Data Conversion Controller for Ink Jet Printing

Pey-Huey Chen and Hui-Huang Chang
Printing Technology Dept., Electro-Photography Technology Div.,
**Opto-Electronics and Systems Laboratories*
Industrial Technology Research Institute, Taiwan, R.O.C.

Abstract

An effective and flexible data conversion controller for ink jet printing is proposed in this paper. It provides the capability of processing firing data to meet the requirements of both firing sequence and firing timing of the cartridge. The print data is arranged according to the nozzle layout of a selected print cartridge and the printing direction. Then output the arranged data to the firing driver of print cartridge.

A hardware architecture is proposed to serve the needs of data conversion. It is an effective design that consists of two appointed selections of nozzle firing sequence and fixed nozzle pad mapping. Moreover, the proposed architecture provides programmable firing timing and it can be switched between black or color printing mode. The core technology of this data conversion hardware is now applied to an ASIC of ink jet fax engine by OES/ITRI*.

1. Introduction

With increasing demands of plain paper printing output, the ink jet printing market is growing rapidly. For ink jet printing, the key technologies are the ink jet firing data conversion control and the print cartridge motion control. In the last decade, this controller was implemented by a CPU such as 8051 with complicated firmware programs and peripheral hardware circuits [1], [2] and [3]. Such implementation takes a heavy CPU loading and causes multi-CPU design in a Multi-Function Peripheral (MFP) system . The main disadvantages are high cost, hard to promote the printing speed, and difficult for productivity. For this reason, a single chip controller design for ink jet printing was proposed to provide the mentioned functions and to overcome these disadvantages.

The single chip controller consists of a firing data conversion controller, a print cartridge motion controller and a paper feed controller. The hardware design of data conversion controller is interested in this paper. In this paper, a new type of hardware architecture is proposed to serve the needs of data conversion. This type of hardware architecture is designed for the circumstance of limited gate count.

The rest of this paper is organized as follows. Section 2 introduces the architecture of a printing controller. Section 3 discusses the data conversion implementation and the associated conversion algorithm. Section 4 concludes this paper and introduces the future work.

2. A Printing Controller

The architecture of ink jet printing controller is shown in Figure 1. As illustrated in Figure 1, the printing controller consists of a 68000 microprocessor system and an integrated print module. The microprocessor system provides the needs of data pre-processing for print module and the capabilities of fax, scan, copy and print in a MFP system. The print module consists of several individual sub-modules for ink jet printing control as shown in the shaded area in Figure 1. A brief description of these modules is introduced as follows.

The print module control unit supervises the operation of each module and handshakes with the peripheral interfaces. The cartridge motion controller serves the needs of printing speed control and records the cartridge position. The data conversion module process printing data in SRAM and sort printing data based on the selected print cartridge, then print out these data according to the position of the print cartridge. And, the stepping motor control module handles the paper feeding of ink jet printing output.

In printing mode, the print module control unit supervises the whole printing process and provides the associated control signals to data conversion controller

- line start,
- fire start,
- direction,
- address Bus, Data Bus, w/r, clock, and reset.

