program of VLSI Design and Education Center (VDEC), the University of Tokyo in collaboration with Rohm Corporation and Toppan Printing Corporation.


## References


[1]B. R. Gaines, “Stochastic Computing Systems,” Advances in Information Systems Science, J. F. Tou, ed., vol. 2, chapter 2, pp. 37 – 172, New York: Plenum, 1969.

[2] M. Ueda et al., "A processor designed for the fast approximation of Manhattan distance using stochastic computing system," Proceedings of the 2005 IEICE General Conference, A-1-11, March 2005 (in Japanese).

[3]K. Murakoshi et al., “ An Arbitrary chaos generator core circuit using PWM/PPM signals,” Asia and South Pacific Design Automation Conf., pp.23-24, 2000.


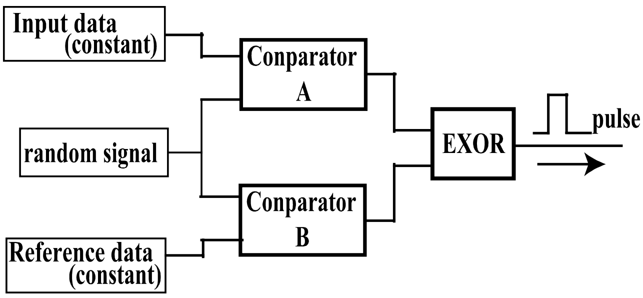


Fig. 1. Stochastic computing system for measurement of Manhattan distance.

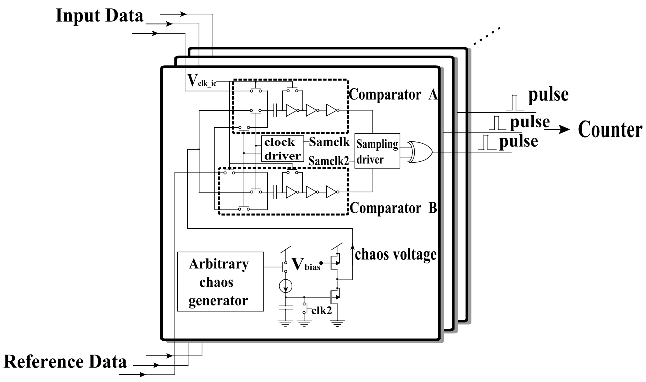


Fig. 2. Circuit based on stochastic computing system

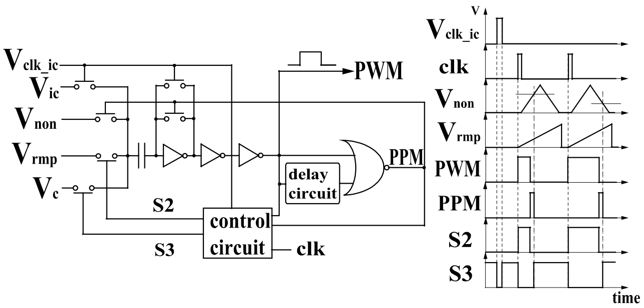


Fig. 3 Arbitrary chaos generator circuit

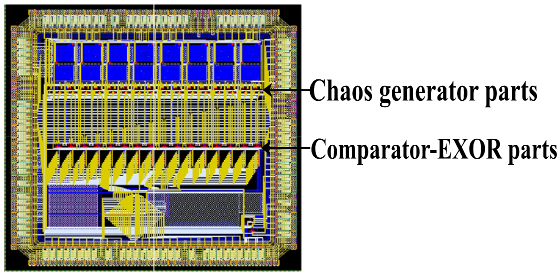


Fig. 4. The chip layout of a stochastic computing chip (16units)

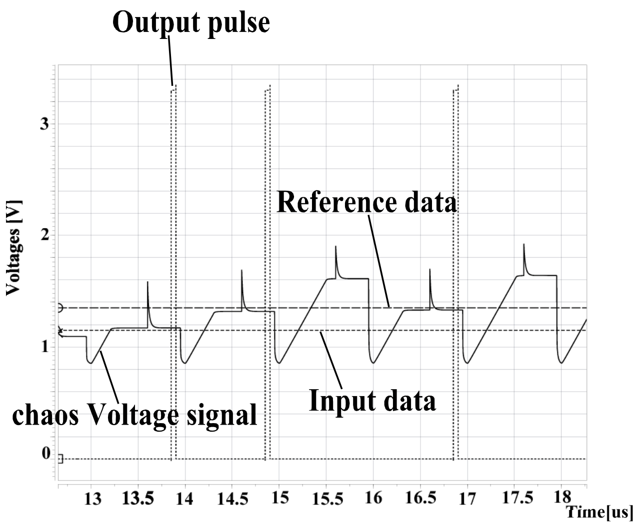


Fig. 5. Waveforms of stochastic computing system for Manhattan distance in HSPICE simulation.

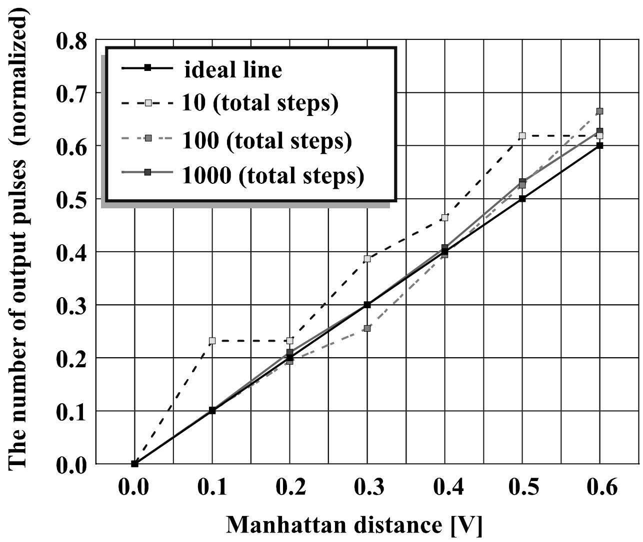


Fig. 6. HSPICE simulation results of measurement of Manhattan distance based on Stochastic computing system utilizing tent chaos signal.