Xilinx at Work in Digital Printers

WP102 (v1.1) December 13, 1999 White Paper

Summary

This white paper focuses on the market size for the various printer technologies, both by performance and geographic region. It then discusses the basics of the technologies, to give a view of their capabilities, limitations and future directions. A functional block diagram is provided which shows the presence of several important application specific standard products (ASSP) providers. It will then focus on exactly where Xilinx XC9500XL CPLDs and Spartan FPGAs play a vital role in this important market, then take a look into the future direction it is headed with Internet influence and the new photographic quality printers and MFPs. Finally, a set of additional resources is provided for further study.

Introduction

Printers are everywhere. When cash is collect from an ATM, the receipt is automatically delivered through a slot from an internal impact printer. The same happens when purchasing gas from the local self-serve pump. Dropping into the local record store, a receipt is impact printed by the cash register and concert tickets are imprinted thermally (keep them out of the sun!) At home, Inkjet printers makes Tee-shirt appliques and at work, the group laser printer creates a final quarterly report. We live in a printer world.

Overview

As suggested in the introduction, printers are everywhere. Their price range and technologies are all over "the map". This paper focuses primarily on Inkjet and Laser printers in this paper, because those are the most likely candidates for Xilinx programmable solutions. Thermal and impact printers are typically either on last buy basis or so price sensitive that they cannot support any price erosion by adding features at no additional cost to the end user. Inkjet and Laser printers are another matter. They continue to grow in both features and geographic markets as prices plummet.

It is interesting to note that critical features are not always obvious in the printer world, or what was previously acceptable behavior is no longer acceptable. For instance, the U.S. Department of Energy "Energy Star" rating is typically an assumed feature in today's printers. Not so, in the past. As discussed later in this paper, printers do have a substantial power budget—due to the nature of the media and process—that can consume substantial power (i.e., several watts). Saving power entails turning the controller on and off. Naturally, there is also a strong trend to reduce "warm-up" time, which is increased by Energy Star features! Because features tend to expand over time, programmable logic is a natural technology for printer makers to embrace.

Figure 1, Figure 2, and Figure 3 summarize the 1997-1998 market split-outs for printers in the U.S.

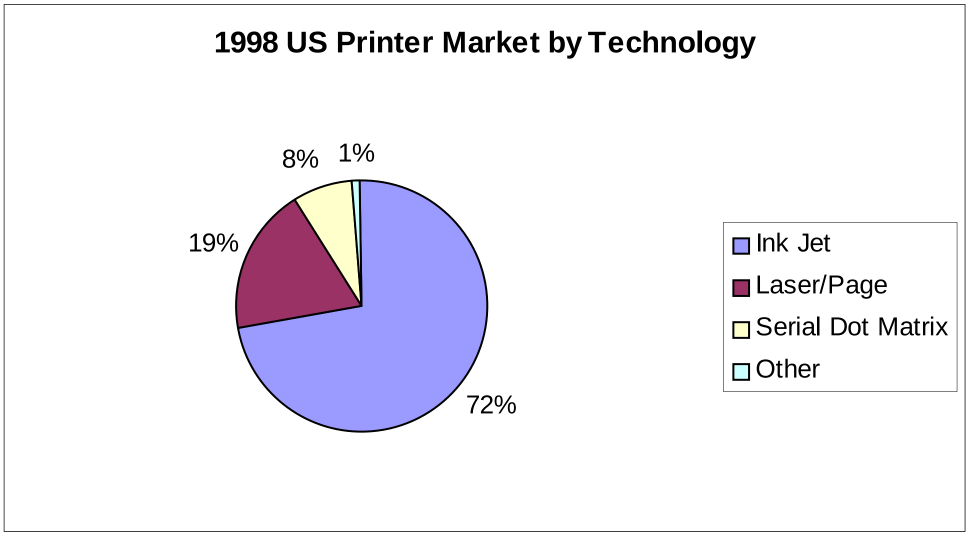

Figure 1: 1998 US Printer Market by Technology (Dataquest: 1998)