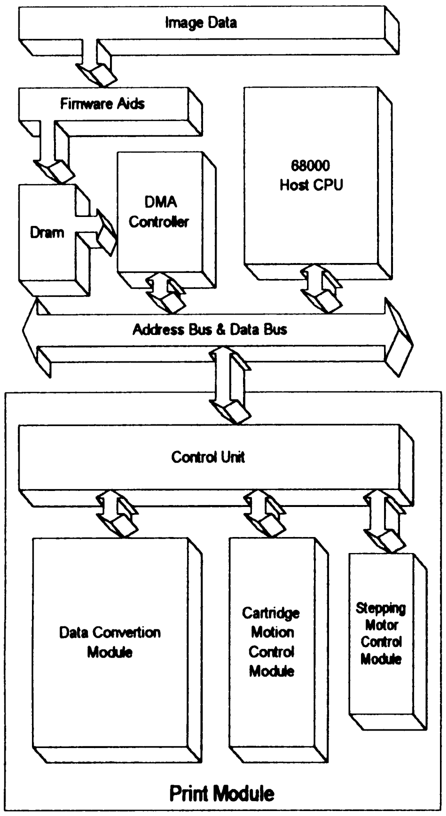

Figure 1. Architecture of ink jet printing controller

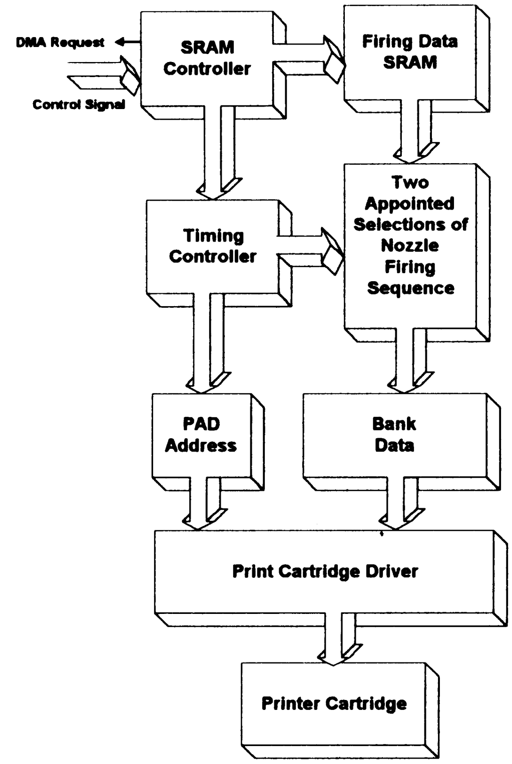

Figure 2. Data Conversion Control Module Architecture

Where 'line start' means the beginning signal when the cartridge start to move in printing mode. 'fire start' means the signal which indicates to fire printing data. 'direction' means the signal which indicates the cartridge moves forward or backward. The rests are system control signals. The architecture of the data conversion control module is shown in Figure 2.

Typically, the image of a document is stored in memory line by line horizontally. However, the print cartridge prints data vertically with complicated nozzle arrangement. In this printing architecture, the rearrangement of image data from horizontal to vertical is implemented by firmware programs with a hardware barrel shifter to speed up the process. The conversion algorithm will be discussed in section 3. The arranged printing data is then stored in DRAM. When the rearrangement procedure is completed and a DMA request signal is sent from the data conversion module, the DMA controller fills printing data into the firing data SRAM in the data conversion module.

Before the 'fire start' signal is triggered, a firing data SRAM controller reads printing data from SRAM and shifts them serially to shift registers. According to the two types of appointed nozzle firing sequence selections, firing data is mapped and latched to firing registers when the 'fire start' signal is triggered. Then a sequence of firing pulse is generated to complete the printing process.

3. Data Conversion Control Module

In this section, the data conversion algorithm and a practical implementation of data conversion controller are discussed.

Data Conversion Algorithm

Consider a print cartridge contains n nozzles. The nozzles are divided into two groups: even nozzles and odd nozzles. A fixed distance D between these two groups are illustrated in Figure 3. Therefore, dots fired by even nozzles or odd nozzles should be shifted in order to print a vertical line. The number of shift dots depends on the printing resolution. Assume that there are m dots between these two groups, m is given by

$$m = D(inch) \times dpi \, .$$

As the vertical line show in Figure 3, where black nozzles fired on i-th and white nozzles fired on $(i + m)$-th.

Therefore, a barrel shift is required to align the printing data shift caused by m. For example, if the m equals 7 and a printing line contains x bytes of data, then the image data processed for forward printing and backward printing should be expressed as the format shown in Figure 4.

