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Photo Printing with Inkjet Printers

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Introduction

If you thought that *taking* photographs was complicated, just wait till you start thinking hard about printing them. It really is a wonder that we get anything worth looking at out of a desktop inkjet printer. To begin to understand what happens when you click the 'Print' button in your favourite photo editor, you need to think about human vision and something about the way that inkjet printers work.

1. Human vision

Try an experiment. Take one of your photos that you like and view it at 100% ('Actual pixels' in some editors) on screen. It doesn't matter if you can only see part of it. Now look at the screen from about 500 millimetres (20 inches). I'll assume that you have an LCD screen with about 1280 by 1024 pixels at least.

If you are quite young, with '20-20' vision, you may *just* be able to see the individual dots on the screen. Most of us need to move in to peer at the screen from about 200 to 220 mm before the dots are clearly visible.

Most screens have about 100 pixels per inch (often nearer 90 and usually a rather odd number). The conclusion from the experiment is that you get a visually good image at about 200 pixels per inch at normal viewing distance of about 250 mm. (Half as far as the experiment, so you need twice as many pixels per inch.)

So, even printing at 240 pixels per inch (ppi) gives a safety margin for album-sized prints and 300-360 ppi gives a good safety margin. This fits in well with long-standing practice in the glossy magazine market (also designed for reading at 200-250 mm) of using the equivalent of 150 to 250 ppi.

There's another conclusion to be drawn: the eye can probably distinguish features that are about 1 pixel wide (1/100 inch) at normal reading distance.

2. Inkjet printers

Each pixel on your screen can display any one of millions of colours. This is *not* true of each dot that your printer can put on paper. That is why printing is so complicated.

My photo printer claims to be able to print up to 5760 by 2880 **dots** per inch. (Note that these are emphatically not pixels.) Each of these dots can be one or more of several colours, usually anything from four to ten (8 for mine) and each coloured dot can be exactly one size from a limited choice of sizes (Epson aren't very helpful about exactly how many).

Some printers can't vary the dot size but many above the very bottom of the price range can.

So what? Taking a 360 ppi image and my Epson claiming 5760 by 2880 dpi, each pixel has a 16 by 8 rectangle of dots available ($5760/360 = 16$). A medium yellow pixel might be printed by using half the dots in the 16×8 rectangle and a dark yellow by printing all the dots. By the way, these rectangles are sometimes called **cells** in the trade.

Now 16×8 is 128 which is half the number of different levels you get from an '8-bit' image for each colour. By printing anything from zero to all the dots, the printer can, apparently, cope half of the colours that the programme can throw at it. If only life were that simple!

Firstly, a lot of printers have a maximum dpi of 1440, which only gives 4×4 for each 360 ppi pixel. It isn't even clear that my Epson actually achieves the claimed dpi that I've quoted.

Secondly, How does the printer decide which dots to print for, say, a medium blue that you get in sky? If it always prints the same selection of dots in each cell, then you'll see 'banding' in the print because there's a regular pattern present. You will see this effect on cheap printers with simple printer drivers.

Thirdly, what happens if you feed it an image at something other than 360 ppi? You might simply print a full 12MP image (4256 by 2832) on a 6 by 4 album print. That's 708 ppi and no printer we can afford to put on our desks is going to cope with that.

3. Lack of information

Most printer manufacturers are very secretive about the way their printers work. Since they make most of their money from inks and paper, not the printer, this is a bit surprising. Some manufacturers are better than others and some vary the information according to model, very odd!

So, what information would be really useful?

- How much intelligence is in the printer and how much is in the driver software? This varies by maker. Epson put very little intelligence in the printer and the driver has to give very 'low level' instructions to the printer. HP and Canon both seem to put a bit more intelligence in the printer. In the case of HP, I *think* that the printers have both dumb and smart modes. Canon ones *may* have both modes.

Which approach is better depends on what you are trying to do. A 'smart' printer is very easy to write drivers for. A 'dumb' printer opens the way for people other than the manufacturers to write drivers with extra features.

- What is the 'best' image resolution (ppi) to feed the printer and driver? I have drawn a complete blank on this with my Epson; Canon and HP owners may have better luck.

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The only clues available are any warnings that the printer driver issues for low resolution images. I think that I have had warnings when the resolution dropped below 220 ppi, but that may have been the program not the printer driver.