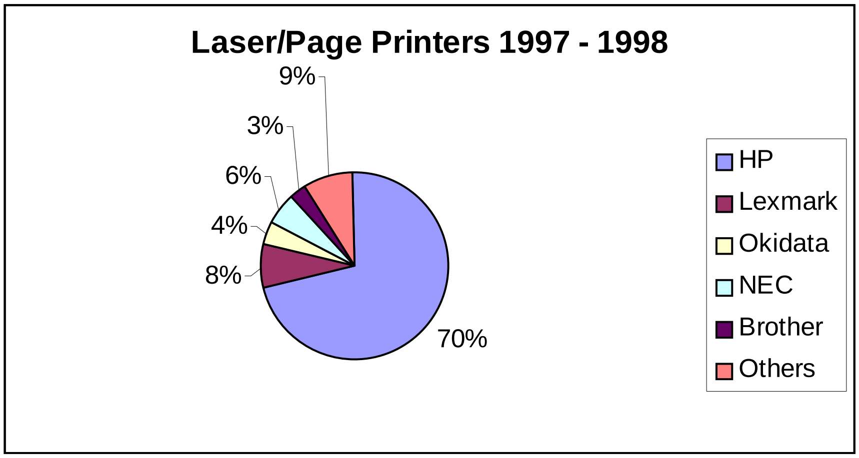

Figure 2: US Laser/Page Printer Market (Dataquest: 1998)

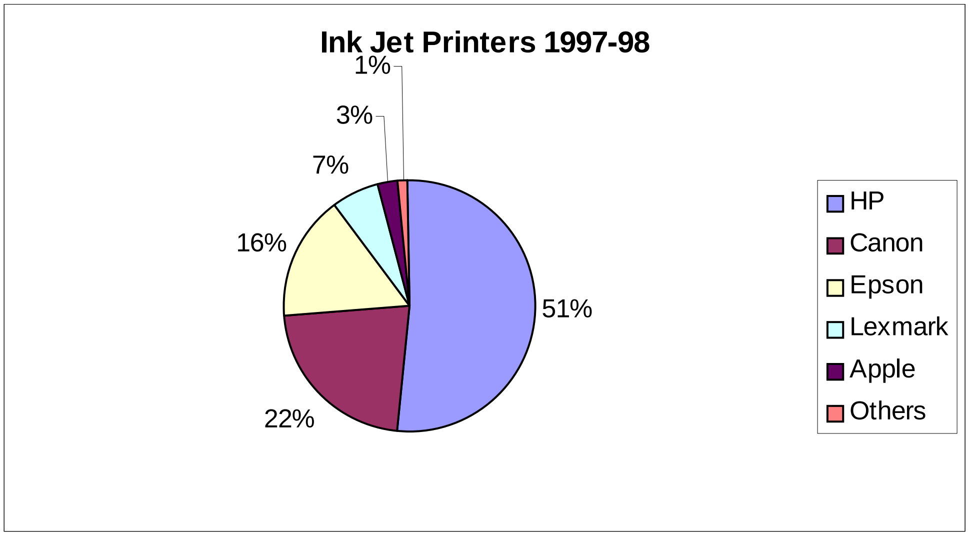

Figure 3: US Inkjet Printer Market (Dataquest: 1998)

As noted above, the Inkjet Market is largest, but with either laser or inkjet printers, Hewlett-Packard is the largest player. Table 1 below assigns some numbers for the appropriate percentages listed above, to show the magnitude of this huge market.

Table 1: Annual Units Shipped for 1997 – 1998 (Source: Dataquest 1998)

Printer Type	Americas 1997	World 1997	Americas 1998	World 1998
Laser/page	2,484,000	9,509,000	2,717,000	9,897,000
Inkjet/serial	3,357,000	40,019,000	5,386,000	43,498,000

Inkjet Printers

Inkjet printers are the largest selling today. They were the first to deliver full color capability to the average PC owner. The advent of sub $1000 PCs has driven their price down to where almost anybody can own a sophisticated, fast printer right on their desktop. For the single user, they are very close to ideal. Their primary downside is simply operation cost. Ink cartridges are not cheap. If high quality final copies is important, expensive paper may also enter the picture. This is the case for PC digital photography, discussed later. 300 to 600 dots per inch (dpi) are common, and provide more than acceptable hard copy for today's desktop publishing needs for day to day report writing and limited publishing.

Typical color Inkjet printers use two cartridges—a black one and a color one. The black one is most economical for text and the color is typically used for color graphics. Ink technology for both cartridges has evolved substantially in the last few years. Not only do many printers include automatic "stirring" functions to keep the ink from plugging, but many include reservoir measuring chips to let users know how much remaining ink is in the cartridge. Some printers even use capacity information to determine in advance whether enough ink remains, to complete a print task prior to beginning it!

