Electronics for Industrial Digital Printers: The Architecture of a Universal Solution

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Abstract

Over the last two decades there has been a continuous increase in the variety of types of digital printheads (industrial inkjet printheads from various suppliers, laser diode arrays, LED arrays, thermal inkjet printheads etc) and the variety of print systems that embody these printheads has also diversified into many new industrial applications. In the early years each printer required a unique custom development of electronics and software, as is still the case for mass-produced printers today. However, recent developments in IT technology and communications standards now make it possible to use a "universal printhead controller" to control any printhead type used in most industrial and commercial applications. This possibility of universal printhead control electronics will catalyze the expansion of digital printing (particularly piezo inkjet printing) into new industrial markets and is therefore of great interest to many at IS&T. This presentation explains the challenges of print engine design and the recent changes in electronic technology that make a universal architecture practical.

Introduction

A universal print controller is of great value for several reasons:

- it reduces the development effort required to integrate a new industrial or commercial printer
- it provides a common software and electronics platform for OEMs who handle a variety of different print technologies within their product ranges
- it lowers costs through higher volume manufacture of common parts.

Until recently, however, a universal print controller was impractical as the costs of such components would make the development of alternative printer-specific components financially advantageous, despite the longer development time. The costs were driven up by the need to use expensive electronics to handle the extremes of the potential functionality that may be required of a print controller that claims to be "universal".

We look now at what these demands on a universal system are and what architecture and low cost IT technologies can be applied to meet these needs.

The challenges of print controller design

The variety of digital print systems – from an electronics viewpoint

Digital print systems use arrays of digital printheads to image onto media. At one extreme an electro photographic LED array may contain a single row of 12,880 LEDs mounted at 600dpi native resolution on a 20" print bar. Another extreme would be a low cost solvent printer with four 128-nozzle printheads mounted behind each other scanning multiple times across the same area of media. Whilst digital printers appear extremely different from each other, in data terms each digital printer can be described in a few lines of a configuration text file and the task addressed in the same way: an image data file needs to be separated into firing information for each LED or nozzle and the timing of the actuation needs to be synchronized to the actual passing of the LED or nozzle relative to the target pixel positions on the media. The data rate in these two examples mentioned above is maybe 100MBytes/second/colour for the EP system down to just 320kBytes/sec total for the solvent printer. However the task is the same and if the components used for the solvent printer are modular then both can be addressed using mostly the same modular hardware components.

Tasks for all print engine controllers

Image data, residing on a storage media controlled by a PC, and consisting of color planes of bitmap data giving the desired grayscale level for each pixel in the image needs to be split up into data streams and fed to each printhead. We would argue that this task of allocating the data should be performed on a PC. In the past such a task was too demanding for a PC and custom electronics would be required. However it is now possible to run 100-200MBytes/sec of data through a typical single-processor PC.

The next task is to send the data to each printhead, buffering the data until the moment that each print line of data is required. The PC can buffer an extremely large amount of data in fast-access RAM however it is not guaranteed that access to it will be available exactly at the moment that the data is required. It is therefore necessary to buffer the data on print electronics where the synchronization to the printing can be guaranteed.

A data transfer protocol must be selected for the transfer of data between the PC and the print electronics so that standard electronics designs can be utilized and cable lengths specified appropriately.

After receiving the image data from a PC assigned to each printhead the print electronics can be designed so as to have a largely separate data path for each printhead, however it is necessary to synchronize these paths to a small fraction of the print firing frequency. If this is not achieved then it can be possible to see print artifacts in the image, especially where printheads are using the same color and are interlaced to each other. The firing frequency of the heads is defined by synchronizing a very high speed clock to an external encoder signal that gives information as to the physical movement of the printhead relative to the media.

Usually the print image is not as wide as the print swath available. Thus extra "zeros" must be added to the print data to complete each print line of the printhead so that the printheads can be correctly filled with firing data. This can be done at a late stage in the data path to avoid burdening the data rates required further upstream in the data path.

Finally there needs to be start print trigger signal. Whilst this signal might come from a keyboard action or other PC source it is more typical that it needs to be triggered by a sensor on the media path so a trigger sensor input to the print electronics is usually necessary.

Tasks for print engine controllers with more than one printhead

Larger digital inkjet systems use multiple printheads for each ink color in order to increase the width of the print swath beyond that possible with just one printhead and/or to create a swath of image which has a multiple of the native resolution of the printhead. Thus the print engine controller must allocate data carefully to each printhead depending on its position in the array and on how the stitching between overlapping heads of identical ink color is to be achieved. Stitching the data using pseudorandom algorithms is not unusual. When heads are not level with each other then the timing of the print data must be delayed on later heads so that the image is correctly printed. This timing needs to be accurate to a small part of an image pixel (and therefore often a small part of an encoder pulse) so that the mismatch is not visible in the print. It is essential therefore that all electronics modules used in a large array are linked via high speed clock to ensure synchronization to a single interpretation of an analogue encoder signal.