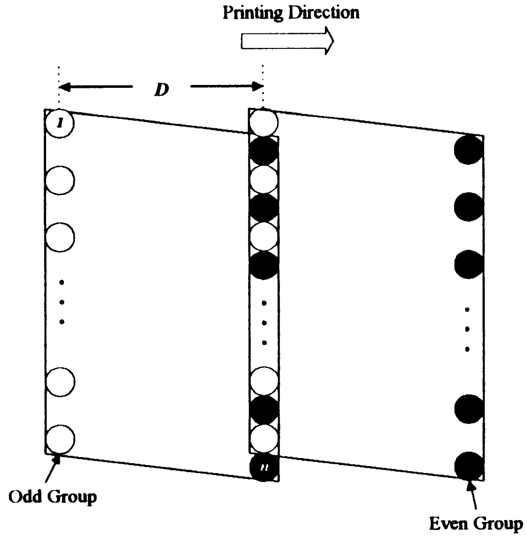

Figure 3. Print Cartridge Illustration

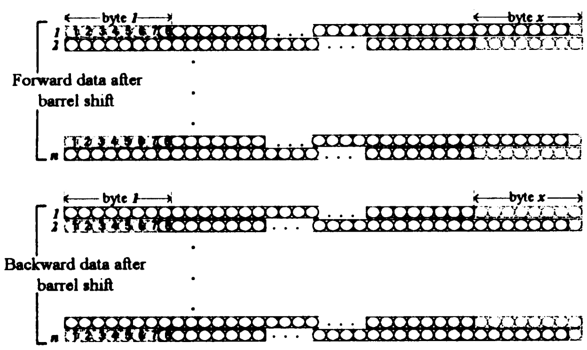

Figure 4. Forward and Backward Image Data Processed After Barrel Shifter

byte 1.1	byte 1.2	. . .	byte 1.x
byte 2.1	byte 2.2	. . .	byte 2.1
.	.	.	.
byte n.1	byte n.2	. . .	byte n.x

byte 1.1	byte 2.1		byte n.1
byte 1.2	byte 2.2	. . .	byte n.2
.	.	.	.
byte 1.x	byte 2.x	. . .	byte n.x

Figure 5. Printing Data Rearranged by Firmware

As discussed in section 2, the data conversion SRAM is filled with the printing data by a DMA controller. Since the DMA controller accesses DRAM data byte by byte sequentially, the printing data in DRAM should be rearranged to a vertical arranged format by firmware before DMA accesses data. Figure 5 illustrates the result of data rearrangement.

Practical Implementation

Figure 6 illustrates the detailed structure of the data conversion module. Suppose that a host CPU accesses data with 16-bits width. Consider the case that a sequence of DMA request, as shown in Figure

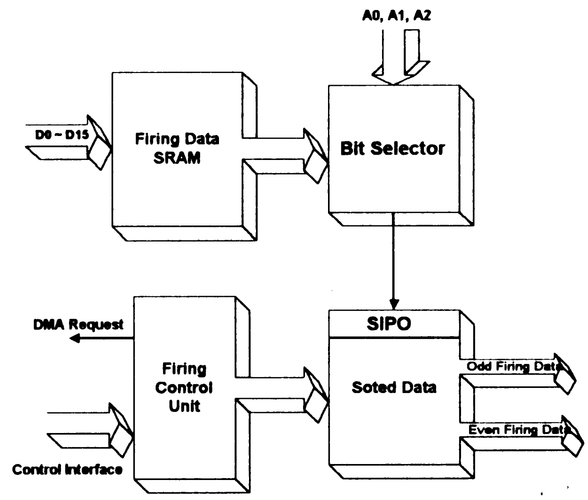

Figure 6. Detailed Structure of Data Conversion Module

7, is sent from the data conversion module to a DMA controller, to ask for filling the printing data into the 'firing data SRAM'. Then the action of data conversion is described as follows.

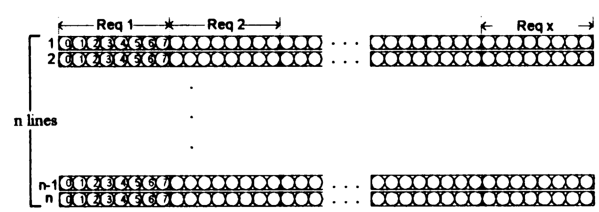

Figure 7. An Illustration of Request Signal

When a 'line start' signal is triggered, as illustrated in Figure 10, the first DMA request signal was sent out to ask for writing the first bytes of ***n*** lines. Then SRAM controller reads firing data from SRAM and prepares for firing. Meanwhile, a bit selector selects ***j***-th bit of ***n*** bytes and shifts it serially to the serial-in-parallel-out (SIPO) shift register, where ***j*** is defined by ***A0, A1 and A2***, as illustrated in Figure 6.

Additionally, the permutation is different depends on the type of print cartridge. For example, consider a black print cartridge illustrated in Figure 8. These nozzles are divided into four banks, each bank contains 13 labeled nozzles. The nozzles with the same label are fired at the same time. The nozzle firing sequence should be arranged by this data conversion controller. So that, the output of shift register is mapped to the latch registers according which nozzle sequence was selected.