The basic mechanism of ink delivery for Inkjets is heat based. A small chamber of fluid is heated up and the expanding liquid is "squirted" out a hole onto the target paper. This is called a nozzle. Canon calls this process "bubble jet" where others simply call it "inkjet." There is a new technology using piezoelectric expansion as a mechanical stimulus for jet delivery. Piezoelectric jetting avoids thermal issues with ink properties changing as heat is applied. Piezoelectric market impact is still being determined.

What you see is what you get (WSYWYG) rears its head again with color printing. When viewing a color monitor screen, the displayed image is constructed from adding components of red, green and blue (RGB). The eye is excited by the light sourced from the color monitor. In a similar, but not identical way, the printed image tracks the screen image by assigning color to appropriate sites on the white sheet of paper. Sometimes, the screen version does not track the paper version. What you see is NOT what you get. Color applied to a white sheet of paper is not a light source, but rather reflected and filtered white light. This is a subtle difference, but an important one. When reflecting light, the Inkjet ink components are usually Cyan, Magenta and Yellow (CMY). These colors subtract with each other to create the color image, rather than add as RGB do. The process of reconciling the screen image and the paper image is called "color management." Most Inkjets use three colors and black. More expensive units use six or more colors. Lots of software is employed to assure a consistent image between the screen and the sheet.

An interesting aside is that black is typically not created well with CMY—it usually turns out brown or grey. Hence, the inclusion of a separate black cartridge for this key color.

The tasks that the printer must do are complex. The printer must accept data from the computer, control positioning the print head over the sheet, feed the sheet (as needed), alter the data appropriately and deliver the ink image to the sheet. It must subsequently eject the sheet and obtain the next sheet until the job completes. As expected, it is usually under the control of another processor contained inside the printer chassis.

Inkjet and laser printers have a lot in common, so a basic laser operation is first outlined before going deeper.

Laser Printers

Laser printers are usually the choice for printing at work. Several reasons exist for this. First, the expense of making a printed sheet is less. Toner and paper costs for laser printing are cheaper than Inkjet even though printer costs are higher. Laser printers are typically configured in work group local area network (LAN) configurations and shared by many users. The higher unit cost is amortized across multiple users, but laser printers must deliver higher throughput—pages per minute (ppm)—to support the higher workload and maintain an acceptable delay time.

Color laser printing is not mainstream, today. Black and white is the workhorse. With black and white, resolutions have improved dramatically from 300 and 600 dpi to 1200 dpi in some systems.

The laser printing mechanism is more complex than that of the inkjet. Basically, a rasterized signal is driven into the laser, which is scanned (via mirror) across a photosensitive drum. Where the laser strikes, a local charged area exists. This attracts a fine black powder called toner to the drum surface, tracking the path of the laser. By direct contact of the paper with the drum, the toner is transferred. Because the toner would fall off the sheet, a subsequent process of binding the toner to the paper is undertaken. This is called "fusing." Fusing may involve both pressure and a chemical called "fuser." The process is similar to xerographic imaging in a copier. Remember this for later, when multi-function peripherals (MFP) are discussed.

Specialty Printers

In this section, other printers are discussed that miss the typical Xilinx high-volume price points, but would be incomplete to not include. They include the low-priced impact and thermal printers as well as the very high-priced production printers.

Impact Printers

Impact printers are the basic dot matrix printers that build up the image of characters from individual, visible dots applied to an inked ribbon and struck onto a sheet of paper. The Centronix corporation made its name with this technology back in the late 1960s and early 1970s. There is an important legacy left behind by this technology. Many printers still contain "centronix" compatible sockets. This is a basic pinout and signal protocol that has persisted for about 25 years as an industry standard. The advent of Firewire and USB should relegate that standard as obsolete, soon.

Thermal Printers

Thermal printing minimized mechanical interaction with the media. However, it always had the problem that the image was frequently weak and could be modified by heat applied after the "printing" process. Many concert ticket sellers still use thermal processes as well as some cheaper FAX machines. Their day is expected to end soon. Thermal paper tends to be expensive, too.

Production Laser Printers

Production laser printers are extremely high-end laser printers capable of spitting out a finished text book. Literally. They have very high resolution, typically support color, and exceed the PPM limits of the fastest workgroup laser printers.

Printer Controller Architecture

This section discusses a little more detail regarding the operation of a printer. As mentioned earlier, many of them have microprocessors or controllers on board. One of the things that the processors do is deal with the encoded data formats that have evolved to streamline the dataflows. The data formats are called "page description languages."

