Voltage control considering the chip temperature in the three-dimensional stacked multi-core processors

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1 Introduction

Cube-1 was developed as a prototype of the building block computing system that can be rearranged flexibly for its usage. It is consisting of multiple chips stacked by inductive coupling wireless interface. Heat dissipation is one of the most serious problems in such a chip stack connected with wireless links. Unlike TSV which can be used for heat dissipation for intermediate chips, wireless links cannot be used a heat inductors and so the temperature of chips sandwiched with other chips is easily increased.

Here, we control the supply voltage of each chip by using the leakage monitor attached to each chip. Also, the measured temperature is used to improve energy efficiency of the chip by decreasing the margin of the supply voltage.

2 Cube-1

Cube-1 is a prototype heterogeneous multiprocessor using inductive coupling wireless TCI (Through Chip Interface)[1]. As shown in the photo of chip stacking (Fig. 1), a host CPU, Geyser-Cube and multiple accelerator chips called CMA-Cubes are stacked.

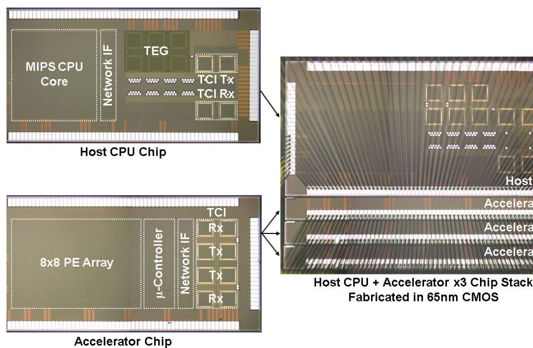

Figure 1: Picture of the chip stacking

The host Geyser-Cube is placed at the top, since more number of bonding wires can be used. It is a MIPS-R3000 compatible CPU core. This chip manages I/O and communication between accelerators as well as contriving the supply voltage of other chips. CMA-Cubes are placed from the second layer to the fourth layer. It is a reconfigurable accelerator which is consisting of two parts, PE Array and μ-controller. They are connected by an NoC (Network-on-Chip) using the wireless inductive coupling links.

3 Voltage control considering the chip temperature

Instead of common temperature monitors using diode, each chip of Cube-1 provides a leakage monitor to measure the leakage current[2]. We have measured the relationship between the chip temperature and the value of the leakage monitor. As shown in Fig. 2, the value from the leakage monitor can be used for measuring the temperature of each chip.

Next, we also measured the delay of CMA-Cube at each chip temperature. Like other chips, the operational speed of CMA-Cube is designed with some margin so that it can work even at the high temperature. By checking the chip temperature from the value of the leakage monitor, we can improve the energy efficiency by setting the optimal voltage to the chip temperature for each. The optimal supply voltage and delay is shown in Fig. 3.

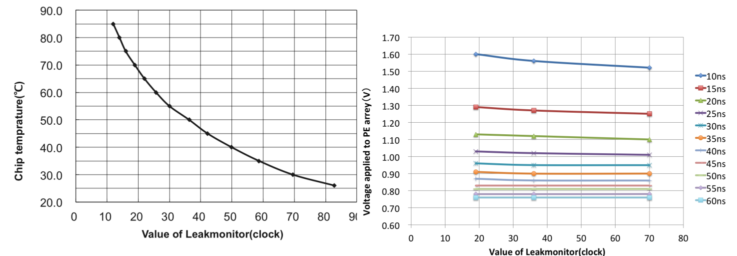

Figure 2: Temperature VS Leakage monitor

Figure 3: Optimum voltage of each chip temperature

From these results, a flowchart of the voltage control considering the chip temperature can be drawn as shown in Fig. 4.

First, the value of the leakage monitor is checked. If the value is larger than a limit, the power supply of the CMA-Cube must be shut off in order to save the chip. Then, the value of the leakage monitor is checked again after a few minutes. If the value shows the normal temperature, the optimum supply voltage of each chip temperature is applied. This loop is iterated until the end of calculate.

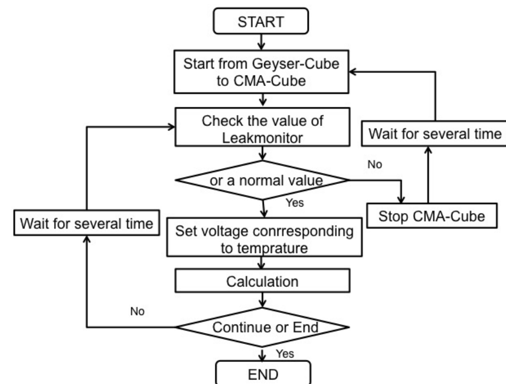

Figure 4: Voltage control flowchart

4 Conclusion

A voltage control method for three-dimensional stacked multi-core processors is proposed.

By examining the relationship between the chip temperature and leakage monitor, it can be used as a temperature sensor. Then, the delay time of each chip temperature is measured and optimum voltage for each hip temperature is calculated. By using the proposed control, the energy efficiency can be improved by 5% at maximum.

References

[1] N.Miura, et al. "A-Scalable 3D Heterogeneous Multicore with an inductive ThruChip Interface", *IEEE Micro, Vol.33, No.6 6–15, 2013.*

[2] K.Usami, et al. "On-Chip detection methodology for break-even time of power gated function units", *Proc. of the International Symposium on Low Power Electronics and Design (ISLPED), 241–246, 2010*