BY SAM GOLDWASSER

Printer and Copier Basics

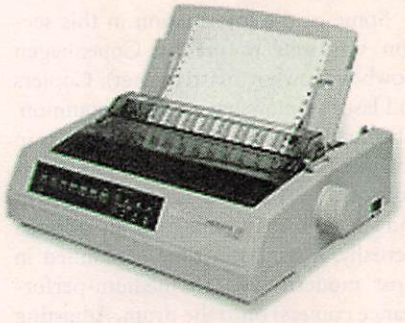
THIS MONTH, WE ARE GOING TO DO SOMETHING THAT'S A LITTLE DIFFERENT: RATHER THAN DEALING WITH SPECIFIC SERVICING PROBLEMS AND SOLUTIONS, WE ARE GOING TO PRESENT A BRIEF OVERVIEW OF COMPUTER PRINTERS AND HOW THEY work. Note that some of the following information was sent to my Web site by others; in those cases, I have given credit to the original contributor.

Let's start off by taking a look at dot-matrix printers. In that printer, a set of steel pins—as few as 9 and as many as 24—strike the paper through a fabric or carbon-film ribbon. The pins are activated by solenoids that are controlled by the printer's control logic. Multiple passes are sometimes used to increase the effective number of pins and improve print quality (letter versus draft mode).

For text, an internal character generator (ROM) converts ASCII codes to pin-firing patterns. For arbitrary graphics, the actual bitmap is read out and used to control the pin drive. The paper, carriage, and sometimes ribbon movement are all controlled by stepper motors. Those motors, their drivers, or the interconnect cables, are the most common problem areas. Note that dot-matrix printers are about the only type of impact printers still in wide use, and fewer and fewer are being sold each year.

Ink-Jet Printer Basics

Much of what follows on ink-jet printers comes from Tony Hardman (tony@f54x19.demon.co.uk): There is a US publication called *The Hard Copy OBSERVER* from Lyra Research Inc., Tel: 617-322-0708. It discusses the latest technologies and who does what. It may not cover the print-head technology in very great detail, but it is still a good read if you are into print technology in general. There are many companies that sell variable print processes. One I have heard of is RALFLATAC. They publish a brochure that presents an excellent brief of most technologies available for printing. They have locations in the UK (and around Europe) and the US. By telephone, you can reach them in the UK at 01732-583661, and in the US at 704-684-3931. I have no idea if you can get copies of either publication from them, so here is a very brief description:



DOT-MATRIX PRINTERS are the only type of impact printers widely sold today.

There are two main types of ink-jet printing—continuous ink jet (CIJ) and drop-on-demand (DOD) impulse printing. Each of those can use either a single jet or an array of jets. CIJ is a continuous jet of ink cycling round a system and occasionally (when required) a drop is deflected out of the stream onto the paper. The stream is modulated to break it into a consistent drop size. The deflection works like the beam on an oscilloscope. If you charge one drop and pass it between two high-voltage plates, it is deflected. This system also requires cunning mechanics, but the support electronics is much more complex, and probably one of the reasons for its performance limitations; the calculations of the aerodynamics of drops being deflected is no small task, even if look-up tables are used. For the most part, CIJ, as a single jet, is used in high-speed industrial applications, such as product marking (sell-by dates, serial numbers, etc.).

In contrast, DOD most often uses an array of small jets and is the system used in most desk-top printers. In principle, DOD works like a dot-matrix pin printer, but instead of firing a pin at a ribbon, a drop of ink is fired at the paper. The drop is fired by either a piezoelectric crystal squeezing the ink out of a small tube, or by boiling the ink and having the vapor force the ink out of the chamber. The key to both of those processes is in the mechanical design of very small components. The control electronics is a bit cunning, too, but I figure that is the easy bit.

How Many Colors?

I use a Hewlett-Packard DeskJet 680C in the office. It has two cartridges: one for black and one for color. If the printer fires one drop of each ink at a given point, we can have only six different colors (ignoring white and black). If it can fire two or more drops at a given point, maybe we can have more colors, but I suspect that the printer uses this to control the quality of the presentation, not the number of colors (does anybody knows for sure?). With dithering it can make more colors, with reduced resolution.

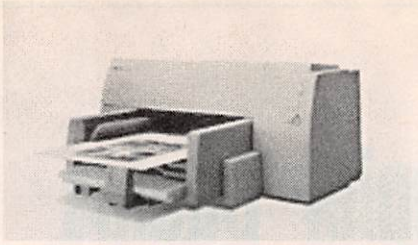
As in most print processes, you only have a limited selection of inks to use. Full color can be derived from three colors, just like a monitor. For monitors, those colors are red, green, and blue because monitors emit light, resulting in an additive color process. Inks, on the other hand, absorb light, so printing is a subtractive process. The resulting inks should then be cyan (blue plus green or blue minus red), magenta (red plus blue or red minus green), and yellow (red plus green or red minus blue). Therefore, the colors used in common ink-jet printers are not really capable of producing true full-spectrum, photo-realistic quality since they are red (not magenta), blue (not cyan), and yellow. Those inks are optimized for nice saturated primary colors when used independently. One of the newest color inkjet printers is the Epson Stylus Photo. It uses a five-color ink cartridge, in addition to black, to create high-quality realistic color images.