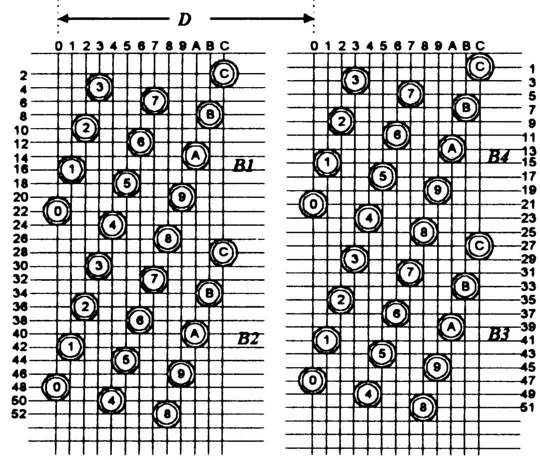

Figure 8. Black Print Cartridge Nozzle Permutation and Firing Sequence

Similarily, consider a color print cartridge as shown in Figure 9. These nozzles are divided into four banks, too. The nozzles with the same label are fired at the same time. So that, the output of shift register should be mapped to the latch registers according to the color printing sequence.

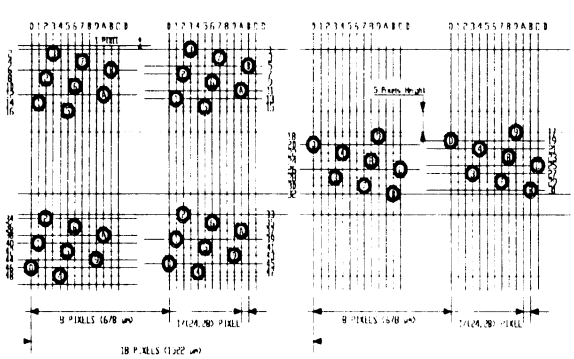

Figure 9. Color Print Cartridge Nozzle Permutation and Firing Sequence

When the first bytes of ***n*** lines have been read already, the next bit can be read and prepared for firing, while the firing data is latched, i.e. after reading bit *7*, next request is sent again to ask for filling the second bytes of ***n*** lines. It is obvious to find that the advantage of this architecture is suitable for high frequency printing because reading data and firing data are parallel runs.

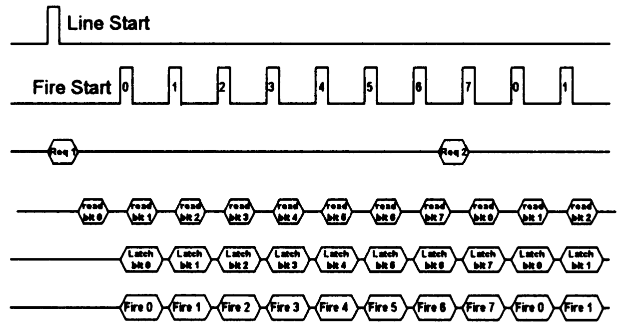

Figure 10. Data Conversion Module Timing Illustration

4. Conclusion and Future Work

In this paper, the whole architecture of a ink jet printing ASIC and the associated data conversion controller are introduced. The proposed data conversion module is discussed in this paper. It provides two appointed selections of nozzle sequence, which is effective because of minimizing hardware circuits and saving ASIC gate counts. Moreover, it is suitable for ink jet printing product design.

Furthermore, a new architecture of data conversion controller for more flexibility in printing cartridge is under developed. And it will be applied to the next generation of ink-jet printers and/or multi-function printers by OES/ITRI.

References

[1] Hong-Yu Lin, Ming-Chyuan Lu, Jiuun-Hwa Horng, Tsai-Bao Yang, "DC Servo Speed Control of an Ink Jet Print Head Transport System Using a Phase-Locked Loop," AMC'96-Mie 4th International Workshop on Advanced Motion Control, pp. 458-463, 1996.

[2] Hong-Yu Lin, Shu-Cheng Hsieh and Ming-Chyuan Lu, " Optimal Speed Profile Design of Stepping Motors for an Ink Jet Printer," IS&T 10th International Congress on Advances in Non-Impact Printing Technologies, pp. 458-460, 1994.

[3] Chu-Yong Shiao, "The Design and Implementation of DC Servo Controller for Ink jet Printer," Master Thesis of Power Mechanical Engineering Department of National Tsing Hua University, 1996.

Acknowledgement

The authors would like to thank Dr. Han-Chung Wang, Mr. Shu-Cheng Hsieh, Mr. King-Lung Huang, and Miss Te-Mei Wang for valuable comments on this paper.