Page Description Languages (PDL)

Several standards exist. The most prevalent are PostScript and PCL. There are several flavors of each. Of late, there is also the Microsoft standard, GDI and a new Adobe entry called PrintGear. Part of the task of the PDL is to encode the data in an efficient manner to avoid shipping the raw bitstreams to the printer. This is a lot like datacom compression. This creates a local task for the printer processor to reconstruct the bitstream that will be shipped as dots to the print heads. Other tasks must be dealt with, but this summarizes a key one. PostScript has at least two levels (Level 1 and 2) and PCL, HP’s standard has at least six versions. A restriction for PostScript is that it comes with licensing issues from Adobe. PCL is provided as an open standard, suitable for the mass cloners. Various HP printers use the different versions of PCL. Note that all the compression and need to hold buffers of data means the printer must contain significant chunks of RAM—typically DRAM. That in turn, means DRAM controllers, which are standard Xilinx CPLD and FPGA applications.

A Look Inside a Printer Controller

Figure 4 shows the inside of a typical, basic laser printer. Due to using PDLs, a processor and DRAM is required, as mentioned above. There is also necessary interface logic for the processor to the DRAM (i.e., DRAM controller) as well as the interfacing to the PC to obtain the image to be printed. These tasks are handled by the System Controller, which is a natural site for programmable logic. Typically, the system controller handles device selection for the various chips to access the internal bus, it implements DMA data transfer, creates interrupts and may also include the clock distribution. Programmable logic can do the entire job.

The PC data passes right through the system controller and lands in the DRAM. The microprocessor passes the data through the EPROM for local font creation, the Raster Image Processor (RIP) for creates the scan lines and Resolution Enhancement chip for extremely crisp clarity. Both the RIP and RET are available in a number of different versions from ASSP purveyors. Once the data is properly formatted, it is shipped to the Print Engine interface. At this point, the Print Engine Controller drives various motor controls, advancing the paper, positioning the laser mirror (or ink cartridge nozzles), turning on fuser pumps, and so forth.

Going back to the microprocessor and memories, low-end units have 8- or 16-bit controllers, with meager memory (say 4 MB) and higher end units have 32-bit RISC processors with upwards from 16MB of DRAM. Variations on this design may include SRAM or both serial and parallel port interfaces. Some manufacturers are attaching USB or Firewire as their processor datapipe connections. Naturally, Xilinx CORE solutions address both these important PC standards.

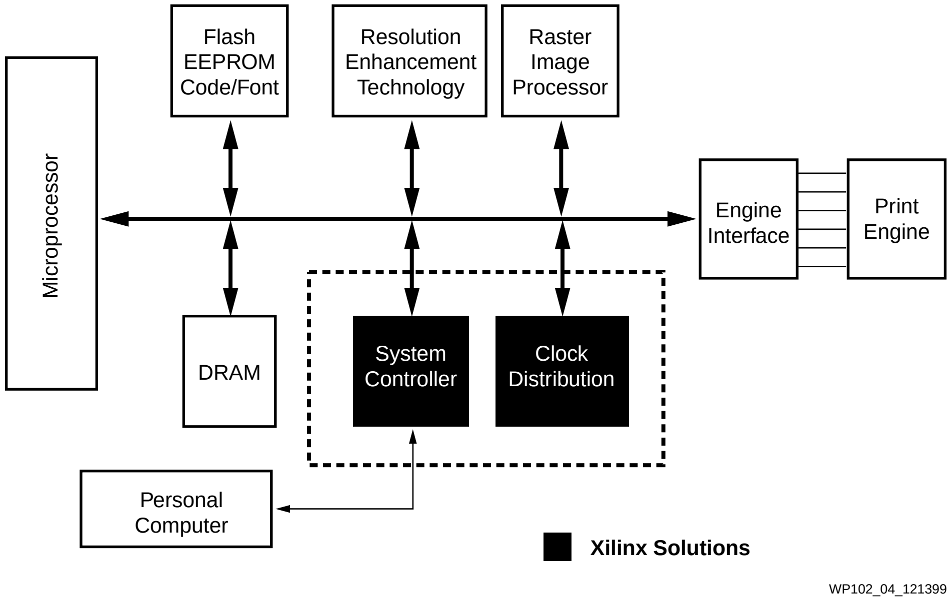

Figure 4: Printer Controller Block Diagram

ASSP Providers

ASSP providers typically do the RIP and RET functions mentioned above. The business model that most of them embrace is based on engaging partners (ie, high volume printer manufacturers) who work through their VP of IP to embrace the specific intellectual property provided with the ASSP. Table 2 below gives a list of some of the ASSP providers that have significant offerings today. Like many of the graphics ASSP providers, many of these chips are directed toward very specific processor and bus interfaces, so Xilinx can participate by neatly handling the interface to other processors and buses.