From Tony Hardman comes the following: If you can vary the drop size, you can change the drop spread on the paper. That can be done by firing bigger slugs of ink, or multiples of the drop at the same position. As you can understand, the ink will either spread and make a bigger drop, or stay the same size and become denser. Depending on the resolution you want, either technique could improve color density, depending on two key components: the ink, and the paper.

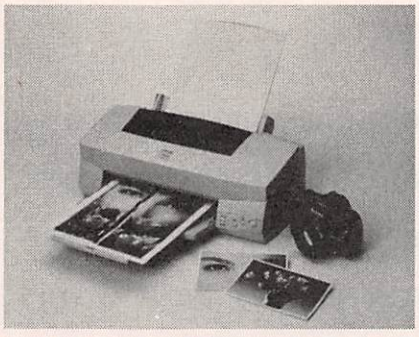
The problems with laying down multiple drops on paper is that if you do a large block, the paper will curl and the overall image becomes worse. That is why you can pay as much as $1 for a sheet of really high-quality, really white paper.

Another problem with this is speed. Firing two drops in the exact same place is difficult unless the head is stationary, but that is not good either. You may notice that most DOD printers operating in their high-resolution mode do a number of passes over the same place. That allows dithering and other techniques that improve resolution/color enhancement. These printers usually only print while going in one direction for improved mechanical control.

Inks are a problem too. They can dry at different rates because of the different dyes used, or they may not mix the way you expect if you place two colors on top of each other. It's only ink, but to get the best balance of surface tension, drying time, viscosity, color, stability and more is not as straightforward as it might seem. I have noticed that the water-based inks are improving, and there are some that do not run if they get wet (after drying on the paper).



THE HEWLETT-PACKARD DESKJET 680C has two ink cartridges: One for black ink and one for the three color inks.



THIS COLOR INKJET PRINTER from Epson uses a five-color ink cartridge (plus black) to provide more realistic colors.

Laser Printers

Some of the information in this section was sent to me by Copenhagen Cowboy (cowboy@fastlane.net): Copiers and laser printers have a lot in common. The major difference between them is in how the image is formed on a photosensitive drum. A copier uses a bright light and lens to focus an image of the original (actually, a strip at a time is scanned in most modern low- to medium-performance copiers) onto the drum. Adjusting the lens-to-original and the lens-to-drum distance is used to vary the reduction or magnification.

A laser printer uses a low-power, sharply focused laser beam to scan one line at a time on the drum. Modern laser printers use infrared, solid-state laser diodes similar to those used in CD players and optical disk drives. The digital image is generated from a bit map stored in the printer's memory and modulates the laser beam. Scanning is mechanical—a high-speed motor spins a multifaceted deflection mirror to get the X-axis, and the paper moves to get the Y axis. LED "page printers" use a large array of LEDs as the image source, but are otherwise similar to laser printers. Plain-paper fax machines also use similar techniques in their printing mechanism.

The only other significant difference between copiers and laser printers is that copiers use a positive process (dark areas in the original result in marks on the paper) and laser printers commonly use a negative process (a spot of light results in a dark mark on the paper).

The photosensitive drum is the heart of the laser printer or copier. In larger machines, it may be a separately replaceable unit. In many laser printers and smaller copiers, it is part of the toner cartridge and is a throw-away (or could be recycled). The drum is coated with a photosensitive material that has an extremely high resistance when in darkness. Its resistance drops to a low value when illuminated.

All of the following takes place as a continuous process as the drum rotates. Note that the actual photosensitive drum in most copiers and laser printers has a circumference that is much smaller than the length of the printed page. Therefore, only a portion fits at any given time; and the charging, exposure, transfer to the paper, cleaning, and erasing is a continuous process.

The drum's surface is charged to a high positive voltage (typically 5 to 6 kilovolts DC) by a set of charging corona wires in close proximity to the drum. The exposure process differs for copiers and laser printers.

For copiers, a swath of the original is focused onto the drum. As the drum turns, a quartz lamp and strip mirror moves along the original, with a second strip mirror moving at half the speed of the first. The result is that the entire original image is kind of "peeled" onto the rotating drum. (Look through the glass platform that supports the original as the machine is copying, and you will see what I mean.) For laser printers, the negative image of the page stored in the printer's buffer memory (the laser is turned on where the print is to be black) is read out and scanned onto the drum one line (e.g., $^1/_{300}$th or $^1/_{600}$th of an inch) at a time. Where the light hits the drum's surface, its resistance drops dramatically and the charge in those areas is dissipated.