Tasks for scanning print engines

Scanning printers require that the image data is transformed into swaths. These swaths may be printed unidirectionally or bi-directionally. If bi-directional then the data on every alternate swath needs to be reversed, the order in which the printheads travel is reversed, the time of flight correction for drops ejected by the printheads needs to be reversed, and, if the printheads contain multiple rows of nozzles then the timing of the printhead needs to be reversed.

A scanning printer's image has an origin defined by home position sensors. However, as sensors are not repeatable, each swath then needs to be started on an encoder position without recourse to the home sensor.

Most scanning printers use exact step sizes so each swath can be predicted in advance by a knowledge of the size of the swath. In extremely rare cases the swaths can be non-parallel and not of equal step size. In these cases the task of calculating the data for each swath is a far more time consuming a calculation.

Typically in graphics printing all the image colors are printed simultaneously however in many inkjet deposition applications the ink is being deposited to create a pattern that is registered to a pattern already present on the media. In this case the image data may need to be translated and rotated prior to splitting into print swaths.

Tasks for single pass print engines

In single pass printing the task is often short-run production and/or product identification.

Short run production requires that every image is identical. Typically the images cover a large area on the product, and are colorful. A lot of data is required to be sent to the printhead array to perform this feat; however it is usually the same data for each product so it is practical to store the image data in RAM mounted on the print electronics rather than download it each time from the PC.

Product identification typically covers only a very small area as only a small amount of information is presented e.g. a date, barcode or similar. If the date & time information is not required to be accurate to the nearest second then the formatting of the date & time image is easiest performed on a PC and then the information can be easily transmitted to the print electronics and superimposed on the image data.

Arrays of printheads can often be large enough to be printing on more than one product at a time: before the first product has passed the last printhead at least one more has begun passing under the first printhead. Thus, the print controller must store each 'product detect' and synchronize the printing of several images at the same time.

Whilst most product decoration printing using single pass printing will have at least some period of time in between products where the data is not being used as there is nothing to print beneath the printheads there are some applications where this is not the case. Commercial printing of books, literature and wallpaper, floor coverings etc can have extremely long or no repeat patterns at all. The data usage here is so large that neither a single hard disk drive nor a single cable can provide the required data rate and it is necessary to consider how to use multiple IT components in parallel.

Tasks for print controllers in inkjet deposition systems

The image may need to be aligned correctly to existing deposition patterns. Fiducial inputs need to taken account of and the image rotated or displaced. The media may need to be addressed several times using ‘redundant’ passes in order that it is possible to avoid having to use a badly-performing nozzle. The image may be defined on a grid size far smaller than the drop size created by the ink, thus careful RIP design is required.

Data rates of digital printers

The first stage of print data management is to manipulate the image data into swaths for each printhead and to send this data from a PC to buffers on print electronics. Some typical average data rates required are shown below:

- Average data rate of a low cost wide format inkjet printer with 100 sfph, 600 dpi and 4 colors:

  100 x 144 x 600 x 600 x 4 bit/pixel /3600 = 0.7 MBytes/sec.

- Average data rate of a high value flatbed inkjet printer with 1000 sfph, 400 dpi printer and 8 colors:

  1000 x 144 x 400 x 400 x 8 bit/pixel /3600 = 6.4 MBytes/sec.

- Average data rate of a single pass 8” narrow web printer with 20 ips speed, 8-level grayscale, 300 dpi and 4 colors:

  8 x 20 x 300 x 300 x 4 x 4 bit/color = 29 MBytes/sec.

The buffers on the print electronics may need to store the entire image if it is repeated many times. An 8MByte buffer per printhead is typical. For a printhead on a single pass print engine with 256 nozzles and printing at 400 dpi this is a repeat length of 8M x 8 /256 /400 /12 = 52 feet. Alternatively, it is 52 stored images each one foot long, or any other combination of stored images.

The final leg of the data path is to feed each printhead; some typical data rates for this leg are shown below:

- Maximum data rate of a thermal inkjet printhead:

  1200 nozzles x 12kHz x 1bit/drop = 1.8 MBytes/sec.

- Maximum data rate of a piezo inkjet printhead:

  256 nozzles x 40kHz x 1 bit/drop = 1.3 MBytes/sec.

- Maximum data rate of a grayscale piezo inkjet printhead:

  760 nozzles x 13kHz x 4bit/drop = 5 MBytes/sec.

Print Controller Architecture

Common hardware and printhead technology specific hardware

There are great advantages to using common electronics hardware across different industrial and commercial printers. The manufacturing volumes of the hardware are higher, leading to better component pricing. The software is common and easier to maintain. The systems are easier to service. There are less component suppliers to deal with. The hardware is flexible enough to preclude the need for further development expense whenever a new printer configuration is desired.

This philosophy also works in the way in which print electronics hardware is designed. The use of commonly-used microprocessors, RAM etc makes pricing better and the likelihood of obsolescence less. The most cost-effective pricing for electronics is that within a PC – thus making full use of a PC’s capabilities is an essential concept in the design of cost-effective print electronics.