Table 2: Printer ASSP Providers

ASSP Provider	Products	URL
Conexant (Rockwell Semi)	MFC1000/PIF-LM1	www.conexant.com
Peerless	QuickPrint ASIC	www.peerless.com
Xionics	XipChip, PS3	www.xionics.com
Destiny	D5001	www.destiny.com.tw
Pixel Magic (Oak Technologies)	PM-2016,32,50	www.pixelmagic.com

So, what do the processor and ASSPs do? They deliver performance. Conceptually, both the RIP and RET functions can easily be done in software. In fact, some simpler printer controllers basically interface the print engine to the serial or parallel port. In these situations, the PC processor is basically doing everything—font translation, rasterization, edge enhancement and color management. Naturally, this bogs the processor down, with large graphic oriented images to print. By using PDLs and gaining compression, file sizes are smaller, and pass faster to the printer, but require local processing to reconstruct the final image.

Rasterization is basically creating scan lines for the paper—very similar to video processing. This is both I/O and boolean intensive, so an onboard processor (within the RIP) handles these actions and creates the line buffers.

Edge enhancement is the trick of making 600 dpi output from 300 dpi input. Edge enhancement is usually implemented with a series of lookup table mappings, and typically uses a small processor with internal blocks of RAM to create the enhanced image chunks. The printer engine itself frequently has a processor (or two) inside, handling the motor controls, laser mirror spinning and on/off management of the laser or inkjet nozzles. Literally, a small system of multiple simultaneous processors all running in parallel.

Although HP has traditionally used Motorola processors (Coldfire) for on-board processing, others have embraced the ARM RISC family, which is low power and considered very efficient. ARM is also a very popular ASIC building block available from several ASIC vendors.

All of this needs to be glued together with cost effective logic like Xilinx XC9500XL CPLDs or Spartan-XL FPGAs.

Future Trends

The internet and very high-quality printing techniques are driving interesting new printer trends. Although only two are mentioned here, others are in the works. First, there are photographic printers, then Multiple Function Peripheral devices. Both are at the very early stages of product development, with early models available in stores today. Prices will be due to plummet as competition arrives, but these are particularly fertile areas to address with Xilinx Spartan-XL and XC9500XL programmable devices.

Photographic Printers

Photographic printers are a boon for the ink cartridge business. Typically in a smaller format output, these printers frequently deliver six ink colors at 1200 dpi. Purveyors of photo quality (read expensive) paper also love these printers. With new Internet business models whereby some photo developers scan in regular film and make MPEG files available over the world wide web, then prints can be downloaded, edited and enlarged, and printed from a photo printer.

MFP — Multiple Function Peripherals

As mentioned earlier, these new devices combine a printer, scanner, copier and FAX machine in a single product. Takes up less space on the desk and products can be bought at discount stores in the $400-500 dollar range, today. This market is just ramping up, but the ASSP providers are working at full steam. In fact, there is already an organization called MFP Alliance that is a clearing-house of chipset and software purveyors subscribing to the MFP approach.

Resources

Technical Tutorials

1. HP DeskJet 1200C Printer, Bockman, Tabar, Erturk, Giles and Schwiebert
   HP Journal, February 1994, pp 55-66 (http://www.hp.com/hpj/94feb/toc-02-9.htm)
2. PC TechGuide
   Laser Printers http://www.pctechguide.com/12lasers.htm
   Inkjet Printers http://www.pctechguide.com/13inkjets.htm
   Solid Ink Printers http://www.pctechguide.com/23oprint.htm
3. On-line textbook on laser printers
   A Laser Printer Book, Copyright © 1994 by Steven Burrows
   http://www.dungeon.com/~poota/lpbook/00-toc.html
4. U.S. Energy site: http://www.epa.gov/energystar/

Printer Market Summaries

1. Data Processing Semiconductor Application Markets, 1997 to 2002,
   Dataquest, 1998, pp 81-94

Revision History

Date	Version	Revision
8/1/99	1.0	Initial release posted as html web only.
12/13/99	1.1	Formated for PDF printing.