Regardless of the machine type, at that point, a swath of the image of your ultimate copied or printed page resides as areas of electrostatic charge on the drum. That is a "latent" image and must be "developed."

As the drum continues to turn, the

latent image rotates past the developer unit, which contains a mixture of developer and toner. For the most part, developer is not really used up during the printing process, but some is lost and may need to be replenished from time to time (depends on the machine's design).

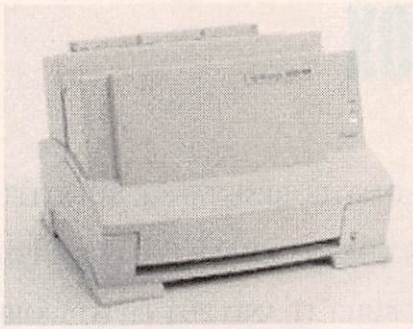
Developer is a material that includes powdered iron or another powder that is attracted by a magnet. Toner is the actual ink and consists of very finely powdered, thermoplastic particles. Those are "fixed" in the fuser by literally melting the image onto the paper. Depending on design, the developer material may be separate or actually combined with the toner. A magnet in the developer unit, which is as long as the page is wide, causes the developer along with trapped toner to stand out, following the lines of force off of its long N-S pole pieces. That forms a kind of brush of toner and developer material that is in contact with the drum as it rotates with its latent image. Normally, the developer-material brush is C-shaped, and toner particles are carried in the C-shape (the back of the "C" is against the drum).

Here is where the developing processes of copiers and laser printers differ. For copiers, the relative charges of the drum and toner are set up so that toner is drawn to the unexposed (dark parts of the original) portions of the drum resulting in a positive image on the paper. For laser printers, the relative charges of the drum and toner are set up so that toner is drawn to the exposed (where the laser beam was turned on) portions of the drum resulting in a negative image on the paper.

The drum continues to rotate around and comes in contact with the paper. Below the paper is another corona, the "transfer corona." Another high voltage is applied to the back of the paper (around 7 or 8 kilovolts DC) to draw the toner from the drum to the paper. Remember, all that is going on in a continual cycle and it is all in motion.

Depending on the manufacturer of the machine, there may or may not be a third corona, the "separation corona". That is needed to separate the paper from the drum, but not disturb the toner on the paper. The separation corona is usually at around 4 or 5 kilovolts AC (if it was DC, you would separate the paper from the drum, but will have very smeared toner all over the page, making it unreadable). The separation corona usually has guides over it to keep the paper from dipping down too far into the corona shell.

Paper is then transported to the fuser, which fixes the toner to the paper via heat (to soften the toner particles) and pressure (to embed them in the paper fiber). There are parts in the fuser that also keep the paper from sticking to the hot rollers. A thermostatically-controlled quartz-tube lamp provides the heat inside the anti-stick (Teflon-coated) fuser roller.



LASER PRINTERS, like this one from Hewlett-Packard, work very much like laser copiers, though there are some significant differences.

Finally, your copy or printed page is ready. However, we are not completely done as there is still some toner on the drum—it is not possible to get it all off electrically—so there is usually a rubber or plastic blade that rubs in direct contact with the drum. That drum blade scrapes the toner off the drum, and the recovery blade catches it to keep it from falling back into the machine. A used-toner auger transports the used toner, which is now changed both physically and electrically, and is also contaminated with paper dust. Don't reuse your used toner, because it will eventually damage the developer unit, cleaning blades, fuser sections, and other parts of the mechanism.

Now that all the toner has been scraped off the drum, there is still some residual charge on the drum from the previous exposure process. You obviously can't scrape the static charge off the drum, so the cleaned drum is now fully exposed to a bright light to discharge the drum surface and prepare it for the next charge.

That is the basic process. Many variations are possible and, depending upon the machine and manufacturer, some of this may be a little different in your printer or copier. Where a toner cartridge is used, many of the components mentioned—typically the drum, the toner and developer (usually combined into a single powder), developer magnet, cleaning blades, and some of the corona wires—are part of that cartridge and are replaced each time the cartridge is changed.

Wrap Up

Well, I told you that it was going to be different this time. While we did not get to any hard-core servicing information, I felt that, since so little information on printers is readily available, the information I did have was worth presenting.

Anyway, that's all for this month. Between now and my next column, why not visit my sci.electronics.repair FAQ site on the internet at www.repairfaq.org. If you wish, you can reach me directly via e-mail at sam@stdavids.picker.com. See you next time. EN