Printhead technology specific hardware is required for the final stage of interfacing to a printhead as there are many different suppliers of printheads and ways in which they have chosen to configure their printheads.

One example of printhead specific hardware is electronics required to provide a voltage fire pulse to a piezo crystal within a piezo inkjet printhead. The shape of the pulse is ideally digitally-defined so that the pressure pulse created can be matched to the efficiency of the crystal and the physical parameters of the ink and the ink pressure in the chambers being excited.

A key advantage of having the core of print engine based on common hardware is the freedom it brings to change printheads without large development effort. This freedom permits a variety of different printheads to be used to differentiate printers within a product family and it brings some commercial leverage for the OEM over the printhead suppliers.

Architecture: summary

To summarize our argument so far:

- Print engine software can now run a great many tasks on a PC, reducing the need for expensive print electronics.

- Print electronics should include one component which contains all the functionality that can be performed independently of the type of printhead used, and a further component, with the minimum of complexity, which is specific to the printhead type.

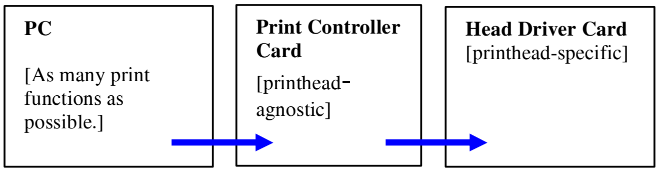

Fig1. Diagram of proposed architecture

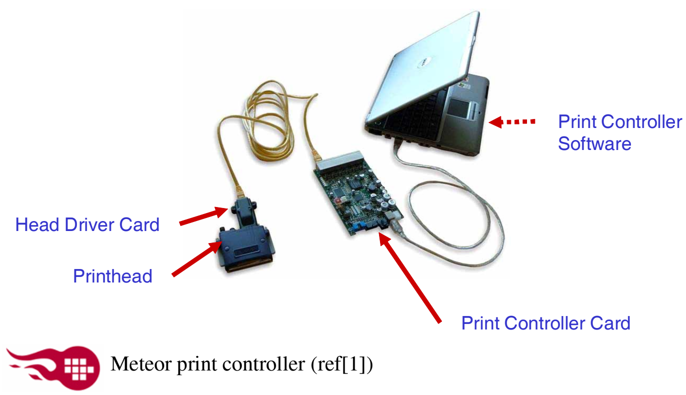

Fig 2. Example implementation of proposed architecture

Data transfer technology Options

A number of standard data transfer protocols are suitable for sending high speed data from a PC to a print controller card. These include:

- USB 2.0 ref[2]
- IEEE 1394 (Firewire™) ref[3]
- Gigabit Ethernet

Each of these interfaces has its merits:

USB 2.0 has the significant advantage that it is present as standard in almost all PCs. It has a raw data rate of 480 Mbit/s, and in our tests, over 400Mbit/s (50Mbyte/s) is achievable. Additional host-controllers can be added to the PC for under $20 each, so higher data rates can be achieved if necessary. USB is also very asymmetric, meaning that the device-end of the link is very low cost. USB cable length is limited to 5m, but this can be extended (up to 25m) using active repeater cables, which are available at low cost. Finally, USB transfers are error-corrected so data errors are eliminated.

IEEE 1394 is a symmetric (peer-to-peer) interface and shares many of the merits of USB 2.0. However, it is not fitted as standard to most PCs, and the peer-to-peer capability makes the device-end implementation more expensive.

Gigabit Ethernet ports are now fitted as standard on many PCs, but by no means all. Cables can be very long, but data-rates are not guaranteed and a complex protocol stack is required at the device-end of the link, making the implementation more expensive. This is particularly true where error-correction is required.

Other interfaces (Fibre, LVDS etc) are also often used, but these require custom interface boards at the PC end.

We conclude that USB2.0 is the preferred interface for the transfer of data to print controller cards.

The developer of the print controller has control of both the print controller card and the head driver card designs, thus it is not necessary to use a standard interface here. Using a standard cable (Firewire, USB or preferably Ethernet) is a cost effective approach although the signal protocol used can be selected in order that, for example power supply lines can be provided within the cable to power the printhead.

Summary and Conclusion

We have argued that the speed of modern PCs and the introduction of the USB 2.0 protocol have enabled, for the first time, the use of architecture for print control electronics and software that gives it the flexibility to be used with any printhead type and in most industrial and commercial digital print applications.

The speed of commercial success in new applications is limited by the development effort required to use new digital technologies. The development of new software and electronics for each new printer takes time and cost, adding to the risks of market success and thus impeding the progress of digital printing. A universal print controller enables new printer configurations to be quickly configured even if new or different printheads are used from those used on previous printers. We expect that this reduction of the development hurdle will catalyse the growth of new printers for the myriad of emerging digital print applications.

References

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