4. Printer drivers

With all this aggravation, it's a wonder that printer drivers ever get written. Apart from allowing the user to set paper sizes and the like, what must the driver do?

1. It may well resample the image to get the number of pixels per inch that suit the mechanics of the printer (and possibly the paper in use).
2. It must translate the numbers representing the red, green and blue colours in the image (RGB values) to numbers representing suitable amounts of the colours used in the printer. These will always include cyan, magenta, yellow and black (CMYK) and may include others.
3. It must lay down patterns of dots in the 'cells' to get the colour levels right without getting banding and other undesirable effects.
4. It must do all the above and compensate for the slight spreading of ink dots as they dry in the paper surface.

I feel quite sorry for writers of printer drivers!

Item 1 is where it would be good to know what the 'native' ppi for the printer is. Then we could control the resampling by doing it in our image editors. The printer driver *might* use a good technique, or it might not. Without a bit less secrecy, we just don't know. At least if we did the resampling, any quality reduction would be our fault.

Item 2 is where proper colour management comes in and that we *can* control by using the right colour profiles for the printer, inks and paper.

Items 3 and 4 are where we just have to hope that the driver writers are good at their job. Well, almost. There are a number of 'third-party' ways of dealing with all the issues above although most are quite expensive.

5. Raster image processors

A number of companies make what are called raster image processors (RIPs for short). They are really printer drivers by another name, though the pedantic detail is a bit different.

Most are quite or very expensive (£500 upwards) and most commonly support Epson printers (see comments about 'dumb' printers earlier on). Other printer models are increasingly being supported now.

The main thing that they do differently from the manufacturers' drivers is how they translate pixels into patterns of dots in the cells. Some of the RIPs offer different methods of translation for different image resolutions.

There is only one free full RIP available, as far as I know, and that is in the Gutenprint printer driver set. This is fine for Linux and Mac(tm) OS X users but is not currently available for Windows(tm). Gutenprint is not only free but open

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source and if you are really inquisitive, you can find out a lot about your Canon, HP or Epson printer by looking at the code. This is not a task for the faint-hearted.

There is a very useful RIP for monochrome work. Google for “Quad Tone RIP” and you’ll find links to the downloads. This is free for non-commercial use and works on Windows and Macs. Those who do a lot of B&W work claim that it produces better results than Epson’s Advanced Black and White mode (which isn’t available for a lot of their printers anyway).

6. Practical implications

Ideally, we would prepare a version of an image especially for printing. It would be correctly sized to the finished size we wanted. It would also be resampled so that the ppi exactly matched the best value for the printer; unfortunately, we probably don’t know that value!

It would also be appropriately *sharpened*. This is a huge subject in its own right and authors will argue endlessly about it. Some authors (Martin Evening amongst them) claim that sharpening for printing is a mechanical process and the settings you should use depend on the ppi of the image and the type of paper. Others disagree but PixelGenius’s PhotoKit Sharpener(tm) is based on this approach and is highly thought of (it is the method built in to Adobe Lightroom’s print facility).

If you are using the (relatively) simple unsharp mask approach, roughly speaking the ‘radius’ setting should be about ppi divided by 100 and you should inspect the results at 100%/actual pixels. The screen image will look fairly horrible because you are sharpening for (say) 360 ppi and viewing at 100 ppi. You are likely to see halos along edges. A print is probably the only way to convince you that it’s ok when printed!

The PixelGenius kit uses a more complex approach using both unsharp mask and a high pass filter (actually, two high pass filters).

Why ppi/100? Because 1/100 of an inch is about what your eye can discern at normal viewing distances. So, you need enough pixels to fill up 1/100 of an inch to show up at all (which is why thin spiders’ webs can disappear in prints but be visible on screen).

7. Resources used

I’ve drawn on a number of different sources for this stuff. Here are the main ones, with grateful thanks to all those involved.

- Adobe Photoshop CS4 for Photographers; Martin Evening, Focal Press. The chapter on printing and print sharpening has been very useful.
- Gutenprint Project; Documentation and source files (from Sourceforge). The documentation has an extensive discussion of the tasks a RIP has to do. The code shows how to make Canon, HP and Epson printers dance to your tune (if you are a programmer).
- Epson reference manual for the ESC/P2 printer control language. (Epson Corpn.)

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- Old reference documents for HP's PCL printer language.